Design and Case Study Application of a Participatory Decision-making Support Tool for Appropriate Safe Water Systems Development in Marginalized Communities of the Global South

by

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ABSTRACT

DESIGN AND CASE STUDY APPLICATION OF A PARTICIPATORY DECISION-MAKING SUPPORT TOOL FOR APPROPRIATE SAFE WATER SYSTEMS DEVELOPMENT IN MARGINALIZED COMMUNITIES OF THE GLOBAL SOUTH

Syed Imran Ali
University of Guelph, May 2012

This dissertation presents the design and case study application of a participatory decision-making support tool for appropriate safe water systems development in marginalized low-income communities of the global South. The tool focuses on the resolution of two key design decisions: 1) selecting the appropriate level of application (i.e. household or community level) for a safe water system; and 2) selecting an appropriate water treatment technology (or technologies). The tool breaks the process down into four stages. First are pre-implementation steps which develop a contextualized, baseline understanding of the local community. Second is community-based field research, including focus groups and key informant/informal interviews, to investigate the two key design questions by exploring local preferences, capacities, and circumstances with community-members, government officers, NGO workers, and other stakeholders. Third are analytical steps to integrate information from baseline, informal, and primary research to generate recommendations on the two key design questions. This includes a comparative analysis of household and community level systems; a technology feasibility flowchart; performance assessments of technological alternatives with respect to appropriate technology criteria; and a multi-factor analysis to integrate information from the preceding analytical steps. Fourth are community forums in which further participatory action and research is planned on the basis of the recommendations emerging from the tool. Through these steps, the decision-making support tool guides implementing organizations through the stages of safe water systems design and planning in a manner that centres local people in the process. The tool weaves together several theoretical and methodological strands including humanitarian engineering,
post-normal science, appropriate technology, participatory development, grounded theory, engineering decision-making, and water treatment engineering. The case study application of the decision-making support tool was conducted in a marginalized peri-urban community called Mylai Balaji Nagar in Chennai, India. This indicated that a household level approach is more appropriate for the case study community and that the TATA Swach filter, alum coagulation with chlorination, or boiling, in order of decreasing suitability, may be appropriate technologies for household application in the case study community.
Acknowledgments

This dissertation is the story of several years of work and learning. There are many people who have joined me along the way to whom I owe thanks today.

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What I learned during this degree was not just limited to the classroom or the laboratory or the field. The countless discussions I have had over the years with Dr. Jonathan VanderSteen, Jamie Miller, Lesley Herstein, Morgan MacDonald, and Usman Mushtaq—my friends and peers—have shaped my worldview and taught me to ask the right questions. Thank you guys, I look forward to keeping our conversations going.

Starting a whole new project in India has been an exciting, overwhelming, sometimes miserable, but always deeply educational process. I owe a great deal to my partners in India who have been with me every step of the way. Prof. Ligy Philip, Prof. Vallam Sundar, Prof. Prema Rajagopalan, and Prof. B. S. Murty—thank you for putting up with me and welcoming me into the IITM community. Moreover, the debt I have to my project staff in India can never be repaid. Thank you Srinivasan, Jincy, Arun, Vinothini, Faridha, Manikandan, Pradeep, Soundar, Kumaran, and Saraswathi for gracefully managing under my clumsy leadership. I hope we will have occasion to work together again. Next, this project would have been a non-starter were it not for the support of IDRC, especially Dr. Carrie Mitchell and her team. And finally, but most importantly, I owe a great deal of thanks to the residents of Mylai Balaji Nagar. Though I cannot name you for reason of REB guidelines, I thank you for the cups of tea, the good humour, the time and the support you offered me over the course of this research. Thank you all for taking this journey with me.
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<td>ADMK</td>
<td>All India Anna Dravida Munnetra Kazhagam</td>
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<td>AWSP</td>
<td>Alternative Water Systems Project</td>
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<tr>
<td>ADP</td>
<td>Area development project (World Vision)</td>
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<td>BIS</td>
<td>Bureau of Indian Standards</td>
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<td>BOD</td>
<td>Biochemical oxygen demand</td>
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<td>BPL</td>
<td>Below poverty line</td>
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<td>BWU</td>
<td>Bottled-water user</td>
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<td>CBO</td>
<td>Community-based organization</td>
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<td>C.I.</td>
<td>Confidence interval</td>
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<td>CBWSS</td>
<td>Community-based water supply service</td>
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<td>CMDA</td>
<td>Chennai Metropolitan Development Authority</td>
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<td>CMWSSB</td>
<td>Chennai Metropolitan Water Supply and Sewerage Board</td>
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<td>COD</td>
<td>Chemical oxygen demand</td>
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<td>COPAR</td>
<td>Community-oriented participatory action research</td>
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<td>CRG</td>
<td>Community reference group</td>
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<td>CSWS</td>
<td>Community safe water system</td>
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<td>DALY</td>
<td>Disability-adjusted life year</td>
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<td>DBP</td>
<td>Disinfection by-product</td>
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<td>DMK</td>
<td>Dravida Munnetra Kazhagam</td>
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<td>EAWAG</td>
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<td>Electricity Board</td>
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<td>Executive Officer</td>
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<td>Environmental Protection Agency</td>
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<td>Focus group discussion</td>
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<td>Gastro-intestinal (illness)</td>
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<td>GOI</td>
<td>Government of India</td>
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<td>HWTS</td>
<td>Household water treatment and storage</td>
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<tr>
<td>ICC</td>
<td>Informed choice catalogue</td>
</tr>
<tr>
<td>IDRC</td>
<td>International Development Research Centre</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>IIT-M</td>
<td>Indian Institute of Technology Madras</td>
</tr>
<tr>
<td>INR</td>
<td>Indian rupee</td>
</tr>
<tr>
<td>INT</td>
<td>Interview</td>
</tr>
<tr>
<td>IS</td>
<td>Indian Standard</td>
</tr>
<tr>
<td>JMP</td>
<td>Joint Monitoring Programme</td>
</tr>
<tr>
<td>JNNURM</td>
<td>Jawaharlal Nehru National Urban Renewal Mission</td>
</tr>
<tr>
<td>LRV</td>
<td>Log reduction value</td>
</tr>
<tr>
<td>LWU</td>
<td>Lorry-water user</td>
</tr>
<tr>
<td>MBN</td>
<td>Mylai Balaji Nagar</td>
</tr>
<tr>
<td>MD</td>
<td>Managing Director</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goal</td>
</tr>
<tr>
<td>MFA</td>
<td>Multi-factor analysis</td>
</tr>
<tr>
<td>MPN</td>
<td>Most probable number</td>
</tr>
<tr>
<td>MRTS</td>
<td>Mass Rapid Transit System</td>
</tr>
<tr>
<td>MWA</td>
<td>Matrix-weighting array</td>
</tr>
<tr>
<td>NOC</td>
<td>No objection certificate</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-governmental organization</td>
</tr>
<tr>
<td>NTU</td>
<td>Nephelometric turbidity unit</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and maintenance</td>
</tr>
<tr>
<td>OR</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>ORT</td>
<td>Oral rehydration therapy</td>
</tr>
<tr>
<td>PAR</td>
<td>Participatory action research</td>
</tr>
<tr>
<td>PoU</td>
<td>Point-of-use</td>
</tr>
<tr>
<td>PRI</td>
<td>Panchayat Raj institution</td>
</tr>
<tr>
<td>REB</td>
<td>Research Ethics Board</td>
</tr>
<tr>
<td>RO</td>
<td>Reverse osmosis</td>
</tr>
<tr>
<td>RR</td>
<td>Risk ratio/Relative risk</td>
</tr>
<tr>
<td>SC-IQ</td>
<td>Social Capital Integrated Questionnaire</td>
</tr>
<tr>
<td>SHG</td>
<td>Self-help group</td>
</tr>
<tr>
<td>SOCAP</td>
<td>Social Capital Assessment Tool</td>
</tr>
<tr>
<td>SODIS</td>
<td>Solar UV disinfection</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>TNSCB</td>
<td>Tamil Nadu Slum Clearance Board</td>
</tr>
<tr>
<td>TWU</td>
<td>Tap-water user</td>
</tr>
<tr>
<td>UF</td>
<td>Ultra-filtration</td>
</tr>
<tr>
<td>ULB</td>
<td>Urban local body</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>WASH</td>
<td>Water, sanitation, and hygiene</td>
</tr>
<tr>
<td>WAWTTAR</td>
<td>Water and Wastewater Treatment Technologies Appropriate for Reuse</td>
</tr>
<tr>
<td>WISDOM</td>
<td>Wastewater Infrastructure Systems DecisiOn Matrix</td>
</tr>
<tr>
<td>WQ</td>
<td>Water quality</td>
</tr>
</tbody>
</table>
CHAPTER 1: INTRODUCTION

On April 12, 2010, the grim reaper’s scythe struck Chennai—so read the front page of the New Indian Express. Twenty people had been hospitalized at a communicable disease hospital in the north of the city after succumbing to what authorities believed to be cholera. One man would later die from complications arising from the disease. All of the victims came from a single slum neighbourhood on Wall Tax Road in north Chennai, a place where fifty-odd families shared a single public water standpipe. It was the public water supply that the residents blamed for the outbreak. They were anxious for their loved ones and they were angry with officials from the city and the Metro Water authority. The residents had long suspected that the water was unfit for consumption. As one woman whose husband had had been admitted to hospital put it: “some odd smell emanates from the water. It is very hard to drink…but we have no other choice” (Shivakumar 2010). The cholera outbreak confirmed their worst fears.

The story of the community on Wall Tax Road is, unfortunately, hardly unique. Throughout the world today, hundreds of millions of people lack access to safe drinking water, contributing to a global pandemic of infectious waterborne disease. The problem is particularly acute in the
marginalized low-income neighbourhoods of the rapidly expanding megacities of the global South, or on their periphery, or in the vast rural areas still relatively untouched by development. Expanding access to safe water to those currently without is one of the world’s greatest challenges today (UNICEF and WHO 2011).

1.1 Study rationale

In recent years, more and more attention has come to focus on the global safe water challenge. Progress in expanding access to safe water via the standard approach of large-scale, capital-intensive centralized systems has been slow. Moreover, where such systems do exist, they are plagued by operational difficulties that render them almost ineffective with respect to water safety. In response to this, decentralized safe water systems—at the household or the community level—have emerged as a leading strategy to address the global safe water challenge (Mintz et al. 2001; Sobsey 2002; Thompson, Sobsey, and Bartram 2003; Montgomery and Elimelech 2007).

As decentralized safe water systems begin to be scaled up around the world, decision-making support tools that can assist implementing organizations in selecting the most appropriate safe water system for local circumstances are required (Lantagne et al. 2009; Murphy 2010; Palaniappan, Lang, and Gleick 2008). This dissertation aims to address this need.

1.2 Purpose and objectives

The present work develops a participatory decision-making support tool for the design of appropriate safe water systems in marginalized low-income communities of the global South. It focuses on the resolution of two key decisions in the design and planning stages of a safe water system:

1. Selection of the appropriate level of application; and
2. Selection of an appropriate water treatment technology (or technologies).

A case study application of the decision-making support tool in a marginalized peri-urban community called Mylai Balaji Nagar (MBN) in Chennai, India also comprises part of this dissertation.
1.3 Scope

The decision-making support tool developed here is intended to be as general as possible, but there are some important limitations to its scope, as there are with respect to the dissertation in general. Both of these are detailed here.

First, an attempt has been made in this dissertation to structure the decision-making support tool in such a way that it is as universally applicable as possible. However, it must be acknowledged at the outset that the tool emerged from a specific setting and, inescapably, has been shaped by it. As such, the tool has a special focus on marginalized low-income urban/peri-urban communities (pejoratively “slums”), and on the South Asia region and India in general. On the technical side, it deals primarily with surface water sources rather than groundwater, and focuses on microbiological rather than chemical contamination of drinking water, as these are more prevalent risks in the South (Ashbolt 2004a).

The larger task of safe water systems development and implementation entails aspects beyond those covered in the present work. The two key design questions that the present work addresses (identified above) relate to the hardware of a safe water system. Further elements relating to the software of a safe water system—notably, selecting an appropriate operations and maintenance (O&M) framework and instituting appropriate technology transfer mechanisms—are only partially treated in the present work. Though these elements lay beyond the scope of the present work, they are at least partially discussed here because they are inevitable threads that run throughout the entire task of safe water systems development and implementation. Further guidance tools are required to address these software elements.

Finally, the present work does not constitute a validation and calibration of the decision-making tool. The case study application that is included in the present work is intended only as a test case simulation and demonstration of the methodology because of constraints posed by operating in the context of a larger project. This is discussed further in the next section and in section 3.3.1.7. The considerable task of calibrating and validating the tool must be the subject of future work.
1.4 Context of the Alternative Water Systems Project

As alluded to above, the present work is embedded within a larger project. The Alternative Water Systems Project (AWSP) is an international research collaboration between the University of Guelph, the Indian Institute of Technology Madras (IIT-M), and Queen’s University funded by the International Development Research Centre (IDRC) in Ottawa, Canada. The AWSP is focused on the research, development, and implementation of appropriate safe water systems for marginalized low-income communities. Its case study site is that of the present work—the peri-urban community of Mylai Balaji Nagar in Chennai, India.

I undertook exploratory work in Chennai for the larger project beginning in August 2007. With my collaborators at IIT-M, I wrote a project proposal and grant applications, eventually being awarded a three-year research grant by IDRC in March 2009. Formal research activities of the project began in June 2009. The project has been engaged in a number of research and community development activities at Mylai Balaji Nagar, of which the present work is just one. The primary research of the present work began in March 2011, and as such, was preceded by a number of research activities in the case study community that were part of the larger project. These preceding research activities have very much informed the present work. The larger project also presented constraints upon the present work that affected what could be accomplished here. It is for this reason that the present case study application is a simulation rather than a full implementation of the methodology. This is discussed further in section 3.3.1.7.

A note is required here to explain an unusual feature of this dissertation. Typically it is the case in engineering academic writing that the third-person voice is used. For the present work, I have elected to write in the first-person as this dissertation is inescapably a personal account of five years of experience in Mylai Balaji Nagar—from the exploratory work I undertook in 2007, to establishing a research collaboration between the Canadian and Indian universities, to obtaining research funding for the project, to coordinating a research team of more than a dozen local and expatriate staff, to defining and carrying out several formal research activities in the community, to carrying out complementary community development activities with local partners. Throughout all of this, I have been immersed in the context of Chennai and Mylai Balaji Nagar and learning constantly. Thus, I have decided to use the first-person voice in the present work to
more accurately represent the years of personal learning—of which this dissertation is just the latest part—this project has been for me.

1.5 Outline of dissertation

This dissertation is divided into seven chapters. This chapter, Chapter 1, contains the introduction to the whole. Chapter 2 presents the literature review for the present work. It discusses, at depth, the global safe water challenge and the decentralized alternatives for safe water provision which were briefly alluded to above, and then proceeds on to discuss the theoretical foundations upon which the present decision-making support tool is built. Chapter 3 presents the study approach of the present work, in doing so, laying out the design of the decision-making support tool. This chapter details the primary research and the analytical approach taken in resolving the two key design questions identified earlier on. It also presents the pre- and post-implementation steps of the decision-making support tool which—although they do not constitute a part of the primary work of this dissertation—round out its logic and contextualize its place in the larger project. Chapter 4 presents the findings of the baseline research of the larger project, in doing so, developing a background of the case study community for the present work. The results of the case study application of the support tool at Mylai Balaji Nagar are presented and discussed in two parts, each one dealing with one of the two key design questions. Chapter 5 presents and analyzes the findings of the investigation into the first key design question: what is the appropriate level of application for a safe water system at Mylai Balaji Nagar? Chapter 6 presents and analyzes the findings of the investigation into the second key design question: what is an appropriate water treatment technology (or technologies) for application at Mylai Balaji Nagar? Finally, Chapter 7 concludes this dissertation by summarizing what has been done and by laying out future steps.
CHAPTER 2: LITERATURE REVIEW

This chapter presents a review of the literature relevant to the present work. The first section explores the problem of interest: the global safe water challenge and the global public health crisis it contributes to. The second section moves on to discuss decentralized alternatives for safe water provision as a means of addressing the global safe water challenge. Here the present debates and research gaps in the field—those which this dissertation aims to address—are elaborated upon. The third and final section of this chapter develops the theoretical and methodological foundations upon which the decision-making support tool is built.

2.1 The global safe water challenge

Among the most critical challenges facing marginalized communities in the world today is the lack of access to safe drinking water. Recent estimates indicate that approximately 884 million people lack access to improved water globally (UNICEF and WHO 2011).\(^1\)^2 The outlook is even

\(^1\) Improved water refers to sources that are in some way ‘better’ than traditional or natural sources because of some level of human intervention (UNDP 2006). For instance, a borehole well tapping a deep aquifer is considered to be improved with respect to a shallow open-pit dug well. ‘Unimproved’ sources are not necessarily unsafe, but may
more distressing with respect to sanitation, with about 2.6 billion people without access (UNICEF and WHO 2010). As a result, marginalized peoples throughout the global South are restricted to the consumption of unsafe water and are exposed to a polluted ambient environment. These two factors underlie a pandemic of infectious diseases that plagues much of the underdeveloped world today (Montgomery and Elimelech 2007). Addressing this global pandemic requires that ambient environmental conditions be improved and protected, and that access to safe water be extended to those currently without. The present work focuses on the latter, but does so with the full acknowledgement that this is only part of the solution. The following sub-section will explore the global safe water challenge in more detail, first, by looking to its impact on health around the world, and then to the specific role that safe water plays.

2.1.1 The scourge of waterborne disease

The scourge of disease arising from unsafe water and environment has been, and unfortunately remains, one of humanity’s greatest and most persistent threats. Its staggering scale is captured in a global epidemiological study by Smith, Corvalán, and Kjellström (1999) that showed that one-quarter to one-third of total ill-health in the world is attributable to environmental risk factors of poor air, food, and water quality. Moreover, the study showed that it is marginalized populations in the South that are most affected. It is a tragic injustice that these diseases which, if not entirely, are largely preventable continue to exact such a massive toll.

represent a greater risk to public health as they are more easily affected by pollution from population, industry or agricultural activities. Ranging from treated piped water to simple borehole well-water, improved water may be—but is not necessarily—microbiologically and chemically fit for human consumption.

2 In response to this optimistic assertion from the WHO and UNICEF’s Joint Monitoring Programme (JMP), researchers from the Water Institute at the University of North Carolina at Chapel Hill estimate that, when considering microbial water quality and sanitary risks, 1.8 billion people lack access to safe water (Onda, Lobuglio, and Bartram 2012).

3 Similarly, improved sanitation represents any enhancement over totally unmanaged discharge of sewage into the ambient environment (i.e. open defecation), from pit latrines to septic tanks to centralised sewage systems (WHO and UNICEF 2004).

4 In the literature, several terms are used to describe the presently low-income, industrially and economically underdeveloped, and mostly post-colonial nations of the world. In the earlier days of the development discourse, the term ‘third world’ was favoured, but this has largely been abandoned since the end of the Cold War. Today, terms like ‘developing’, ‘low-income’, or ‘underdeveloped’ countries or the ‘global South’ (each with their specific connotations and limitations) are commonly used to describe the vague but comprehensible collection of nations under discussion here. In the present work, the terms ‘underdeveloped’ or the ‘global South’ are preferred and used interchangeably.
Diseases associated with water supply can be sub-divided into four categories on the basis of how their aetiological agents are transmitted through the aqueous environment (Table 2-1).

<table>
<thead>
<tr>
<th>Group</th>
<th>Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-borne diseases: diseases spread through water in which water acts as a passive carrier for the infecting pathogens. These diseases depend also on sanitation.</td>
<td>Cholera, Typhoid, Bacillary dysentery, Infectious hepatitis, Leptospirosis, Giardiasis, Gastroenteritis etc.</td>
</tr>
<tr>
<td>Water-related diseases: diseases spread by vectors and insects that live in or close to water. Stagnant ponds of water provides the breeding place for the disease spreading vectors such as mosquitoes, flies and insects.</td>
<td>Yellow fever, Dengue fever, Encephalitis, Malaria, Filariasis (all by mosquitoes), Sleeping sickness (Tsetse fly), Onchocerciasis (Simulium fly) etc.</td>
</tr>
<tr>
<td>Water-based diseases: diseases caused by infecting agents spread by contact with or ingestion of water. Water supports an essential part of the life cycle of infecting agents such as aquatic snails.</td>
<td>Schistosomiasis, Dracunculosis, Bilharziosis, Filariasis, Onchocerciasis, Treadworm and other helminths</td>
</tr>
<tr>
<td>Water-washed diseases: diseases caused by the lack of adequate quantity of water for proper maintenance of personal hygiene. Some are also depended on poor sanitation.</td>
<td>Scabies, Trachoma (eye infection), Leprosy, Conjunctivitis, Salmonellosis, Ascarisiasis, Trichiniasis, Hookworm, Amoebic dysentery, Paratyphoid fever etc.</td>
</tr>
</tbody>
</table>

It is the group referred to as waterborne diseases that are the specific focus of the present work. These are diseases caused by pathogens that are excreted by infected individuals and passively transmitted by water to the next victim, who then ingests the contaminated water and also becomes infected. The pathogenic agents associated with waterborne diseases can be divided into four broad groups: bacteria, viruses, protozoa, and helminths (Table 2-2).

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5 For this reason, these diseases are also referred to as faecal-oral diseases. This terminology is also used in the present work.
Table 2-2 | Pathogens causing waterborne diseases of particular concern in the South (Ashbolt 2004a).

<table>
<thead>
<tr>
<th>Name of micro-organisms</th>
<th>Major diseases</th>
<th>Major reservoirs and primary sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella typhi</em></td>
<td>Typhoid fever</td>
<td>Human faeces</td>
</tr>
<tr>
<td><em>Salmonella paratyphi</em></td>
<td>Paratyphoid fever</td>
<td>Human faeces</td>
</tr>
<tr>
<td><em>Other Salmonella</em></td>
<td>Salmonellosis</td>
<td>Human and animal faeces</td>
</tr>
<tr>
<td><em>Shigella spp.</em></td>
<td>Bacillary dysentery</td>
<td>Human faeces</td>
</tr>
<tr>
<td><em>Vibrio cholera</em></td>
<td>Cholera</td>
<td>Human faeces and freshwater zooplankton</td>
</tr>
<tr>
<td><em>Enteropathogenic E. coli</em></td>
<td>Gastroenteritis</td>
<td>Human faeces</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>Gastroenteritis</td>
<td>Human and animal faeces</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>Gastroenteritis</td>
<td>Human and animal faeces</td>
</tr>
<tr>
<td><em>Legionella pneumophila and related bacteria</em></td>
<td>Acute respiratory illness (legionellosis)</td>
<td>Thermally enriched water</td>
</tr>
<tr>
<td><em>Leprosy spp.</em></td>
<td>Leptospirosis</td>
<td>Animal and human urine</td>
</tr>
<tr>
<td><em>Various mycobacteria</em></td>
<td>Pulmonary illness</td>
<td>Soil and water</td>
</tr>
<tr>
<td>* Opportunistic bacteria*</td>
<td>Variable</td>
<td>Natural waters</td>
</tr>
</tbody>
</table>

**Enteric viruses**

<table>
<thead>
<tr>
<th>Enteroviruses</th>
<th>Polioviruses</th>
<th>Poliomyelitis</th>
<th>Human faeces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coxsackie viruses A</td>
<td>Aseptic meningitis</td>
<td>Human faeces</td>
<td></td>
</tr>
<tr>
<td>Coxsackie viruses B</td>
<td>Aseptic meningitis</td>
<td>Human faeces</td>
<td></td>
</tr>
<tr>
<td>Echo viruses</td>
<td>Aseptic meningitis</td>
<td>Human faeces</td>
<td></td>
</tr>
<tr>
<td>Other enteroviruses</td>
<td>Encephalitis</td>
<td>Human faeces</td>
<td></td>
</tr>
</tbody>
</table>

**Rotaviruses**

<table>
<thead>
<tr>
<th>Adenoviruses</th>
<th>Upper respiratory and gastrointestin al illness</th>
<th>Human faeces</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hepatitis A virus</em></td>
<td>Infectious hepatitis</td>
<td>Human faeces</td>
</tr>
<tr>
<td><em>Hepatitis E virus</em></td>
<td>Infectious hepatitis; miscarriage and death</td>
<td>Human faeces</td>
</tr>
<tr>
<td><em>Norovirus</em></td>
<td>Gastroenteritis</td>
<td>Fomites and water</td>
</tr>
</tbody>
</table>

**Protozoa**

<table>
<thead>
<tr>
<th>Acanthamoeba castellani</th>
<th>Amoebic meningoencephalitis</th>
<th>Human faeces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balantidium coli</td>
<td>Balantidiasis (dysesterny)</td>
<td>Human and animal faeces</td>
</tr>
<tr>
<td>Cryptosporidium hominis, C. parvum</td>
<td>Cryptosporidiosis (gastroenteritis)</td>
<td>Water, human and other mammal faeces</td>
</tr>
<tr>
<td>Entamoeba histolytica</td>
<td>Amoebic dysentery</td>
<td>Human faeces</td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td>Giardiasis (gastroenteritis)</td>
<td>Water and animal faeces</td>
</tr>
<tr>
<td>Naegleria fowleri</td>
<td>Primary amoebic meningoencephalitis</td>
<td>Warm water</td>
</tr>
<tr>
<td><em>Helminths</em></td>
<td>Ascariasis</td>
<td>Animal and human faeces</td>
</tr>
</tbody>
</table>

Waterborne diseases also subsume the *diarrhoeal diseases*—some of the most prevalent and pernicious diseases in the South. These are the illnesses that induce diarrhoea and are spread by contact with human faeces including, but not limited to, gastroenteritis, cholera, dysentery, and typhoid (Butterton and Calderwood 2004). With an estimated four billion cases annually throughout the world, the diarrhoeal diseases are the most detrimental of all ailments related to water, sanitation, and hygiene (Schuster-Wallace et al. 2008). Every year, diarrhoeal diseases are responsible for more than 1.5 million deaths globally and the loss of 52 million DALYs (Prüss-Ustun et al. 2008).\(^6\) Tragically, they disproportionately affect children under the age of five, with almost 1.4 million of the 1.5 million deaths caused by diarrhoeal diseases being among children (ibid.). Diarrhoeal diseases also have serious non-fatal implications. Often associated with

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\(^6\) DALYs, or *disability-adjusted life years*, measure the years of life lost to premature mortality and the years lost to disability (Prüss-Ustun et al. 2008).
malnutrition, the diarrhoeal diseases can result in life-long impacts for children by stunting growth, impairing cognitive development and weakening immune resistance (Baqui et al. 1993; Berkman et al. 2002).

The diarrhoeal diseases are afflictions of marginalization. Young children living in impoverished conditions in urban and peri-urban slums are especially vulnerable (Marsh et al. 1995). Hussain, Ali, and Kvåle (1999) showed, in a study investigating determinants of child mortality in urban slums in Dhaka, Bangladesh, that diarrhoea was the leading cause of death among children one to five years of age, and was second, after tetanus, among infants under one year of age. In South Asia, which has the greatest proportion of slum-dwellers anywhere in the world (UNFPA 2007), the diarrhoeal diseases account for an alarming 24% of total child mortality (Black, Morris, and Bryce 2003). The diarrhoeal diseases exert a tragic and excessive toll upon the most vulnerable populations in the underdeveloped world.

The urgency of this global public health crisis has found expression in the United Nations Millennium Development Goals (MDGs). Two targets under MDG 7 aim to reduce the burden associated with diarrhoeal and other waterborne diseases. One seeks to halve, by 2015, the proportion of the global population without sustainable access to safe drinking water and basic sanitation. The second aims to achieve, by 2020, a significant improvement in the lives of at least 100 million slum-dwellers through improved sanitation, safe water provision, and durable housing of sufficient living area. Furthermore, MDG 4 seeks to reduce by two-thirds, between 1990 and 2015, the under-five mortality rate, for which diarrhoeal diseases are a major cause (UN 2008). Controlling the global pandemic of diarrhoeal and other waterborne diseases is thus a central part of the MDGs.

2.1.2 Safe water for the protection of public health

The essential tragedy of the global pandemic of waterborne disease lies in that it is almost entirely preventable. Pathogens in human and animal excreta are transmitted via complex and manifold faecal-oral pathways involving surface and groundwater, soil, hands, flies and other vectors. Humans ultimately become exposed via the ingestion of contaminated water, food, or by direct unsanitary contact. It is the uncontrolled transmission of faecal-oral pathogens that is at the
root of this pandemic. However, pathogenic transmission can be disrupted and infection prevented by the introduction of various barriers (Figure 2-1).

![Figure 2-1](image)

**Figure 2-1** Pathways and barriers in the transmission of faecal-oral pathogens (modified from Prüss et al. 2002).

Important barriers to the transmission of faecal-oral pathogens thus include:

- sanitation and source water protection;
- hygiene and food safety; and
- water treatment and safe distribution.

Sanitation preserves environmental hygiene by preventing faecal contamination of source waters and the ambient environment. Along with the promotion of hygienic practices, supplying an adequate quantity of water is a necessary precondition for the maintenance of personal and domestic hygiene and food safety, which protect against direct unsanitary and food-borne transmission. For this reason, the dominant paradigm in the global water, sanitation, and hygiene (WASH) community, at least until the end of the 1990s, was largely focused on increasing the quantity of water available, irrespective of its quality (Esrey 1996; Esrey et al. 1991).

Clasen and Cairncross (2004) observe that globally, since the mid-1990s, there have been substantial reductions in mortality due to diarrhoeal diseases; however, as Kosek, Bern, and
Guerrant (2003) report, morbidity has remained largely unchanged. Clasen and Cairncross suggest that the widespread introduction of effective case management techniques, such as oral rehydration therapy (ORT), is implicated in the observed decline in mortality. However, the WASH paradigm centred on water quantity has not made similar strides in reducing transmission, infection, and subsequent morbidity. Though this is an ecological observation, it is corroborated by epidemiological evidence coming from intervention studies.

Gundry, Wright, and Conroy (2004) observe that the review by Esrey et al. (1991) examined water quality studies that focused on quality at-source rather than at point-of-use. This, they argue, is responsible for the dismal performance of the water quality interventions in that review. Water treated at-source is subject to recontamination during distribution, collection, storage and drawing of water in the home (Rufener et al. 2010; Ahmed, Hoque, and Mahmud 1998; Brick et al. 2004; Wright, Gundry, and Conroy 2004). If recontamination is likely to occur, treatment at or near the point-of-use becomes necessary in order to ensure safe drinking water quality at the time of consumption (Luby et al. 2001). In light of this observation, Gundry, Wright, and Conroy (2004) systematically review point-of-use (PoU) water quality interventions (rather than at-source water quality interventions) for their impact on cholera and diarrhoeal diseases in general. Their findings indicate that PoU water quality interventions have a significant positive effect, especially in households that have adequate sanitation. With respect to cholera, the authors estimate a pooled odds ratio of 0.35 (95% C.I.: 0.21–0.56). For diarrhoeal diseases in general, PoU interventions were found to be effective, but featured significant heterogeneity between studies, suggesting the influence of unknown confounding factors.

The importance of safe drinking water quality is further corroborated by other meta-analyses of diarrhoeal disease prevention studies. Clasen et al. (2007) report a pooled rate ratio of 0.62 (95% C.I.: 0.47–0.82) for PoU water quality interventions compared with only 0.87 (95% C.I.: 0.74–1.02) for at-source water quality interventions. Fewtrell et al. (2005) similarly report an overall relative risk of 0.65 (95% C.I.: 0.48–0.88) with PoU water quality interventions, compared to 0.89 (95% C.I.: 0.42–1.90) for at-source interventions. Furthermore, Fewtrell et al. also examine the effectiveness of PoU water quality interventions in different settings. For PoU water quality intervention studies conducted in urban, peri-urban, and refugee camp settings (that were deemed
to be of good enough quality), the authors estimate a relative risk of 0.74 (95% C.I.: 0.65–0.85), suggesting that PoU water quality interventions may be somewhat less effective in densely populated areas.

Altogether, the epidemiological evidence suggests that the WASH paradigm centred on increasing water supply is not incorrect so much as it is incomplete: ensuring safe drinking water quality is also important for the protection of public health. This reaffirms the scenario presented in Figure 2-1. There are several components that are necessary—but are alone insufficient—for the control of diarrhoeal diseases including: improved sanitation and hygiene; safe water quality at the point of consumption; and sufficient quantities of water.\(^7\)

**The special challenge of safe water in slums**

Slums are a ubiquitous part of the urban landscape throughout the underdeveloped world. At the confluence of overpopulation, economic deprivation, and environmental degradation, people living in slums occupy a precarious position at the very fringes of urban life. Of the 3.2 billion people living in cities around the world today, one in three live in ‘slum’ conditions defined as housing lacking at least one of four basic features (UN 2007):

- adequate sanitation;
- safe water supply;
- durable housing material; and
- adequate living space.

As urban population growth continues to far outpace infrastructural development in the South, migrants to cities will continue to improvise at the margins. Health risks arising from unsafe

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\(^7\) The health benefits of other interventions have also been explored. Esrey et al. (1991) report that improved water and sanitation produced a median reduction of 65% (95% C.I.: 43–79%) in mortality due to diarrhoeal diseases, and a 22% (95% C.I.: 0–100%) reduction in morbidity across all reviewed studies. In a systematic review of studies examining hand-washing with soap, Curtis and Cairncross (2003) report a relative risk of 0.53–0.58 for diarrhoeal disease across all reviewed studies. Fewtrell et al. (2005), in their systematic review, find that all WASH interventions are relatively equal at controlling diarrhoeal diseases. In addition to the relative risk figures for at-source and point-of-use water quality improvements given above, Fewtrell et al. also report that hygiene interventions were associated with an overall relative risk of 0.63 (95% C.I.: 0.52–0.77); sanitation interventions, 0.68 (95% C.I.: 0.53–0.87); and water supply interventions, 0.75 (95% C.I.: 0.62–0.91). Interestingly, Fewtrell et al. also find that studies with multiple interventions performed no better than studies with a single intervention, both having with a relative risk of 0.67 (95% C.I.: 0.59 – 0.76). They speculate that the reason for this may be the dilution of attention and resources across several interventions in multi-faceted projects, such that no single intervention is performed as well as it would have been were it the sole focus.
water and environmental degradation are exacerbated by the poverty and social marginalization people living in slums face (Sverdlik 2011). And as the world’s slums continue to grow, the environmental and social pressures that threaten the health and well-being of people living within them will only intensify (Davis 2006). The delivery of basic services, including safe water, to the slums that increasingly characterize the modern city is one of today’s pressing challenges.

In the absence of safe piped water supply, people living in slums are forced to improvise to meet their daily needs. Water supply in slums often comes from four major sources:

- groundwater;
- nearby surface water bodies;
- vendors (from both improved and unimproved sources); and
- illegal connections to nearby municipal water lines.

All of these sources of water may be subject to contamination owing to the general under-coverage of sanitation systems in many cities of the South. The first two sources are often found to be directly compromised by sewage contamination (Chaplin 2011; Gronwall, Mulenga, and McGranahan 2010). The latter two sources may also be indirectly compromised. Water sold by vendors is often of unknown provenance, and though it is sometimes drawn from the municipal supply it is often of worse quality (Hutin, Luby, and Paquet 2003). For those slum settlements that are near municipal water lines, illegal connections are also a major source of water. Oftentimes, such connections are controlled by informal or criminal elements who retail water at exorbitant rates to people living in slums. As discussed in greater detail in the next section (section 2.1.3), water in distribution lines may already be contaminated, but because reduced flows are often routed to marginalized or low-income neighbourhoods and because of pressure losses from excessive tapping, water quality in mains that serve slums or low-income areas may

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8 In India, among the poorest quartile of the urban population, 82% do not have access to piped water at home (Agarwal 2011).
9 Agarwal (2011) reports that, of the poorest quartile of the urban population in India, 53% do not have access to a sanitary flush or pit toilet.
10 Chaplin (2011) examines the evolution of the regrettable sanitation situation in Indian cities. She finds that it has emerged from the legacy of the colonial city and the nature of the post-colonial state. As such, her description can be extended to all post-colonial nations of the South.
11 Though vendors selling water from carts or water trucks in bottles and small tanks/drums are filling a critical gap in municipal service delivery, vended water is still considered an unimproved source of water (UNDP 2006).
be even more deteriorated. Regardless of the source, water supply in slums has a high risk of being unfit for consumption.

A case study in slum sectors of Jakarta, Indonesia by MercyCorps illustrates many of the challenges faced by marginalized urban communities (Prabaharyaka and Pooroe 2010). In Jakarta, the project implementers found that:

- Poor households faced intermittent supply and inconvenient timing of water availability.
- Poor households had to purchase water from vendors at exorbitant rates without any guarantee of water quality, such that they paid disproportionately more for worse quality water than richer households with regular access to public infrastructure.
- Water companies/public utilities were disinclined to connect poor households due to the low levels of consumption they represent, the difficulty they may have in paying initial connection fees, and because of legal issues relating to land tenure.
- Uncertainty of municipal development plans affects projects to improve public water facilities and infrastructure in slum areas.
- Lack of trust between government/public water utility and low-income marginalized communities may forestall investment in water supply infrastructure in slum areas.

Specifically, this work focussed on an alternative water supply arrangement—a community-based water supply service (CBWSS). Through a participatory approach, the CBWSS created roles, responsibilities, and incentives for public (municipal government), private (water company), non-profit (NGO) and community-based (CBO) organizations. Most important was the role of the CBO which was charged with organizing water-users in the slum to own, maintain, and operate the communal water system. The infrastructural and institutional innovation in the CBWSS was the use of a master meter. The master meter allowed the water utility to deliver water to a single bulk consumer—the CBO—forgoing the need to physically connect numerous small users to the system, regularly monitor their consumption and collect their fees. The master meter was connected to a communal water storage unit, from which water was distributed to enrolled households in the slum by either an above or below ground small-scale spaghetti distribution system, all of which was managed, operated, and maintained by local people through the CBO. Each connected household also had either its own meter to record individual usage and pay accordingly, or paid a flat rate to the CBO. The master meter recorded communal usage which was then billed by the utility to the CBO, which paid as a bulk consumer on behalf of all of the connected households. For a water utility (public or private), a single bulk consumer is much more attractive an investment and much easier to manage than numerous small users, thereby creating an incentive for utilities to service previously excluded areas. In the end, the CBWSS emerged as “an institution managed and controlled by communities…without the need for formal legalization [that is] distinct from services managed by legally registered [private or public] institutions” (Prabaharyaka and Pooroe 2010). The CBWSS represents an alternative water supply model for low-income urban communities that, in turn, presents a ‘plug-and-play’ site for community-based water treatment technology, should the water quality demand such an intervention. Though there are not many examples of community level safe water systems being applied in marginalized low-income urban settings, this pilot project implemented by MercyCorps reveals that there is considerable potential for it.
Conflicts may emerge between users and non-users of community water supply projects if coverage is not extended to all at once.

There is inadequate public access to information on how water tariffs are set by the government.\[^{13}\]

These are common challenges facing water supply in marginalized urban communities throughout the South.

Beyond safe water supply, all of the faecal-oral transmission pathways in Figure 2-1 may well be active in slums. Slums often occupy marginal urban lands including those adjacent to wastelands at the urban periphery, along the banks of sewage-polluted rivers, or other contaminated sites where faecal contamination in the ambient environment may be considerable. The lack of proper sanitation that is almost always the case in slums ensures that even those sites that are free of contamination from without, quickly become contaminated from within. In slums, drinking water, food, hands, and utensils readily become contaminated by faecal-oral pathogens. Waterborne diseases become chronic conditions that threaten lives and deplete the capacity of individuals and communities to enhance their own well-being (Asthana 1994). The environmental health situation in slums is one of constant crisis.

Though much is required to ameliorate the environmental health challenges prevalent in slums, the present work focuses only on alternatives for the provision of safe water.\[^{14}\] As it was only briefly discussed above, the next section offers a closer look to some of the challenges facing standard centralized approaches for safe water provision in low-income settings.

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\[^{13}\] Prabaharyaka and Pooroe (2010) identify ways in which the CBWSS (or community water supply projects in general) can address these concerns: 1) By raising issues of public water services, the community can encourage the coordination of municipal infrastructure plans with self-identified community needs. 2) The existence of a CBO to manage community water supply can prove to others that it is possible to operate and manage a public water service, and furthermore, that a community is capable of doing it themselves. This may open doors for communities to become more involved in planning of municipal development plans. 3) Once a CBO is established and has proven itself, it has an opportunity to become involved with all levels of urban water supply management including the setting of tariffs. 4) The CBWSS, as a bulk costumer, can encourage the central provider (public water utility) to increase pressure and credit capacity to community-members.

\[^{14}\] This is of course tempered with the full understanding that safe water is only a piece of the puzzle, necessary but alone insufficient. Ultimately, effective sanitation, adequate quantities of water, hygiene promotion, and safe drinking water quality at its point-of-consumption are all necessary.
2.1.3 Challenges facing centralized safe water systems

Many strategies for development in the South are modelled on the historical experience of the industrialized North. However, these strategies may not necessarily be appropriate to the particular contexts found in the South (Schumacher 1973). For this reason, a major challenge in addressing the global pandemic of waterborne diseases is the development of contextually appropriate approaches for water and sanitation.\textsuperscript{15} Significant progress has been made with respect to the latter. For example, community-led sanitation projects have been found to be effective in both urban and rural areas in South Asia (Khan 1996; Kar and Pasteur 2005).\textsuperscript{16} These projects represent models that have been successfully adapted elsewhere in the South. As contextually appropriate approaches have been developed for sanitation in low-income settings, so too are they required for safe water provision. In order to understand what appropriate alternatives may look like, we now turn to the challenges that standard centralized approaches for safe water provision face in low-income communities in the South.

Centralized water treatment and distribution systems—the standard approach imported from the North—continue to be sought in the South despite having largely fallen short of expectations. Today, coverage by centralized systems remains woefully inadequate in both rural and urban areas (especially low-income sectors of rapidly expanding cities), leaving hundreds of millions without access to safe water. In rural areas, low population densities, coupled with general rural neglect, has and will most likely continue to bode poorly for the extension of safe water coverage by standard means. Likewise, in countless cities of the South, municipal authorities are faced with burgeoning population growth and, as such, the demand for essential services—of which water is but one—far outstrips the available resources (Elimelech 2006). Even where such systems are in place, they are plagued by operational challenges that reveal their inappropriateness to the context. The reasons for this situation are many, but most apparent are resource and institutional limitations at the level of local governments. Whereas centralized

\textsuperscript{15} The concept of appropriate technology is discussed in greater detail later on (section 2.3.3).

\textsuperscript{16} Of course, though some progress has been made with respect to appropriate sanitation, the challenge is far from being resolved, as attested by the numbers. Joshi, Fawcett, and Mannan (2011) elucidate many of the failings of sanitation and hygiene programs in a three-year ethnographic study in urban slums of Dhaka, Chittagong, Nairobi, and Hyderabad. They find that many of these programs provided ‘inappropriate’ sanitation, demanded personal investments in situations of high land tenure insecurity, and/or taught hygiene practices that did not suit local beliefs or understand the complex realities of urban poverty.
water treatment and distribution systems require considerable capital investments, the limited availability of public sector capital remains a definitive constraint on infrastructural development in the South (Illich 1997). The expansion of effective centralized water networks to vast portions of the rural and urban population currently without in the South remains, unfortunately, unlikely in the foreseeable future.

Even where centralized systems do exist, inadequate institutional resources at the municipal level give rise to a host of persistent problems, typically affecting those areas of the city that are already marginalized, for instance, low-income, unplanned, and informal neighbourhoods. Generally speaking, in the North, centralized systems supply treated water without substantial change in microbiological quality between the treatment plant and the consumer. Even so, on infrequent occasions, operational inadequacies result in the recontamination of treated water during distribution, resulting in outbreaks of various infectious waterborne diseases (LeChevallier et al. 2003). Unfortunately, in much of the South, operational inadequacies appear to be the rule, not the exception. Widespread distribution system failures are caused by an array of deficiencies including (Lee and Schwab 2005):

- improper disinfection and inadequate disinfection residual;
- low pipeline pressure;
- intermittent service;
- illegal connections and excessive network leakages;
- system corrosion;
- inadequate sewage containment and removal; and
- inequitable pricing and usage of water.

A case study of the municipal water network in Karachi, Pakistan by Rahman, Lee, and Khan (1997) revealed how these faults interact and lead to the failure of centralized systems in large cities of the South. Though finished water leaving treatment plants may be of adequate quality, water is readily recontaminated during distribution. Urban water distribution infrastructure is widely compromised due to inadequate institutional capacity and resources for on-going repairs and maintenance. Sewerage and water lines are laid in close proximity and, being highly deteriorated, leak profusely. Frequent power outages and inadequate supply relative to demand result in low flow rates and low pressure in water distribution lines, whereas flow rates and
pressure are consistently high in sewerage lines. The high pressure and compromised containment in the sewerage network leads to the ubiquitous contamination of the subsurface with sewage, while chronically low pressure and dilapidated conditions of water distribution lines result in the widespread ingress of sewage-contaminated groundwater. Ultimately, the water arriving to the urban consumer is unfit for consumption. The financial costs associated with rehabilitating deteriorated centralized infrastructure in densely populated urban areas is prohibitive. It is in the absence of alternatives to centralized water treatment and distribution systems that the immense public health emergency brought on by diarrhoeal and other waterborne diseases is allowed to persist in underserviced urban and rural areas.

This section has explored the global safe water challenge. It has discussed the health impact of diarrhoeal and waterborne diseases around the world, the important role of safe water in protecting public health, and finally, the limitations of standard centralized safe water systems. Now that the core problems have been discussed, the next section looks to decentralized alternatives as a potential solution.

2.2 Decentralized alternatives for safe water provision

The critical vulnerability with centralized safe water systems in the South lies not so much with treatment, but with distribution. It is possible then to conceive of alternatives that circumvent recontamination vulnerabilities by having decentralized treatment capacity closer to end-users. Alternative safe water systems could see treatment shifted from centralized plants to points at, or near, where drinking water is consumed—that is, to either the household level or the community level.\(^{17}\) The capital costs associated with decentralized systems may also be substantially lower than with centralized systems, owing to savings on distribution networks. Decentralized safe water systems, especially HWTS, are increasingly being advocated as a means to fill the safe water gap until effective centralized water networks expand into areas currently without (that is, if they ever do). Such an approach could achieve immediate public health gains among

\(^{17}\) There is a multiplicity of terms used to describe these approaches in the literature. Household level systems are also referred to as point-of-use (PoU) or household water treatment and storage (HWTS) systems. Community level systems can also be described as semi-centralized systems or, in the case of urban areas, neighbourhood level systems. Generally, household level and community level systems are the preferred terms here, but the others also appear in the present work.
vulnerable underserviced rural and urban populations throughout the South (Mintz et al. 2001; Sobsey 2002; Thompson, Sobsey, and Bartram 2003; Montgomery and Elimelech 2007).

2.2.1 Household level systems

Though decentralized safe water systems can be implemented at either the household or community level, much of the work that has been done thus far, particularly in urban areas, has been at the former. Various water treatment technologies have been developed into bench-top systems that can purify enough water to meet the drinking water needs of a single family. These small-scale PoU systems are typically owned and operated by individual households, who may receive on-going material or operational support from public or private agencies or NGOs, but are otherwise responsible for the systems themselves. Field implementations of PoU systems have been conducted in both rural and urban settings. Examples of PoU water treatment systems are numerous.\(^{18}\)

2.2.2 Community level systems

Decentralized water treatment may also be applied in a ‘semi-centralized’ manner at the community level. Treatment occurs at a small-scale facility, typically centrally located in the community it serves, from which treated water is distributed in a safe manner (i.e. sealed safe storage containers) to community-members. It is ‘semi-centralized’ in that water is treated en masse to meet the needs of many households. What distinguishes it from the standard centralized approach is the scale (i.e. it is much smaller) and the proximity to users (i.e. water treatment occurs both temporally and physically closer to end-users limiting the opportunity for recontamination during conveyance in safe water containers rather than distribution pipes).\(^{19}\) As with household level systems, community level systems are amenable to a range of treatment

\(^{18}\) To name just a few illustrative examples, Arnold and Colford Jr. (2007) look at PoU chlorination; Chiller et al. (2006) look at combined flocculation-disinfection; Rose et al. (2006) look at SODIS; and Brown, Sobsey, and Loomis (2008) look at ceramic water filtration. The number of studies done with household level systems are quite large. The meta-analyses discussed in section 2.1.2 present thorough bibliographies of these studies.

\(^{19}\) A similar concept for potable water sustainability in cities of the industrialized North has been proposed by Weber Jr. (2002) called distributed optimal technology networks (DOT-NET systems).
technologies. Much of the work done with community level systems in the South has been in rural areas.\textsuperscript{20,21}

2.2.3 Comparison of household and community level systems

Household and community level systems differ in important ways, such that, depending on the context, one approach may be more appropriate than the other.

2.2.3.1 Infrastructural requirements

The need for infrastructural development is one of the main ways in which the two approaches differ. Whereas community level systems require a substantial capital investment for the creation of a small-scale treatment facility, household systems do not require any infrastructure. Similarly, household level systems do not entail on-going infrastructural upkeep costs—at least beyond material inputs—whereas community systems may face significant upkeep costs especially if they feature piped distribution networks. Where development of public infrastructure is technically, economically, socially or institutionally infeasible, household level systems may be more viable than community level systems.

\textsuperscript{20} One illustrative example comes from the village of Bomminampadu, in the Krishna District of the southern Indian state of Andhra Pradesh, where a \textit{community safe water system} (CSWS) has been implemented by local NGOs (Naandi Foundation and WaterHealth India 2007). The CSWS utilizes simplified filtration and ultraviolet (UV) disinfection technology developed by Gadgil et al. (1998). The water treatment unit is housed in a small-scale facility in a central location in the village, from where community-members collect drinking water in sealed safe storage containers (i.e. 20 L ‘water cooler’ bottles). The CSWS is implemented and managed as a tripartite partnership between the local government, the NGOs, and local community-members, in which the latter contribute a portion of the capital costs and on-going user fees (typically Rs. 1 INR per 12–15 L of drinking water), while the local government and NGO actors provide technology, technical support and further financing, in addition to facilitating social mobilization, behavioural change and systems O&M.

\textsuperscript{21} Another community-based approach is taken by the \textit{iJal small water enterprise programme} in the village of Nizampalli in Warangal district, Andhra Pradesh, India (Safe Water Network 2010). The basic technical design of the system is the same as that of the CSWS, except that it utilizes reverse osmosis technology that is capable of treating the local fluoride-rich source water. It is also operated as a tripartite partnership, but unlike the CSWS, it takes more of a market-based approach and features greater private sector participation. NGOs facilitate a social mobilization program while private sector actors provide technology, technical training, and offer micro-credit financing for individuals and community groups who are interested in investing in and operating the safe water system on an entrepreneurial basis. These small businesses then sell 20 L containers of safe water to local residents from a central treatment facility (at a cost of Rs. 4 INR per 20 L, a rate substantially greater than that for the CSWS). The treatment facility also features a wash station at which consumers can wash their safe water storage containers before paying for a refill. The iJal program is part of an effort to demonstrate the viability of market-based approaches to safe water provision in rural areas. It is a business model similar to the many ‘water-cooler’ bottle water retailers that have proliferated in urban areas of the South, for instance, the \textit{isi-ulung} retail network in Jakarta, Indonesia that is described by Weimer (2006).
22.3.2 Financing/implementation approaches

The two levels of application differ with respect to the financing/implementation approaches they are amenable to. The self-contained nature of household level systems invites a market-based approach, and most PoU implementations have been done in this way. Generally, market-based approaches do not require collective community involvement, with most, if not all, of the costs borne by individual households. Though widely promoted, the sustainability of market-based approaches for household level systems is not uncontroversial (Harris 2005). Usage of PoU systems has been observed to decline once external supports are removed, as individual households may perceive costs to outweigh benefits (Luby et al. 2008). As costs are borne by individual households, a market-based approach may limit the accessibility to safe water for poorer socio-economic groups, though targeted subsidies and other external supports may be able remedy this.

Though market-based approaches have also been investigated for their suitability to community level systems, these offer the added advantage of being more amenable to collective action in community-based approaches. These may have the substantial advantage of increased accessibility for all socio-economic segments of the community. Many kinds of arrangements are possible with community level systems, bringing together NGO/CBO actors, local government, businesses, and local community-members.\(^{22}\) Oftentimes with community level systems, user fees are sought for capital recovery and maintenance costs; however, progressive fee structures can be adopted to ensure accessibility to lower-income groups. Initiating collective development efforts with marginalized populations is, however, challenging in its own right. There may also be considerable challenges in mobilizing support from the many diverse actors required.\(^{23}\) This is especially true in urban/peri-urban slums where there may be high population turnover and limited levels of existing social capital.\(^{24}\)

\(^{22}\) These can reduce the burden upon any one group—most importantly, upon individual households. This is an important factor to consider given the tendency of development initiatives, especially those that purport to be ‘participatory’, to overburden people from marginalized communities, particularly the women.

\(^{23}\) For instance, there is the risk of elite capture. Elite capture refers to the tendency of participatory processes to become dominated by local elites at the expense of poorer sections for whose benefit the participatory process was ostensibly started (Classen et al. 2008). This is discussed at greater length in section 2.3.4.5.

\(^{24}\) The concept of social capital is discussed in section 2.2.3.7.
2.2.3.3 Economies of scale
An additional point can be made with respect to the economics of safe water supply. Community level systems offer an extremely important advantage: they may be able to realize economies of scale that household systems cannot. With large-scale production of safe water, the cost per litre produced is substantially lower compared to that produced on a single-household basis. Previous evidence from the field suggests that cost is one of the most significant determinants for local sustainability of a safe water system (Luby et al. 2008; Harris 2005), making community level systems attractive in this respect.

2.2.3.4 Local governance
Another important dimension is how the two approaches relate to local governance. Governments are the primary agents of development in their respective jurisdictions and have a moral and political responsibility to the public for the provision of basic services such as safe water. Household level systems, especially when deployed in a market-based approach, devolves the responsibility of safe water provision to the individual household and abrogates this responsibility. On the other hand, community systems, by virtue of their semi-centralization, may be better able to involve local government in various kinds of partnerships, and thereby, reaffirm this responsibility. Moreover, community systems, more so than household systems, may also lend themselves to effective public monitoring to ensure a universal standard of water quality, whereas user compliance and other operational issues are perennial concerns with household systems (Luby et al. 2000).

2.2.3.5 Land tenure
In the particular case of slums and other informal settlements, one of the most significant factors affecting development is the legal/institutional matter of land tenure. Individuals without secure title to the land they inhabit are less likely to invest in its improvement, as lacking legal protections, they could be evicted without warning or opportunity for compensation (Joshi, Fawcett, and Mannan 2011; Sjostedt 2011; Davis 2006; Omambia 2010). In these settings, community level systems face challenges in two ways. On the implementation side, people may be less willing to invest scarce time and resources into a collective venture from which it is
unclear how much benefit they can derive. On the on-going O&M side, population turnover may lead to high levels of free-riding and other difficulties in collectively running the system. Household systems, compact and without infrastructure, may be more appropriate than community systems for application in slums or other places where land tenure is highly insecure.

2.2.3.6 Water treatment complexity

Though many of the available technologies can be applied at either level, some of the more complex ones cannot. The complexity of treatment can be greater with community systems, as semi-centralization may allow for (semi-)trained personnel to operate and maintain them or because the scale of the treatment process justifies the use of advanced technologies. This enables community systems to handle more challenging water quality concerns, such as heavy metals and other inorganic contaminants, and to treat water to a higher output quality. With respect to microbiological quality, there is an advantage for household systems in that they may face lower levels of recontamination risk as purification occurs closer to the time and place of consumption.

2.2.3.7 Social capital

Finally, technological systems are not inert but actively influence, and are influenced by, the social environment in which they exist (Franklin 1990). One of the most significant dimensions in which household and community level systems differ has to do with social capital. Krishna (2004) defines social capital as the quality of inter-personal relations within a well-defined social group (i.e. a community) that enables members of this group to undertake collective action toward a common, shared goal that yields mutual benefits. Grant (2001) also distinguishes

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25 In fact, Joshi, Fawcett, and Mannan (2011), in an ethnographic study of the urban poor across India, Bangladesh, Pakistan, and Kenya, found tenure security to be a key factor in creating an enabling environment in which poor urbanites could plan and design locally appropriate sanitation systems. Likewise, Sjöstedt (2011) conclude, from their comparative review of land policies and safe water coverage in Botswana and Zambia, that reforms to improve land tenure security are a prerequisite for improving access to safe water in both urban and rural areas.

26 This risk can and should be ameliorated in either household or community systems by distributing, storing, and dispensing water from safe water storage containers (Clasen and Bastable 2003). Safe storage containers have a narrow-mouth to prevent the insertion of foreign objects and materials. Stored water is extracted via a tap or valve at the base in order to limit the chances of recontamination.

27 Social capital is an abstract concept that is not directly observable; it is something, as Krishna (2004) describes, that “people carry it inside their heads.” According to Uphoff (2000), what can be measured are some of the manifestations or behavioural consequences of social capital, which include both structural and cognitive elements, referring respectively to the social network connections and the attitudes toward trust in a given community (Mitchell and Bossert 2007). Social capital can be broken down to five key dimensions (World Bank 2011): 1)
between the *horizontal* and *vertical* aspects of social capital wherein the former represents the relationships of social support between members of a community, family, or household, and the latter represents those between communities and institutions (i.e. government bodies). Social capital is one of the key determinants of whether a community can successfully cooperate on a community level water system (Kahkonen 2002). Whereas community systems require high levels of existing social capital, household systems do not necessarily, as they do not require collective action and mostly depend on the effort of individual households. Household level systems may be more appropriate in settings where social capital is lacking.

Community level systems can also act as a space, in both the social and physical sense, for community organization and action by facilitating communication and cooperation among community-members (Janakiram 2009). By building on existing social networks, norms, and interactions between users, and thereby reinforcing the tendency toward collective action, community level systems can also enrich the stock of social capital in the community (Kahkonen 2002). To put it more generally, community systems collectivize a shared response to a shared problem. In contrast, household systems individualize what are typically considered to be public goods: the degradation of the environment and public water supply.

One can speculate that this may have the effect of reducing the collective social and political impetus to protect the environment and public health on the grounds that, as the level of responsibility for the provision of safe drinking water is devolved to individual households, the collective responsibility for providing safe water to the public is undone. As a consequence, the poorest and most vulnerable

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*Groups and networks:* collections of individuals that promote and protect personal relationships which improve welfare.  
*Trust and solidarity:* elements of interpersonal behaviour which fosters greater cohesion and more robust collective action.  
*Collective action and cooperation:* the ability of people to work together toward resolving communal issues.  
*Social cohesion and inclusion:* mitigates the risk of conflict and promotes equitable access to benefits of development by enhancing participation of the marginalized.  
*Information and communication:* breaks down negative social capital and also enables positive social capital by improving access to information. These manifestations of social capital are socio-culturally determined and thus, locally unique. Therefore, measures of social capital that are socio-culturally appropriate to the local context are required (Krishna 2004).

Krishna, in his 2004 study on the comparative development performance of sixty-nine north Indian villages, found the combination of social capital and capable agency to be most closely associated with high development performance, compared to other prominent explanatory factors such as the degree of commercialization, modernization, and others.

Gleick et al. (2002) provide excellent definitions of ‘public’ and ‘private’ goods: “Private goods are those for which consumption (or use) by one person prevents consumption (or use) by another….Public goods are those that can be used by one person without diminishing the opportunity for use by others. Water-supply systems [and a healthy ambient environment] are public goods because, in most circumstances, delivery of water to one household does not prevent delivery of water to another household.”
tend to be those left without access. In this way, it is conceivable that household systems may
degrade social capital.

2.2.3.8 Summary of features of household and community level systems

The features of household and community level systems discussed in the preceding represent
their respective suitability to different contexts. The discussion above, and further related points,
are summarized in Table 2-3. This table is intended to help us think more clearly about the
situations in which household or community level systems may alternately be more appropriate.

Table 2-3 | Summary of features of household and community systems (modified from Ali 2010).

<table>
<thead>
<tr>
<th>DIMENSIONS (with pertinent questions given)</th>
<th>Application Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Household</td>
</tr>
<tr>
<td><strong>Technical Dimensions</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Treatment complexity</strong></td>
<td></td>
</tr>
<tr>
<td><em>Q: Are there water quality concerns that necessitate more complex treatment methods?</em></td>
<td>Water quality concerns must be simple and relatively straightforward to treat, as untrained lay-persons are operators at the household level. Only relatively basic water treatment techniques are applicable at the household level.</td>
</tr>
<tr>
<td><strong>Number of water supply sources</strong></td>
<td></td>
</tr>
<tr>
<td><em>Q: Does drinking water come from several sources?</em></td>
<td>Household systems can take input from a number of different water sources, however, treatment effectiveness may be affected.</td>
</tr>
<tr>
<td><strong>Recontamination risk</strong></td>
<td></td>
</tr>
<tr>
<td><em>Q: Is there ambient contamination in the community that increases the risk of recontamination of treated water?</em></td>
<td>Household systems may be preferable where there is considerable ambient contamination, as there are fewer opportunities for recontamination when treatment occurs closer in time and space to consumption. Safe storage is also critical for preventing recontamination.</td>
</tr>
</tbody>
</table>
| **Quality control and monitoring**  
Q: Is centralized water quality control and monitoring desired or mandated (by regulation)? | Centralized water quality control and monitoring is not feasible with household level systems. As a result, end-users may not be confident in the quality of their drinking water. Decentralized methods of water quality testing may be applied to improve end-user confidence, however, this may not satisfy regulatory requirements for central authorities to monitor and assure water quality (if they exist). | Centralized water quality control and monitoring is entirely feasible with community level systems. As such, community systems may be better suited for meeting central authority mandates to monitor and assure water quality. This may improve end-user confidence in water quality. A considerable risk however is that water quality is typically monitored at plant outlet and may not necessarily be representative of water quality at the point of consumption. |
| **Rate of deployment**  
Q: How quickly must the water treatment system become operational? | Household systems can be rapidly deployed as no construction or infrastructure is required, although some mobilization of local people and institutions may be necessary. | Community systems have a longer horizon to become operational as construction of facilities and infrastructure is required. Moreover, mobilization of local people and institutions may be more complex and slow-moving. |

| **Economic Dimensions** |
| **Availability of capital funding**  
Q: Is funding available (from community, government, NGO, and/or private sector sources) to support large up-front capital costs in the development of a safe water system? | Household systems may be preferable where start-up capital is limited as they have fewer up-front costs (due to the lack of infrastructure). | Community systems are only viable where start-up capital is sufficient to support the development of the necessary infrastructure. |
| **Availability of upkeep funding**  
Q: Is on-going funding available (from community, government, NGO, and/or private sector sources) for the O&M of a safe water system once it has been implemented? | Household systems require upkeep funding for consumables, replacement parts, and repairs of household units. For household systems, upkeep can be done on a collective or an individual basis, though the latter is more common when a market- or NGO-based approach is taken. | Community systems require upkeep funding for consumables, replacement parts, and repairs of infrastructure. Economies of scale typically make costs lower than with household systems. For community systems, upkeep can be supported on a collective or an individual basis, with the former typical of NGO/CBO-based approaches and the latter typical of market-based approaches. |

| **Economies of scale**  
Q: Does either level of application offer economies of scale? | No economies of scale possible with individual treatment at the household level. | Economies of scale are possible with water treatment en masse at the community level. |

| **Social and Political-Institutional Dimensions** |
| **Local capacities**<br>*Q: Which level of application is viable with the capacities available in the local community?* | Household systems are typically simple enough to be operated and maintained by lay-persons. As such, they do not demand many technical or managerial capacities from the local community aside from: a) widespread literacy; b) a basic level of education; and c) familiarity with technical tasks and devices. These enable the training of households in the use and maintenance of household devices. Additionally, demonstrated entrepreneurial/business capacities may be required for product distribution if a market-based approach is taken. | Community systems are complex pieces of technical and institutional infrastructure. They require that a number of technical and managerial capacities be present in the community including: a) plumbing; b) concrete work/masonry; c) electrical; d) community organizing; and e) entrepreneurial/business (in addition to those three basic capacities required for household systems). |

| **Propensity to collective action**(horizontal social capital)**10**<br>*Q: What is the propensity toward cooperation, cohesion, and collective action in the community?* | In situations where horizontal social capital is lacking, household systems may be preferable as they rely primarily on individual households taking care of themselves. | Where there is demonstrated cooperation and cohesion in the community (i.e. positive horizontal social capital), community systems may be feasible as they rely on collective action between community-members toward the common good. |

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30 It should be noted that the present work does not set out to ‘measure’ social capital per se. As its manifestations are socio-culturally determined, social capital lends itself more to customized indices for each application rather than universal metrics. Even if a universal metric was available, it would be highly suspect to ascribe a given ‘quantity’ of an abstract (and “definitionally chaotic”, as SOAS professor Ben Fine puts it) concept such as social capital as being indicative of either a household or community level safe water system—or any other development strategy for that matter (Fine 2007). Quantitatively measuring social capital, be it with a customized index or a universal metric, is, besides, something more of interest in comparative studies, which this is not. What was of interest here was developing a qualitative understanding of how well the community has been able to work together collectively in the past and may be able to do so in the future. The concept of social capital, and its applications in the literature, are useful insofar as they were able to guide the present work on what to investigate with respect to how well (or not) a community works together.
<table>
<thead>
<tr>
<th><strong>Relationships with local institutions (vertical social capital)</strong></th>
<th><strong>Fostering of social cohesion</strong></th>
<th><strong>Land tenure</strong></th>
<th><strong>Government development plans</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q: What is the nature and quality of the relationships between the community and local institutions (government, NGOs, private sector)? What of the relationships between institutions? Are effective partnerships with local institutions for a safe water system at either level of application possible?</td>
<td>Q: What social tendencies may either level of application engender?</td>
<td>Q: How secure is land tenure in the community?</td>
<td>Q: What are government development water supply plans for the community and do they conflict with either level of application?</td>
</tr>
<tr>
<td>In cases where: a) local government neglects or is unable to fulfil its responsibilities (i.e. a good governance deficit) and thereby has a strained relationship with the community; and/or b) local NGOs have a poor relationship with the community or are unable or unwilling to provide support, household systems may be more feasible as they can rely on individual households taking the initiative themselves. Though governmental/non-governmental support can help, it is not required as household water treatment products are often widely available on the market (in urban areas at least).</td>
<td>The household approach may reinforce individualistic behaviour, especially when undertaken through a market-based approach. There is some possibility for encouraging collective action if different kinds of partnerships with NGOs, businesses, community-members, and government are initiated.</td>
<td>Household systems are more feasible in places that have low tenure security as they are portable and do not require community mobilization for infrastructural development.</td>
<td>Household systems are not affected by government development plans as they are individual units that are located within each household. It should be noted however that household systems may reduce the political and social impetus to provide public goods however by displacing governmental responsibilities to provide safe water.</td>
</tr>
<tr>
<td>In cases where: a) local government fulfills its basic obligations and has a positive relationship with the community (i.e. good governance); and/or b) local NGOs have a positive relationship with the community and are willing and able to provide support, community systems may be possible as they often rely on governmental/non-governmental/private sector actors joining into different kinds of partnerships with the community.</td>
<td>Community systems both require and foster community cooperation. They reinforce the tendency toward collective action and positive social capital.</td>
<td>High tenure security is necessary for community systems. This is to assure community-members of a return when investing time, labour, or money in a collective endeavour to develop community infrastructure and organization. Substantial community mobilization may be required for this.</td>
<td>Community systems may conflict with government development plans. If the government is going to develop new water supply infrastructure in the near future, it may not be preferable to go to the considerable expense and effort of developing a community level system. Community systems, if they do not involve local authorities, risk displacing governmental responsibilities for the provision of safe water.</td>
</tr>
</tbody>
</table>
This table is the basis of the exploration into the appropriate level of application for a safe water system—that is, the first of the two key design questions that this decision-making support tool address (section 1.2). It is an attempt to provide a way of thinking critically about household and community level safe water systems based on previous experiences documented in the literature, and is not purported to be exhaustive. This table will be returned to in a later chapter.

### 2.2.4 Water treatment technologies

A wide range of water treatment technologies are available for application at the household and community level. A summary of water treatment technologies utilizing various physical and chemical operations/processes, and their performance with respect to a range of criteria, are given in Table 2-4 and Table 2-5 respectively.31

#### Table 2-4 | Water treatment technologies utilizing physical operations (modified from Sobsey 2002).

<table>
<thead>
<tr>
<th>TREATMENT TECHNOLOGY</th>
<th>CRITERIA</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Application Level (H or C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Availability &amp; Practicality</td>
<td>Technical Difficulty</td>
<td>Annual Cost Est. ($USD/household)</td>
<td>Microbial Efficacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiling with fuels</td>
<td>Varies</td>
<td>Low to moderate</td>
<td>Varies</td>
<td>&gt;99%</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>Exposure to sunlight (UV)</td>
<td>High (except during monsoon)</td>
<td>Low to moderate</td>
<td>&lt;$10</td>
<td>90% to 99%</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>UV lamp</td>
<td>Varies</td>
<td>Low to moderate</td>
<td>&gt;$10 to &gt;$100</td>
<td>&gt;99%</td>
<td></td>
<td>H and C</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>High</td>
<td>Low</td>
<td>&lt;$10</td>
<td>&lt;90%</td>
<td></td>
<td>H and C</td>
</tr>
<tr>
<td>Filtration</td>
<td>Varies</td>
<td>Low to moderate</td>
<td>Varies</td>
<td></td>
<td></td>
<td>H and C</td>
</tr>
<tr>
<td>Aeration</td>
<td>Moderate</td>
<td>Low</td>
<td>&lt;$10</td>
<td>&lt;90%</td>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

#### Table 2-5 | Water treatment technologies utilizing chemical processes (modified from Sobsey 2002).

<table>
<thead>
<tr>
<th>TREATMENT TECHNOLOGY</th>
<th>CRITERIA</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Application Level (H or C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Availability &amp; Practicality</td>
<td>Technical Difficulty</td>
<td>Annual Cost Est. ($USD/household)</td>
<td>Microbial Efficacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coagulation-Flocculation</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Varies</td>
<td></td>
<td></td>
<td>H and C</td>
</tr>
<tr>
<td>Adsorption (i.e. activated carbon)</td>
<td>High to moderate</td>
<td>Low to moderate</td>
<td>Varies</td>
<td>Varies w/ adsorbent</td>
<td></td>
<td>H and C</td>
</tr>
<tr>
<td>Ion exchange</td>
<td>Low to moderate</td>
<td>Moderate to high</td>
<td>&gt;$100</td>
<td>&lt;90% to 99%</td>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

31 Sobsey (2002) provides an exhaustive review of these technologies, so this will not be duplicated here. Additionally, Baffrey (2005) provides an excellent overview of several key HWTS technologies in the second chapter of his thesis.

32 H: household level system; and C: community level system.
Chlorination carries with it the risk of creating potentially carcinogenic disinfection by-products, such as trihalomethanes (THMs) (Viessman Jr. and Hammer 2004). It should be noted however, that the risks associated with faecal-oral pathogens far outweigh the slightly elevated population risk of cancer (Ashbolt 2004b; Havelaar et al. 2000).

In this paper, Sobsey et al. in fact go further to select ceramic filtration as “the best” possible option available—for anywhere in the world!—based on a general global analysis. This is discussed (and critiqued) in the next section (section 2.2.5).

Estimate of diarrhoeal disease percent reduction and associated 95% C.I.

Of these, Sobsey et al. (2008) identify five PoU technologies which have had been featured widely in field implementations and represent, in their opinion, the most viable options for scaling-up HWTS in the future (Table 2-6).³⁴

### Table 2-6 | Key PoU technologies and performance against key criteria (adapted from Sobsey et al. 2008).

<table>
<thead>
<tr>
<th>TREATMENT TECHNOLOGY</th>
<th>Microbial efficacy (log₁₀ reduction values)</th>
<th>Health impacts³⁵</th>
<th>Sustainability criteria (scored 1–3 for low to good performance)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Microbe class</td>
<td>Field</td>
<td>Lab</td>
</tr>
<tr>
<td>Chlorination with safe storage</td>
<td>Bacteria, Viruses, Protozoa</td>
<td>3</td>
<td>6+</td>
</tr>
<tr>
<td>Combined coagulant-chlorine disinfection</td>
<td>Bacteria, Viruses, Protozoa</td>
<td>2–4.5</td>
<td>9</td>
</tr>
<tr>
<td>SODIS (solar UV + thermal effects)</td>
<td>Bacteria, Viruses, Protozoa</td>
<td>3</td>
<td>5.5+</td>
</tr>
<tr>
<td>Ceramic filters</td>
<td>Bacteria, Viruses, Protozoa</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Biosand filters</td>
<td>Bacteria, Viruses, Protozoa</td>
<td>1</td>
<td>47% (21–64%)</td>
</tr>
</tbody>
</table>

---

³³ Chlorination carries with it the risk of creating potentially carcinogenic disinfection by-products, such as trihalomethanes (THMs) (Viessman Jr. and Hammer 2004). It should be noted however, that the risks associated with faecal-oral pathogens far outweigh the slightly elevated population risk of cancer (Ashbolt 2004b; Havelaar et al. 2000).

³⁴ In this paper, Sobsey et al. in fact go further to select ceramic filtration as “the best” possible option available—for anywhere in the world!—based on a general global analysis. This is discussed (and critiqued) in the next section (section 2.2.5).

³⁵ Estimate of diarrhoeal disease percent reduction and associated 95% C.I.
From the tables above, it can be seen that there are a range of technologies that can be applied at different levels and that vary a great deal with respect to their feasibility in different circumstances. How different technologies fit into different situations is a central theme of the present work; this aspect is captured in the second key design question given in section 1.2.

2.2.5 Present debates and research gaps

The primary research gap that the present work responds to is captured by a debate in the journal *Environmental Science and Technology* in 2008-9. To date, most reports of decentralized safe water systems in the literature—at both the household and community level—have featured water treatment technologies selected on an *a priori* basis by researchers primarily concerned with investigating their technical effectiveness or epidemiological impact in the field. However, to facilitate the expansion of safe water coverage, further investigation into matters relating to contextual appropriateness is required. Specifically, practitioners require tools to help guide the design of safe water systems that are appropriate to, and therefore sustainable within, unique local contexts.

A preliminary attempt at this was made by Sobsey et al. (2008). Sobsey et al. present a generalized, global analysis of five major PoU water treatment technologies. From this, the authors offer recommendations on what they believe to be the “most effective” PoU technologies—for any setting in the world. This approach is critiqued however by Lantagne et al. (2009) on the grounds that it is subject to bias due to vague and incomplete definitions of ranking system criteria; that it has scores assigned from insufficient evidence; and that it lacks key sustainability criteria including consumer preference, economic considerations, and local water quality. Lantagne et al. characterize the “silver bullet” approach taken by Sobsey et al. as “vague, potentially biased, [and] oversimplified”. Instead, Lantagne et al. argue that more complex decision-making tools for water treatment selection need to be developed that will enable practitioners to “select the most appropriate, cost-effective, and sustainable option for the local

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36 C.f. Sobsey et al. (2008), Lantagne et al. (2009), and Sobsey et al. (2009).
37 This critique by Lantagne et al. regarding the inappropriate “silver bullet” approach taken by Sobsey et al. resonates with the post-normal science critique of the generalizing tendencies of normal science, which is discussed later on in section 2.3.2.
circumstances” as “the needs of more than a billion people will necessitate a variety of HWTS technologies.” This is the central task of the present work.

This need has also been identified by other workers in the field. In analyzing ceramic and biosand filters with respect to appropriate technology criteria, Murphy (2010) finds there is no clear way to determine whether a given technology is appropriate or not in a generalized, global manner. Instead, she finds that determining which water treatment technology is most appropriate is an assessment that can only be made with reference to a specific context. She states that “the process for matching a technology to a particular water source is missing from current POU implementations” and advocates for the development of “tools to make better informed decisions”.

A thorough examination of existing decision-making support tools—with a view to the entire WASH sector—is conducted by Palaniappan, Lang, and Gleick (2008). Though their scope is much larger than that of the present work—going beyond safe water to also look at sanitation and hygiene projects—they similarly identify a presently unmet need for effective decision-making tools to facilitate the selection of appropriate technologies and approaches for all types of WASH projects. They argue that “efforts to address [the] water supply and sanitation shortfall have shown that no single technological solution, economic tool, or institutional structure can be applied to all populations” (emphasis theirs). Because of this, “practitioners need an effective decision-making support tool to assist them in identifying, evaluating, and choosing a technology or approach that best suits the conditions and needs of their community.” The authors define an ideal decision-making support tool for the WASH sector as:

“A product that combines information on a user’s given situation with information on available technologies and approaches, and then helps a practitioner select the

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38 The concept of appropriate technology is discussed at length in section 2.3.3.
39 Murphy also continues on to describe, in a preliminary manner, a flowchart for technology selection that could be further developed further as part of a robust tool. This is discussed further in section 2.2.6.
40 All in all, Palaniappan et al. envision a systemic approach to support global WASH efforts, of which a decision-making tool is but a component. They advocate for the development of a system that can address the “interconnected factors of water supply, drinking water treatment, sanitation, wastewater treatment, and hygiene” in which decision-making support tools are partnered with a global network of WASH practitioners supporting new efforts in their own regions and continuously updating databases and providing case studies of successes and failures. The scope of the project envisioned by Palaniappan et al. is much larger than that of the present work.
The importance of community involvement in the design and planning of safe water systems is also highlighted by this passage. This is discussed further in section 2.3.4.

The present work also contributes to another on-going debate in the literature, albeit in a less direct manner than the one just discussed. Though there has been a great deal of advocacy promoting decentralized safe water systems as a potential solution to the global safe water challenge (Sobsey 2002; Clasen 2009), this position is not uncontroversial. Today there is a major debate within the WASH community as to whether further research is required before HWTS safe water systems are scaled-up for widespread implementation.

With such an ideal in mind, Palaniappan et al. review the literature in order to identify critical gaps in the content, design, and implementation of existing decision-making support tools. Upon analyzing the available resources, the authors identify several gaps including: 1) Economics/cost: economic analyses for technologies were found to be consistently out-of-date or absent. 2) Financing: available resources did not compare the applicability of different financing mechanisms on the basis of the technology selected and the community’s institutional environment, local economy, or personal wealth. 3) Social implications of technology and financial choices (equity considerations): most existing resources did not give consideration to whether the choice of technology or financing scheme exacerbated or reduced existing inequalities along class, gender, age, and other lines, or how they influenced local control of resources, the end-user ability to pay, social cohesion, resource conflict and other social implications. 4) Regional specificity: decision-making tools should consider local factors including source water quality, institutional landscape, social structure, cultural practices and other specific contextual factors. 5) User interface: few existing resources had user-friendly interfaces that permitted practitioners to input information on local water quality, quantity, and contaminants as well as parameters relating to the demographic, environmental, institutional, and social characteristics of their community, and then presented feasible options in a clear and informative way. 6) Information access: resources should be made available in both electronic (computer/internet access) and hard copy formats in order to be as widely available as possible. Translation of the tool into local languages is also an important consideration. 7) Comprehensive WASH directory: a major outstanding need, to complement the decision-making support tool, is a worldwide database of WASH practitioners by region and expertise who are available to advise in specific locales. 8) Scalability and replicability: information must be provided on the conditions conducive to scaling up or replicating a particular technology or approach. 9) Evaluation and monitoring: information should be provided on a technology’s long-term effectiveness deriving from previous implementation experience in order to inform similar projects in similar locales. And finally: 10) Hygiene approaches: being highly sensitive to local cultural and educational norms, there is a dearth of documented experience on the effectiveness of different approaches to hygiene education and promotion. The tool developed in the present work aims to respond to at least some of these gaps.
Proponents of HWTS argue that they are ready to be scaled-up for widespread implementation (Clasen 2009). However, others contend that the evidence is not yet sufficient to justify widespread implementation and further investigation is required. Schmidt and Cairncross (2009a), in a critical review of the HWTS literature, suggest that the acceptability and scalability of HWTS is still unclear and that the significant heterogeneity among studies is cause for concern. They find that the typical diarrhoeal disease reductions of 30% to 40% associated with HWTS may be strongly biased, with current evidence not excluding the possibility that observed reductions are largely or entirely due to bias. They recommend further high quality health outcome and acceptability studies to build the evidence base prior to the widespread promotion of HWTS.

Clasen et al. (2009), in response to this critical review, suggest that the observed heterogeneity is due to highly variable exposure, prevention, intervention, compliance, methodological and other influencing factors in the study communities—all of which admittedly need to be better understood—but that this does not weaken the evidence for the effectiveness of HWTS. They recommend assessments of large-scale implementation programs in order to elucidate the determinants of uptake and effectiveness, better target interventions, and improve access. Schmidt and Cairncross (2009b) respond insisting that further studies investigating effectiveness and acceptability are necessary in order to clarify the doubts that arguably exist as “public health has a long and unfortunate history of scaling up well-intended interventions that after rigorous evaluation at a later stage had to be abandoned.” Understanding user preference and acceptability, scalability and replication, as well as factors contributing to heterogeneity remain significant gaps in the field today, giving rise to considerable debate. The present study will contribute to these questions by exploring the appropriateness of various water treatment technologies in a marginalized peri-urban setting in India.

With this section having looked to the need for complex decision-making support tools for the selection of appropriate water treatment technologies, the next section will briefly review the previous work that has been done in this vein. This review of previous work informs the development of the present decision-making tool.
2.2.6 Review of previous decision-making support tools

It is on a foundation laid by many researchers and practitioners in the WASH sector that the present work ventures to build a decision-making support tool for appropriate safe water systems development. Previous works run the gamut from simple technology comparison arrays through to complex multi-factor analyses. A critical review of these previous works was undertaken in order to inform the present development. The works reviewed are identified in Table 2-7. In-depth critical appraisals of these tools are included in the appendices (Appendix A).

<table>
<thead>
<tr>
<th>AUTHOR &amp; DATE</th>
<th>TOOL TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sobsey et al. (2008)</td>
<td>Comparison array</td>
</tr>
<tr>
<td>BORDA Indonesia (2006)</td>
<td>Informed choice catalogue</td>
</tr>
<tr>
<td>Brikke and Bredero (2003)</td>
<td>Comparison array with informed choice catalogue (for water supply options)</td>
</tr>
<tr>
<td>Baffrey (2005)</td>
<td>Multi-factor analysis</td>
</tr>
<tr>
<td>EAWAG (2009)</td>
<td>Multi-factor analysis (for sanitation system alternatives)</td>
</tr>
<tr>
<td>Finney and Greenheart (2005)</td>
<td>Multi-factor analysis computer program (for water and wastewater treatment options)</td>
</tr>
<tr>
<td>Murphy (2010)</td>
<td>Flowchart with comparison array (for technology selection based on water quality)</td>
</tr>
</tbody>
</table>

Comparison arrays represent the simplest available approach for decision-making support on selecting appropriate water treatment technologies. Generally, a comparison array is simply a chart or table featuring several technologies characterized against relevant criteria. This arrangement allows for ease of comparison between alternatives. It is exemplified by the work of Sobsey et al. (2008) that was discussed (and critiqued) in section 2.2.5. As comparison arrays do not feature an explicit model (i.e. an evaluation or a matrix weighting array) to find the intersection of technology performance and the relative importance of various performance criteria, the decision-making process embodied in them is non-transparent and subject to bias, as Lantagne et al. (2009) point out. The tool put forward by Sobsey et al. can also be critiqued for being non-participatory and entirely expert-driven; not having a clear and comprehensive ranking system for performance data; drawing on insufficient evidence to characterize performance; gives no consideration to local consumer preferences, environmental factors (i.e. water quality is not considered), social implications or equity factors; has no user interface as it is a generalized, global analysis outputting only one solution for the whole world; incorporates
little information on previous applications of technologies; and only considers safe water systems at the household level.

Similar to comparison arrays are informed choice catalogues. In essence, informed choice catalogues (ICC) are a form of comparison array adapted for public presentation and sharing. They are an excellent tool for bottom-up planning as they can succinctly and rapidly communicate basic, relevant information on the main features, strengths and drawbacks, and risks of various technological options to an array of stakeholders, including lay-persons. An ICC is typically structured as a ‘technology sheet’ which outlines the basic design and function of the technology in question, followed by an ‘evaluation sheet’ in which the technology option is assessed according to various criteria of interest (i.e. cost, ease of use, capacity, etc.). Though not necessarily always the case, assessment is usually highly simplified (i.e. with +ve or –ve type rankings only) so as to clearly and unequivocally communicate the main points to lay-users; with this however, important caveats are lost. The ICC approach can promote the emergence of an informed debate amongst participants on what viable options could be for their community, and as such, can encourage truly participatory decision-making (BORDA Indonesia 2006). Weimer (2006), in an USAID-sponsored project in underprivileged urban communities in Jakarta, Indonesia, provides an excellent example of informed choice catalogues and comparison arrays being used in conjunction for the participatory selection of appropriate PoU water treatment technologies. Weimer’s work provides an excellent example of how to make household water treatment decisions more participatory. As with the previous example of a comparison array, the work doesn’t feature an explicit model to find the intersection between different informational inputs however. Moreover, the tool does not feature scores assigned on the basis of previous implementations, but rather on reasoned arguments specific to the case study site; it does not feature explicitly a site to include local peoples’ preferences; it is limited to only considering microbiological contamination; it does not consider social implications or equity factors; it does not include a user interface nor does it provide information on scaling up or replicating technologies; and it only considers systems at the household level. A more thorough process-oriented approach on expanding safe water options integrating comparison arrays and informed choice catalogues is offered by Brikké and Bredero (2003), but this is not a fully developed tool
per se, but rather just an outline of how participatory safe water systems development should proceed. This work does however serve to guide the present decision-making support tool.

More complex approaches to safe water systems development are presented by the multi-factor analyses that have been previously developed. A key example here is the selection tool developed by Baffrey (2005). Importantly, multi-factor analyses are geared towards creating an explicit, transparent model of how the intersection point between different informational inputs is found. Baffrey makes the disclaimer that the tool is but a prototype, and there are significant gaps that need to be improved upon including:

• It is limited to only household level systems, and does not give any consideration to the possibility of community level systems.

• Though Baffrey states that it is designed to be participatory in process, he simultaneously acknowledges that his approach is “expert-driven”, in that the selection of relevant criteria, the preference for various criteria as defined by their weightings, and the assignment of performance scores for each technological alternative remain in the purview of a single assessor, most likely an external ‘expert’. He suggests that this problem can be ameliorated by incorporating the perspectives of multiple stakeholders, but does not propose a method by which to do this, nor does he follow through with the suggestion in his own case study applications.

• Similarly, he also claims that the tool is designed to be transparent in its assumptions and straightforward in its design—so as to allow modifications (and indeed modifications may well be required as the assumptions he makes are highly site specific)—but he does not propose any methods by which local, contextual information could be gathered in a participatory way in order to modify the assumptions he has made and which determine the outcomes so strongly. The role of local stakeholders is simply to furnish input data regarding local conditions. Specific participatory methods need to be stipulated and built into a tool so that valid and representative local information can be gathered at any site of implementation.

• The deterministic outcome, with the ‘best’ technology indicated by a ‘high score’, is cause for some concern, bringing to mind the “silver bullet” critique from earlier discussion on post-normal science (section 2.3.2). As Murphy (2010) says “a prescriptive
tool has the danger of allowing the user to ‘bypass’ detailed examination of issues such as technology delivery mechanisms, subsidy, sustainability, user feedback and perceptions.” Does arriving at a discrete number do justice to a complex, uncertain, and ethically significant matter such as the provision of safe water to marginalized communities? It would be more in line with the precepts of post-normal science to pursue an approach that facilitates the emergence of dialogue between different groups of stakeholders on what is a desirable strategy for action, its challenges and its opportunities.

- Baffrey attempts to include too many considerations into a single point-scoring matrix system, whereas some criteria are really more akin to on/off switches (i.e. will work/will not work) rather than contributors of a certain limited number of points. Such concerns may be better addressed to a logic model such as a flowchart, or as a point of concern in a group discussion. These may be more appropriate strategies than a multi-factor analysis when dealing with criteria that could represent certain system failure in some cases.

- Baffrey acknowledges that multi-factor analysis is susceptible to distortion via the “halo effect” wherein an excessively high or low score in a single factor can overwhelmingly detract from the overall score for a particular alternative. To remedy this he suggests that a “cursory analysis” be pursued but does not elaborate on what this might entail. There are a range of distortive possibilities with ranking systems that are discussed further in section 3.4.4.

- Several of the site-specific criteria he utilizes are superfluous in that they reflect no real variation between all possible alternatives and are then uninformative (e.g. occurrence of disease).

- Baffrey utilizes technology-specific criteria in sets unique to each technology in question. On closer inspection, these reflect broader concerns which could be better expressed as general criteria applicable to all possible technologies, in order to streamline what is otherwise a somewhat ‘clunky’ process, so to speak.

- The numbers-driven approach taken by Baffrey may serve to curtail engagement with local community-members on desired outcomes, necessary tradeoffs, and preferred solutions, critical matters that are perhaps better handled through open discussion (in fact, much to the contrary, he claims that the tool only requires 30 minutes to generate an ‘answer’!)
With respect to consumer preferences, there is some limited consideration of factors relating to willingness to pay, but not much else. Baffrey acknowledges, but then excludes, some criteria (what he calls “applicability criteria”) which include important considerations such as user-friendliness, maintenance complexity, etc. He suggests these should be included in future developments on decision-making support tools.

- Only considers microbiological contamination and not chemical contaminants.
- Only considered systems at the household level.

The work by Baffrey strongly guides the present work, both in terms of what it does well, and by exemplifying the ways in which a decision-making support tool could be more effective.

Another example of a multi-factor analysis is the WAWTTAR program developed by Finney and Greenheart (2005). Though this work is aimed at selecting water and wastewater treatment system options, it does offer some important guidance as well. However, it too has some shortcomings that the present work aims to respond to including: it does not offer a place for the involvement of local community-members and is entirely expert-driven; it does not consider consumer preferences, social implications, or equity considerations; and it is a computer program that is only usable by trained experts. Similarly, the Wastewater Infrastructure Systems Decision Matrix (or the ‘WISDOM’ project) from the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) also offers some guidance on how to structure a multiple-criteria group decision making problem on appropriate technology, however, it is still in its inception stages and not yet developed (EAWAG 2009). Its basic structure does however offer some guidance on factors that are important for the present work.

The final class of tools reviewed were flowcharts, of which the preliminary development by Murphy (2010) is an illustrative example. This work offers guidance on the types of tasks that a flowchart is well-suited for, and for which tasks it is not. Its shortcomings point out important points of improvement for the present decision-making support tool including. For instance, it has no space for end-user involvement and is entirely expert-driven; and, as it has no ranking of technologies, decision-making is ultimately non-transparent and implicit. This work is just a preliminary sketch, but serves to guide the design of the technology feasibility flowchart.
presented in section 3.4.2. Further details and critical assessments for each of these tools are available in Appendix A.

Now that the previous decision-making support tools have been reviewed, some comments can be made on how the present decision-making support tool advances the state of the field:

- Instead of limiting the present development to a single tool type, a more articulated and comprehensive approach would be to integrate different tool types to meet the various goals subsumed in the larger task of appropriate safe water systems development. The present decision-making support tool deploys different tool types to accomplish the various tasks of safe water systems design.
- The present support tool considers both household and community level safe water systems.
- It features an explicit additive model in the form of a matrix-weighting array to make the integration of technology performance data and appropriate technology criteria preference data transparent. Bias can be observed and tested in the decision-model via sensitivity analyses.
- It centres local people in the development process, positioning them as the ultimate decision-making authority. Various informational inputs are participatory, creating opportunities for local stakeholder leadership. It details specific methods by which to pursue participatory development and deeply involve local peoples in investigatory and decision-making processes. It is designed to not be a ‘black box’, rather, focusing on engagement with local community-members on desired outcomes, necessary tradeoffs, and preferred solutions—critical matters that are better handled through open discussion.
- It has a clear and comprehensive ranking system for technology performance data.
- It draws on previous experiences in the literature to drive appropriate technology selection.
- It centres consumer preferences in the process, as well as gives consideration to social implications of technology and equity factors.
- Local water quality is an important controlling input in the present support tool. It considers water quality issues that are prominent with surface water sources in the developing world including excessive turbidity, organics, and microbiological
contamination, but also includes consideration of important chemical water quality parameters including iron, manganese, pH, fluoride, nitrate, and others that are relevant for both surface and ground water sources.

- It can be scaled up as an accessible online platform with a user-friendly interface to encourage usage. This online platform can also tie into and build up databases that will make future applications all the more informed by experience.
- The tool has been designed to be as open-ended as possible so as to facilitate adaptation to unique local circumstances.
- The tool is designed to generate a ranked list of recommendations that can then feed into subsequent participatory processes instead of generating a deterministic outcome.
- The tool is built around two sets of dimensions/criteria on a) the factors affecting the relative contextual appropriateness of household and community level systems; and b) factors relating to appropriate technology. Both of these have been drawn from an exhaustive review of monitoring and evaluation studies of previous safe water applications, studies of consumer preferences, previous decision-making tools, and other sources. These two sets of criteria develop a comprehensive taxonomy on appropriate safe water technology.

In all of the ways identified above, the present work advances the state of the field. In developing a decision-making support tool that addresses many of the gaps with previous support tools, the present work has the potential to go far in facilitating appropriate safe water systems development in the real world.

To summarize, this section has explored decentralized safe water systems as an alternative to the standard approach of centralized systems and as a means to address the global safe water challenge. It looked at household and community level approaches to safe water provision and the ways in which they differ. Next, it offered a brief overview of some water treatment technologies that could be part of a decentralized safe water system. Current research gaps and debates that the present work aims to address were identified and elaborated upon. Finally, an overview of previous decision-making support tools was carried out in order to inform and guide the present development. With the core problem that this dissertation addresses now fully
articulated, the next section moves on to look at the theoretical and methodological approaches deployed to address it.

2.3 Theoretical and methodological background

The first two sections of this chapter have defined the central problem of the present work, a potential means of addressing it, and the core research gaps that need to be addressed. This section now moves on to discuss the theoretical and methodological traditions that were drawn upon to address the core problem in the present work. The present decision-making support tool weaves together several methodological and theoretical strands including humanitarian engineering, post-normal science, appropriate technology, participatory development, grounded theory, and engineering decision-making. As will be seen in Chapter 3, the principles and precepts from these methodological and theoretical bases were drawn upon to inform various aspects of the tool’s methodology.

2.3.1 Humanitarian engineering

The present work aims to contribute to the emerging discourse on humanitarian engineering by building upon the foundations laid by VanderSteen (2008), Miller (2008) and Mushtaq (2011) of Dr. Kevin Hall’s Humanitarian Engineering Group at Queen’s University in Kingston, Ontario, Canada.

VanderSteen (2008), in his PhD dissertation on humanitarian engineering in the engineering curriculum, defines humanitarian engineering as:

“...the application of engineering skills specifically for meeting the basic needs of all people, while at the same time promoting human (societal and cultural) development. It involves making the social consequences of technology the key constraint in the design procedure.”

VanderSteen elaborates on the concept by proposing ten basic premises for humanitarian engineering:

- **Premise 1**: Humanitarian Engineering is not a sub-discipline in itself but a philosophy that must infiltrate all engineering and must encourage work with other disciplines.
• *Premise 2:* Not all problems require technical solutions; technology can only go so far.

• *Premise 3:* The right answer is often difficult to determine, but sometimes it is the discussion that is critical.

• *Premise 4:* Awareness without action is meaningless, and action without awareness is dangerous.

• *Premise 5:* Technology and tools are cultural entities, just like music and dress.

• *Premise 6:* The goal cannot be to make the world more like us. Development must mean change for everyone.

• *Premise 7:* It is patronizing and dangerous to think that we know what is best when we do not understand a culture. Cross-cultural work requires deep commitment, immersion, flexibility, and humility, and must be seen as a privilege.

• *Premise 8:* While specialization is rewarded in society, many of our complex problems require interdisciplinary thinking.

• *Premise 9:* Many cultures are stuck in a difficult place where traditional ways are cherished, but the globalized world promises opportunity and wealth.

• *Premise 10:* We are better suited to address the marginalized in our own community, although it is always easier to see the needs of an outside populace.

All of VanderSteen’s premises are important and influence the present work, but one is particularly revealing and deserves special attention. The fourth premise (“awareness without action is meaningless, and action without awareness is dangerous”) highlights an important tension in humanitarian engineering. Humanitarian engineering can be conceived as being composed of two elements:

1. A politicized systemic **critique** of standard engineering approaches focused on social justice and structural change; and

2. Pragmatic on-the-ground **practice** to design and implement solutions for presently unmet needs, and for the relief of suffering driven by the humanitarian imperative.

All humanitarian engineering initiatives should embody both elements—that is, they should be practical efforts to achieve real impacts “on the ground”, while also embodying a critique of
standard approaches that may no longer be effective. Individual efforts may place at different points along a continuum between the two poles, but all humanitarian engineering initiatives should contain aspects of both.

From VanderSteen’s premises, it can be seen that humanitarian engineering is indeed a philosophy running throughout all engineering practice, rather than another discipline of engineering. As such it requires deep changes in the way engineering is done. Miller (2008), in his work on reforming engineering curriculum, highlights the attitudinal shift necessary for humanitarian engineering, identifying humility, appreciation, and cooperation as core attitudes when he states that humanitarian engineering encourages engineers to “apply their skills with a greater sense of humility through a holistic, socially and environmentally conscious approach.” Mushtaq (2011), in his theoretical work on socially just engineering, identifies the ways in which traditional engineering approaches, mobilized to serve those at the “center of knowledge, power, and wealth”, may act to deepen social and environmental inequity by utilizing exploitative social, political, and economic methods that marginalize certain types of knowledge, people, and cultures. He identifies humanitarian engineering as a reformist subculture within engineering that seeks to not only minimize this damage but to create more equity. Mushtaq finds that much has been already been written about changing engineering curriculum, but little has been written about how engineers may actually design technology that values and advances the knowledge, people, and culture at the margins. Mushtaq builds on the curriculum reform work of Miller and VanderSteen and articulates an engineering design theory, predicated on power and resistance, that integrates alternative design methods including participatory, eco-feminist, deep ecological, and decolonized design that resist oppressive structures. The work of VanderSteen, Miller, and Mushtaq are important predecessors to the present work and influence the methodology developed here. All three works constituted critiques of traditional engineering—with VanderSteen and Miller focused on reforming engineering education and Mushtaq focused on promulgating a theory of socially just engineering practice. The present work builds on these theoretical contributions in attempting to apply the concept of humanitarian engineering in the

42 He also identifies peace engineering, socially just engineering, and social justice and engineering as engineering subcultures with a similar reform agenda.
real world. As such, the present work places more toward the *practice* side of the humanitarian engineering spectrum, whereas the previous works placed more toward the *critique* side.

### 2.3.2 Post-normal science

In the face of global challenges that are as unprecedented in their gravity as they are in their complexity, the practice of science is changing. Funtowicz and Ravetz (1993) argue that the science that has formed the core of modern industrial society up to the present—an analytical, reductionist science—is fast becoming obsolete in the face of the fundamental uncertainties inherent to current global challenges concerning human society and the environment, challenges such as climate change or the global safe water challenge. In its place, a new practice of science is emerging, what they refer to as *post-normal science*.\(^{43}\) This section explores this concept and examines how it relates to the present work.

In contrast to normal science, post-normal science is “based upon assumptions of unpredictability, incomplete control, and a plurality of legitimate perspectives.” Funtowicz and Ravetz (1993) elaborate:

“In [post-normal science], uncertainty is not banished but is managed, and values are not presupposed but are made explicit. The model for scientific argument is not a formalized deduction but an interactive dialogue. The paradigmatic science is no longer one in which location (in time and place) and process are irrelevant to explanations.”

Post-normal science thus seeks to produce specific and contextualized outcomes instead of the generalized and abstract ones predominant in normal science. Post-normal scientific practice is an exchange between the different members of society affected by a specific issue, instead of a prescriptive practice carried out by technocratic actors for the ostensible betterment of the silent ‘clients’ that comprise the rest of society. Its outcome cannot then be a discrete deduction

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\(^{43}\) ‘Post-normal’ refers to the concept of ‘normal science’ used by Kuhn (1962). For Kuhn, ‘normal science’ refers to that period of routine scientific exploration between major scientific revolutions when uncertainties are managed, fundamental assumptions are unquestioned, and values are implicit. ‘Post-normal science’ emerges then when these values, assumptions, and uncertainties become destabilized in the vicinity of a scientific revolution (Funtowicz and Ravetz 1993).
resolved via the application of static procedures; rather, it must result in the emergence of unique solutions, weighed for their strengths and drawbacks on the scales of public debate.

Funtowicz and Ravetz (1993) see post-normal science becoming inevitable as nature “reinvade[s] the lab”, that is, as the modern global scientific-industrial project, by virtue of its sheer immensity, collides with nature and manifests its inherent contradictions. In such a scenario, decision stakes and system uncertainties both run high. The former refers to “all the various costs, benefits, and value commitments that are involved in the issue through the various stakeholders” and the latter refers to the difficulty in “the comprehension or management of an inherently complex reality.” When these are the prevailing conditions:

“…the term ‘problem’, with its connotations of an exercise where a defined methodology is likely to lead to a clear solution, is less appropriate. We would be misled if we retained the image of a process where true scientific facts simply determine the correct policy conclusions. However, the new challenges do not render traditional science irrelevant; the task is to choose the appropriate kinds of problem-solving strategies for each particular case.”

The deterministic outputs of normal scientific practice are seen to be less valid under conditions of uncertainty, but that is not to say that the analytical problem-solving strategies of normal science are dispensed with entirely in the post-normal scientific approach. At lower levels of uncertainty and decision stakes, normal scientific practices can still be applied to yield useful insights for further consideration with more complex post-normal scientific practices.

Two post-normal scientific practices are proposed by Funtowicz and Ravetz (1993) to specifically handle the decision stakes and high levels of uncertainty that make post-normal science necessary. Under the latter condition, assessing and communicating the uncertainty of scientific information to stakeholders in a clear and intelligible manner is necessary. To this end, they propose a standardized system of notations called NUSAP for expressing the kind and degree of uncertainty in a transparent and accessible manner (Funtowicz and Ravetz 1990). For

44 NUSAP is an acronym for the categories of uncertainty that are encountered in mature experimental science where: N stands for numeral; U, unit; S, spread; A, assessment; and P, Pedigree. For further details on the NUSAP system, please refer to Ravetz and Funtowicz (2002). The NUSAP system is geared toward problems where the “data on their effects, and even data for baselines of ‘undisturbed’ systems, are radically inadequate,” for instance, in
the former condition—that of significant decision stakes—Funtowicz and Ravetz (1993) propose another post-normal scientific practice. They argue that, today, scientific expertise is a prerequisite credential for involvement in public decision-making and with this a great deal traditional and local knowledge is systematically marginalized. Thus, post-normal science seeks to undo the total domination of other systems of knowledge by the “subject-specialism” of normal science, and draw them into the process via an extended peer community:

“When problems lack neat solutions, when environmental and ethical aspects of the issues are prominent, when the phenomena themselves are ambiguous, and when all research techniques are open to methodological criticism, then the debates on quality are not enhanced by the exclusion of all but the specialist researchers and official experts. The extension of the peer community is then not merely an ethical or political act; it can positively enrich the processes of scientific investigation. Knowledge of local conditions may determine which data are strong and relevant, and can also help to define policy problems...Those whose lives and livelihood depend on the solution of the problems will have a keen awareness of how the general principles are realized in their ‘back yards’. They will also have ‘extended facts’, including anecdotes, informal surveys, and official information published by unofficial means.”

Members of local communities, once spurned by ‘expert-driven’ decision-making processes, become central to decision-making in post-normal science though the application of extended peer communities.

The sorts of challenges that populate the terrain of post-normal science and that make it necessary are known as wicked problems. Verhagen, Butterworth, and Morris (2008), following after Rittel and Webber (1973), define wicked problems as having “incomplete, contradictory, and changing requirements; and solutions to them are often difficult to recognize as such because of complex interdependencies”. Wicked problems have several characteristics including:

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modelling complex ecological or economic systems. The NUSAP system allows practitioners to communicate to a wide range of stakeholders the quality of predictions and the information upon which they are based (Funtowicz and Ravetz 1990).
There is no definite formulation of a wicked problem and every problem is essentially unique and dynamic. Solutions cannot be simply replicated but need to be reinvestigated and adapted for each specific situation.

There is no stopping rule and therefore one can always improve the solution.

Solutions are often inventive or creative and require a ‘group effort’.

Perfect solutions do not exist—they are not true or false but rather more or less suitable for a specific problem.

The view on problems and their solutions is subjective and context dependent. Different stakeholders hold different viewpoints and preferences and this makes it problematic to judge the quality of the solution.

Wicked problems can never be completely solved. They can only be improved.

Wicked problems are thus those complex and dynamic challenges that confound normal science. Verhagen, Butterworth, and Morris (2008) identify the challenge that the present work is focused on—safe water supply in marginalized communities—as exactly one of those wicked problems that demand a post-normal scientific approach. Addressing a wicked problem such as the present challenge requires, as Kelly and Farahbakhsh (2008) describe, “avoiding the conventional one size fits all ‘silver bullet’ solution to controversial and complex environmental issues.” Solutions to wicked problems are unique and varied, and emerge when the “boundaries between scientists and practitioners and outsiders and insiders [are] softened” through the application of participatory methods (Verhagen, Butterworth, and Morris 2008).

As the challenge of safe water supply in marginalized communities can be described as a wicked problem, it follows that addressing it requires moving beyond normal science into the realm of post-normal science. This entails several methodological demands upon the present work:

- The present work seeks to move away from a formalized deduction and toward an interactive dialogue between a range of stakeholders. In order to acknowledge a plurality of legitimate perspectives and embody the concept of extended peer communities, a participatory approach that centres local community-members in the research process is

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45 This resonates with the concept of extended peer communities put forward by Funtowicz and Ravetz (1993).
adopted. The present work thus accepts unpredictability and incomplete control as part of the practice of post-normal science.

- The present work acknowledges that context—time and place—are relevant to explanations and solutions. As such, the present work draws on the principles of *grounded theory*.
- Moreover, there are no right or wrong answers, just more or less suitable ones with respect to the unique local context. Potential solutions ought to be specific and contextualized, and as such, the concept of *appropriate technology* figures prominently in the present work.
- Potential solutions should emerge more from a weighing of positives and negatives on the scales of public debate rather than from a deterministic and discrete deduction. As such, the present work aims to blend traditional *engineering decision-making* approaches with more participatory methods.

The following sections will explore these methodological and theoretical strands and build up the foundation for the present decision-making support tool.

### 2.3.3 *Appropriate technology*

The concept of appropriate technology figures prominently in the present work. This section aims to understand it and elaborate on how the concept is applied with respect to the core challenge of the present work. The development of a suite of appropriate technology criteria for safe water systems is the main output here.

Starting in the 1960s and through the 1970s, with the failure of many large-scale development projects aimed at ‘modernizing’ industry and infrastructure in newly independent post-colonial nations, critical voices began to emerge on technology and its application in the international development sector. The idea that technologies and approaches from the industrially advanced North could be successfully dropped—as is—into entirely different contexts in the underdeveloped South began to be questioned and an idea of technology that is ‘appropriate’ to its context began to emerge. This concept was first popularized by E. F. Schumacher in his

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46 In the present work, NUSAP is not adopted as the particular kind of uncertainty that it aims to address is not a concern at the scale that the present work operates at.
seminal book, *Small is Beautiful* (1973). In it, Schumacher argues that what we see of any technology in operation is only the “tip of the iceberg”; beneath it are an array of systems—from institutional to financial to educational—that support its operation. If these foundational components are not in place, then a technology cannot be sustained. In other words, the technology would not be appropriate for the context in which it is applied and, as a consequence, will inevitably fail.

Since then, the concept of appropriate technology has been defined and debated endlessly. It has undergone considerable evolution, moving from tightly-defined prescriptions for technology to more fluid concepts as an engineering design philosophy. Murphy, McBean, and Farahbakhsh (2009), building on these debates, outline what they see to be the basic characteristics of appropriate technology today in the WASH sector:

“[Appropriate technology] is always context specific and depends on the local circumstances in which it is applied… [It] is a strategy that enables men and women to rise out of poverty and increase their economic situation by meeting their basic needs, through developing their own skills and capabilities while making use of their available resources in an environmentally sustainable manner. The [appropriate technology] concept incorporates both ‘hard’ and ‘soft’ aspects of technology, meaning not only the physical tools, but the knowledge transfer mechanisms, capacity building and communication methods as well as social, cultural, and gender implications of technology implementation.”

Appropriate safe water systems, having the general characteristics described above, are the desired output sought from the application of the decision-making support tool developed in the present work.

Assessing technology options for their performance with respect to appropriate technology criteria is central to the second key design question (section 1.2). There are a number of studies that discuss the contextual appropriateness of safe water technologies from which appropriate technology criteria are drawn for the present work (Table 2-8).

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47 For an excellent overview of the evolution of the concept of appropriate technology, please refer to Murphy, McBean, and Farahbakhsh (2009) or VanderSteen (2008).
Table 2-8 | Literature on appropriate safe water technology informing criteria development.

<table>
<thead>
<tr>
<th>AUTHOR &amp; DATE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sobsey et al. (2008)</td>
<td>General analysis for identifying the ‘best’ technology from amongst five prominent PoU water treatment technologies.</td>
</tr>
<tr>
<td>Lantagne et al. (2009)</td>
<td>Critique of the general analysis by Sobsey et al. (2008) which identifies criteria that they either entirely missed or were inadequately treated.</td>
</tr>
<tr>
<td>Murphy, McBean, and Farahbakhsh (2009)</td>
<td>Discussion on appropriate technology in the WASH sector.</td>
</tr>
<tr>
<td>Ali (2010)</td>
<td>Exploration of alternative approaches for safe water provision appropriate to the context of urban and peri-urban slums in the South.</td>
</tr>
<tr>
<td>DeWilde et al. (2008)</td>
<td>Case study application in rural Mexico of a framework for evaluating the long-term performance of community level safe water systems, which identified the ability of a safe water system to meet user preferences—primarily convenience—as being the greatest determinant of systems uptake and local sustainability.</td>
</tr>
<tr>
<td>Palaniappan, Lang, and Gleick (2008)</td>
<td>Critical review of existing decision-making support tools in the WASH sector which identified several gaps that existing resources failed to adequately address.</td>
</tr>
<tr>
<td>Weimer (2006)</td>
<td>USAID-sponsored action research project examining performance and end-user preference of different PoU water treatment options in a low-income urban households in Jakarta, Indonesia.</td>
</tr>
<tr>
<td>Harris (2005)</td>
<td>Study on the challenges facing the commercial viability of PoU water treatment systems in low-income settings.</td>
</tr>
<tr>
<td>PATH (2008; 2011)</td>
<td>Multi-year end-user testing study of several HWTS products available on the market in urban, peri-urban and rural Andhra Pradesh, India examining user preferences and product feedback, and ultimately offering recommendations for product design and marketing/scaling-up strategies.</td>
</tr>
<tr>
<td>Brikké and Bredero (2003)</td>
<td>Guidance document from the WHO on linking technology choice with operation and maintenance requirements for community water supply and sanitation projects.</td>
</tr>
<tr>
<td>Baffrey (2005)</td>
<td>HWTS technology selection tool developed for, and implemented in, the Kenyan context.</td>
</tr>
<tr>
<td>Figueroa and Kincaid (2010)</td>
<td>Report reviewing previous experiences of HWTS around the world to identify its social, cultural, and behavioural correlates.</td>
</tr>
</tbody>
</table>

Table 2-9 presents the appropriate technology criteria utilized in the present decision-making support tool.
Table 2-9 | Definition and explanation of appropriate technology criteria for assessing technological alternatives.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>FACTORS TO CONSIDER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>End-user preference criteria</strong></td>
<td></td>
</tr>
<tr>
<td>Costs (capital)</td>
<td>Initial capital cost of unit less any start-up subsidy that may be locally available, on a per-household basis.</td>
</tr>
<tr>
<td>Costs (on-going)</td>
<td>Cumulative annual sum of recurring costs (including consumables/chemicals, labour costs, or replacement parts) less any long-term subsidy that may be locally available, on a per-household annual consumption basis.</td>
</tr>
<tr>
<td>Health impact</td>
<td>How effective is the alternative at controlling diarrhoeal disease?</td>
</tr>
</tbody>
</table>
| Ease of use/difficulty                                | How technically easy or difficult is the alternative to use and maintain? This includes:  
• the need to make difficult subjective decisions;  
• whether procedural errors can lead to treatment failures;  
• the time required to train people in the use and maintenance of the alternative;  
• whether on-going technical support would be required; and  
• whether children can also use the alternative.                                                                                                                                                                                                                             |
<p>| Time and effort required (convenience)                | How much time and effort is required to use the alternative and maintain it? Considerations here include: how many steps are involved; how much time processes take and how laborious they are; and how often the alternative needs to be maintained, repaired, or cleaned.                                                                                      |
| Production rate                                        | How much time does the alternative take to produce enough water to meet the daily drinking requirements of a single family?                                                                                                                                                                                                                      |
| Appearance of product water                           | How well does the alternative eliminate cloudiness, colour, or other objectionable appearance issues? Does the alternative impart any objectionable appearance issues to the water?                                                                                                 |
| Taste, odour, and palpability of product water        | How well does the alternative eliminate objectionable taste and odours from the water? Does the alternative impart any objectionable tastes, odours, or other palpability issues to the water that children especially may not like?                                                                                                                                        |
| Aspirational appeal                                    | Does the alternative have an appearance that evokes perceptions of quality, value or prestige? Is it something that households would want visitors to see? (Applicable to household level systems only.)                                                                                                           |
| Durability                                             | How likely is the alternative to break or become damaged? (Applicable to household level systems only.)                                                                                                                                                                                                                                    |
| Fit in the home environment                            | How well does the alternative (and additional safe storage, if required) fit into local homes? This includes considerations of size, bulkiness, and stability. (Applicable to household systems only.)                                                                                                                |
| <strong>Technical criteria</strong>                                 |                                                                                                                                                                                                                                                                                                                                                   |
| Technical effectiveness (turbidity control)           | How effective is the alternative at reducing turbidity? Consider both 1) field-effectiveness and 2) lab-efficacy, if data are available. (Applicable only if a clarification stage is required.)                                                                                                                                         |
| Technical effectiveness (microbiological control)     | How effective is the alternative at reducing microbiological contamination? Consider both 1) field-effectiveness and 2) lab-efficacy, if data are available. (Applicable only if a disinfection stage is required.)                                                                                                                                   |</p>
<table>
<thead>
<tr>
<th>Criteria relating to socio-cultural and local appropriateness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Availability</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
</tr>
<tr>
<td><strong>Robustness</strong></td>
</tr>
<tr>
<td><strong>Absence of environmental impacts and hazards</strong></td>
</tr>
<tr>
<td><strong>Risk of recontamination</strong></td>
</tr>
<tr>
<td><strong>Absence of hazards to users</strong></td>
</tr>
<tr>
<td><strong>Traditional knowledge, practices, and perceptions</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Local taste preferences</strong></td>
</tr>
<tr>
<td><strong>Perception of treatment process by users</strong></td>
</tr>
<tr>
<td><strong>Relation to institutional environment</strong></td>
</tr>
</tbody>
</table>

The table above is an attempt at developing a taxonomy of relevant appropriate technology criteria that have emerged from previous experiences, but is not purported to be exhaustive. These criteria represent the arenas in which technological alternatives will be assessed for contextual suitability. This is discussed further in the next chapter.
What is clear from the preceding discussion is that appropriate technology is about more than just technology or outcome—it is about process. The next section explores the sort of processes that may be conducive to the creation and implementation of appropriate technology.

2.3.4 *Participatory development*

With the previous section having explored why addressing the global safe water challenge demands a participatory approach, this section will explore the concept of participation in development and some of the approaches that have emerged in recent decades for involving local stakeholders in the innovation process.

2.3.4.1 Why a participatory approach?

*Participatory development* encompasses flexible, process-oriented methodologies that aim to facilitate greater participation of, and control by, local people in the development process (Mitlin and Thompson 1995). They arose as the limitations of mainstream development thinking—top-down and focused primarily on economics—became increasingly apparent through the 1970s and 80s.\(^{48}\) One of leading proponents of participatory development, Robert Chambers, describes the fundamental fault in mainstream development thinking as being the projection of the “universal, reductionist, standardized, and stable” realities of development professionals from the urban, industrialized North—particularly economists—on the “local, complex, diverse, and dynamic” realities of poor people in the South (Chambers 1995).\(^{49,50}\) For development to have a sustainable positive impact he argues that a “reversal of roles” is necessary wherein development

\(^{48}\) An excellent overview of the emergence of participatory development is available in Mitlin and Thompson (1995).

\(^{49}\) Chambers (1995) critiques the priorities of the mainstream development enterprise as a whole, particularly the measures commonly used and the values they represent. Almost exclusively, these are focused on concepts determined by Northern development professionals, especially economists, which are easy-to-measure and reflect their priorities—for instance, monetary income. In doing so, mainstream development practitioners ignore the priorities which the poor may voice for themselves. Though some may be difficult to quantitatively measure—values such as self-respect, powerlessness, vulnerability, livelihood opportunities or physical weakness—they ultimately represent improvements in the real, lived experiences of poor people and ought to be the focus of a people-centred development enterprise (Chambers 1995). The demand that development efforts should put “poor people and their priorities first” is incumbent upon all sectors and is germane to the present work.

\(^{50}\) A clear resonance with post-normal science can be seen here. Whereas traditional development thinking, deeply rooted in a normal scientific perspective, has tended to be top-down and focused on abstract concepts such as economics rather than on people, participatory approaches place local people at its centre and adapts to the demands of a post-normal scientific environment. Chambers (2007) describes participatory development as “…resonat[ing] with theories of chaos, complexity, emergence and deep simplicity, especially self-organising systems on the edge of chaos”, the same concepts that appear in post-normal science.
professionals put aside their projections and put “poor people and their priorities first of all”.51 The participatory approach “enable[s] poor people to analyze and express what they know, experience, need and want”. The participatory approach seeks to re-centre development research and practice on marginalized people.

Since local circumstances cannot be known to external actors on an a priori basis and will remain obscure until elucidated by local people (Mitlin and Thompson 1995), re-centring the process on marginalized peoples enables practitioners of participatory development to “…identify and respond to the local cultural, historical, socio-economic, geographical and political factors that influence the behaviour and practices of a community” (Beazley and Ennew 2006).52 To achieve this, Chambers (1995) advocates for a deep involvement of local peoples “…not only in the design and implementation phases of projects but also in identification, monitoring and evaluation, and policy formulation.” The participatory approach thus seeks to realize goals including (IFAD 2000; Mitlin and Thompson 1995):

- Identify relevant and viable local development options;
- Increase awareness and understanding about the key actors and groups at the local level;
- Improve the quality and quantity of information about local conditions;
- Enable local people to identify constraints, set priorities and take action;
- Ensure design reflects the real priorities of beneficiaries;
- Increase ownership and therefore motivation of local participants;
- Mobilize local and external resources for development options;
- Strengthen the self-confidence and capacities of local people and organizations; and
- Develop and support mechanisms to resolve local conflicts.

Though the participatory approach may take more time and demand more and different kinds of effort from external actors, all in all, they are worth the investment. Recent evidence has

51 Chambers (1995) clarifies that the ‘poor’ can refer to whole communities that are chronically disadvantaged, but may well also refer to segments within communities that are especially marginalized—for instance, women or certain socio-economic or ethnic groups.
52 In this way, the participatory approach also resonates with the concept of appropriate technology.
demonstrated that participatory approaches can generate more accurate quantitative data and are adept at capturing local priorities and the different perspectives amongst marginalized peoples, resulting in more relevant, appropriate, and successful development interventions (Mayoux and Chambers 2005). Moreover, for Chambers (2007), participatory development seeks to “empower local and subordinate people, enabling them to express and enhance their knowledge and take action.” Participatory approaches can not only yield better development research and practice, but they can also be the launching pad from which communities become empowered to organize around other self-identified priorities. A study of woman’s participation in water management in rural Maharashtra, India by Devasia (1998) showed that not only did the participatory endeavour help women secure better access to safe drinking water and sanitation, but also helped them to organize against exploitation and human rights violations in their lives. In addition, they also independently began to address other self-identified environmental concerns, for instance, by initiating social forestry and rainwater harvesting programs. At a systemic level, Mitlin and Thompson (1995) argue that participatory development can also strengthen civil society by empowering local community groups to demand greater transparency in public decision-making, enabling them to better hold governments and institutions accountable.

2.3.4.2 Principles of the participatory approach

It would be erroneous to think that taking a participatory approach to development research or practice consists of just simply applying a set of specific ‘participatory’ methods. In reality, its methods reflect a fundamentally different conception of people in the development process. Participatory development is predicated upon the understanding that, as Mayoux (2006) puts it, human beings are subjects, rather than objects, in their lives. Chambers (1994) explains that participatory development draws its philosophy (and much inspiration) from Freire’s Pedagogy of the Oppressed (1968) and its theme that poor and exploited people are not objects, but subjects whom are able to, and should be allowed to, analyze, understand, and thereby work to change their own reality. From this philosophy arise the principles of the participatory approach (Beazley and Ennew 2006; Scheyvens, Scheyvens, and Murray 2003):

- People should be active agents in their own lives;
- Development research and practice should respect research participants’ own words, ideas, and understandings;
Internal and external participants are equal;
The methods used should be flexible, exploratory and inventive;
Both internal and external participants should enjoy the research or development project;
Development research and practice must respect the knowledge, skills, and experience of the local people with whom outside researchers are working;
The external participant’s involvement with the marginalized group should be characterized by committed involvement rather than impartial detachment; and
There should be positive outcomes of the project for the marginalized group, and any anticipated negative outcomes should be eliminated if possible.
The present work bears these principles in mind and attempts to apply them so far as is possible.

Moreover, these principles necessarily reflect back upon the researcher. In fact, it demands a “new professional” as Chambers (1995) puts it, a person who:
“…is committed to the poor and the weak and to enabling them to gain more of what they want and need. She is democratic and participatory in management style, is a good listener, embraces error and believes in failing forwards, finds pleasure in enabling others to take initiatives, monitors and controls only a core minimum of standards and activities, is not threatened by the unforeseeable, does not demand targets for disbursements and achievements, abjures punitive management, devolves authority expecting her staff to use their own best judgement at all times, gives priority to the front-line, and rewards honesty.”
In other words, the researcher should, as Chambers (1994) puts it, “hand over the stick” to local people. The researcher’s role is to act as a facilitator, to develop trust and rapport with participants through listening and learning, and then working alongside them. This philosophy is borne in mind throughout the present work.

2.3.4.3 Participatory action research
Of the many participatory approaches that have emerged over the decades, participatory action research (PAR) is one that is especially influential in the present work. Parkes and Panelli (2001) define PAR as an approach that combines research and action in an iterative cycle in which
issues are defined, addressed, and reflected upon by a group comprised of both the researchers and the ‘researched’. In this model, complex and wicked problems are not discretely ‘solved’ but iteratively experimented with and gradually improved (Figure 2-2).

This is a departure from the conventional linear approach of action and inquiry in normal science and early development practice which typically involves three sequential stages: problem definition, solution identification, and implementation, with the involvement of lay-persons restricted to the final stage (Kelly and Farahbakhsh 2008). Moreover, PAR encourages researchers to “recognize the contexts of their work and engage in a relational and adaptive iteration of inquiry”, highlighting a clear resonance with the concept of appropriate technology (Parkes and Panelli 2001). Indeed, PAR has been identified as a suitable methodology for humanitarian engineering efforts (Miller 2008).

The two core elements of PAR—action and research—refer to both the goals of the activity and the means by which they are achieved. ‘Action’ signifies an interest in doing or achieving some
larger social or community-directed goal through the research process. This requires two fundamental components:

1. Explicit discussion on what are the intended goals of the exercise; and
2. Continuous reflection on the evolution of goals and progress towards them.

Unlike other forms of research, action research does not shirk from becoming involved in the problems, risks, and politics of the place it occurs in. ‘Research’ signifies that PAR approaches involve modes of inquiry in which the researchers and the ‘researched’ form collaborative relationships of various kinds in order to identify, understand, and address issues of mutual interest.

The word ‘kinds’ is used quite deliberately above when describing the range of possible relationships. PAR—in fact, participatory approaches in general—vary widely in the degree of real partnership between the local ‘researched’ population and external interveners. The various kinds of participatory involvement are presented in Table 2-10.

<table>
<thead>
<tr>
<th>MODE OF PARTICIPATION</th>
<th>Involvement of local/researched people</th>
<th>Relationship of research to people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-option</td>
<td>Token representatives are chosen but there is no real input or power sharing</td>
<td>ON</td>
</tr>
<tr>
<td>Compliance</td>
<td>Tasks are assigned with incentives but outsiders decide the agenda and direct the actions</td>
<td>FOR</td>
</tr>
<tr>
<td>Consultation</td>
<td>Local opinions are sought but outsiders analyze and decide on the best course of action</td>
<td>FOR/WITH</td>
</tr>
<tr>
<td>Cooperation</td>
<td>Local people work together with outsiders to determine priorities but responsibility remains with outsiders for directing the process</td>
<td>WITH</td>
</tr>
<tr>
<td>Co-learning</td>
<td>Local people and outsiders share their knowledge to create new understandings and they work together to form action plans with outside facilitation</td>
<td>WITH/BY</td>
</tr>
<tr>
<td>Collective Action</td>
<td>Local people set their own agenda and mobilize to carry it out in the absence of outside initiators and with or without outside facilitators</td>
<td>BY</td>
</tr>
</tbody>
</table>
All participatory projects can be placed somewhere along the continuum in Table 2-10. Furthermore, it is entirely possible for various components of a single project to have different modes of participation. The present work aims for co-learning, but some aspects may be better described as cooperation or as consultation.

2.3.4.4 Participatory methods

Participatory methods aim to create an enabling environment for marginalized people to share information, increase their understanding of a particular issue, and become involved in creating and implementing sustainable solutions, all the while providing more reliable, representative, and realistic information to external researchers—information that is crucial for the emergence of appropriate and sustainable interventions (Mayoux 2006). The present work incorporates several participatory methods in the study approach (elaborated upon in the next chapter). These are identified in Table 2-11.

<table>
<thead>
<tr>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix ranking and scoring</td>
</tr>
</tbody>
</table>

Includes methods to collectively identify, analyze and compare various resources, development options, and individual perceptions of priorities from individual responses (Mitlin and Thompson 1995).

* Investigating user preferences to identify appropriate water treatment technology option(s)

53 This classification scheme is useful for critically assessing the real level of participation in various examples of participatory projects. It has been used for this purpose in the critical review of previous decision-making support tools (section 2.2.6).

54 The degree to which a fully participatory process could be achieved was limited in the present work due to constraints of the larger project in which this research was embedded (section 3.3.1.7). Though the support tool was designed to function at the co-learning stage in Table 2-10, in the present case study application, the degree of participation is perhaps more realistically described as varying between cooperation, consultation, and compliance. It is hoped that in future applications a greater degree of true participation can be achieved, especially if following the recommendations given in the final chapter (section 7.2).

55 Overviews of participatory methods commonly used for development research and practice projects in rural and urban areas are detailed by Beazley and Ennew (2006) and Mitlin and Thompson (1995) respectively.
| **Focus group discussions** | Collectively discuss ideas, as well as to apply matrix rankings. A core group that can sustain momentum and action deriving from discussion (Mitlin and Thompson 1995). | • Participatory assessment of community development priorities  
• Investigating the most appropriate level of application  
• Investigating user preferences to identify appropriate water treatment technology option(s).  
• Research-sharing community forums  
• Complementary community development activities |
| --- | --- | --- |
| **Participatory household surveys** | Working with community-members to design household surveys and then having local participants collect data (Mitlin and Thompson 1995). | • Baseline community survey  
• Baseline diarrhoeal disease monitoring program |
| **Transect walks** | External researchers walk along with local community-members through the community. Done in order to identify a range of features including informal sector activities, housing conditions, community layout, etc. Also provides an excellent opportunity for exploratory informal interviews with community-members on issues of local concern (Mitlin and Thompson 1995). | • Informal explorations  
• Complementary community development activities |
| **Trend analysis/Life histories** | Trend analysis: Working with elderly individuals to discuss the ways in which life has changed in the community, from customs through to infrastructure. Life histories: similar to trend analysis, but working with a general group to discuss important events in individuals’ lives and in the life of the settlement (Mitlin and Thompson 1995). Embodied as key informant and informal interviews in the present work. | • Informal explorations  
• Investigating the most appropriate level of application |

Parkes and Panelli (2001) identify focus groups as an important vehicle for participatory action and research on complex environment and public health challenges.\(^{56}\) Indeed, focus groups are a primary tool utilized for much of the community-based research of the present work, as seen by

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\(^{56}\) Parkes and Panelli outline a specific PAR approach called *Community Oriented Participatory Action Research* (COPAR) that positions the ‘community’ as the main arena in which effective participatory research can occur. The basic unit in which participatory action and research occurs in the COPAR approach are *Community Reference Groups* (CRGs). CRGs are focus groups comprised of both formal representatives (i.e. members of local government) and volunteer members drawn from different sectors of the local ‘community’ with the intended goal of creating “a broadly constituted reference group [that] can result in rich research relationships” (Parkes and Panelli 2001).
the number of research activities utilizing them in Table 2-11. Focus group methods are discussed further in the next chapter (section 3.3.1.1).

2.3.4.5 Critiques of the participatory approach

Although a participatory approach can move projects in a better direction, it is important not to see it as a panacea (Chambers 1995). As we engage in participatory processes, it is important to be aware of the critiques and concerns that have arisen with application. This section will briefly review some of the major operational and fundamental critiques so that the present work, in becoming sensitized to them, may be able to circumvent them where possible, proactively manage their impacts, or acknowledge where the ability to manage these concerns is limited in the present work.

There are several concerns of an operational nature that one should be aware of when embarking on a participatory project. Mayoux’s account of the pros and cons of participatory methods is given in Table 2-12.

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57 The role of focus groups in the larger project of safe water systems development goes beyond research however. Though the scope of the present work is limited to the design and planning stages of safe water systems development, focus groups instituted for research purposes can have their role expanded into the subsequent stages of systems implementation and operations. In this respect, the concept of learning alliances discussed by Kelly and Farahbakhsh (2008) is instructive. Learning alliances are a post-normal scientific approach to integrate technical and scientific expertise with lay expertise and local knowledge in extended peer communities. They take the form of a network of connected multi-stakeholder platforms involving all institutional and individual levels relevant to a particular issue. Central to learning alliances is the view that “local end-users should not be viewed simply as passive consumers of knowledge, but as active partners in the search for long-term sustainability and development of technologies.” Learning alliances require sensitive and reflexive ‘technical’ persons who are capable of facilitating the emergence of an “inter-language” that reflects the understandings, needs, and demands of diverse actors including lay-persons, by which otherwise esoteric technical matters are made accessible to a wider audience, enabling them to participate in decision-making and design processes. Recognizing that much of the technology required to solve today’s pressing challenges, including the safe water challenge, already exists, the “trading zones” of scientific and lay expertise that learning alliances embody facilitate a process by which technology is “adapted to particular circumstances and refined or modified to meet the needs of a particular end-users.” Not only are the solutions that emerge from widely-constituted bodies such as learning alliances more responsive to a wider array of concerns and represent a more robust understanding of the challenge, but they are also legitimated by the inclusion of all relevant stakeholders in the process. Learning alliances are a useful framework for connecting research to real-world action. Work is currently under way in Chennai, as part of the larger project, to facilitate focus groups and local participants taking on larger systems implementation and operations responsibilities.
Table 2-12 | Summary of pros and cons of participatory methods (Mayoux 2006).

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Participatory methods</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Pros</strong></td>
<td><strong>Cons</strong></td>
</tr>
<tr>
<td>Relevance</td>
<td>· Based on local perceptions and priorities</td>
<td>· May be too context-specific</td>
</tr>
<tr>
<td></td>
<td>· May be over-influenced by power relations</td>
<td></td>
</tr>
<tr>
<td>Representation and freedom from bias</td>
<td>· Can rapidly collect large amounts of data</td>
<td>· May be over-influenced by power relations</td>
</tr>
<tr>
<td></td>
<td>· Captures diversity</td>
<td>· Difficult to control who attends</td>
</tr>
<tr>
<td>Reliability of information</td>
<td>· Careful targeting and collective discussion increases the voice of the most vulnerable</td>
<td>· Participation in discussion depends on the skill of the facilitator</td>
</tr>
<tr>
<td></td>
<td>· Can capture non-linear complexity</td>
<td>· Depends on who participates</td>
</tr>
<tr>
<td></td>
<td>· Collective discussion enables more reasoned responses and immediate cross-checking of different accounts</td>
<td>· Depends on the skill and understanding of the facilitator</td>
</tr>
<tr>
<td></td>
<td>· Can clarify complex issues</td>
<td>· Difficult to sift all the information at the time of the exercise</td>
</tr>
<tr>
<td>Credibility of analysis</td>
<td>· Collective and immediate analysis of information enables immediate cross-checking of different accounts</td>
<td>· Difficult to aggregate</td>
</tr>
<tr>
<td></td>
<td>· Can clarify complex issues</td>
<td>· May be over-influenced by power relations and expectations</td>
</tr>
<tr>
<td></td>
<td>· May be difficult to interpret</td>
<td>· May be difficult to interpret</td>
</tr>
<tr>
<td></td>
<td>· It is often the process rather than the product which is key</td>
<td></td>
</tr>
<tr>
<td>Ethics</td>
<td>· Concerns about empowerment are integral to the process</td>
<td>· Empowerment may be assumed rather than actual</td>
</tr>
<tr>
<td></td>
<td>· People learn from one another and reach new understandings</td>
<td>· May raise unrealistic expectations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>· May make some people more vulnerable</td>
</tr>
</tbody>
</table>

There are other operational concerns that project implementers should also be aware of:

- While participatory approaches require, as Scheyvens, Scheyvens, and Murray (2003) describe, that external researchers’ involvement with marginalized peoples be characterized by “committed involvement rather than impartial detachment”, this can become problematic as well, for instance, when attempting to gather unbiased and reliable data from informants who have become friends (Hall 2009).

- Much attention is focused on the perspectives of various stakeholders from the local community, but it must also be borne in mind that the external actor is also a participant in the participatory process. External researchers are stakeholders in the process and possess their own views, biases, and predispositions, which if not acknowledged and critically considered, can become unduly influential on the proceedings of a participatory project, especially when considering the considerable power that external actors have relative to local marginalized peoples (Poolman and van de Giesen 2006; Hopkins 2007).
Along similar lines, the projection of cultural biases by the external researcher (regardless of how justified one may feel), onto vastly different cultural contexts may also lead to impediments in the participatory process or the erosion of trust with local participants (Mandel 2003).

Participatory approaches may raise unrealistic expectations of upcoming interventions in the eyes of local participants (Mayoux 2006).

Participatory approaches may make some people more vulnerable for sharing information they otherwise would not (Mayoux 2006).

Another, perhaps more widespread, concern is that the information generated from participatory methods is simply common knowledge for local participants and therefore, solely benefits the outside researcher (Mayoux 2006).

All stakeholders from a given group are not homogenous. Insufficient consideration of the different needs, interests, and views of stakeholder groups, as well as diversity within these groups, can lead to inappropriate interventions and wasted time and resources (Poolman and van de Giesen 2006).

Khwaja (2004) cautions that, in some community development projects, while community participation improves outcomes in non-technical decisions, increasing community participation in technical decisions may lead to worse outcomes.

These concerns are borne in mind throughout the present work.

To make matters more complicated, the participatory approach faces special challenges when applied in marginalized urban communities. Botes and van Rensburg (2000) see the participatory approach to development research and practice in urban areas as being complex and difficult, though an essential and challenging endeavour. They identify “nine plagues” of participatory development, representing common obstacles and impediments in urban areas, and “twelve commandments” to address these challenges. Jongpiputvanich, Veeravongs, and

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58 Mayoux (2006) specifically cautions that “care must be taken...in conflict or highly politically charged environments and/or where the prime intended beneficiaries of the research are very vulnerable.”

59 The nine plagues include: 1) the paternalistic role of development professionals; 2) the inhibiting and prescriptive role of the state; 3) the over-reporting of development successes; 4) selective participation; 5) hard-issue bias; 6) conflicting interest groups within end-beneficiary communities; 7) gate-keeping by local elites; 8) excessive pressures for immediate results and the accentuation of product at the expense of process; and 9) the lack of public interest in becoming involved. The twelve commandments for external actors include: 1) demonstrating an
Wonsekiarttirat (1998) report disappointing results from their PAR project in a low-income urban community in Bangkok. They suggest that PAR may not be well-suited for preventative health projects in low-income urban communities given the heterogeneity of participants; the priority given to income-generation and housing (i.e. land tenure) problems over health matters; social/family problems; gift-seeking behaviour; population transience; and a lack of positive experiences with collective action. These are some considerations which should be borne in mind by external actors when embarking on a participatory project in an urban area. The present work grapples with many of the challenges unique to urban settings, but is motivated to do so by the gravity of the challenges in marginalized urban areas.

There is a particular issue that appears several times in Table 2-12 that warrants further consideration at this point. Participatory methods may capture diversity, including the voices of the most vulnerable and the marginalized, but at the same time the whole exercise may be overly influenced by local power relations wherein dominant actors reinforce the silence and exclusion of weaker segments (Mayoux 2006). In this way, while participatory methods often claim to endow empowerment, this may be more assumed than real. As Mitlin and Thompson (1995) describe, participation can be “a double-edged sword”: on one hand, it can “bring about increased access to, and control over, vital resources and decision-making processes by local people, cutting away bureaucratic red tape and institutional constraints as it proceeds”; but at the same time, it can be used “to justify and reinforce inequitable social relations of power. For this reason, the key question remains: who participates in whose project?” This is especially a concern in societies that are highly stratified, or where hierarchies are codified in tradition. This concern is depicted in a study by Sahu (2008) in which he examines what happens in practice when ‘participatory’ systems for local water management (“pani panchayats”) are enacted via awareness of their status as outsiders; 2) respecting the community’s indigenous contribution; 3) becoming good facilitators and catalysts of development that assist and stimulate community based initiatives; 4) promoting co-decision-making in defining needs, goal-setting, and formulating policies and plans; 5) communicating both program/project successes and failures; 6) believing in key values such as solidarity, conformity, compassion, respect, human dignity and collective unity; 7) listening to community-members, especially the more vulnerable, less vocal and marginalized groups; 8) guarding against the domination of some interest groups; 9) involving a cross-section of interest groups to collaborate as partners; 10) acknowledging that process-related soft issues are as important as product-related hard issues; 11) aiming to release the energy within a community without exploiting or exhausting them; and 12) empowering communities to share equitably in the fruits of development (Botes and van Rensburg 2000).
legislation in rural Orissa state in eastern India. He finds that the novel ‘participatory’ form of water management fares no better than previous centralized forms, with marginalized peoples still suffering the same levels of, if not more, exclusion. This occurs for a number of reasons including:

- lack of attention given to local socioeconomic realities;
- dominance by upper caste and wealthier sections of communities;
- lack of effective group dynamics; and
- the exclusion of local needs and institutions.

Sahu finds that local elites are able to monopolize the system to an even greater extent when authority is devolved to the local level. This phenomenon, known as elite capture, is a significant concern in many participatory projects. More powerful members of the local ‘community’ are often able to present their private interests as public concerns, and then monopolize the benefits, by positioning themselves as key participants in participatory processes (Gibbon 2002; Classen et al. 2008; Mitlin and Thompson 1995; Mansuri and Rao 2004).

Fortunately, there are several strategies by which to address elite capture. Brockington and Sullivan (2003) argue that group settings create a certain kind of knowledge depending on the participants and their perceptions of the researchers and vice versa, making participatory

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60 Interestingly, these pani panchayats were enacted for reason of a general state failure in providing basic services. In effect, responsibility is downloaded to lower levels in an ostensible attempt to decentralize management, while the central concern remains, as Sahu (2008) argues, a lack of resources and inadequate service delivery, not a supposed inability to manage the system at higher levels!

61 This challenge is also reflected in the problematization of the concept of ‘community’ by Parkes and Panelli (2001). They criticize the concept of ‘community’ as having “exclusionary and homogenizing tendencies…[that] often result from its use.” As Poolman and van de Giesen (2006) argue, all stakeholders of a given grouping are not homogenous. Insufficient consideration of the different needs, interests, and views of stakeholder groups, as well as diversity within groupings, can lead to inappropriate interventions and wasted time and resources. Relationships between different actors also affect how they can work together and how successful a participatory project may be. Certain individuals within a given grouping may also have significantly more influence over others and may come to dominate participatory processes, for reasons that may not be immediately knowable to external interveners (Gibbon 2002; Lloyd-Evans 2006). As such, Parkes and Panelli recommend that ‘community’ action and research purposefully retains “the possibility of recognizing and supporting social diversity (and even disagreement).” With the understanding that a community is not a homogenous entity but rather a diverse, complex, and mutable entity with both commonalities and conflicts, participatory methods can “highlight the collective issues and the disagreements and the axes of tension inherent in any given case or ‘community’.”

62 Mansuri and Rao (2004), in a review of community-based and community-driven development projects, suggest that community participation is not particularly effective at targeting the poor. On the other hand, they do find some evidence that community-based projects are effective at creating successful community infrastructure, lending support to the present work.
processes generally unreliable and highly mutable. They suggest that a highly developed contextual understanding of the setting on the part of researchers is necessary prior to inaugurating a participatory process, in order to recognize those things that are promoted and those that are excluded in group discussions. They also recommend that researchers follow up privately with less vocal, more marginalized individuals to garner their views, which may otherwise go unheard in larger group settings. Along these lines, Mitlin and Thompson (1995) recommend that significant effort be invested in: “…consulting widely, creating non-threatening opportunities in which less powerful individuals are given an opportunity to express opinions and challenge prevailing views.” Farahbakhsh (2010) also cautions that powerful members of a ‘community’, especially political representatives, bureaucrats, or agents of various public or private institutions can, and often do, dominate community platforms. Thus, it may be advisable to subdivide participatory platforms into smaller, more homogenous groups—at least in the initial phases—to allow the freer emergence of multiple perspectives, and to bring the various groups together for resolving and enacting action plans at a later stage. These are strategies that are adopted in the present work.⁶³

Beyond these operational concerns, there are also some fundamental critiques of the participatory approach. Cooke and Kothari (2001) and Mayoux (2006) both point out that, as participatory methods focus in on local perceptions and realities, research outcomes emerging from participatory processes are highly context specific and may not be conducive to comparative analysis between different places and times, or to producing generalizable information. Furthermore, the data emerging from participatory methods may be difficult to analyse with sufficient rigour so as to be a reliable basis for program design and monitoring. Subsequently, interventions may be developed on impressions rather than scientific deductions. More generally however, Cooke and Kothari (2001) put forward a rather scathing critique of the

⁶³ A note should be made here about the limitations imposed by the larger project. While the decision-making support tool is structured to realize the principles and practices of the participatory approach, the degree to which this could be accomplished was limited in the present case study application due to constraints of operating within a larger project. This is discussed more in section 3.3.1.7, among other places. With specific reference to that which is discussed here, though the decision-making support tool is structured in such a way as to “allow the freer emergence of multiple perspectives, and to bring the various groups together for resolving and enacting action plans at a later stage”, these were aspects that could not be fully realized, as a full-scale participatory process could not be implemented owing to the constraints of the larger project. These are features that the support tool is designed to achieve in future applications.
entire institution of participatory development, describing it as a “new tyranny”. They call it this because they see participatory development as coercing vulnerable peoples into activities and decisions for which they are unprepared and which generally overburden them, all the while rarely achieving the ‘empowerment’ that is used to justify the use of participatory approaches. Since typically it is only the most marginalized segments of society that are involved—not powerful groups—it is unlikely that practical policies for improving the living conditions of the poor and powerless can emerge from participatory projects. The demand upon participants in participatory processes is quite high, which can eventually lead to burnout and disillusionment when intensive techniques are used without bringing about the promised improvements. Cooke and Kothari specifically use the word ‘tyranny’ as the downside of participatory processes is that various structures of oppression suffered by marginalized peoples can sometimes be reinforced. For instance, many participatory interventions at the household level focus on ‘empowering’ women to achieve some development goal themselves. As burdened as women often are managing the responsibilities of the household, earning income, caring for children, and the other activities they are engaged in, additional responsibilities—regardless of their potential benefit—often result in women exclusively becoming even further burdened. Another example that is also pertinent to the present work is the displacement of governmental responsibilities that can occur when external actors facilitate local peoples to take on some public service themselves—for instance, the provision of safe water. In doing so, what was a collective, public concern becomes an individual, private concern with all the concomitant social and political implications. In this way, participatory development can also be seen as part of a larger program of structural reform led by major donor countries and international financial institutions toward greater privatization of public services (Mitlin and Thompson 1995). In such a case, Mitlin and Thompson argue, people’s participation in the delivery of services that were previously part of government mandate becomes a cost-cutting measure to download responsibilities onto local communities while reducing external supports. Though these systemic critiques are difficult to circumvent, they should be duly acknowledged as general concerns of participatory development.

This section has reviewed participatory development at its intersection with engineering in the context of marginalized low-income communities. It has looked to why a participatory approach is sought for the present work, as well as its principles and precepts, methods, and critiques.
Participatory approaches to development are a cornerstone of humanitarian engineering practice and are necessitated by the post-normal scientific nature of the core challenge. The next section looks to another theoretical strand necessary for the present work—grounded theory.

2.3.5 Grounded theory

*Grounded theory* is a social sciences approach in which “theory [is] derived from data, systematically gathered and analyzed through the research process” (Strauss and Corbin 1998). In grounded theory, the researcher does not begin with a preconceived theory or hypothesis in mind, but rather, she or he “…generates a general explanation of a process, action, or interaction shaped by the views of a large number of participants” (Creswell 2007 after Strauss and Corbin 1998). It thus emphasizes researcher participation in the social milieu of the ‘researched’ and learning from local people via various forms of participant observation, such as informal/semi-structured interviewing (Farahbakhsh and Kelly 2008). Grounded theory derives general explanations from interview transcript data by coding for constituent ideas, gathering these into similar concepts, then to thematic categories, which are then the basis for the creation of a theory or general explanation (McCullough 2011). Memoing—the creation of notes to document emergent linkages and concepts—is also an important method in the grounded theory approach (Creswell 2007). Farahbakhsh and Kelly (2008) identify the grounded theory approach as a powerful tool for achieving meaningful user engagement.  

Through the present work does not embody a grounded theory approach in the full sense of the term, it is influenced by its basic premise of going to the experiences and perspectives of local peoples in order to discern what may be appropriate development strategies for a given community. Moreover, the methods utilized in grounded theory investigations inform the methodology of the present work (this is discussed in detail in Chapter 3). Briefly, the present work deploys informal explorations, focus groups, and interviewing as primary research tools in

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64 As can be seen, grounded theory resonates with the participatory approach to development.

65 Some analogies can be drawn to illustrate the relation of grounded theory to the present work. The theory/general explanation sought here is an appropriate strategy for safe water systems design in the case study community. This is composed of two constituent tasks of a) identifying an appropriate level of application, and b) identifying user preferences for appropriate technology selection (Chapter 3). Both of these task draw primarily on the experiences and perspectives of community-members via informal explorations, focus groups, and interviews. Hence, the decision-making support tool seeks to learn and develop from the community a ‘theory’ of what an appropriate safe water system might be for that community.
the case study community, and analyzes transcripts through coding and memoing to generate strategies for safe water systems development. Immersion in the local socio-cultural milieu was also part of this research as I had been living in Chennai intermittently since 2007 (during the exploratory work for the larger project) and for one full year (July 2010 to June 2011) during the period of the primary research. During this time, I was immersed in the milieu of the city at large and of the case study community by being a participant in community life and organizing the ancillary community development activities that our project team was engaged in at Mylai Balaji Nagar (this is discussed in Chapter 4).

2.3.6 Engineering decision-making

Engineering decision-making comprises a suite of techniques and procedures to structure and facilitate transparent decision-making on technical and design matters. The present work incorporates several engineering decision-making procedures including dominance testing, matrix weighting methods, and the Delphi method.

Dominance testing and matrix weighting methods build on the simple pair-wise comparison of alternatives in a decision-making problem by incorporating elements of fuzzy-set theory. Fuzzy-set theory brings subjective interpolation into the realm of decision-making (McBean, Rovers, and Farquhar 1995). Alternatives are assessed for dominance over other options with respect to a range of evaluation factors such that inefficient alternatives (i.e. those that are dominated by other alternatives) are identified and excluded, and the best alternative, given the evaluation factors under consideration, is selected on the basis of demonstrated dominance over other alternatives. Since it is unlikely that one alternative will dominate all evaluation factors, subjective assessments are necessary to rank the evaluation factors for relative importance and thus prioritize the dominance findings. Dominance testing is utilized in the present work on the first of the two key design decisions (section 1.2)—identifying the appropriate level of application for a safe water system (i.e. household or community level). A modification on this is the matrix weighting method which integrates rankings of alternatives with discrete rankings of
evaluation factors in a matrix to generate performance rankings of alternatives.\textsuperscript{66} The matrix weighting method is used in the present work for resolving the second key design question—on identifying appropriate water treatment technology options.

The \textit{Delphi method} also figures in the present work, albeit in a simplified form. The Delphi method is an iterative, systematic method to collect and share information, and achieve consensus amongst a group of respondents (Levangie 2009). The Delphi method generally involves several steps (Linstone and Turoff 1975; Kennedy 2004):

1. An opportunity for respondents to communicate their perspectives of and knowledge around a complex problem. This is typically achieved through the use of a research tool such as a questionnaire. Respondents are typically subject matter experts on a given topic.

2. A form of ‘structured communication’ reporting the results obtained from all participants, sometimes summarized as an assessment of group judgment, back to the participants such that every individual can see how their opinions align with others.

3. An opportunity for each individual to re-evaluate their responses in light of the shared information.

As suggested above, most Delphi applications are highly formalized. However their application in the present work is more informal. Here, it is used primarily to guide the information-sharing aspects of focus group sessions. Though the initial research tool used in Delphi applications is often a questionnaire, in the present work it is a ranking game conducted in these focus groups.\textsuperscript{67} A simplified Delphi procedure figures in three places in the present decision-making support tool:

1. The ranking game conducted in focus groups of local community-members on end-user preference criteria evaluation for appropriate technology selection;

2. The ranking game conducted in focus groups of project staff (subject experts) on technical criteria evaluation for the appropriate technology selection; and

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\textsuperscript{66} Rankings can be either parametric or non-parametric, each with its particular advantages and disadvantages (McBean, Rovers, and Farquhar 1995). This is discussed further in section 3.4.3. This distinction is featured in the critical review of previous decision-making tools (Appendix A).

\textsuperscript{67} Typically, some level of anonymity is required when sharing responses so as to limit peer pressure and the undue influence of authority (Kennedy 2004), however given that these activities were conducted in a focus group setting, this was not possible.
3. The community forums for sharing the results of investigations on the two key design decisions and developing further action and research strategies for safe water systems development in the community.\(^{68}\)

These activities are discussed at length in the next chapter.

Given their deterministic nature, the use of engineering decision-making tools could be criticized as being technocratic and displacing thoughtful consideration and negotiation between stakeholders on a complex decision-making task. However, since the present challenge has a distinctly post-normal scientific nature, the use of these tools is tempered by the need for negotiations in extended peer communities and to centre local community-members in the process (as recommended by grounded theory as well as the participatory approach). These tools are used in the present work because they are useful for structuring large quantities of information and facilitating comparison. The outcomes they generate do not fit into the support tool as concrete determinations, but rather as a range of weighed recommendations that feed further group brainstorming and strategizing in community forums.

This chapter has presented the literature review for the present work. It began with an examination of the core problem that this thesis aims to address—the global safe water challenge. It looked at some of the problems that face the standard centralized approach for safe water delivery in the South and then considered decentralized alternatives at the household and community level. Examining the key debates and research gaps around decentralized alternatives indicated the need for complex decision-making support tools to guide the design of appropriate safe water systems—this is the main objective of this thesis. The chapter then looked to the theoretical and methodological strands which the present decision-making support tool incorporates. Positioned as a humanitarian engineering effort in a post-normal scientific climate, the decision-making support tool is built on a methodological and theoretical foundation that includes concepts of appropriate technology, participatory approaches to development, grounded

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\(^{68}\) As will be discussed in the next chapter, this activity is not included as part of the primary work of this dissertation. The reasons for this are elaborated in section 3.3.1.7. It is mentioned here to round out the logic of the decision-making support tool.
theory, and engineering decision-making. With the problem defined and an idea of how to address it now developed, we move on to the study approach in the next chapter.
CHAPTER 3: STUDY APPROACH (DESIGN OF DECISION-MAKING SUPPORT TOOL)

As discussed in the previous chapter, household and community level safe water systems, as well as the various water treatment technologies available, have unique characteristics that make them more or less appropriate in different circumstances. As discussed in section 1.2, the design and planning of an appropriate safe water system thus encompasses two key design decisions:

1. Selection of the appropriate level of application; and
2. Selection of an appropriate water treatment technology (or technologies).  

An assessment and comparison of the available options, specific to the unique context of the implementation locale, conducted in partnership with local people—primarily community-members, but also government officers, local NGOs and other stakeholders—is vital if safe water systems design is to be appropriate to its setting. The development of a participatory approach

69 A third decision following these two has to do with the ‘software’ of implementation—that is, the identification of an appropriate operations and management (O&M) framework in which to deploy the safe water system. As the present work focuses primarily on the ‘hardware’ side of safe water systems development, a full analysis of appropriate O&M frameworks is beyond the scope of the present work. That said, some ‘software’ aspects inevitably arise with the analysis on the appropriate level of approach in Chapter 5.
decision-making support tool that can accomplish these two tasks is the central objective of the present work. The methodology embodied in this tool is developed in this chapter.

The study approach here utilizes a number of techniques to accomplish the various tasks required of the decision-making support tool, in doing so, weaving together several methodological strands. These methodologies were discussed in the previous chapter and an attempt has been made in this chapter to link specific research tasks back to their theoretical and methodological foundations. This chapter opens with an overview of the whole so that the reader may quickly grasp the role of the parts. Each of the individual research tasks is then discussed in greater detail. The chapter concludes with a discussion on how the present work fits into the larger picture of safe water systems development.

3.1 Methodological overview

This section offers an overview of the methodology of the decision-making support tool. It should be noted that not all of the steps outlined below are part of the primary research of this dissertation. Whether or not a specific step is part of the primary research is indicated in the footnotes below. All of the steps have been given here for the purpose of illustrating the logic of the decision-making support tool.

1. **Pre-implementation steps** set the stage for the design and planning of an appropriate safe water system in a given community.

   a. Community-members identifying safe water as a priority is a necessary **pre-condition** for undertaking safe water systems development. Thus, a **participatory assessment of community development priorities** must be conducted and demonstrate a demand for safe water.

   b. **Baseline research** must be carried out prior to the initiation of an intervention in order to develop a contextualized understanding of the community. This includes aspects relating to water quality, environment, public health, demographics, as well as the political, economic, and socio-cultural milieu of the community. Research activities here include: paper studies; informal explorations; a baseline
community survey; and longitudinal water quality and diarrhoeal disease monitoring programs.\(^{70}\)

2. **Community-based field research**—specifically, focus groups and key informant interviews—to explore the two key design questions:
   
   a. **Investigating the most appropriate level of application** for a safe water system in the case study community.
   
   b. Investigating community circumstances and stakeholder capacities and preferences in order to inform the **identification of appropriate water treatment technology(-ies)**.\(^{71}\)

3. **Analyzing data from baseline and primary research activities in order to identify appropriate safe water strategies** for the case study community. The specific tasks here include:
   
   a. **Assessing the appropriate level of application** by analyzing data gathered from relevant baseline and community-based research activities (#1b and 2a) with respect to the application level criteria given in Table 2-3.
   
   b. On the basis of water quality requirements, identifying suites of potential technological alternatives with a **technology feasibility flowchart**.
   
   c. **Assessing the performance of selected technological alternatives** with respect to the appropriate technology criteria given in Table 2-9.
   
   d. Utilizing a **multi-factor analysis** to integrate information relating to community circumstances and stakeholder capacities and preferences (#2b) with technological assessments (#3b and 3c) in order to identify the most appropriate technological alternative(s) for the case study community.\(^{72}\)

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\(^{70}\) As the present work is embedded in a larger project, the primary research for this dissertation does not include these pre-implementation steps (#1a and 1b). These pre-implementation steps have already been completed as part of the larger project which has been active in the case study community since August 2009. They are briefly outlined here for the sole purpose of providing a fuller view of the logic of the decision-making support tool. The results of these pre-implementation steps are presented in the next chapter (Chapter 4) as part of the background to the present work.

\(^{71}\) This step of community-based field research (#2a and 2b) constitutes the primary research of this dissertation.

\(^{72}\) These analytical steps (#3a, 3b, 3c, and 3d) constitute the analytical portion of this dissertation. The results are divided into two chapters. Chapter 5 presents the analysis on the appropriate level of application (#3a). Chapter 6 presents the analyses on appropriate technological alternatives (#3b, 3c, and 3d).
4. **Post-implementation steps** centring around **community forums** to share results with stakeholders and guide further community action on safe water systems development and implementation.\(^7\)

Now that we have an idea of the whole, we can proceed on to the parts. As discussed above, the pre-implementation (#1) and post-implementation steps (#4) are integral components of the logic of the decision-making support tool, but were not part of the primary work of this dissertation; as such, they are discussed separately from the primary research and analysis sections in this chapter (which were elaborated upon in sections 3.3 and 3.4, respectively).

### 3.2 Pre-implementation steps

Prior to the initiation of the primary research for this dissertation, two pre-implementation steps were carried out. The first, quite naturally, was a participatory assessment of community development priorities. The second was a series of baseline research activities to develop a contextual understanding of the case study community, Mylai Balaji Nagar.

#### 3.2.1 Participatory assessment of community development priorities

A fundamental tenet of participatory development is that community-members—not external interveners—should define development priorities (Chambers 1995; Mitlin and Thompson 1995). Thus, the identification of safe water as a local development priority is a necessary pre-condition for applying this decision-making support tool. Only if and when such a condition is met should an effort to develop a safe water system proceed in a given location. This task was completed prior to the initiation of the present work as part of the larger project. The outcome of this activity is detailed in the next chapter as part of the background (section 4.6).

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\(^7\) This post-implementation step of community forums (#4) was not included as part of the primary research of this dissertation. As per the limitations discussed in section 3.3.1.7, the present work was not able to initiate a full scale participatory action process because of conflicts with pre-existing activities of the larger project. A small forum was however conducted with participants from the community-based field research (#2a and 2b) in order to fulfil the ethical obligation of sharing research outcomes with participants. This is detailed in a later section (section 3.5). Though not ideal, this was an inescapable condition of operating in the context of the larger project.
3.2.2 Baseline research activities

Once a demand for safe water has been articulated by local people, the next step is to develop a contextual understanding of the community. This includes aspects relating to its water, environment and public health situation, as well as its political, economic, and socio-cultural milieu. There are several important questions to be explored (Table 3-1).

<table>
<thead>
<tr>
<th>MAIN QUESTION</th>
<th>CONSIDERATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the sources of water in the community?</td>
<td>• What proportions of household water supply are received from the various sources? How does it vary with season?</td>
</tr>
<tr>
<td></td>
<td>• What is the microbiological and chemical quality of the various water sources? How does it vary with season?</td>
</tr>
<tr>
<td></td>
<td>• How is the quality of water perceived by consumers?</td>
</tr>
<tr>
<td></td>
<td>• How is water stored and managed in the home?</td>
</tr>
<tr>
<td></td>
<td>• What are the costs associated with obtaining water from various sources?</td>
</tr>
<tr>
<td></td>
<td>• What is the availability and timing of the water supply in the community for the various sources?</td>
</tr>
<tr>
<td></td>
<td>• How much water do households consume for drinking and cooking purposes on a daily basis?</td>
</tr>
<tr>
<td></td>
<td>• How do households treat their drinking water, if they do so at all? How regularly is water treatment practised?</td>
</tr>
<tr>
<td>What is the overall environmental condition of the community, especially with respect to sanitation and waste management?</td>
<td>• What is the location and physical environment of the community?</td>
</tr>
<tr>
<td></td>
<td>• What are the defecation practices in the community?</td>
</tr>
<tr>
<td></td>
<td>• What happens to the wastewater? Is there open sewage in or around the community?</td>
</tr>
<tr>
<td></td>
<td>• How is solid waste disposed of? Where?</td>
</tr>
<tr>
<td></td>
<td>• How is drainage in the community? Is it prone to flooding or waterlogging? Is sewage contamination of open, standing water an issue?</td>
</tr>
<tr>
<td></td>
<td>• What is the status of basic municipal services in the community? What are the coping strategies that residents have developed in response to service gaps, if there are any?</td>
</tr>
<tr>
<td>What is the public health burden in the community attributable to unsafe water and inadequate sanitation?</td>
<td>• What is the diarrhoeal disease burden in the community?</td>
</tr>
<tr>
<td></td>
<td>• How do people perceive the risks associated with unsafe drinking water and inadequate sanitation?</td>
</tr>
<tr>
<td></td>
<td>• What are the health services available in the community?</td>
</tr>
<tr>
<td></td>
<td>• How are diarrhoeal and other waterborne diseases treated?</td>
</tr>
<tr>
<td>What are the socio-economic and demographic characteristics of the community?</td>
<td>• What are the demographics of the community?</td>
</tr>
<tr>
<td></td>
<td>• How is the community socio-economically stratified? How does this relate to water supply and treatment practices?</td>
</tr>
<tr>
<td></td>
<td>• What sources of water are the poorest households constrained to using?</td>
</tr>
<tr>
<td></td>
<td>• What are the roles of men, women, and children with respect to household water management, sanitation and hygienic practices?</td>
</tr>
</tbody>
</table>
What is the institutional and political environment of the community?

- What is the land tenure status in the community?
- What is the community’s history of (re-)settlement and development?
- What are the different stakeholder groups on the issue of water supply in the community? What are their roles, responsibilities, and perspectives? With whom does the responsibility for the provision of safe water lie? In theory, and in reality?
- What are the NGOs active in the community and what have they been involved with? How is the relationship with different NGOs?
- What is the nature of the relationship between the community and the present government at the panchayat or higher levels?
- What are the infrastructural development plans for the community? Upon what factors are the implementation of these plans contingent? How would such plans affect the development of a safe water system in the community?

These questions were explored through five baseline research activities. These included: 1) paper studies; 2) informal explorations; 3) a baseline community survey; 4) a longitudinal water quality monitoring program; and 5) a longitudinal diarrhoeal disease monitoring program. These activities are briefly elaborated upon below. Information gathered from these activities is presented in the next chapter (Chapter 4).

### 3.2.2.1 Paper studies

One of the first steps in coming to know a place is to look to what has previously been written about it (Table 3-2).

<table>
<thead>
<tr>
<th>AUTHOR &amp; DATE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meunier-Marécal and</td>
<td>Report from audit and pre-feasibility mission by Kynarou/Sogreah NGO</td>
</tr>
<tr>
<td>David (2009)</td>
<td>collaboration at Mylai Balaji Nagar.</td>
</tr>
<tr>
<td>Caprera and Teklemedhin</td>
<td>Report from Kynarou/Sogreah NGO collaboration assessing feasibility of</td>
</tr>
<tr>
<td>(2010)</td>
<td>rehabilitation of the public taps and of storage systems at Mylai Balaji Nagar.</td>
</tr>
<tr>
<td>Dutasta (2010)</td>
<td>Report from Kynarou/Sogreah NGO collaboration assessing feasibility of</td>
</tr>
<tr>
<td></td>
<td>water supply augmentation for Mylai Balaji Nagar.</td>
</tr>
<tr>
<td>TNSCB (2010)</td>
<td>Document from the Tamil Nadu Slum Clearance Board outlining resettlement</td>
</tr>
<tr>
<td></td>
<td>plans in Chennai.</td>
</tr>
</tbody>
</table>

These items were reviewed as the first step in developing a contextual understanding of the case study community.
3.2.2.2 Informal explorations

Informal meetings and discussions with community-members, government agencies, and local NGO/CBO actors also helped in developing a better understanding of the community. Gillham (2000) describes this method of informally taking in information as *participant observation*. He identifies three main elements of participant observation including observing people going about their daily lives, listening to what they have to say, and asking clarifying questions when in conversation with them. I have been involved in the larger project in which this work is embedded since August 2007. Since that time, I have been interacting with community-members and research participants on a regular basis, as well as participating in community life—from simply chatting with people informally during walks to organizing WASH workshops, health camps, sporting events, and other community activities (section 4.6.1). These informal explorations also offered the important benefit of building trust and rapport with community-members (Khan 1996). To document what I learned during these explorations, I have been keeping a field journal since the beginning of my time in the case study community (VanDonge 2006).

3.2.2.3 Baseline community survey

A baseline community survey was carried out in the case study community as part of the larger project. It investigated the demographics, socio-economic status, household water management, and WASH practices prevalent in the case study community—as well as the seasonal variation of these features—by surveying representative samples of the population of interest on a biweekly basis over the period extending from January 2010 to January 2011.

The baseline survey was divided into two phases: during the first phase, from January to March 2010, the sample population was representative of all of Mylai Balaji Nagar as it utilized systematic random sampling across the entire community.\(^\text{75}\) Descriptive features about the community presented in Chapter 4 are drawn from this first dataset. The second phase, from

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\(^{74}\) Since 2007, I have filled out four field journals. They are too voluminous to include in print, and they cannot be scanned and included in the appendices. However, they are available upon request.

\(^{75}\) The sample size was selected on the basis of sufficient statistical power to observe diarrhoeal disease incidence. As the expected rate for this variable was relatively low, a relatively large sample size was required. As such, the sample size was more than sufficient to accurately observe other variables having a much higher prevalence in the community than diarrhoeal disease.
April 2010 to January 2011, was inaugurated by a re-sampling event that focused attention on tap-water users (TWUs) in Mylai Balaji Nagar.\textsuperscript{76} This sample population was no longer representative of the community as a whole, as it was skewed toward TWU households. This enabled some important insights into TWUs, the specific sub-population of interest, but meant that only data from the first phase was representative of the community as a whole. Further details on the baseline community survey are available in the AWSP Baseline Community Survey Report included as Appendix B.

3.2.2.4 Longitudinal diarrhoeal disease monitoring

An add-on module to the baseline community survey constituted a diarrhoeal disease monitoring program. This quantitative tool tracked the prevalence of diarrhoeal disease amongst the sample population over the same period as the baseline survey. Details on this module are available in the AWSP Baseline Health Monitoring Status Report (Appendix C) with further details and results available in Appendix B.

3.2.2.5 Longitudinal water quality monitoring

The chemical and microbiological quality of a community’s main water source—as well as its seasonal variation—is obviously an important informational input for the design of a safe water system. As part of the larger project, a baseline water quality monitoring program was conducted on the public tap water supply.\textsuperscript{77} Over the period extending from August 2009 to December 2010, samples were taken on a biweekly basis from several points—including the lake, in the infiltration well, and from randomly-selected households in the community—and assessed for several prominent health-related and aesthetic water quality parameters. Further details on the water quality monitoring program are given in section 4.5.5.2 and in the AWSP Baseline Water Quality Monitoring Report (Appendix D).

\textsuperscript{76} This was done in order to strengthen the epidemiological data on TWU households.

\textsuperscript{77} This monitoring program was preceded, in July 2009, by an informal grab sample analysis of a wider array of chemical water quality parameters in order to determine which parameters should be monitored on an on-going basis as part of the baseline monitoring program. Heavy metals (including arsenic and lead) were analyzed at this time and were not found to be of concern at the case study site. This grab sample was conducted informally by our project partner at IIT-M and was not documented in a report.
3.3 Community-based field research methodology

The primary research for this dissertation utilized focus groups and key informant interviews. These sought to gather information pertaining to the two key design questions identified at the beginning of this chapter. Before describing the specifics of these investigations, a brief overview of the methods utilized is presented.

3.3.1 Overview of research methods

3.3.1.1 Focus groups

As Farahbakhsh & Kelly (2008) argue, recognition of the importance of lay expertise and its inclusion in the design process is necessary to ensure that real needs are identified and that appropriate solutions can emerge. In the present work, focus groups were the central arena for engaging lay expertise. Focus groups are small group discussions featuring specially selected participants that are led by a moderator to explore specific topics and the perceptions that participants have of them in a permissive, non-threatening environment (Litosseliti 2005). Focus groups are well-suited to exploring matters related to group views, beliefs, and reasons for collective action, and are also a suitable platform for applying participatory tools such as rankings (Lloyd-Evans 2006). Going back to the two key design questions, focus group discussions (FGDs) were the primary research tool utilized to:

1. Garner views, perceptions, and arguments on which level of application (i.e. household or community) may be more appropriate in the case study community from the perspective of residents; and
2. Explore perceptions on what community-members value in a safe water system by ranking the appropriate technology criteria (specifically the end-user preference criteria in Table 2-9). A focus group with subject matter ‘experts’ was also utilized to generate the weightings for the technical criteria in Table 2-9. These subject matter ‘experts’ were

78 Litosseliti (2005) recommends that unique focus groups should be composed of people from similar gender, ethnic, economic or cultural backgrounds, reflecting the specific population of interest in the investigation
79 While Litosseliti (2005) suggests that focus groups in research should not be used for any other purpose besides collecting data, both Mitlin and Thompson (1995) and Beazley and Ennew (2006) identify focus groups, in the context of PAR projects, as an appropriate method for identifying community priorities and forming a core group around which to launch subsequent PAR activities. In this way, the focus groups utilized in the present work are similar to the learning alliances discussed by Kelly and Farahbakhsh (2008). Regardless, practical guidance on focus group methodology from Litosseliti (2005) and others is still relevant and informative for the present work.
my field staff from the larger project as well as faculty at IIT-M, our partner institution in Chennai.

Focus group participants were recruited from all four sectors of the case study community. In this particular community, households utilize a variety of water supply strategies depending upon seasonal availability and household socio-economic status (this is discussed further in the next chapter on the background of the case study community). Households fall into three categories on the basis of primary drinking water source:

1. Those that use the contaminated public water supply as their primary drinking water source. This source does not cost anything. (i.e. tap-water users or ‘TWU’);
2. Those that purchase water at a moderate price (i.e. Rs. 2-3 for 12, 15 or 20 litres) from water lorries (i.e. lorry-water users or ‘LWU’); and
3. Those that purchase water at a high price (Rs. 20-25 for a 20 L container) from bottled water vendors (i.e. bottled-water users or ‘BWU’).

Focus group participants were recruited from all water-user type households found in the community. Potential participants were randomly selected from each water-user group and invited to participate on a volunteer basis.

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80 Though Hopkins (2007) recommends focus groups be composed of between four and ten participants, given previous experience from the larger project of conducting workshops with children present (as they always seem to be!) in the less-than-ideal venues that are available in the case study community, in addition to the complexities of conducting focus groups in a language not understood by the investigator (i.e. Tamil), a more manageable four to five participants was sought for each focus group, though it did get up to twelve participants on one occasion!

81 An effort was made to focus on marginalized groups in the community, hence households that were TWUs were specifically sought out and feature disproportionately as research participants. Though LWU and BWU households were not using the water source that would be subject to a potential safe water system (i.e. the tap water supply) at the time of the research, they are potential users of that water source should its quality improve. Furthermore, observation of water consumption practices in the community through the baseline survey (Figure 4-13) demonstrated that drinking water behaviour changes throughout the year, depending on the availability and quality of the various water sources as well as the state of household finances. It was observed that houses that were BWU/LWUs may shift to become TWUs at certain times of the year, and vice versa. Thus, BWU and LWU households are as much stakeholders in the design and planning of a safe system as are TWU households, and were also included in this research.

82 The participants we invited to join were randomly selected from around the neighbourhood in which the FGD was being held, but often we found that people who had been involved in the baseline studies participated more often. This may have been because these were people whom had more interest in the research as they had previously agreed to the survey, or because they had good relationships with our community-based field staff. As such, there is an element of self-selection at play in the voluntary approach. However, we did not see any other driving factor behind willingness to participate beyond water user type.

83 Initially it was proposed that different focus groups would be conducted for unique water-user groups (i.e. several focus groups with only TWUs, others having only BWUs or LWUs, etc.). However, this was found to be

84
The research team for the focus group sessions in the present work consisted of up to five members (Table 3-3), though it varied from session to session.

<table>
<thead>
<tr>
<th>ROLE</th>
<th>PERSONNEL</th>
<th>RESPONSIBILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderator</td>
<td>Syed Imran Ali (Investigator)</td>
<td>- Question development and outlines sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Leads session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Directs questioning, probes</td>
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<tr>
<td></td>
<td></td>
<td>- Ensures all participants contribute</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Analysis of results</td>
</tr>
<tr>
<td>Co-Moderator (if required)</td>
<td>Mr. Srinivasan Sekar (Field coordinator)</td>
<td>- Helps to lead the session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Directs questioning, probes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Maintains interest and focus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ensures all participants contribute</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Back-translation check of English transcript</td>
</tr>
<tr>
<td>Translator</td>
<td>Mr. John Jacob or Mrs. Vedha Gopalan</td>
<td>- Translates for investigator during FGD session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Transcribes recording to Tamil and then translates to English</td>
</tr>
<tr>
<td>Observer/Notetaker</td>
<td>Ms. G. Vinothini or Mr. Srinivasan Sekar</td>
<td>- Keeps notes during session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Observes para-linguistic behaviour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- With Translator, annotates transcript</td>
</tr>
<tr>
<td>Aide</td>
<td>Mr. Manikandan J., Ms. Faridha Begum, and/or Mr. Pradeep</td>
<td>- Assists with logistics—refreshments, seating, participant requests, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Write general messages on flipchart during session</td>
</tr>
</tbody>
</table>

The focus groups were conducted primarily with women because, in addition to being the primary caregivers in the home, women are also responsible for the collection and management of household water supply (Khosla 2009a). Men’s involvement was also sought, though not in

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84 Women’s participation in safe water interventions has been shown to be essential for sustainability. Serafini (2005) demonstrated that, with basic training in WASH matters, women can take on a advocacy role and enable behavioural change in their communities. This was also demonstrated in a five-year follow-up study on a WASH intervention in rural Bangladesh by Hoque et al. (1996). This study showed that women’s participation contributed to project sustainability by promoting behavioural uptake: the involvement of women, along with the support of men, led to a positive attitude among the whole community toward improving water, sanitation and hygiene practices. In addition, as women are the primary care-givers in the home, they may be more knowledgeable about the water used in the household and its implications to the health of their family. Women may also be more sensitized to the value of preventive health practices, as they care for sick children and seek out medical attention when necessary. For these reasons, women are the primary group sought for this field research. Further discussion on the role of gender in the present work and the reasons for greater inclusion of women is given in Chapter 5.

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85
the focus groups, as there is an ever-present risk of men dominating sessions at the expense of the women present (Litosseliti 2005). Initially, it was proposed that men-only focus groups would also be conducted alongside the women’s focus groups, but this was found to be impracticable as men from the case study community were not as forthcoming for group research or community development activities as women were.

3.3.1.2 Key informant and informal interviews

In order to gain access to the perspectives of powerful individuals in local governance, men who were influential residents in the local community, or officers in various government agencies responsible for the provision of water supply and other basic services in the community, key informant interviews were also conducted. These interviews looked into matters relating to the first of the two key design matters (i.e. selection of an appropriate level of application). Key

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85 The people who agreed to participate were more often than not mothers of young children who did not have other employment outside the home. These women tended to have the most time to be available for FGDs, and also perhaps more interest in health improvements for their children and improving their water supply. Also, we had more interest in gathering people who were from TWU households, as improving the water quality was a more immediate concern for them. These people tended to be lower income (they were more often from homes of thatch or other kuccha construction). In addition to young mothers, there were also some older women and grandmothers who were at home and helped out with the children and household responsibilities. When we did FGDs in the evenings, we were able to have more participation from working women, but they still they had other responsibilities in the home and had less time to spare (sometimes women would come for half an hour, but then excuse themselves having to leave as their husband was coming home and they had to make tea/food). Also, the newer settlers tended to be wealthier as they had purchased plots on the informal market and constructed larger pucca homes; they tended to be BWU/LWUs, and joined our research less often. Thus we more often had long-time (re)settled residents.

86 This is especially true in the patriarchal cultures that prevail in the Indian subcontinent.

87 The local project staff (who live in the case study community itself) informed us that it is extremely difficult—if not outright impossible—to get men from this particular community to sit and participate in voluntary collective action—let alone research activities conducted by an outsider—especially if an immediate return, financial or otherwise, is not available. The local staff informed us that only a few men would be willing come to a focus group session and even if they did, they would be generally unresponsive. The women on the other hand are much more willing to cooperate in both research and development activities, without the prospect of remuneration or reward. Indeed, our attempts in the field confirmed this. This is discussed further in section 5.9. Another factor affecting the willingness of men to participate was that most men worked outside of the community during the week. When they were home, they had limited time for other activities and were thus, less interested in participating in the research activities. Moreover, this was also observed to be the case with women who held employment outside of the community. We carried out FGDs both during the days of the workweek and in the evenings so that we could get perspectives from people who worked outside of the community and within it (people who go out to work were home in the evenings).

88 Involving powerful individuals in the same groups as weaker segments of the population is not an appropriate strategy as the former will almost certainly dominate the discussion. Thus, the strategy adopted here was to solicit the views of powerful stakeholders in individual targeted interviews, separate from the focus groups with community-members (Farahbakhsh 2010; Litosseliti 2005).

89 The second key design question (on user preferences and appropriate technology selection) was done only with women through the focus groups as they are the primary managers of household water supply. As Harris (2005)
informant interviews were also conducted with NGO/CBO actors who had previously worked or were working in the case study community. The aim of these interviews was to learn more about the history of collective action in the case study community. Finally, some informal follow-up interviews were also conducted if further elaboration was sought from a particular participant in the focus groups, or if there were quieter members of focus groups that may have not been able to articulate their thoughts in a group setting. Guidance on interview methodology was drawn from Willis (2006) and Gillham (2000).

3.3.1.3 Methodological rigour
As Litosseliti (2005) explains, focus groups (and likewise, interviews) are not necessarily representative of the population from which participants are drawn, but this was not the goal here anyway. The intent here was to explore the narratives relating to the two key design decisions from people “on the ground” in the case study community. Methodological rigour was achieved via two strategies: saturation and snowballing. The number of focus groups discussions and interviews that were ultimately conducted on either design question was contingent upon reaching saturation (Creswell 2007), such that, focus groups and interviews continued to be conducted until similar themes were seen to be repeatedly emerging (on either of the two key questions). Recruitment for interviews was done via snowball sampling on a volunteer basis. Snowball sampling identifies further research participants based on the recommendations of earlier participants who know other people to be knowledgeable on a given topic (Creswell 2007). Specific themes, or key individuals and community-leaders, that were identified during focus group sessions were explored through further key informant interviews. Similarly, describes, men control much of household and community decision-making on matters relating to spending. Though this approach does not gain the assent of men on the particular choice of technology, it does allow it for exploring men’s perspectives on the larger question of which level the water system should be deployed at. Gaining wider community participation and the assent of men on a particular strategy is a larger task that is beyond the scope of the present work, which is limited to a test case simulation. As such, the involvement of men in this research is somewhat less than what would be ideal. Gaining the assent of men could be accomplished in subsequent PAR stages in community forums; but again, this is beyond the scope of the present work.

90 In focus group research there is a risk of some participants being silenced by other more dominating participants. Likewise, there may be some participants who, for any number of reasons, are more or less inclined or able to voice their views during the sessions. To ensure that the perspectives of quieter individuals were not lost, if we observed that an individual had been wanting or trying, but unable, to contribute during a focus group, we followed the recommendation of Litosseliti (2005) and sought them out for a one-on-one follow-up interview. In the end, this was not a concern as we found almost all participants to be open and forthcoming during the sessions.

91 This follows from the grounded theory approach in which the investigator aims to generate a theory that is shaped by the views of a large number of people who experience a given phenomena (Creswell 2007; Strauss and Corbin 1998). It is also concordant with the precepts of participatory development.
interviews identifying key individuals begot further interviews. This process continued until saturation was reached. By the end of the primary research, there had been ten focus group sessions and nineteen interviews, in total representing the perspectives of sixty-seven unique participants.

3.3.1.4 Data collection and processing

Focus group and interview sessions were documented primarily by use of audio-recordings, when it was possible to do so and acceptable to participants. Session content was summarized to notes when it was not possible or permitted to record. Audio recordings of focus group and interview sessions were fully transcribed and translated to English by a professional translator (Ms. Vedha Gopalan). Textual and other ambiguities in interpretation were resolved by comparing transcripts against the observer’s notes and through consultation with the translator, co-moderator and observer.

3.3.1.5 Reporting

This section describes how specific pieces of data are attributed to various sources in this dissertation. Where baseline research activities are drawn upon, this is clearly indicated in the text (with reference to appendices if supplementary documentation is included). Where existing literature or publications are drawn upon, these were cited using standard conventions. Where informal or primary research activities are drawn upon, a coding system was utilized (Table 3-4). The codes indicate the focus group or interview that a specific piece of data was drawn from. Similarly, there is a code representing informal explorations to represent data captured in field journaling. These codes appear as in-text citations following standard conventions. Where conversational data is presented, my question (as the interviewer) may be required for comprehension of the passage. In this case, my comments are indicated by my initials (SIA) whereas participant responses are indicated by the letter ‘P’. Where the co-moderator or the interpreter is speaking, this is represented as ‘C’ or ‘I’, respectively. Furthermore, in some passages, words in [square] brackets may have been added to clarify or contextualize the passage. Ellipses (…) may also have been added to indicate where unnecessary words or sentences were removed. As it is an ethical requirement to maintain the anonymity of research

92 For example, as (FGD1).
participants (section 3.3.1.12), respondents are not identified by name. However, an indication of their role is given in Table 3-4, so as to allow for their responses to be understood with respect to their positionality. Additionally, the key design question the specific research event pertained to is also given in Table 3-4.

<table>
<thead>
<tr>
<th>CODE</th>
<th>DESCRIPTION/ROLE OF RESPONDENT(S)</th>
<th>DATE OF EVENT</th>
<th>RESEARCH QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGD1</td>
<td>Group of five women residing in sector 1; mixed group of LWUs and BWUs</td>
<td>March 25, 2011</td>
<td>1</td>
</tr>
<tr>
<td>FGD2</td>
<td>Group of six women residing in sector 4; all TWUs, some using the AWSP filter at home</td>
<td>April 7, 2011</td>
<td>1</td>
</tr>
<tr>
<td>FGD3</td>
<td>Group of three women residing in sector 2; all BWUs</td>
<td>April 12, 2011</td>
<td>1</td>
</tr>
<tr>
<td>FGD4</td>
<td>Group of five women residing in sector 3; mixed group of TWUs and BWUs</td>
<td>April 29, 2011</td>
<td>1</td>
</tr>
<tr>
<td>FGD5</td>
<td>Group of five women residing in sector 4; mixed group of LWUs and TWUs</td>
<td>May 18, 2011</td>
<td>2</td>
</tr>
<tr>
<td>FGD6</td>
<td>Group of four women residing in sector 2; all BWUs</td>
<td>May 20, 2011</td>
<td>2</td>
</tr>
<tr>
<td>FGD7</td>
<td>Group of six women residing in sector 1; mixed group of mostly BWUs, but one LWU and TWU</td>
<td>May 24, 2011</td>
<td>2</td>
</tr>
<tr>
<td>FGD8</td>
<td>Mixed group of four women and one man residing in sector 3; mixed group of BWUs, LWUs, and TWUs</td>
<td>May 26, 2011</td>
<td>2</td>
</tr>
<tr>
<td>FGD9</td>
<td>Group of eleven women residing in sector 4; mixed group of BWUs, LWUs, and TWUs</td>
<td>May 27, 2011</td>
<td>2</td>
</tr>
<tr>
<td>FGD10</td>
<td>Group of nine subject matter ‘experts’</td>
<td>August 25, 2011</td>
<td>2</td>
</tr>
<tr>
<td>INT1</td>
<td>Officer, World Vision</td>
<td>March 31, 2011</td>
<td>1</td>
</tr>
<tr>
<td>INT2</td>
<td>Respected elder, community leader for women’s groups, worker on erstwhile waste management program, BWU and resident of sector 2</td>
<td>March 21, 2011</td>
<td>1</td>
</tr>
<tr>
<td>INT3</td>
<td>World Vision community-based worker, BWU and resident of sector 2</td>
<td>April 27, 2011</td>
<td>1</td>
</tr>
<tr>
<td>INT4</td>
<td>Community leader associated with self-organized “Voluntary Association” in sector 4, BWU and resident of sector 4</td>
<td>May 14, 2011</td>
<td>1</td>
</tr>
<tr>
<td>INT5</td>
<td>Community leader associated with MBN church groups and World Vision, respected elder, BWU and resident of sector 4</td>
<td>May 19, 2011</td>
<td>1</td>
</tr>
<tr>
<td>INT6</td>
<td>Officer, Pallikaranai Panchayat</td>
<td>May 24, 2011</td>
<td>1</td>
</tr>
</tbody>
</table>
3.3.1.6 Validity and reliability

Validity was established in three ways: 1) respondent validation; 2) research team validation; and 3) triangulation. Respondent validation was formally affected via the research sharing forum (FRM1 in Table 3-4) during which the results of the research were summarized and presented back to the research participants for feedback (Appendix S). More generally however, validating what was learned in the field was an ever-present feature of this research given its cross-cultural nature. Throughout the primary research in India, I was constantly seeking clarification and confirmation from participants and our project staff about what was learned during formal and informal research events. The process of research team validation was formally embodied in the clarification and confirmation (with the interpreter, co-moderator, and the observer) of the
session transcripts (section 3.3.1.4), but it was in fact an on-going feature of working in the field with an interpreter and the local project staff. Triangulation of research findings was also an integral part of establishing validity. Information garnered during interviews and FGDs was compared to that gathered during other sessions, and was corroborated by the baseline research and the literature review.

Reliability of the research approach was established in several ways. Foremost was the use of a consistent field methodology for each formal research activity. Interviews and FGDs were guided by the use of protocol documents (i.e. session guides). There were subject to pre-testing and were also refined following after the first few field applications. All research sessions involved a standard preamble that introduced the goals of the research, the methods used, and the ethical guidelines. Field notes were completed within twenty-four hours of a research session, although translation and transcription of audio-recordings took more time to complete. With that said, it must also be noted that the research was, by nature, highly contextual and specific to the locale. The core of this research was to learn from community-members and other stakeholders about their circumstances, experiences, and perspectives. The present work has collected the perspectives of sixty-seven unique individuals. It presents what was learned through this research, but it must be acknowledged that others may well find differently.

3.3.1.7 Limitations

The present work was subject to a number of limitations. One of these was alluded to earlier on in section 3.1. The present work takes place in the context of a larger project and this placed constraints on what could be accomplished here. Although the decision-making support tool is designed to be a participatory action research process, the degree to which this could be realized was limited in the present work. Specifically, the post-implementation step of community forums (section 3.5), which would have moved the recommendations emerging from the application of the decision-making support tool from the identification to the implementation stage of the PAR cycle (Figure 2-2), were not possible to implement. This was for the reason that a field intervention study of a household safe water system (the AWSP study filter) had already been initiated in the case study community as part of the larger project, prior to the initiation of the primary research for this dissertation in March 2011. The pre-existing intervention meant that
another safe water system implementation following from the recommendations of the decision-making support tool was not possible, as resources were already tied up in the pre-existing filter study. Clearly, it would be unethical to initiate a full-scale representative community process to design and plan a safe water system—as it would inevitably create the impression that a further intervention would follow—when the larger project did not have the resources to undertake such a task. It is for this reason that the present case study application was not a full implementation as would have been ideal, but rather a test-case simulation of the methodology—an ‘academic’ exercise, so to speak. The PAR principles discussed in Ch 2 are embedded in the structure of the decision-making support tool; however, given the constraints, it was not possible to fully realize them in the present case study. This is a major limitation of the present work.

The challenge of operating in another language also engendered limitations. The local language in Chennai is Tamil, which I do not speak. As such, for all formal and informal interactions with research participants I required an interpreter to be present. This meant that during interviews and FGDs, my ability to probe and seek clarification was limited by the delay in interpretation. To cope with this, I trained my co-moderator (the field coordinator of the larger project, Mr. Srinivasan) on the subject matter of the investigations and relied on him to do much of the probing during the research session. After every research session, I had a debriefing with the co-moderator and the interpreter in order to identify how we could improve moderation and better probe the subject matter. Furthermore, once session transcripts were prepared, the co-moderator, interpreter, observer, and I discussed interpretations, clarified ambiguities, resolved how to improve our moderation for the next session, and identified points that required further exploration. Another limitation arising from the use of interpreters was that FGD transcripts had to be aggregated—that is, it was not possible to identify who said what in the transcripts—as often the interpreter present during the session was not the same person who translated and transcribed the audio-recording and because it is difficult to identify speaker by audio-recording alone. This limited the depth of analysis (i.e. the relationship between an individual’s

93 It was clearly explained, as part of the research ethics preamble before focus groups and interviews and in the ethics consent forms, that the research was being conducted for academic purposes only and that no intervention would follow.
positionality and their perspective could not be explored), but was beyond the scope of the present work anyway.

Another limitation had to do with the inclusion of men in the primary research. The investigation on the second key design question (on the weighting of end-user preference criteria which will be discussed in section 3.3.3) was done only with women as they are the primary managers of household water supply. However, men control much of household and community decision-making on spending related to water supply (Harris 2005; PATH 2012). The perspective of men was sought however for the first question on the appropriate level of application (section 3.3.2). The process of instigating wider community participation, including gaining the assent of men, was limited in the present work as it was a test-case simulation rather than a full participatory implementation, as discussed above. Further reasons on why men’s involvement was as limited as it was are detailed in section 5.9. Future methodological improvements, including those related to WASH and gender, are presented in section 7.2.

3.3.1.8 Novel aspects

The preceding chapter included an overview of existing decision-making support tools (section 2.2.6). With only a few exceptions, most of these existing tools were built around a single method—an informed choice catalogue (ICC) or a multi-factor analysis (MFA), for example. In the previous chapter’s review, this was seen to be problematic as it led to complex issues being presented in an inappropriate manner, rendered them unclear, or ignored others altogether. The present work aims to improve on this by integrating several methods into a single cohesive and articulated decision-making support tool. It breaks down the design and planning of a safe water system to its constituent tasks, and then, for each of these tasks, it utilizes the specific method that best suits its unique nature. Moreover, whereas all of the previous decision-making support tools focused on household level systems exclusively, or as with a few, on community systems exclusively, the present includes consideration of both and enables a decision to be made as to

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94 Women are the primary managers of household water supply in poor urban communities the world over (Crow and Mcpike 2009), just as they are in Mylai Balaji Nagar.
95 Men are often excluded from the research and planning of water and sanitation interventions, as women are seen as being the primary focus; however, this will only limit their participation and acceptance of interventions. There is a need to better understand men’s priorities as they relate to water and sanitation issues and include them in decision-making processes (PATH 2012; Figueroa 2012)
which level of application is best suited for a particular community—something that no other tool addresses.

Furthermore, in response to the challenges posed by the ‘wicked’ nature of the global safe water challenge, the present methodology eschews the tendency seen almost universally in previous works to utilize a formalized, deductive method to arrive at a deterministic, ‘silver-bullet’ solution. Instead, the present tool seeks to instigate an interactive, participatory dialogue in which deductive elements are limited to a supporting role and generate a range of potential solutions for further discussion. As such, the present work aims to be the first participatory, comprehensive, and articulated decision-making support tool for the selection of appropriate safe water systems that is responsive to the pressures unique to a post-normal scientific problem. Further details on how the present work advances the state of the field were given in section 2.2.6.

3.3.1.9 Potential sources of bias

As the present work took place in the context of a larger project, there was potential for activities of the larger project influencing this research. By the time the primary research described here began in the field (March 2011), some members of the case study community had already received a newly-developed household water filter (the AWSP filter) as a field trial for that technology as part of the larger project (as was described in section 3.3.1.7). With any type of participatory research where there is a significant power differential between the researcher and the ‘researched’, there is always a risk of participants “tell[ing] you what they think you want to hear, on the basis of their perception of your background and depending on what and how much they know beforehand about the research” (Litosseliti 2005). This was especially a concern here as participants may have skewed their responses in order to favour the household level sand filter that was being field-tested in the community as part of the larger project (i.e. the AWSP study filter). Though dealing with this bias was partially addressed in the design of the tool itself (i.e. technological options were not discussed directly, but rather indirectly through the relative desirability of their features), to mitigate this risk it was stressed to the participants during the introductory pre-amble that the focus group discussions were separate from the field trial of the AWSP filter and that they should not feel any pressure to skew their responses in any way.
Regardless, it must be acknowledged that this was a risk in the present case study application of the decision-making support tool.

One more point should be made here. The methodology of the present decision-making support tool was very much a product of the specific case study site (specifically, from the technology feasibility flowchart in section 3.4.2 onwards). Although an attempt was made to make it as general as possible, it is inescapable that the design of the support tool has been influenced by the context. As will be seen in Chapter 5, even preliminary findings strongly suggested a household level approach would ultimately be the most appropriate for the case study site. As such, the methodology developed and applied is more articulated with respect to household level systems rather than for community level systems, as this was the learning that happened to unfold in the community we were working in. Future work in sites where a community level system is more viable will be required to better articulate the support tool in that direction; this is part of the calibration and validation of the tool and beyond the present scope. Similarly, the tool is particularly geared toward microbiological rather than chemical water contamination. This was the situation encountered at the case study community, and is, generally speaking, common for communities using contaminated surface water bodies for household purposes in the South.

3.3.1.10 Researcher positioning

It is inescapable that a researcher’s own perspective colours how she or he interprets the world, and also, how she or he is perceived by the world. For this reason, it is important to understand who the researcher is.

To start with, I am a Canadian, born in Toronto to parents who emigrated from Pakistan, and whose families, before the Partition of the subcontinent, hailed from India. My mother’s family was from Uttar Pradesh state in the north, while my father was born in, but after Partition emigrated away from, Hyderabad, now the capital of the south Indian state of Andhra Pradesh. I was raised in a Muslim household and identify as one, and my name clearly indicates to others that I am Muslim. (Names are an important indicator of religion, caste, genealogy, and/or place of origin in the subcontinent.) I did not reveal to research participants during my time in India that my parents are from Pakistan given the antagonism between the two nations, although my
local staff and colleagues (and the Indian government!) were aware of this fact. In 2007, when I began the exploratory work for this research in India, I was twenty-three, and twenty-seven by the time the field research was completed in 2011. I am a visible minority in Canada, but in India look like I could be a local were it not for my relative height and odd manner of speaking, dress, and behaviour. This made me appear, at once, familiar but also foreign to research participants, and my identity was often confusing to people. I speak Urdu/Hindi but am unable to speak Tamil, which positioned me as a north Indian, linking myself to long-standing cultural and linguistic conflicts between north and south Indians. Having been raised in an immigrant household in a working class neighbourhood of Toronto, my cultural upbringing was hybridized, which has enabled me to adapt quickly to different cultural contexts and has provided a unique lens by which to interpret them. There is little doubt that my specific identity influenced how people in Chennai interpreted me, though the way in which this played out is difficult to say as I engendered, at once, both a sort of confusion and a sort of familiarity. Finally, my own confused alienation from, and confused familiarity with, the case study context belies claims to total ‘objectivity’ in the present study. A clear and robust methodology was utilized to minimize the influence of personal bias, or at least make clear where it was active.

3.3.1.11 Value-added research

Embarking upon international development work is a conflicted and morally ambivalent endeavour. It is undertaken with the best intentions but often either erases or entrenches various forms of exploitation. In order to minimize this, the project sought to respond to local priorities and become part of the local community, so far as was possible. Beyond the specific research tasks of the larger project, concurrent community development activities were undertaken at the request of, and in cooperation with, community-members. These are discussed further in section 4.6.1.

3.3.1.12 Ethical guidelines

University of Guelph Research Ethics Board approval was received for this research. The ethical guidelines for this research included:

- Explaining the ethical requirements of the research to participants and obtaining informed consent prior to each research activity;
Maintaining the privacy and confidentiality of participants through the use of an alphanumeric coding system for reporting information (section 3.3.1.5). Furthermore, this also meant keeping notes, transcripts, questionnaires, and electronic data in a secure manner; and

- Minimizing consequences and the potential for harm by discussing concerns and questions and being clear about the expected outcomes of the research.

An informed consent form in Tamil was given to participants and fully explained before each research session. The Tamil and English ethics consent forms, along with the University of Guelph Research Ethics Board (REB) certificate, are appended (Appendices E, F, and G, respectively).

Now that the methods utilized in the primary research have been discussed, we can turn to the details of the investigations into the two key design decisions.

### 3.3.2 Investigating the appropriate level of application

Resolving the appropriate level of application for a safe water system is one of two key design decisions. As was discussed in the previous chapter, household and community level systems have unique characteristics that make them more or less appropriate in different circumstances (Table 2-3). The intent of the investigation here was to generate arguments for and against either level of application with respect to the dimensions in Table 2-3. Information on this comes from two main sources: from the baseline research activities undertaken as part of the larger project (section 3.2.2), and from the primary research including focus groups and interviews.

Focus groups and interviews for this investigation followed a semi-structured format that was outlined in *session guides*. The semi-structured format sought to encourage participants to speak generally on the issue of water supply in their community, possibilities for improving it, and the various dimensions in Table 2-3, but allowed conversation to flow naturally to participants’ areas

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96 Ultimately, the balance of these arguments would indicate whether the household or community level was more appropriate in the case study community. But this is the subject of a later section (section 3.4.1).

97 To be more specific, the baseline research activities mostly provide information for those dimensions listed as technical dimensions in Table 2-3, whereas the primary research activities focus more on those criteria listed under economic dimensions and social and political-institutional dimensions.
of interest or confidence (Marvasti 2004). Guidance on this investigation was drawn from the resources identified in Table 3-5.

<table>
<thead>
<tr>
<th>AUTHOR &amp; DATE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murphy (2010)</td>
<td>A preliminary POU Decision Flowchart which considers factors such as water quality, water supply and demand, and external stakeholder support.</td>
</tr>
<tr>
<td>Grootaert and van Bastelaer (2002)</td>
<td>The Social Capital Assessment Tool (SOCAP), specifically the Community Profile and Asset Mapping Interview Guide, Community Questionnaire, and Household Questionnaire which gather data on community level social capital via community focus-groups and a structured community questionnaire.</td>
</tr>
<tr>
<td>Grootaert et al. (2004)</td>
<td>The Social Capital Integrated Questionnaire (SC-IQ) which gathers information on social capital at the household and individual level via a module of questions to be included in household surveys.</td>
</tr>
<tr>
<td>Krishna (2004)</td>
<td>A comparative study examining the correlation between community level social capital and development performance in north Indian villages.</td>
</tr>
</tbody>
</table>

The session guide that was utilized for focus groups discussions in this investigation is appended (Appendix H). Visual aids were also used to help illustrate the concept of household and community level systems to participants (Appendices I and J, respectively). Focus groups typically lasted between 1 and 2.5 hours, and interviews ranged from 15 minutes to up to an hour.

### 3.3.3 Investigating appropriate water treatment technology options

The appropriate technology criteria given in Table 2-9 are divided into three suites: end-user preference criteria; technical criteria; and criteria relating to socio-cultural and local appropriateness. These criteria must to be weighed for relative importance in order to be integrated into the multi-factor analysis. The methods by which these three suites were evaluated for relative importance was unique, reflecting their specific nature. The end-user preference criteria were evaluated for importance by community-members in order to integrate their preferences into the decision-making process. The technical criteria were weighed by a group of

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98 Though the precise measures Krishna (2004) uses were developed for north Indian villages, the general structural and cognitive elements they represent are still particularly relevant to the present case study of a south Indian peri-urban community.

99 The session guide underwent significant evolution with each successive application in the field. It is the final version that is appended.

98
subject matter ‘experts’. The criteria relating to socio-cultural and local appropriateness were subject to a different approach, owing to their highly contextual nature.¹⁰⁰

Weighting end-user preference criteria
Albert, Luoto, and Levine (2010) conclude their study of end-user preferences of PoU water treatment technologies in rural Kenya by stating that “product dissemination at scale to the poor will not occur until we better understand the preferences, choices, and aspirations of the at-risk populations.” It is with this in mind that the present work sought to identify end-user preference criteria and have local community-members assess, for themselves, what is important in a safe water system.

This task was accomplished through the use of a ranking game conducted in focus group settings. The session guide that was utilized for these focus groups is appended (Appendix K). The basic outline of the procedure is:

1. In the focus group session, an informal presentation on the end-user preference criteria was made by the research team. Visual aids (criteria information cards) were used to illustrate the concepts and link ideas to images (Appendix L).

2. Discussion was encouraged during the presentation. We asked participants to explain to one another what they felt was the meaning and importance of the different criteria. We invited questions and comments from the participants at any time, and invited them to consider:
   a. Were the criteria relevant to participants?
   b. What considerations were missing?
   c. What did the criteria mean to them in their daily lives?
   d. What were examples and stories that came to mind as they were discussing the criteria?

¹⁰⁰ Following from Cooke and Kothari (2001), an effort was made in the present work to balance the countervailing imperatives of deep community involvement in decision-making on one hand, and to not overwhelm local participants with decisions and activities they are unprepared for on the other. As such, community-members were sought for assessing the importance of end-user preference criteria, as this was something that was immediately perceptible to them. On the other hand, they were not asked to assess the importance of the other two suites of criteria, as these represent technical or otherwise esoteric concepts which run the risk of making their eyes glaze over, so to speak. Khwaja (2004) cautions against involving local people in technical decisions that they are not prepared for it may lead to worse outcomes. For these reasons, community-member involvement was limited as it is.
3. Following discussion, a ranking game was carried out. Each of the participants was asked to indicate which source of water they were using as their primary drinking water source in the home. The criteria information cards were placed before the participants and they were asked to select the criteria (by removing the card) that was most important in their view. This was repeated until all the cards were removed, thereby generating a ranked list of the criteria (from most important to least). The research team assisted each participant in this process, marking down their selections as the first round ranking on a ranking sheet (Appendix M).

4. Once the participants had completed the first round of the ranking game, a simplified Delphi session was initiated in which each participant was asked to share with the group their top and bottom two selections and the reasons for opting this way. Sharing and mutual learning on what different participants considered to be more and less important was affected by this procedure. The participants were then invited to re-consider their own rankings and a second round of ranking was done following the same steps as above. This generated a suite of rankings—one for each participant—of end-user preference criteria.

Weighing technical criteria

The technical criteria were weighed for importance in a focus group with nine subject matter ‘experts’ following a procedure similar to that above. Technical criteria information cards (Appendix N) were utilized to facilitate explanation of the criteria. Ranking sheets (Appendix O) were used to record respondent preferences. The subject matter ‘experts’ from whom responses were solicited are identified in Table 3-6.

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101 It was initially desired to have respondents actually weigh the end-user preference criteria by distributing 100 points amongst the various criteria on the basis of their relative importance. This proved to be impracticable given the educational status of some of the respondents (some had very little education and had difficulties with arithmetic, or were illiterate). Thus, we opted for a simple ranking.

102 Having individual responses enabled the generation of a customized recommendation on appropriate water treatment technology options for each respondent, as discussed in section 3.4.4.

103 These subject matter experts were the project team members. I opted to use people who are intimately acquainted with the specific field-site, instead of independent, external subject matter experts as the intent of the present work was not to develop a universally-applicable ranking, but one that was contextualized to the local site and thereby could resolve locally appropriate strategies. This method can be re-applied anywhere to generate locally specific rankings preserving the general nature of the tool. Alternatively, with further field applications, a body of expert rankings can be developed to support applications when locally knowledgeable experts are not available. This possibility for scaling-up is discussed in the final chapter.
Table 3-6 | Subject matter ‘experts’ solicited for ranking the appropriate technology technical criteria.

<table>
<thead>
<tr>
<th>CODE</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tech-1</td>
<td>Faculty collaborator at the Indian partner institution for AWSP</td>
</tr>
<tr>
<td>Tech-2</td>
<td>Incoming project coordinator, AWSP</td>
</tr>
<tr>
<td>Tech-3</td>
<td>Field coordinator, AWSP</td>
</tr>
<tr>
<td>Tech-4</td>
<td>Project attendant (lab staff), AWSP</td>
</tr>
<tr>
<td>Tech-5</td>
<td>Project attendant (field staff), AWSP</td>
</tr>
<tr>
<td>Tech-6</td>
<td>Project attendant (field staff), AWSP</td>
</tr>
<tr>
<td>Tech-7</td>
<td>Project assistant (lab staff), AWSP</td>
</tr>
<tr>
<td>Tech-8</td>
<td>Project assistant (lab staff), AWSP</td>
</tr>
<tr>
<td>Tech-9</td>
<td>Investigator</td>
</tr>
</tbody>
</table>

There was however a slight difference in the ranking activity here compared to the last. In addition to ranking the criteria from most to least important, respondents were also asked to distribute 100 points among the seven criteria on the basis of relative importance, adding to the richness of the data by allowing proximity information on the rankings to also be captured.¹⁰⁴

Weighing criteria relating to socio-cultural and local appropriateness

The criteria relating to socio-cultural and local appropriateness were integrated into the selection tool in a different way owing to their unique and highly contextual nature. This suite was not weighed and integrated into the matrix analysis as the previous two suites were, as such an approach is less intuitive with respect to these criteria.¹⁰⁵ These criteria basically function as promoting or inhibiting factors in the local context. As such, they were integrated into the matrix analysis as merit/demerit factors. This is discussed further in section 3.4.4.

3.4 Analytical approach

The following section describes how data from the literature, baseline research, and primary research was analyzed in order to elucidate the two key design questions. The analytical portion of this dissertation is divided into two parts, one for each of these two key design questions (Table 3-7).

¹⁰⁴ This was attempted, but found to be impracticable, with the end-user preference criteria as mentioned earlier. It was successful in this case given the higher educational level of the subject matter ‘experts’.

¹⁰⁵ To elaborate, how does one intelligibly determine which of these socio-cultural appropriateness criteria is more important than the others? As they deal with specific instances of local cultural and social practices, how can it be said which is more important, especially on an *a priori* basis? How important any of these factors are is entirely dependent on the substantive content within it. Because of the peculiar nature of these criteria, they were handled in an altogether different manner. This is discussed further later on.
Table 3-7 | Summary of analytical components of the present work.

<table>
<thead>
<tr>
<th>PART</th>
<th>KEY DESIGN QUESTION</th>
<th>ANALYTICAL PROCEDURE</th>
<th>SECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the appropriate level of application for a safe water system in the case study community?</td>
<td>Assessing the appropriate level of application</td>
<td>3.4.1</td>
</tr>
<tr>
<td>2</td>
<td>What are appropriate water treatment technology(-ies) for the case study community?</td>
<td>Technology feasibility flowchart</td>
<td>3.4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assessment of technological alternatives</td>
<td>3.4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multi-factor analysis</td>
<td>3.4.4</td>
</tr>
</tbody>
</table>

3.4.1 Assessing the appropriate level of application

The first analytical part of the dissertation examined to the first key design question: what is the appropriate level of application for a safe water system in the case study community? Following from the field research described in section 3.3.2, there was a great deal of data in the form of focus group and key informant interview transcripts. Content analysis was the analytical method utilized on these transcripts (Litosseliti 2005; Gillham 2000). Content analysis involves identifying the key substantive points in the transcripts and assigning them to thematic categories. From integrating these categories, an idea about what would be a potential solution emerged. This process was facilitated by the use of NVivo 9 software (QSR International, Cambridge, MA, USA). The general outline of the analytical procedure is as follows:

1. Each transcript was read through once to obtain general impressions, edit text, and resolve any ambiguities with the co-moderator, session interpreter, and transcript translator.

2. Each transcript was then read though again, this time identifying the substantive content that related to the dimensions in Table 2-3, as well as other emergent features. These were coded to the appropriate dimension(s) using the NVivo 9 software. Data from the baseline research activities were similarly examined and coded.

3. Simultaneous to coding, memoing was also done to articulate emergent themes and relationships between concepts in the primary and baseline data.

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106 An analogy can be drawn here with the grounded theory method wherein the outcome presently sought, that is, the appropriate level of application, can be positioned as the general explanation/theory sought in the grounded theory approach. Information from the field is then analyzed to build up to this ‘theory’ of what is the best approach to take in the case study community.

107 Emergent themes were also captured during the coding process so that—as McCullough (2011) puts it so well—“unanticipated connections and complexity could emerge from the data that otherwise may have been perceived to be irrelevant”.
4. The baseline and primary data coded to each dimension in Table 2-3 were analyzed so as to generate an interpretation on whether a household and/or a community level approach would be viable—with respect to that dimension—in the case study community. Additional dimensions that were not foreseen prior to the outset of the primary research and that emerged during its course were also analyzed.

5. Certain dimensions emerged during the primary research as being more influential to the decision than others in the specific context of the case study community. Following McBean and Zukovs (1983), I evaluated the relative importance of dimensions on the basis of an informed contextual understanding on the case study community.

6. The assessments for each dimension were parsed using dominance testing to generate a ‘total’ recommendation on the appropriate level of application for a safe water system in the case study community.

Through the analytical procedure detailed above, data from the literature, baseline research, and primary research were interpreted to yield a recommendation on the appropriate level of application for a safe water system at Mylai Balaji Nagar. The results of this analysis are presented in Chapter 5. Further details on the analytical steps, including coding tables and memos emerging from the analysis are presented at the beginning of the results section (Chapter 5). The next sections move on to discuss the analyses by which the second key design question was elucidated.

3.4.2 Technology feasibility flowchart

With the first part of the analytical section of this dissertation having shed light on what may be the most appropriate level of application for a safe water system in the case study community, the second part turns to the second key design question: what are appropriate water treatment technology(-ies) for the case study community? This section details the first procedure of the second part of the analysis (Table 3-7).

The first step in decision analysis is to eliminate alternatives that are either non-viable or unnecessary, and identify those alternatives that warrant further analysis (McBean and Zukovs 1983). Here this means identifying those technological alternatives that are viable and to
eliminate those that are not on the basis of source water quality. This task was accomplished through the use of a technology feasibility flowchart. The basic logic of the technology feasibility flowchart is as follows:

1. Determine what kinds of treatment processes are required on the basis of source water quality;
2. Identify suites of technological alternatives at the household and community level that can provide the required improvements; and
3. Account for special considerations, exceptions, and counter-indications raised by specific water quality and/or technological compatibility issues.

Some comments must be made before presenting the flowchart. The flowchart emerged from the context of the present case study site and, as such, is designed to address common water quality concerns associated with the use of surface water for drinking water in the developing world. Because of this, it focuses on microbiological—not chemical—contamination of water. Consideration of heavy metals, arsenic and pesticides is not included here. (However, some more common chemical contaminants, such as iron, are considered.) Given its focus on surface water sources, the flowchart emphasizes a multi-barrier approach to water safety (Logsdon, Hess, and Horsley 1999). The technological options included in the flowchart are not comprehensive but are limited to those that have been widely featured in developing world applications and are well-documented in the literature. Finally, as the case study here takes place in the Indian context, the tool has been designed with the drinking water quality requirements set by the Bureau of Indian Standards (BIS) in Indian Standard IS-10500:1991. Given the challenging scenarios that this tool has been designed for, the least conservative limits—that is, the permissible limits in the absence of an alternate source as identified by the Bureau of Indian Standards (2003)—have been utilized here. The flowchart also accommodates for situations where long-term water quality monitoring data is not available by incorporating water quality proxies in order to enhance its utility. The flowchart presented here is informed by several previous works (Table 3-8).

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108 Though these can easily be modified to suit different standards as required.
109 This was not a concern in the present case study application as long-term water quality monitoring data is available for the site from pre-implementation activities of the larger project.
Table 3-8 | Previous works informing the design of the present technology selection flowchart.

<table>
<thead>
<tr>
<th>AUTHOR &amp; DATE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murphy (2010)</td>
<td>Preliminary POU Decision Flowchart which considers various water quality parameters and their implications upon technology selection.</td>
</tr>
<tr>
<td>Sobsey (2002)</td>
<td>Critical review of physical and chemical water treatment processes at the PoU and community level.</td>
</tr>
<tr>
<td>Preston et al. (2010)</td>
<td>Study indicating an exception for alum coagulation at low turbidity.</td>
</tr>
</tbody>
</table>

The flowchart is presented on the following pages.
Step 1: WQ concerns requiring specialized treatment

- Assess **source water quality** (including seasonal variation).
- Identify water quality parameters of concern that are in excess of local (BIS) or international (WHO) drinking water quality guidelines.

Step 2: Is a clarification stage required?

- **Is turbidity > 10 NTU** often or do community-members complain that the water is murky or cloudy?
  - If so, then a **CLARIFICATION stage is required**.
  - Consider the following clarification options at the appropriate level of application:
    - **Household**: sedimentation, ceramic filtration, biosand filtration, rapid granular media filtration, cloth filtration, alum or moringa coagulation, combined coagulant-disinfectant
    - **Community**: rapid granular media filtration, slow sand filtration, alum or moringa coagulation, bankside/subsurface infiltration

Step 3: Is a disinfection stage required?

- **Is the water microbiologically contaminated?** Remedial action is necessary if the following conditions, stipulated by the BIS, are not met:
  a) Throughout any year, 95 percent of samples should not contain any coliform organisms in 100 ml;
  b) No sample should contain E. coli in 100 ml;
  c) No sample should contain more than 10 coliform organisms per 100 ml; and
  d) Coliform organisms should not be detectable in 100 ml of any two consecutive samples;
  - or do local people complain about waterborne/G.I. illnesses affecting their families and is there open sewage in the environs?
    - If so, then a **DISINFECTION stage is required**.
    - Consider the following disinfection options at the appropriate level of application:
      - **Household**: chlorination, UV lamp irradiation, SODIS, boiling, combined coagulant-disinfectants, ceramic filtration, biosand filtration
      - **Community**: rapid granular media filtration, slow sand filtration, alum or moringa coagulation, bankside/subsurface infiltration

Step 4: Special considerations

- **Is iron > 1.0 mg/l** often or do community-members complain of a metallic taste and/or rust-colour staining of laundry/vessels?
- **Is manganese > 0.3 mg/l** often or do community-members complain of blackish staining of laundry/food?
  - If so, it may be **preferable to use coagulation (for suspended insoluble form only) or biosand/slow filtration** at either level of application to treat these metals.

Continued on next page
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*Is pH outside the range of 6.5 – 8.5 often?*
- If so, there are two courses of action:
  1) pH levels outside the normal range may reduce the effectiveness of some treatment options which may need to be **precluded from consideration** including:
    - Clarification via *alum* or moringa coagulation-flocculation
    - Disinfection via *chlorination*
  2) If these treatments are desired, may need to include a **preceeding pH CONTROL step** via *lime* or *acid addition.*

*Is nitrate > 45 mg/l often or is the area highly agricultural with substantial levels of fertilizer use in the vicinity and/or is there open animal or human sewage in the surrounding environment?*
- If so, there are two courses of action:
  1) **Preclude boiling, ceramic, or slow sand filtration** due to an increased risk of methaemoglobinemia
  2) Alternatively, it may be **preferable to use chlorine** (or other chemical oxidant) to convert nitrite to less-harmful nitrate and reduce this risk.

*Are organics excessive (i.e. COD > 20 mg/l) often or do community-members complain of taste, odour, or colour issues associated with excessive organic matter?*
- If so, then may need to **include a charcoal/coal or granular activated carbon adsorption filtration component or alum coagulation** to remove organics.

*Is fluoride > 1.5 mg/l often?*
- If so, then may need to **include an activated alumina absorbent filter stage** to remove fluoride.

**Step 5: Exceptions and counter-indications**

- **Exception:** if utilizing boiling for disinfection, clarification may not be necessary; this may not be in accordance with local WQ standards, but the output water may still be safe(r).
- **Exception:** if using a high-performance type of clarification (i.e. ceramic filtration), further disinfection may not be necessary.
- **Exception:** if influent turbidity is >50 NTU exclude slow sand filters as they are subject to rapid fouling when influent turbidity is high.
- **Exception:** if influent turbidity is <10 NTU, alum coagulation may be ineffective and should be excluded.
- **Exception:** if influent turbidity is <50 NTU, moringa coagulation may be ineffective and should be excluded.
- **Counter-indication:** *moringa coagulation* is not compatible with *chlorine disinfection* (because of organics enrichment and excessive chlorine demand with moringa addition). When using *moringa, SODIS* or *UV lamp irradiation* may be preferable means of disinfection.
From the application of the technology feasibility flowchart, suites of technologies at the household and community level that could deliver the required water quality improvements, along with relevant special considerations and counter-indications, were identified. Special considerations emerging from this flowchart were integrated into the multi-factor analysis as merit/demerit factors (discussed further in section 3.4.4.1). The results of this component of the analysis are presented in Chapter 6.

3.4.3 Assessment of technological alternatives

Going back to Table 3-7, once potential technologies were identified on the basis of water quality constraints through the application of the flowchart, the next task was to assess the performance of selected alternatives with respect to the appropriate technology criteria defined in Table 2-9.

The appropriate technology criteria in Table 2-9 vary in nature. Just as their relative importance was weighed in different ways (section 3.3.3), the strategies by which technological alternatives were assessed with respect to these criteria also varied (although assessment strategies did not precisely follow the lines of criteria suites as it did in section 3.3.3):

1. Some criteria—like cost or technical effectiveness—are discrete concepts for which quantitative data can be obtained either from the literature or from the field. The collected quantitative data was then used to ‘objectively’ rank the alternatives relative to one another.

2. Other criteria however—like availability or ease of use—are not discrete concepts for which quantitative data can be obtained. Moreover, published information on such criteria for each technology for every possible field-site are clearly not available. Thus, these criteria demanded that an ‘expert’ assessment be made by the investigator on how each alternative measures up qualitatively relative to others on the basis of an informed understanding of the realities of the specific field-site and of the technologies in question.

\[108\] With respect to the literature, an attempt was made to gather data from as many relevant sources as possible, but this did not constitute a systematic review of the literature.

108
On the basis of these qualitative performance assessments, the technological alternatives were ranked with respect to each pertinent criterion.\textsuperscript{111}

3. Finally, the suite of criteria relating to socio-cultural and local appropriateness were treated in a different manner, as alluded to in section 3.3.3. Alternatives were assessed on these criteria on the basis of qualitative field and literature data, but they were not ranked as was the case with the previous two suites. Here the strategy was to generate advisories that captured the promoting or inhibiting effect of the criterion on each alternative. These advisories were then integrated into the multi-factor analysis as merit/demerit factors. This strategy is described further in the next section (section 3.4.4.1).

Table 3-9 summarizes how each criterion was assessed with respect to the three strategies defined above.

<table>
<thead>
<tr>
<th>APPROPRIATE TECHNOLOGY CRITERIA</th>
<th>Assessment on the basis of quantitative literature or field data (#1)</th>
<th>Qualitative 'expert' assessment and ranking (#2)</th>
<th>Qualitative 'expert' assessment and merit/demerit points (#3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-User Preference Criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost (capital)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost (on-going)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health impact</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of use/difficulty</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Time and effort required</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>(convenience)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production rate</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Appearance of product water</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Taste, odour, and palpability of treated water</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Aspirational appeal</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Fit in the home environment</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Technical Criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical effectiveness (turbidity control)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical effectiveness (microbiological control)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Robustness</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Absence of environmental impacts and hazards</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

\textsuperscript{111} Baffrey (2005), Sobsey (2002), and Sobsey et al. (2008) all encountered this challenge in the selection tools they created, and ultimately, addressed it in the same manner as that described here.
For each criterion subject to strategies #1 and #2, once relevant data was gathered and the performance of each alternative assessed, the alternatives were ranked relative to one another. McBean, Rovers, and Farquhar (1995) distinguish between non-parametric and parametric ranking. Non-parametric ranking is a simple relational ranking wherein alternatives are assigned a rank on the basis of how they compare to the other alternatives. Conversely, parametric ranking is a normalized approach wherein alternatives are compared against a fixed scale. Often, the best and worst performing alternatives are defined as the end-points of the scale (e.g. a rank of one for the best and ten for the worst). For alternatives in between, a rank commensurate to their proximity to the best or worst is then assigned.

Both parametric and non-parametric ranking have their respective advantages and disadvantages. For one, parametric ranking allows variable proximity information to be captured. Conversely, non-parametric ranking does not allow for this, and assumes equal distance between adjacent ranks. On the other hand, parametric ranking can conflict with criterion weighting by introducing another dimension of variability that over- or under-influences a criterion in which there are tied alternative rankings.\(^{112}\) While parametric ranking allows proximity information to be captured,

\(^{112}\) To clarify, consider the following example. Assume there are 6 alternatives to choose from. With non-parametric ranking, they would be ranked as 1 (best) through to 6 (worst). Where ties occur, these are taken as the average of the tied ranks. Thus, in the non-parametric approach, ranks necessarily sum to \([6+5+4+3+2+1] = 21\). This is the case even when there are ties, for instance \([1,5,1,5,3,4,5,6]\) still sums to 21. With parametric ranking on the other hand, the scale could still be defined as 1 to 6, however, the ranks need not be distributed equally amongst the alternatives. This creates a problem when there are many ties in the ranking. For instance, consider the parametric ranking of \([1,1,1,4,5,6]\). The sum of this set is 18. When there are no ties in the ranking, it would sum, as above, to 21. This becomes a problem when we attempt to generate the alternative response (i.e. the product of the alternative ranking and the criterion ranking, as will be discussed in section 3.4.4.1). When calculating the alternative response in situations where there are ties in one alternative ranking, but not in others, the criterion featuring the tied alternatives will become under- or over-influential compared to the criteria that do not feature tied alternatives, as the sum of the available rank ‘points’ would deviate from 21. This is not a problem in the sense that it would potentially benefit one alternative over another (as it would uniformly affect all alternatives), but it would skew the influence of criteria in
this feature is of greater utility when dealing with discrete quantitative variables that can be used to clearly define a fixed scale. However, this feature is less useful when dealing with qualitative assessments; in this case, a simple relational ranking (i.e. a non-parametric ranking) is more intuitive. In the present work, though there are several criteria which draw on quantitative data, the majority are qualitative assessments, as indicated in Table 3-9. Because of the limited utility that parametric ranking offers with respect to qualitative assessments—along with the risk of skewing criteria weights—non-parametric ranking was utilized in the present work. The results of this part of the analysis are presented in Chapter 6.

3.4.4 Multi-factor analysis

Once the viable technological alternatives had been assessed for their performance vis-à-vis the appropriate technology criteria, the next task was to integrate the outcomes from the preceding steps in a multi-factor analysis in order to generate a solution to the second key design question (Table 3-7).

A multi-factor analysis is a systematic approach for exploring the performance of alternatives by integrating various informational components (McBean, Rovers, and Farquhar 1995; Logsdon, Hess, and Horsley 1999). This chapter has developed two informational components that need to be integrated in order to develop a solution to the question of what appropriate technology(-ies) might be for the case study community:

1. The weightings of the appropriate technology criteria (section 3.3.3).
2. The assessment of the performance of technological alternatives with respect to appropriate technology criteria (section 3.4.3).

At the intersection of these two informational inputs lay the most appropriate technology(-ies) for the case study community (Figure 3-1).

which there are ties amongst the alternative rankings, thereby conflicting with the weightings of the criteria themselves. For the present work, preventing this effect was deemed more important than capturing proximity information; thus, non-parametric ranking was utilized.
One way of structuring a multi-factor analysis is the use of a matrix-weighting array. A matrix-weighting array (MWA) is an additive model in which the intersection of two informational components can be developed. The present work utilized a MWA, built as a Microsoft Excel spreadsheet, in order to integrate the two components identified above (Appendix T). Guidance on the development of the MWA came from McBean, Rovers, and Farquhar (1995). The logic of the MWA is discussed in the following.

3.4.4.1 Development of the matrix-weighting array

The MWA positioned the technological alternatives along the horizontal axis and the appropriate technology criteria along the vertical axis of the matrix. The appropriate technology criteria were conditioned by the rankings/weightings that were developed following the procedure outlined in section 3.3.3. The technical criteria suite was assessed by a group of subject matter ‘experts’ (i.e. my staff members from the larger project and faculty at IIT-M) via a weighting activity. A weighting sum of 100 points was used in the field for ease of application, but had to be converted to a weighting sum of unity for analysis in the MWA. A summary weighting was also generated by finding the mean of the individual responses.

Integrating the end-user preference criteria suite into the MWA was slightly more complicated. As mentioned earlier, it was desired to have community-members do a weighting activity (akin to the technical criteria suite) rather than a simple ranking, but this was found to be impracticable.
in the field. However, to be compatible in the MWA, these rankings (1 best, 10 worst) had to be reversed in order and then transformed to uniformly-distributed weightings normalized to unity (i.e. the more important a criterion was, the greater the fraction of unity it represented—or to put it another way: 1.0 best, 0.0 worst). The following transformation was used to convert the ranking of criterion \( c \) into the weighting for criterion \( c \):

\[
W_c = \frac{(n_T + 1) - R_c}{\sum_{i=1}^{n_T} i}
\]

Where:  
\( W_c = \text{weighting of criterion } c \)  
\( n_T = \text{no. of criteria in total} \)  
\( R_c = \text{ranking of criterion } c \)

As the end-user preference criteria were uniquely ranked by each respondent, each ranking was available to generate a customized outcome space for each respondent. A summary weighting was also developed by finding the mean of all respondent rankings.

The first intersectional area of the matrix—where the alternative columns meet the criteria rows—referred to as the alternative ranking site, featured the alternative rankings that were developed following the procedure described in section 3.4.3. The product of the alternative rankings and the criterion weightings represents the response of the alternative, and these were placed in the adjacent alternative response site. Because the matrix was predicated as an additive model, the alternative rankings—going from 1 as the best to the number of alternatives as the worst—had to have their order reversed before being multiplied by the criterion weighting in order to generate the alternative response. Therefore, to obtain the response of alternative \( a \) with respect to criterion \( c \), the following formula was used:

\[
S_{[a,c]} = [(n_a + 1) - R_{[a,c]}] \times W_c
\]

Where:  
\( S_{[a,c]} = \text{response of alternative } a \text{ with respect to criterion } c \)  
\( n_a = \text{number of alternatives in total} \)  
\( R_{[a,c]} = \text{rank of alternative } a \text{ with respect to criterion } c \)
\[ W_c = \text{weighting of criterion } c \]

An additional complication was presented by the cost (capital) and cost (on-going) criteria of the end-user preference criteria suite (1a and 1b in the MWA). For the purposes of ranking during the field research, the cost criteria were aggregated (i.e. respondents did not rank cost (capital) and cost (on-going) separately, but as an aggregated criterion of cost). However, alternatives were assessed with respect to both cost (capital) and cost (on-going) (i.e. assessment was disaggregated). Given this, alternative responses for cost (capital) and cost (on-going) were developed using the single cost criterion weighting and the two unique alternative assessments and then averaged together to generate a single cost-alternative response. Similarly, the technical effectiveness (turbidity control) and technical effectiveness (microbiological control) were aggregated during ranking, disaggregated during assessment, and then re-aggregated for integration into the MWA, following the same procedure.

Once the alternative response site was populated, the responses for each alternative were summed for both suites. These sums represented the performance of the alternatives with respect to the end-user preference criteria suite and the technical criteria suite respectively. These sums were then subject to the next factor, the suite weight. The suite weight represented the relative contribution of the end-user preference criteria suite and the technical criteria suite in the decision model. For the present analysis, it was desired that the contribution of both suites be the same, so a unity was applied as both suite weights. The product of alternative response sums and the suite weight were placed in the suite response site. The sum of the two suite response values for each alternative was taken as the interim alternative score.

As mentioned earlier on, the criteria relating to socio-cultural and local appropriateness were integrated into the decision-making tool in a different manner owing to their unique nature. This suite, along with the special considerations emerging from the technology feasibility flowchart

\[113\text{ Although the end-user preference criteria suite featured ten criteria, and the technical criteria suite featured only seven criteria, the relative contribution of both suites was the same in the additive model, as both suites distributed a unity of points amongst the available criteria. The suite weight did not need to act as a scaling factor to compensate for the different number of criteria in either suite. It can however act as a scaling factor if it is desired that the two suites be weighed differently.}\]
(section 3.4.2), were integrated into the MWA as merit/demerit points. Each of the criteria relating to socio-cultural and local appropriateness was qualitatively assessed on the basis of an informed understanding of the alternative and the case study site, drawing on data from the field and the literature where available. On the basis of this assessment, a percentage factor of the mean interim alternative score was assigned. Likewise, the special considerations emerging from the technology feasibility flowchart were integrated into the MWA as merit/demerit points also as percentage bonuses of the mean interim alternative score (Table 3-10).

<table>
<thead>
<tr>
<th>STEP</th>
<th>SPECIAL CONSIDERATION</th>
<th>MERIT/DEMERIT FACTOR (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4a</td>
<td>Excessive iron and/or manganese</td>
<td>+10% to all coagulation or filtration treatments</td>
</tr>
<tr>
<td>4b</td>
<td>pH outside of the normal range</td>
<td>-10% for alum/moringa coagulation-flocculation or chlorine disinfection</td>
</tr>
</tbody>
</table>
| 4c   | Excessive nitrate | -10% for boiling, ceramic filtration, and biosand filtration  
+10% for chlorine disinfection or other oxidants |
| 4d   | Excessive organics | +10% for alum coagulation or charcoal/coal/granular activated carbon filtration |
| 4e   | Excessive fluoride | +10% for any treatments including an activated alumina adsorbent layer |

Applicable merit/demerit points were added up and presented as the total merit/demerit points which, in turn, was added to the interim alternative score to generate the final alternative score. This value represented the final, cumulative performance of alternatives. Recommendations on appropriate water treatment technology(-ies) were based on final alternative scores.

To summarize, the MWA featured a number of variable input components that affect the outcome space of the decision model (Table 3-11).

<table>
<thead>
<tr>
<th>No.</th>
<th>INPUT COMPONENT</th>
</tr>
</thead>
</table>
| 1   | a: Appropriate technology criteria weight – end-user preference criteria  
b: Appropriate technology criteria weight – technical criteria |
| 2   | Alternative performance rankings |
| 3   | Appropriate technology criteria suite weights |
| 4   | a: Merit/demerit factors – socio-cultural and local appropriateness criteria  
b: Merit/demerit factors – special considerations from technology feasibility flowchart |
Depending on the identity of these inputs, different outcome spaces can be generated by the MWA. Different scenarios, comprising various arrangements of input identities, can be analyzed in the MWA to investigate outcome spaces specific to various circumstances.

In order to develop a general recommendation of appropriate water treatment technologies for the case study community (Scenario A), the identities given in Table 3-12 were used.

<table>
<thead>
<tr>
<th>Table 3-12</th>
<th>Variable input component identities for general recommendation (Scenario A).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario A: General recommendation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No.</strong></td>
<td><strong>INPUT COMPONENT</strong></td>
</tr>
<tr>
<td>1</td>
<td>a Appropriate technology criteria weight – end-user preference criteria</td>
</tr>
<tr>
<td></td>
<td>b Appropriate technology criteria weight – technical criteria</td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
</tr>
<tr>
<td>4</td>
<td>a Merit/demerit factors – socio-cultural and local appropriateness criteria</td>
</tr>
<tr>
<td></td>
<td>b Merit/demerit factors – special considerations from tech. feas. flowchart</td>
</tr>
</tbody>
</table>

Any number of different scenarios can be analyzed in the MWA in order to generate recommendations for specific circumstances. This is discussed further in the next section.

### 3.4.4.2 Sensitivity analyses

To evaluate the stability of the outcome space under various conditions, sensitivity analyses were carried out with different input scenarios. As the MWA featured several variable input components, in any given scenario, only a single component could be varied at a time in order to study its effect on the outcome space. The sensitivity testing scenarios were selected on the basis of which input possibilities emerged as interesting following the development of the outcome space for Scenario A, or where variability in the input components needed to be assessed in order to study its affect on the outcome space. The scenarios examined included:

---

116 If two or more input components are varied in a single scenario, it will generate a complicated array of output values. To avoid such confusion, it was decided that a single component would be varied at a time. This strategy would also more clearly illustrate the effect on the outcome space of a single input component.
1. **Scenario B**: Each of the unique respondent rankings of the end-user preference criteria generated from the focus group ranking games (section 3.3.3) was analyzed in order to assess the stability of the outcome space vis-à-vis the general recommendations of Scenario A. This also allowed the generation of a customized recommendation for every end-user response.

2. **Scenario C**: This scenario also dealt with the rankings of the end-user preference criteria, but utilized a constructed ranking in which cost and convenience were controlling factors. This was done in order to assess the outcome space under these important conditions.

3. **Scenario D**: As cost has previously been identified as a controlling factor affecting the sustained uptake of water treatment systems in marginalized communities, the decision model was modified in this scenario to have cost treated as a separate criteria suite in order to increase its influence in the model. As with Scenario C, this allowed the stability of the outcome space to be assessed when cost is a high importance criterion.

4. **Scenario E**: This scenario looked at outlier rankings of the technical criteria in order to assess the stability of the outcome space.

5. **Scenario F**: This scenario modified the influence of the special considerations from the technology feasibility flowchart to assess the stability of the outcome space under changing assumptions, and to consider other possibilities for the assumptions in the decision model.

A note is required about the variable input components that were not subject to sensitivity analysis—the alternative performance rankings, the appropriate technology criteria suite weightings, and the merit/demerit factors for the socio-cultural and local appropriateness criteria (respectively, nos. 2, 3, and 4a in Table 3-12). The alternative performance rankings were the product of an extensive assessment as described in section 3.4.3. It is entirely probable that another ‘expert’ could generate an assessment/ranking of alternatives that is dissimilar from the one that I generated here. Though other suites of performance assessments could potentially be tested in the decision model, generating these assessments would greatly expand the scope of the thesis. Though this is an important aspect of calibration and validation of the decision-making support tool, it is recommended as future work and not included here. The appropriate technology criteria suite weights were not subject to sensitivity analysis as these are simple
scaling factors whose impact on the outcome space is apparent. Furthermore, there are any number of ways to modify the relative weighting arrangement for these criteria suites, but no specific reason to believe one or the other was particularly relevant. Finally, the merit/demerit factors for the socio-cultural and local appropriateness criteria were also generated via an ‘expert’ assessment by the investigator, so the reasons for their exclusion from the sensitivity analysis is the same as that for the alternative performance rankings.

3.5 Post-implementation steps (community forums)

With reference to the PAR cycle (Figure 2-2), the pre-implementation steps (#1) identified in the methodological overview at the beginning of this chapter (section 3.1) constitute the problem definition stage, while the preceding research and analytical steps (#2 and 3)—the primary work of this dissertation—constitute the solution identification stage. After this come the implementation and reflection stages (which lead back to the problem definition stage where the cycle begins again). The post-implementation steps here (#4), centred around community forums, correspond to the implementation and reflection stages of the PAR cycle. Given the limitations discussed in section 3.3.1.7, it was not possible to fully implement this step for the present work, however, it is discussed here to round out the logic of the decision-making support tool.

The purpose of the community forums is to seed further action and research on safe water system development and implementation in the community by sharing the recommendations emerging from the decision making support tool with residents and other stakeholders. In this way, the community forums constitute a simplified Delphi-type technique in which the outcomes of the research are shared with respondents who are then invited to reflect, modify, and build upon them. Although a full community mobilization process could not be undertaken, a smaller research-sharing forum was held on August 24, 2011 in the case study community. During this session, the key questions of the investigations were shared, the findings summarized, and the recommendations of the decision-making support tool were presented to research participants. This session also served to fulfil the ethical requirement of sharing research outcomes with participants. The transcript of this session (FRM1) is available in the appendices (Appendix S).
With these steps, the logic of the decision-making support tool and the primary research of this dissertation is fully articulated. The next chapters discuss the background on the case study community (Chapter 4), the results from the investigation into the first key design decision on the appropriate level of application (Chapter 5), and the results from the investigation on the second key design decision on appropriate technologies (Chapter 6).
CHAPTER 4: BACKGROUND OF CASE STUDY COMMUNITY

This chapter develops the background of the case study community, Mylai Balaji Nagar. The purpose of this exploration is to contextualize the development and implementation of the decision-making support tool in the present work. It also serves to lay the foundation for the results presented in the next two chapters. The following features of the case study community are described here:

- location and physical layout;
- resettlement history(-ies);
- land tenure status;
- demographic and socio-economic characteristics;
- status of water supply and other basic municipal services, as well as the coping strategies adopted by community-members;
- public health status; and
- local development priorities and the complementary community development activities undertaken by our project team.
Information on these background features comes from a variety of sources including the baseline research activities, the primary research of this dissertation (i.e. focus groups and interviews), the review of the existing literature on the case study community, and from the informal explorations and discussions that I have had over the four years of being involved in the case study community (since 2007). The relevant sources are identified in each section. Throughout this chapter, an effort has been made to corroborate information using multiple sources. It is acknowledged that some of what is described here may be anecdotal in nature. Nonetheless, it is important to share what is known about the case study community, as it is inescapable (and perhaps even desirable) that the analysis presented in the next chapters will be shaped by what is known to the author. Hence, the purpose of this chapter is to simply share what is known. Attribution of data to primary and baseline sources follows the conventions described in section 3.3.1.5.

4.1 Location and physical layout

The case study community was a low-income peri-urban settlement called Mylai Balaji Nagar, located near the Velachery suburb in south Chennai (formerly Madras) in the south Indian state of Tamil Nadu (Figure 4-1).

![Figure 4-1](Image) City of Chennai with the location of Velachery indicated. North is at the top of the image (Source: Google Maps).
Mylai Balaji Nagar is located on the southernmost periphery of the rapidly expanding metropolitan area of Chennai. Just beyond present city limits, the community currently falls under the jurisdiction of the town panchayat of Pallikaranai.\textsuperscript{115} It is bordered in the north by a municipal solid waste landfill,\textsuperscript{116} by Velachery Main Road to the west (across which there is a wetland), and by wetlands on the southern and eastern sides (Figure 4-2). The community is situated on a rectangular parcel of land measuring approximately 700 metres by 200 metres, for a total footprint of 14 hectares (Dutasta 2010). It is built on an argillaceous platform ‘reclaimed’ from the wetland ecosystem that hosts the community.\textsuperscript{117} The terrain slightly slopes to the west and south, and it is only a slightly higher than the surrounding wetlands (Meunier-Marécal and David 2009).

\textsuperscript{115} The panchayat is the most local level of government in India. It roughly corresponds to a rural municipality in the Canadian context. Mylai Balaji Nagar is part of Council No. 15 of Pallikaranai Panchayat and part of the state administrative district of Kancheepuram (Dutasta 2010). As of June 2011, a process had been initiated to amalgamate the town and village panchayats surrounding Chennai into the greater metropolitan entity of the Corporation of Chennai (Saravanan 2011). This institutional rearrangement will represent a major reconfiguration of Mylai Balaji Nagar’s institutional status and is likely to affect its land tenure status and basic services scenario. At the time of writing, how this will play out remains to be seen. These matters are discussed further later on in this chapter.

\textsuperscript{116} This landfill serves Alandhur Panchayat, not Pallikaranai Panchayat, under whose jurisdiction Mylai Balaji Nagar falls under. On January 9, 2010, the project team undertook a slum clean-up day with partners from the community. An attempt was made to gain access to this facility to dump wastes removed from Mylai Balaji Nagar, however, this request was denied. We were (rather ironically) told that all wastes from Mylai Balaji Nagar must be sent to Pallikaranai Panchayat’s landfill, which is at some distance from the community.

\textsuperscript{117} As a ‘protected’ wetland, the area that hosts Mylai Balaji Nagar technically falls under multiple jurisdictions including those at the state and national levels, not simply the Corporation of Chennai or Pallikaranai Panchayat. It is officially designated as a ‘bird sanctuary’, and should not be subject to development, a policy that is abrogated by the fact of rapid transportation, commercial (e.g. IT sector), and residential development that has radically affected the host ecosystem in recent years (Khosla 2009c). Jurisdictional matters are further discussed in section 4.3.
The layout of the community divides it into four sectors. Sector 1 is the northernmost, bordering the landfill. Sector 2 is to its south, separated by a canal that links the wetlands to the west and east of the community (the canals can be seen as the dark green lines bisecting the built-up areas of the community in a roughly east-west manner in Figure 4-2). Sector 2 is the largest, being approximately twice the size of the other sectors. South of sector 2 is a small residential neighbourhood called Tay Nagar that predates the settlement of Mylai Balaji Nagar.\textsuperscript{118} Tay Nagar, bounded by walls, separates sectors 2 and 3, the latter of which lies to the immediate south of it. A second east-west canal separates sector 3 from the southernmost part of the community, sector 4. A schematic diagram of the community, as laid out by the Tamil Nadu Slum Clearance Board (TNSCB) is included as an appendix (Appendix P).

4.2 Resettlement history(–ies)

The story of Mylai Balaji Nagar, as a development-displaced community, is a tumultuous one (Rajagopalan 2009). Throughout the course of informal explorations, reviewing the existing literature, and the primary research, a single narrative of the case study community’s

\textsuperscript{118} Tay Nagar is an officially recognized ‘colony’ (as the term is used in the Indian parlance), the residents of which have secure land tenure and access to municipal services. It is not considered to be part of Mylai Balaji Nagar and has not been included in the present study.
resettlement history that was, at once, complete and cogent was not encountered. Indeed, all of the accounts given were partial and particular, as is always the case with historical investigations. In order to gain a more ‘full’ view, all of these accounts must be duly considered. In this section, I do not seek to construct a single historical narrative that, by reconciling competing narratives and resolving which account is more ‘correct’, attempts to lay claim to ‘objective truth’. Rather, I seek to simply re-present, for the consideration of the reader, the many narratives that I encountered while collecting stories from the sixty-seven respondents whom were involved in this research. Such an approach is in keeping in spirit with the complexity and ambiguity that characterizes a post-normal scientific endeavour (section 2.3.2).

In order to concisely re-present these narratives, a timeline featuring a combination of written and graphical elements is used. The timeline includes a number of features including those relating to resettlement, institutional relationships, housing, water supply, and others. Only the key points are given here with supplementary information provided in later sections of this chapter. The dates on the timeline are approximate as the dates reported by respondents were either unclear or variable between reports. Attribution of data to primary and other sources follows the conventions described in section 3.3.1.5.

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119 The term *pucca* is defined later on in the text, but because it is used in the timeline, it must be defined here. Pucca refers to housing that is permanent and of durable construction using materials such as cement, brick, or stone. This is compared to *kuchcha* which is housing that is temporary, using materials such as thatch, wood, plastic, and other non-durable materials. Another term that appears here, and is discussed further later on, is *Sangam*. The Sangam is a community organization emerging from SHG activities facilitated by World Vision. It is discussed more in Chapter 5.
MRTS expansion announced by Railway Dept of Central Govt. 2520 families (reports range from 2188 to 2700 to 3420) of "roadside" and informal dwellers, and even some formalized residents, are to be displaced to make way for the new MRTS station at Miyapora. INF: TNSCB 2011, Khosiavi 2009b. The Miyapora 2008 Railway Station and other govt agencies assure evictees they will be resettled at a new location with schools, good roads, electricity, sanitation arrangements, and sufficient water supply, all to be provided by the govt [INF, Rappaguddu 2009]. Some residents also suggested that the plots were offered to them for free by the Railway Dept in order to entice them to leave [INF15].

**Evidence:**

- First school is built in MBN by the charitable branch of a private equity firm (Sriram Chit Co.). Sriram wants to operate it as a private convent school. Residents resist and demand it be a free govt school. Panchayath tells Sriram that the land is built on belongs to the govt, not to them. Sriram reinvests the money and it is converted into a public school [INF3].
- No sanitation is provided by TNSCB. Eventually, World Vision builds several public latrine blocks in each sector to provide basic sanitation [INF, Khosiavi 2009b].
- Community-members stage several roadblocks in order to have a bus stand placed in their locality [INF1, INF7, FGD3].
- 12 fires break out in the community due to the slum fire ecology created by the thrashing and the lack of permanent water supply [INF3]. Some suggest that the fires were caused by criminal elements burning down vacant buildings in order to collect relief money from the govt. The buildings had been left vacant as many people who were resettled at MBN had abandoned their plots to move back into the city for work or want of basic services [INF3].

No water is provided by TNSCB. Eventually, World Vision builds several water distribution systems in the community. Water is supplied from a high-quality borehole sourced at some distance from MBN. TNSCB gives funds to Panchayat to construct the system. People shift from LWVs to TWUs [INF3, FGD4].

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**Timeline of Mylapur Nagar**

**In the wake of the fire, caused in part by the thrashing activity prevalent in the community, the TNSCB undertakes housing rehabilitations for all 2000+ families at MBN. First, they offer jute clath and nails to residents to help them construct a temporary roof, but after community outcry, they construct a simple roof structure consisting of four support posts and an asbestos sheet roof. Following further outcry, the TNSCB capitulates and builds walls with concrete blocks. The new conceals the homes measure 9 x 15 ft. [INF3]. Residents also accelerate the pace of taking housing loans from World Vision and other NGOs in order to build pucca structures [INF3, FGD4].**

**Eviction notices:**

- Lion’s Club of UK builds a large schoolhouse in sector 2 of MBN. This becomes the main public school and the earlier school is abandoned (INF3).
- World Vision initiates public toilet blocks cleaning program (INF3, INF7).
- World Vision initiates housing loan program. In cooperation with private banks, the World Vision offers 10-year housing loans to residents. Some 50-60 pucca houses are built this way at the outset, and many more later. The loans are repaid to the TNSCB so that credit can circulate within the community. Through these loan facilities, residents begin to independently construct their homes from thatch to pucca [INF7, INF3, INF11].

**Quality of tap water degrades further. A major shift from TWUs to LWVs/BNU occurs at this point [INF3]. People complain to the Panchayat, but they refuse to do anything as this is not an election year. No one in the community is interested in addressing the water crisis except in the case of new residents.**

**Fewer children can be seen playing in the streets.**

**Residents complain about the infrequency with which the taps are turned on. Conditions improve for a few weeks and then revert to their previous state [FGD3]. Furthermore, residents resist additional identifications such that fewer households need to share a single one. The Panchayath agrees, residents are prepared to gather the ground to identify the most recent household survey, not others who do not self-advocate as aggressively [FGD1, FGD3].**

**TNSCB ceases their limited support at MBN in order to focus on new re-settlement projects elsewhere [INF7].**
4.3 Land tenure status

Land tenure refers to the legal title or claim of ownership that individuals have to real property (that is, to land). Security of land tenure is a continuum affected by a number of legal and institutional practices including residents having clear documentation attesting to legal ownership of the land, and governments adopting anti-eviction laws, abstaining from forced evictions, engaging in consultative processes for local development with title-holders, and devolving decision-making powers over land management (Sjostedt 2011). Secure land tenure is critical for encouraging self-directed community development and has been linked to positive social capital (Grant 2001). Moreover, it strongly influences local economic development by encouraging the growth of microenterprises (Gulyani and Talukdar 2010). To live without secure land tenure, is to live in fear of eviction; with respect to the topic of the present work, insecure land tenure forecloses citizen investment in improving their own communities—including water infrastructure—as well as excludes them from accessing services provided by the government or private water agencies (Sjostedt 2011). This section discusses the security of land tenure at Mylai Balaji Nagar. The next chapter builds on that discussed here, demonstrating the influence it has on community development.

As suggested by the tumultuous history(-ies) documented in the timeline above, the land tenure situation at Mylai Balaji Nagar is convoluted and deeply contentious. This section re-presents the various accounts given of the land tenure situation through the use of a diagrammatic schema. As with the timeline in the previous section, this schema does not attempt to reconcile which is the ‘most true’ of the varying accounts. Indeed, it appears that no government officer at any agency, resident of the community, or any other stakeholder knows categorically what the actual land tenure status of the community is— or even which government agency is responsible!—at the present moment. A lengthy judicial process may actually be required to resolve this. The representation here remains true to this complexity. This schema is plotted against a highly generalized timeline in order to represent the evolution of the land tenure situation, with the time of resettlement on the left and the present toward the right-hand side of the page. The timeline is

120 Locally, the term patta is used to refer to the legal title to the land.
not to scale and it remains purposefully undefined as precise dates are not known. The schema is organized around three themes which emerged as the major evolutionary stages giving rise to the present land tenure situation. Finally, as a range of very different perspectives were encountered, the schema is also colour-coded according to stakeholder perspectives, so as to facilitate contextualization of the statements made. Attribution of data to primary and other sources follows the conventions described in section 3.3.1.5.
BMN Land Tenure System Perspectives

Emergent Threats

Panchayat
Revenue Dept
TNSCB
MBN Residents

AgroDept
Railway Dept

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Few or more of MBN residents pay the leasing fees [NT7, Khoshala 2009b].

Panchayat continues to supply electricity and water, but carry only minimal maintenance at BMN though it is not collecting any revenue from the community [NT6, INT6, INT15, INT19, INT15, INT19].

TNSCB declares that only original allottees and who are newcomers with newly purchased plots have no legal right to the land and may be displaced again without compensation [NT6, Khoshala 2009b].

Resolution of land tenure situation appears unlikely due to intra-gov't conflicts and antagonism b/w MBN residents and govt agencies.

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MBN Land tenure tenures and government schemes

Rajagopal 2009.

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Involvement of a multitude of agencies across three levels of government results in a lack of clarity on government roles, responsibilities, and expectations in a lack of re-settlement and rehabilitation at MBN.

Revenue Dept (state level) administers land ownership [INT6, INT15]. They assign to the TNSCB - 15 ha of land in Pulivaranthi Panchayat to resolve MRTS excess from Miyapore [Rajagopal 2009].

The Panchayat Ward Member for MBN says that because the land was originally given to the TNSCB by the Revenue Dept. and is still technically owned by the latter. The Revenue Dept. must issue an NCC before patta can be allotted (as done to the area are collocated) [NT6, INT15].

The Panchayat says they have nothing to do with patta; that patta is with the TNSCB exclusively [INT6, INT15].

In other meetings with TNSCB officers, the TNSCB says that MBN residents are already the de facto owners of the land, and need to go to the Panchayat to formally recognize them, not the TNSCB [NT7, INT1, INT6].

Of late, the TNSCB says the 'land status has not yet come down from defacto, suggesting that the situation needs to be resolved on multiple levels of govt' [Khoshala 2009b].

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Time of resettlement

Time

128
4.4 Demographic and socio-economic characteristics

The population of Mylai Balaji Nagar is not precisely known. Estimates range from 2,500 families and 6000 people (INT4), to 7850 people (Dutasta 2010), to 10,000 people (Khosla 2009a, INF). People living in Mylai Balaji Nagar originally hail from a number of places (that is, before they were resettled or moved to the community)—some are long-time Chennaites and others are migrants from the interiors villages of Tamil Nadu, or the neighbouring states of Karnataka and Andhra Pradesh. The community is majority Hindu, although there are sizeable Christian and Muslim communities as well. The majority of the community belongs to the scheduled castes (Meunier-Marécal and David 2009). Tamil is the main language spoken in the community, although other South Indian languages such as Kannada and Telugu are also spoken in migrant households. Many community-members speak some English, and amongst Muslims living in the community Urdu is also spoken. The baseline community survey (Appendix B) indicated that household size varies from three members up to thirteen, with the average family size being 4.7, and the greatest proportion of households (42.3%) having four members (Figure 4-3).

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121 Scheduled caste is a designation used by the Government of India to denote sub-populations that have traditionally been (and still are to this day) marginalized in larger Indian society on the basis of caste. The Government of India maintains special reservations and benefits for people belonging to the scheduled castes as an affirmative action measure attempting to redress the widespread discrimination and social exclusion they face. Scheduled caste people are also referred to as dalits in the common parlance in India or, more pejoratively, as “untouchables”.

122 English has become the lingua franca of contemporary India. It is seen as highly desirable as many well-paying employment opportunities have become available to English-speakers since the liberalization of the Indian economy in the early 1990s. Many people in Mylai Balaji Nagar, particularly the youth, are keen to learn and practise their English in order to increase their employability.

123 As discussed in section 3.2.2.3, this and other descriptive features that are representative of the community as a whole were drawn from the first phase of the baseline community survey.
Mylai Balaji Nagar is also diverse with respect to socio-economic status. Meunier-Marécal and David (2009) found that average household income is approximately INR 4000 to 5000 per month. A small purposive sampling study by Rajagopalan (2009) corroborated this, showing that more than half of households in the community earn a household income between INR 4000 to 5000 per month, and that monthly income ranges from INR 2000 up to INR 8000. The income-based poverty line in India was last assessed in 2004–5 and was set as INR 539 per person per month in urban areas. For the average family size of 4.7 members in Mylai Balaji Nagar, the poverty line corresponds to a monthly household income of INR 2533, suggesting there are households below, or close to, the official poverty line in the community. Residents are engaged in a range of employment activities including (Rajagopalan 2009, INT13, INT5, INT15):

- daily wage labour (i.e. construction workers and painters. Daily labour is the most common livelihood activity in the community);
- various forms of self-employment and small business;
- domestic help;
- transport (i.e. drivers for lorries and auto-rickshaws);
- office and government workers;

There is controversy however that this figure is based on a consumption basket that is far too lean, resulting in an excessively low figure. The implication of this is that a much larger figure is actually required to maintain a basic standard of living in urban India today (GOI Planning Commission 2008). It is interesting to note that the relatively high income at Mylai Balaji Nagar, at least with respect to the official poverty line, still entails that it is a slum community! This highlights the inaccuracy of the official estimate.
· waste pickers and recyclers; and
· masonry, carpentry, plumbing, electrical and other trades.

Most women in the community also hold employment outside the home as domestic help, in food preparation, as labour on construction sites, or as small retailers and hawkers (INT15).

Socio-economic well-being of a household is also reflected in its housing. The baseline community survey (Appendix B) indicated that presently approximately 72% of households own the houses they live in and 27% of households live in rental housing. The baseline community survey also looked into the roofing material of respondent households (Figure 4-4). Roofing materials present in Mylai Balaji Nagar ranged from low-cost temporary materials (kucha) to higher-cost permanent materials (pucca)—from thatch and plastic sheeting (Figure 4-5), corrugated metal or asbestos sheets (Figure 4-6), to ceramic tiles or concrete (Figure 4-7).

Sector 4 has the greatest proportion of thatch and low-income type dwellings, reflecting the greater proportion of below poverty line (BPL) households in that sector. The baseline community survey also asked how many storeys respondents’ homes had. As of January 2010, the vast majority of the community (89.1%) had single level houses; 10.2% had two storey houses; and a small minority (0.7%) had three storey houses. Moreover, some residents have bought adjacent plots and built some of the larger houses that are seen throughout the community (INF).

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125 Indeed, below poverty level (BPL) status for urban dwellers in India has been determined by a range of parameters that includes roof and floor materials of housing ever since the inception of the 10th Five-Year Plan in 2002 (Childline India 2011). For populations that are employed in the informal sector, attempting to record yearly (or even monthly) income may be an inappropriate approach for assessing socio-economic well-being. Housing materials and other features are often used as a proxy for income levels.
126 With respect to the earlier discussion on land tenure, own is to be taken lightly here. Here I mean that most residents do not have formal title to the land, but have built their own homes, rather than pay someone else to live in their home.
127 Kucha and pucca are two common terms in Indian parlance to describe temporary/non-durable and permanent/durable housing, respectively.
128 Number of storeys is also a proxy for income levels as only wealthier individuals can afford to build multi-story pucca housing.

131
**Figure 4-4** | Proportions of roofing materials used for housing at Mylai Balaji Nagar (as of January 2010).

**Figure 4-5** | Typical thatch house in Mylai Balaji Nagar.

**Figure 4-6** | 9 ft. x 15 ft. concrete block house built by TNSCB with asbestos sheet roof.
As was described in section 4.2, the community was quite poor in the beginning, but steadily its economic well-being has improved, as reflected in the evolution of its housing (INT4). Furthermore, anecdotal evidence suggests that recent arrivals tend to be wealthier than the original settlers, as they have had the means to purchase land and build homes (INF).\textsuperscript{129}

4.5 Status of basic services

As was discussed in Chapter 2, the UN (2007) defines slums as dwellings lacking at least one of four basic amenities: adequate sanitation, safe water supply, durable housing material, and adequate living space. As housing status at Mylai Balaji Nagar has been discussed in the previous section, this section moves on to the state of sanitation, safe water supply, and other basic services in the community including:

- electrical supply;
- roads;
- solid waste management;
- sanitation and drainage;
- water supply; and

\textsuperscript{129} The baseline survey did not ask respondents whether they were original (re-)settlers or had moved to the community later on (having purchased a home/land on the informal market). This was not done as it could expose respondents to legal action or increase their risk of eviction, and as such, was ethically impermissible.
The generally inadequate condition of these basic services at Mylai Balaji Nagar has forced residents to resort to a number of coping strategies. These are also discussed in the following.

4.5.1 Electrical supply

As discussed in section 4.2, prior to their resettlement, the evictees from Mylapore recall that the various levels of government involved had assured them that they would be provided with free electricity and other services at their new location (Rajagopalan 2009). When the evictees arrived at what would become Mylai Balaji Nagar in 1995, it was little more than a barren field on the edge of the city with a few streetlights. Residents informally spliced themselves into the electrical grid via the streetlights (FGD2, INT4, INT7).

The Panchayat has allowed this situation to persist and has been paying the Electricity Board (EB) bill since 1995 (Rajagopalan 2009, INT19, INT9). The outstanding electricity bill now figures in the crores of rupees and is one of the things that the Panchayat cites as a barrier to improving services at Mylai Balaji Nagar when residents approach them with complaints.\textsuperscript{130,131} Individual households are unable to obtain formal EB connections as they do not have patta and only very few (5 to 7%) have a No Objection Certificate (NOC) from the TNSCB that proves that they have paid their leasing fees in full (section 4.3). Residents desire formal connections so that they can pay their bills and be assured of electrical supply (INT4, INT15, INT16).

Presently, the electrical supply is unreliable and subject to frequent blackouts with at least one occurring every day in Mylai Balaji Nagar (FGD3, INT2). Due to excessive demand, all of Chennai is subject to rolling blackouts, however residents complain that the supply at Mylai Balaji Nagar is particularly erratic and the timing of blackouts is indefinite (INT15). Furthermore, the power is poorly conditioned, leaving many residents complaining of excessive wear upon their electrical appliances (INF). Blackouts can persist for up to two or three days,

\textsuperscript{130} Crore is common parlance in India for ten million.
\textsuperscript{131} Some community-members suggest that the lump sum given to the TNSCB by the Railway Department at the outset of the resettlement was to cover these and other expenses (INT9). What this lump sum was intended for and how much it totalled remains unclear however, even after several attempts to clarify with both the TNSCB and the Panchayat.
after which point, residents will take collective action. At first, the residents will go and complain to the Panchayat. Sometimes, the government EB workers come immediately and rectify the problem (FGD3). At other times, the Panchayat is reticent to rectify system failures in a timely fashion. In response, residents of sector 4 have self-organized a neighbourhood voluntary association that, among other things, independently collects contributions from community-members and arranges for electrical system repairs (INT4, FGD1, FGD2).

4.5.2 Roads

Along with electricity and other services, good roads at the new site were also promised to evictees by the government prior to their resettlement. Presently, the roads in Mylai Balaji Nagar are in very poor condition. Most roads in the community are only mud and are pockmarked with potholes. This, in combination with a lack of effective drainage, results in the stagnant pools of sewage-contaminated water that are ubiquitous throughout the community in all seasons (Rajagopalan 2009, INF, FGD4). As of April 2011, the Panchayat had undertaken the task of converting the mud roads to permanent concrete or asphalt roads (INT6, INT19). Parts of the community have already been upgraded, but much remains to be done as of August 2011.

4.5.3 Solid waste management

As the resettlement was intended as a ‘sites and services’ scheme, residents say that the government should have been removing solid waste regularly since the time of resettlement (Khosla 2009b). However, to this day, solid waste management by the Panchayat remains spotty at best (Khosla 2009c; Rajagopalan 2009). Piles of solid waste litter the streets and choke the canals between sectors (Figure 4-12).

The Panchayat had initially placed garbage bins around the community for residents to deposit their solid waste in. These bins were to be regularly emptied by workers from the Panchayat. However, residents report that it was not long before the bins were stolen or otherwise removed from the community. After this, people resorted to throwing their garbage in the canals or in makeshift dumpsites along the streets. Vacant lots in the community were also turned into dumpsites in which garbage is periodically burnt (INF). Figure 4-8 illustrates the prevalence of
various solid waste disposal strategies at Mylai Balaji Nagar, as captured by the baseline community survey (Appendix B).

![Prevalence of Various Solid Waste Disposal Strategies](image)

**Figure 4-8** | Prevalence of solid waste disposal strategies in Mylai Balaji Nagar (as of January 2010).

Only a tiny minority of people (3%) deposit solid waste in an appointed place; the vast majority resort to open dumping in the canal (35%) or the roadsides (62%). With no designated site for residents to dump, garbage is dispersed throughout the community and Panchayat workers are unable to effectively collect it. As a result, the Panchayat garbage truck seldom comes—maybe once every two to four weeks—to collect only that which is easily gathered (INF). Once a year, the Panchayat undertakes a larger clean-up operation, but without a proper place to store and remove waste from, the situation inevitably reverts to its previous state (FGD2).

Though the preceding summarizes what the present solid waste situation at Mylai Balaji Nagar is, it is not to say that attempts have not been made, by both residents and the government, to improve it in the past. As was mentioned in section 4.2, in 2004, a community-based waste management program was initiated by the Panchayat in cooperation with the international environmental services NGO Exnora. This program trained approximately twenty-six women living in Mylai Balaji Nagar to collect, sort, and recycle or compost solid waste from the community as an income-generating activity. The Panchayat provided a bicycle trolley and a

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132 Our project team also undertook a community clean-up day in early January 2010. It ultimately ended in much the same way. This is discussed further in a later section (section 4.6.1) and in the next chapter.
waste-sorting building in sector 2, and promised that they would provide funding to supplement the worker’s pay (beyond the Rs. 20/mo. fee levied on households for the garbage collection service). The waste management program continued for three years during which the workers struggled with the Panchayat to get the promised funding. It finally collapsed in 2007, when the workers, fed up with what they say was the Panchayat reneging on its promises, reduced garbage collection service levels—leading residents to stop contributing the Rs. 20/mo. fee. The unpaid workers then ceased any waste management activity in Mylai Balaji Nagar and the program collapsed (INT2, INT5).

Three of the workers have taken the waste management program to the campus of a nearby research institution where it has been financially viable (INF, INT2).

During discussions with community-members over the course of this research, the solid waste situation at Mylai Balaji Nagar has repeatedly come up as a community priority. In fact, the project team has been asked to work with the voluntary association in sector 4 to help improve the solid waste situation there. We have taken on this task in cooperation with the voluntary association and, as of January 2012, the work is on-going.

4.5.4 Sanitation and drainage

Sanitation and drainage are perhaps the most significant (and noticeable) service gaps in the community, as is typical of marginalized low-income urban/peri-urban communities in India (Agarwal 2011; Chaplin 2011).

Homes in Mylai Balaji Nagar presently are not connected to any centralized sewerage network. As a result, a number of coping strategies have emerged to manage sewage (Figure 4-9).

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133 This negative experience of community-government cooperation is discussed further in the next chapter.
134 Further details on community development priorities and the complementary activities we have undertaken are discussed in section 4.6.
135 With respect to the poorest quartile of the urban population in India, some 53% do not have access to a sanitary flush or pit latrine (Agarwal 2011). The situation at Mylai Balaji Nagar is a case study illustration of this deficit.
Figure 4-9 | Prevalence of various sanitation practices at Mylai Balaji Nagar (as of January 2010).

Though only a tiny minority resort to the most basic practice of open defecation (3%), the other alternatives all ultimately end in the uncontrolled release of raw human sewage into the surrounding environment (though they do offer more privacy for users). The other sanitation practices prevalent at Mylai Balaji Nagar are briefly described in the following.

4.5.4.1 Public latrine blocks

About one-fifth of households presently use public latrine blocks as their primary sanitation facility. These blocks have ten toilet stalls, five on either side for men and women, and hand-washing stations. They are equipped with large Sintex water tanks to store and provide water for flushing, washing, and maintenance (Figure 4-10). There are several of these latrine blocks in each sector, following a ratio of one toilet for every ten families (INT16).
The public latrine blocks suffer from a range of maladies that stretch back to when they were built shortly after resettlement, and that have resulted in their present dilapidated and unhygienic condition. Though sanitation is a core requirement of the ‘sites and services’ scheme, the TNSCB acknowledges that they failed to deliver at Mylai Balaji Nagar (section 4.2). There were no sanitation facilities when the TNSCB resettled the evictees at Mylai Balaji Nagar, and the newly-arrived people had to improvise in the most basic of ways (Khosla 2009a, INF). The latrine blocks were built only after community agitation forced the TNSCB to ask an outside agency, World Vision, to build something for the people there (INT16, Khosla 2009a). However, no maintenance plan that identified roles and responsibilities for the NGO, the government agencies, or community-members was ever articulated, resulting in the inevitable mismanagement of these facilities. For one, though there are rooftop water tanks, neither the TNSCB nor the Panchayat fills them, rendering them useless. Residents have to carry their own water to use in the latrine blocks (Khosla 2009b). The lack of stored water for maintaining the latrines has directly resulted in their poor hygienic state (INT12, INT3, Rajagopalan 2009).136

Moreover, no government agency sends workers to clean or maintain these facilities. The latrine blocks drain into septic tanks, however, due to highly irregular evacuation of these tanks by the

136 World Vision attempted to rectify this by developing boreholes and installing pumps to make groundwater available for the water storage tanks. This worked for some time while the World Vision-supported cleaning program (discussed below) was operational, but towards its end, the pumps were stolen (INT3).
Panchayat, the sewage often overflows, inundates nearby surfaces, and eventually wastes into the canals (FGD2, INT12, INT5). As such, the latrine blocks remain unusable for long periods of time, forcing residents to resort to other sanitation arrangements (INT12, INT14, INT4).

Attempts have been made over the course of the community’s history to improve this situation. Nowadays, households utilizing an individual latrine block will sporadically band together, collect money, and independently hire a cleaner to restore the latrine block to usability; however, this is typically the last resort when conditions become unbearable and is not sustained. As mentioned in section 4.2, World Vision had previously supported and organized households, through the self-help groups (SHGs), to contribute to the regular maintenance of the public latrine blocks. However, after several years, this program collapsed due to a growing reticence of individual households to contribute to public goods (INT2, INT3).

4.5.4.2 Makeshift personal latrines

As a result of the poor condition of the public latrines, many households have resorted to individual sanitary arrangements (INT12, INT14, INT4). For those who cannot afford to build in-home toilets, makeshift latrines for individual household use fill the gap, with approximately 64% of households using these. The makeshift latrines are simple, open-roofed, rectangular structures built next to the canals, into which they discharge (Figure 4-11).137

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137 This program initially had World Vision supporting the full wage (Rs. 900/mo.) for a worker from outside the community to come and regularly clean each latrine block. As World Vision attempted to progressively transfer the financial responsibility to individual households—first at a subsidized rate of Rs. 5/mo., and then, to make it fully sustainable, the full rate of Rs. 10/mo.—beneficiary households refused to take on the financial burden, and the program collapsed. Graft of the collected monies may have also contributed to this (INT3). Later on, World Vision also tried to organize volunteers from within the community to clean the latrines, but this too failed (ibid.). This instance of failed community collective action is discussed further in the next chapter. In light of all this, the voluntary association that has recently emerged in sector 4 has identified improving the state of the public latrine blocks as among its primary concerns (INT4).

138 In April-May 2011, the Panchayat had issued an order to demolish all of these makeshift latrines along the canal banks as they were planning to cover the canals with concrete slabs. This was being done in order to prevent residents from throwing their garbage in the canal, which leads to it becoming blocked and stagnant, as it regularly does. This strategy was being pursued in lieu of a proper solid waste management strategy to regularly remove the garbage from the community and take it to a landfill. The Panchayat had demolished all of the latrines, but the work to cover the canal had not materialized as of August 2011 so families have rebuilt their latrines (at a not insignificant cost to them) after a period of not insignificant inconvenience.
4.5.4.3 In-home personal toilets

Wealthier households who have pucca houses often build in-home toilets. Approximately 11% of the community utilize these as their primary sanitation facility. Most of these toilets simply drain into street-side ditches that eventually wind up in the canals. Some households having in-home bathrooms have also constructed septic tanks to store the wastewater, however these are not evacuated safely to a waste disposal location, but rather, are emptied into the canals when full (Khosla 2009a). World Vision has previously offered small loans to residents of Mylai Balaji Nagar for building in-home toilets, but this program has had low enrolment (INT3).\(^{139}\)

4.5.4.4 Drainage

Now that all of the sanitation practices prevalent in the community have been discussed, the next question naturally is—where does it all wind up? Due to the lack of a centralized sewerage network, all of the sewage streams discussed above ultimately waste into the drainage canals, and then, into the surrounding wetlands (Khosla 2009c). The canals are not dredged by the Panchayat and eventually become blocked and stagnant (INT5). The combination of uncontrolled sewage inflow and the dumping of solid wastes has turned the canals into open garbage-choked cesspools that are a breeding ground for all manners of pathogens and vectors (Figure 4-12).

\(^{139}\) This suggests that residents are not interested in investments to improve sanitation.
Though the larger streets in the community are lined by ditches (that waste into the canals), drainage throughout the community is inadequate, resulting in the community being dotted with stagnant pools of sewage-contaminated water, even during the dry season. During the monsoon it is much worse as the community is built on ‘reclaimed’ landfill in a wetland. Every year during the monsoon, parts of the community are totally inundated (INF, Meunier-Marécal and David 2009). As mentioned in section 4.2, in the 2004 monsoon a major flood event occurred that caused much devastation to the community (FGD4).

### 4.5.4.5 Government development plans for sanitation

Recently, the Panchayat has begun construction of a centralized underground sewerage network to serve the whole area, and plans to connect into Mylai Balaji Nagar by late 2013 (INT19, INT6, INT16, Meunier-Marécal and David 2009; Khosla 2009c). The sewerage network under construction however entails that a sewage pumping station be built right inside Mylai Balaji Nagar (in fact, on the grounds of the public school in sector 2). The residents have attempted to
resist this but have been unsuccessful, with work proceeding as planned as of August 2011 (INT15).

4.5.5 Water supply

When we were in Mylapore, the water was clean and we were eager to drink that. That was the [Metro] Corporation water. It would [always] be clean. We never know what source of water is being brought over here. Maybe from a well or a muddy pond...it is not clear!

(FGD4)

Since the time of their resettlement, water supply has been one of the primary concerns for residents at Mylai Balaji Nagar. While access to safe and sufficient water was not as critical a problem in the early years after resettlement, today, there is a severe problem in terms of both water quantity and quality (Khosla 2009a). The water supply scenario at Mylai Balaji Nagar and its evolution was introduced in section 4.2. This section elaborates on that discussed in the timeline.

4.5.5.1 Main sources

Household drinking water at Mylai Balaji Nagar, at present, comes from three main sources: public tap water supply, lorry water, and bottled (‘can’) water. The baseline community survey (Appendix B) looked at the longitudinal distribution of primary drinking water source (Figure 4-13).\(^4\)

\(^4\) An important point must be made about this and other time-series graphs in this section. As was discussed in section 3.2.2.3, the baseline community survey underwent a re-sampling in March 2010 that meant that data collected from April 2010 onward was no longer representative of the community as a whole, but rather, was skewed toward TWUs. Though it is no longer representative, it is still interesting for observing seasonal variations. Representative descriptions of the community as a whole were taken from the data collected during the period of January to March 2010.
From the first four bars in Figure 4-13 (i.e. during the representative sampling period), it can be seen that the proportion of households consuming public tap water supply as their primary drinking water source (i.e. TWUs) ranges from 5% to over 20%. A similar proportion of households purchase their drinking water supply from private water lorries (i.e. LWUs). The vast majority of the community—between 70% to 80%—purchases bottled water from local vendors (i.e. BWUs).\(^\text{141}\)

Water for all other household purposes—bathing, toilet, cleaning the home, washing dishes, laundry—is almost exclusively sourced from the public tap water supply (FGD4). Thus, even those households that purchase their drinking water from either bottled water vendors or water lorries, utilize the larger volumes available for free from the public tap water supply for all other household purposes (Khosla 2009a).

\(^{141}\) The time-series data following the re-sampling event (though no longer representative of the community as a whole) indicates that tap water consumption falls to its lowest levels in late October to early November, a gap that is then filled by lorry and bottled water supply. In 2010, this time period corresponded to the period immediately prior to the arrival of the monsoon in Chennai, which was late that year—the point at which the source lake was at its lowest levels. Community-members report that, at this time, the tap water was only turned on once in 3 to 4 weeks and the limited supply was augmented by deliveries from Metro Water lorries, over which fights broke out (INF).
4.5.5.1.1 Tap water

Public tap water supply comes from a lake (Narayanaapuram Lake) approximately one kilometre to the southwest of the community (Figure 4-14).

![Figure 4-14](image-url)

The lake is a receiving body for runoff from the residential communities that immediately surround it, a watering hole for livestock kept by the local population, and is subject to runoff from commercial and light industrial activity that has recently sprung up nearby. Because of these factors, the water is likely to be highly contaminated. Earlier water quality testing of Narayanapuram Lake by other NGOs (Kynarou Association and the Sogreah Foundation) found excessive levels of faecal and total coliforms in the lake as well as in the standpipes in the community itself (Table 4-1). The water quality of the public tap water supply is discussed further in section 4.5.5.2.

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142 Kynarou and Sogreah have been active doing exploratory work in the community since 2007. They carried out feasibility assessments for improving the water distribution network, augmenting water supply, developing storage capacity, and improving water quality. Work has been proposed, modified, and re-proposed, but not yet carried out
Table 4-1 | Water quality results from grab samples taken at various points in 2007 (Dutasta 2010).

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>WATER RESOURCES</th>
<th>WATER DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Untreated water</td>
<td>Surface water</td>
</tr>
<tr>
<td></td>
<td>- surface lake</td>
<td>- underground</td>
</tr>
<tr>
<td></td>
<td>Vilachery lake</td>
<td>Wells</td>
</tr>
<tr>
<td>Appearance</td>
<td>turbid</td>
<td>clear</td>
</tr>
<tr>
<td>Odor</td>
<td>agreeable</td>
<td>agreeable</td>
</tr>
<tr>
<td>Color</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Temperatures (°C)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
<td>Not representative</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>12</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>Hardness (mg/l)</td>
<td>133</td>
<td>32</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>362</td>
<td>521</td>
</tr>
<tr>
<td>Iron</td>
<td>below detection threshold</td>
<td>below detection threshold</td>
</tr>
<tr>
<td>Organic and oxidizable material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/l)</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>% saturation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidizability (mg/l de O)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogenous material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₃ (mg/l)</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>NO₃ (mg/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate(s)</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>Phosphorus total (mg/l)</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>PO₄³⁻ (mg/l-PQ)</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>Suspended particles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MES (mg/l)</td>
<td>860</td>
<td>1725</td>
</tr>
<tr>
<td>Residual chlorine</td>
<td>&lt; 0.2</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Conductivity (μS/cm)</td>
<td>1640</td>
<td>3470</td>
</tr>
<tr>
<td>Chlorides (mg/l) - Cl</td>
<td>145</td>
<td>550</td>
</tr>
<tr>
<td>Calcium (mg/l) Ca²⁺</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>Magnesium (mg/l) - Mg</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>TAC</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>Sodium (mg/l) - NA</td>
<td>32</td>
<td>55</td>
</tr>
<tr>
<td>Potassium (mg/l) - K</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>Sulfate (mg/l) - SO₄²⁻</td>
<td>71</td>
<td>314</td>
</tr>
<tr>
<td>Mineralization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of gems (μ/ml)</td>
<td>1300</td>
<td>2500</td>
</tr>
<tr>
<td>Escheta Coll (μ/ml)</td>
<td>350</td>
<td>540</td>
</tr>
<tr>
<td>Fecal streptococci (u/100 ml)</td>
<td>present</td>
<td>presents</td>
</tr>
<tr>
<td>Thermo tolerant coliforms (u/100ml)</td>
<td>1600</td>
<td>&gt;1600</td>
</tr>
</tbody>
</table>

(Dutasta 2010). As of November 2011, Kynarou and Sogreah have announced they will not be able to proceed with works at Mylai Balaji Nagar due to institutional hurdles.
The water is pumped from a 107 m deep borehole developed within an open infiltration/storage well at the edge of the lake, in which the pumped water collects (Figure 4-15) (Dutasta 2010). The pumped water is untreated beyond the intermittent ad hoc addition of bleaching powder into the infiltration/storage well by agents from the Panchayat (INT6, Dutasta 2010).  

Figure 4-15 | The infiltration/storage well serving Mylai Balaji Nagar in Narayanapuram Lake. The picture is taken shortly after the monsoons, when the lake is at its highest level (photo credit: Kevin Hall).

There are no household piped water connections in Mylai Balaji Nagar. From the storage well, it is pumped to the community where it is distributed via a network of public standpipes, each serving between five and thirty homes (FGD1, Khosla 2009b). Though the distribution pipes are generally buried at a depth of 1.2 m, in places it is exposed at ground level. The system faces significant risk of contamination as containment is compromised throughout its length. Infiltration is especially a concern where the distribution line crosses the sewage-laden canals.

In 2009 Meunier-Marécal and David (2009) elaborate on the shortcomings of the at-source water treatment currently practised by the Panchayat. Daily chlorination is performed at pump intake, however, there is no dosing pump, it is all manually done, the quantities are unknown, and dosage may not be appropriate given the unknown conditions. The treatment is done by two technical agents from the Panchayat (who are responsible for all of the Panchayat’s water supply, not just this well). Meunier-Marécal and David characterize the management of the system as “…chaotic, with limited financial resources, and on a corrective mode only”. Lack of access to piped water in the home is a common issue in Indian slums. One study estimates that 82% of the poorest quartile of India’s urban population does not have access to piped water at home (Agarwal 2011).

A schematic of the water distribution system from Dutasta (2010) is included as Appendix P. This is a common problem encountered with many distribution systems in the urban South as discussed in section 2.1.3.
and is immersed in contaminated water (Figure 4-16). Breakage of pipes is also a concern for water leakage (INT4). The pipes are often damaged by machines carrying out work for other networks (i.e. telephone) or because of repeated water hammer occurrences (Dutasta 2010). Residents are also concerned about the water supply being contaminated due to the unmitigated release of wastewater and medical waste from the nearby private hospital to the south of the community (INT15). In fact, residents relate that when the tap water is turned on, they have to waste the first dozen pots of water that come out due to the awful smell of water, something that has likely arisen because of sewage infiltration into the lines when they were depressurized (FGD1, FGD2, INT15).

![Figure 4-16 Distribution pipe that brings tap water to Mylai Balaji Nagar where it crosses the canals. There are several breaks (obscured by the trash) in the pipe at this location, driving concerns of contamination due to infiltration.](image)

The tap water supply is intermittent and controlled by panchayat agents (Meunier-Marécal and David 2009). For a few hours of a single day, every one to four weeks depending on seasonal water availability, the public standpipes are turned on in different sectors of the community (FGD1, FGD4, INT12, INT15, INT2, INT4, Khosla 2009b; Rajagopalan 2009). The water comes on without warning and without any fixed schedule, forcing women to forgo employment

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147 Water hammer occurs when the distribution pump is turned on while the outlet valves are closed, resulting in pressure spikes and burst pipes.
opportunities outside the community so that they can remain at home to collect water when it comes on (INT15, FGD1, Khosla 2009c). Improving the availability and predictability of the tap water supply is one of residents’ main development priorities (Khosla 2009a).

When the taps are on, the women from each household collect water in several 12 to 20 litre open-mouthed plastic containers (‘pots’) (Figure 4-17), which are then stored in the home (Figure 4-18). Most commonly, glasses or utensils are dipped into the open-mouthed containers to draw water, representing a potential pathway for recontamination of stored water. Additionally, some households have developed their own dedicated water storage capacity in the form of underground sumps or above-ground concrete storage tanks (Dutasta 2010; Meunier-Marécal and David 2009). Finally, World Vision has plans to provide each household with their own 500 litre Sintex storage tanks in the near future (FGD1, FGD4).

In the period leading up to the arrival of the monsoon rains, the lake level steadily decreases, resulting in tap water being turned on less and less frequently (FGD1). At the height of the dry season, the lake almost completely dries up and water supply has to be delivered by lorries (at relatively low frequencies owing to general seasonal water scarcity throughout the region) (Khosla 2009a). During this time, there is acute water scarcity in the community and conflict over water often breaks out (INF). The poorest are especially hard hit as they are unable to supplement their supply with water purchased from private lorry water retailers (Khosla 2009c). More troublingly however, owing to increasing densification of the communities surrounding Lake Narayanapuram that draw upon the resource, there has been a general trend of declining water availability over the years (Khosla 2009a). Moreover, the Panchayat has been progressively filling in the lake with more landfill to make way for further residential development (the lake is presently half of its original size). If this process continues unabated, soon there will be no lake at all (Khosla 2009c).

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148 Residents also recall that, in the earlier days of the settlement’s history (and occasionally even now), the water would come on after midnight, forcing women to stay awake and collect water in the dark of night (FGD1). Women’s lives and income-generating opportunities in poor urban communities throughout the world are profoundly shaped by inadequate access to water (Crow and Mcpike 2009). This is very true at Mylai Balaji Nagar as well.
4.5.5.1.2 Lorry water

Due to the irregularity of the public tap water supply and the limited quantities that households are able to store between occasions that it is turned on, residents of Mylai Balaji Nagar have adopted two strategies to augment their water supply—purchasing lorry water from private suppliers or bottled water from local vendors. During the early days after resettlement the
TNSCB used to arrange for lorries to bring Metro Water to Mylai Balaji Nagar. This water would be stored in the large *Sintex* tanks (~5000 litre) that the TNSCB, or the SHGs with support from World Vision, had placed around the community (INT9). As discussed in section 4.2, this was the primary source of water in the community until the major fire of 1998 when the public tap water system was finally developed (INT9).

Lorry water can come from a number of sources, but these are rarely known to the residents purchasing it. Sometimes it comes from Chennai Metro Water, other times from well-fields far outside the city, and other times from surface water sources. Accordingly, the quality of lorry water is highly variable (INT15, INF).\(^\text{149}\) Reports on the cost of lorry water vary from Rs. 2 to 3 for a pot of 12, 15, or 20 litres (FGD1, INT15, Khosla 2009b). The SHGs initiated by World Vision, the voluntary association in the fourth sector, and other groups periodically arrange for a lorry to deliver water and purchase the whole load. They store the bulk water in the ~5000 litre *Sintex* tanks found throughout the community, in underground sumps, or in concrete storage tanks, and then retail it to households by the pot for a small profit (but at a cost lower than that which the lorry retailers would retail it for) (FGD1, FGD2, Meunier-Marécal and David 2009).\(^\text{150}\)

### 4.5.5.1.3 Bottled water

For those households that can afford it, the ‘premium’ water available in Mylai Balaji Nagar comes in 20 litre plastic containers (called “bubble top” containers or “can water” locally).\(^\text{151}\) Bottled water comes from a variety of manufacturers and is sold at the small provision shops that dot the community. The price depends on the specific brand name, but they typically retail for around Rs. 20 to 25 each (Khosla 2009a). Bottled water may be treated in a number of ways, including reverse osmosis, ozone disinfection, and/or ultra-filtration, at least for the more

\(^{149}\) Assessing the water quality of retail lorry water was not included in the present study, but represents an interesting question for future research.

\(^{150}\) Reports on the rate of a full lorry load of water (~5000 L) range from Rs. 375 (INT4), Rs. 500 (INT3, INT4), Rs. 650 (Khosla 2009a), Rs. 700 (FGD2), and up to Rs. 1200 (INT5). The rate depends on the time of year and the severity of water scarcity. Selling water at a rate of Rs. 2.50 per 15 L can be highly profitable, earning Rs. 233 of profit on each lorry load of water if it is purchased at Rs. 600 per lorry load. It can also be sold for less (i.e. Rs. 2 per pot) by community-based groups (FGD1, INT4).

\(^{151}\) These are what we may refer to as ‘water cooler’ bottles in Canada.
expensive brands. Though quality is the main selling point for bottled water, there are informal reports that bottled water is sometimes no better than the other sources (INF).

4.5.5.1.4 Local groundwater and rainwater harvesting

In addition to the three main sources of water discussed above, rainwater and groundwater also play a limited role in the overall water supply scenario at Mylai Balaji Nagar. Some pucca homes of durable concrete construction are equipped with roof-top rainwater collection tanks, but more generally, many residents collect rainwater during the monsoon season in barrels and other containers. Rainwater is used to supplement household drinking water supply, as residents feel that it is the highest quality water they can get, aside from bottled water which they must purchase (Khosla 2009a).

A few homes in the community also have either boreholes or shallow dug wells. However, owing to the degraded condition of the local groundwater, its utility is limited and wells are relatively rare (FGD4). As was mentioned in section 4.1, there is a municipal dump located to the north of the community. Leachate issuing from the landfill has resulted in extensive groundwater contamination. In addition to this, groundwater in the area is naturally brackish (FGD4, FGD1, INT3, INT5, Meunier-Marécal and David 2009). General water scarcity in Chennai has led to massive over-exploitation of groundwater aquifers in the region (Dutasta 2010; Khosla 2009a). As a result, there have been significant drawdown issues leading to saltwater intrusion in the coastal aquifer (Brisset 2003; Janardhanan 2011).

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152 Assessing the water quality of retail water bottles was not included in the present study, but represents an interesting question for future research.

153 There are more wells in the Tay Nagar neighbourhood, around which Mylai Balaji Nagar has grown. As this is a regularized community that predates the arrival of the re-settled peoples and the installation of the standpipe system, these homes have always relied on groundwater supply as one of their main sources.

154 Because of this, the Tamil Nadu government is restricting groundwater exploitation and forbidding the development of new borewells. The borewell in Narayanapuram Lake that has supplied the community since 2007 may in fact have been illegally developed by the Panchayat, in contravention of this state restriction, but it is unclear when it was promulgated and whether it applies in this case. The French NGO Sogreah that has undertaken exploratory work to augment water supply at Mylai Balaji Nagar had originally proposed to drill a borewell to supply more water to the community, but this plan was later abandoned as it did not fit Chennai’s development plans and regulations (Dutasta 2010).
4.5.5.2 Water quality of tap water

When residents are asked to describe the quality of tap water, they have some “choice” things to say:

There are many problems. Within two days, worms develop in the water. Children get fever frequently if we drink it. Children suffer from loose motions too. Water is yellow in colour. Mostly we use the [tap] water for washing feet, etc...

(FGD3)

The cooked rice gets spoiled. [...] The water as well as the cooked rice has a bad smell.

(INT15)

Lots of layers and deposits form and there is a lot of cloudiness [in the tap water]. Even the colour of the [tap] water is not good—the water that comes now is yellow in colour.

(FGD1)

This [tap] water does not agree with the health of some boys here. They are allergic to it... The water is not good here. It causes a lot of health problems. They suffer with some or other problems or diseases

(INT12)

Smell is coming, [the tap] water is not drinkable, worms are formed.

(FGD4)

Indeed, the results of our longitudinal water quality monitoring program put into empirical terms what the residents have been saying about the public tap water supply at Mylai Balaji Nagar for years. The results of this program are presented here. This activity was introduced in the previous chapter (section 3.2.2.5) but further details are given here.
The baseline water quality monitoring program tracked eleven key chemical and microbiological water quality parameters including:¹⁵⁵

- hardness;
- chloride;
- alkalinity;
- chemical oxygen demand (COD);
- biochemical oxygen demand (BOD);
- iron;
- nitrate;
- fluoride;
- total coliforms;
- fecal coliforms; and
- turbidity.

Samples were taken from several points around the lake source, one from the infiltration well, and several from randomly selected households dispersed throughout the community. These are indicated as ‘Lake’, ‘Infiltration well’ and ‘All lanes’, respectively, in the following figures.¹⁵⁶ Monitoring results for these parameters were compared against the permissible limits for drinking water (Table 4-2) set in IS-10500:1991 (Bureau of Indian Standards 2003).

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Indian Drinking Water Standards (BIS 10500:1991)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Desirable limit</td>
</tr>
<tr>
<td>Total Hardness (as CaCO₃)</td>
<td>300 mg/L</td>
</tr>
<tr>
<td>Chloride (as Cl)</td>
<td>250 mg/L</td>
</tr>
<tr>
<td>Nitrate (as NO₃⁻)</td>
<td>45 mg/L</td>
</tr>
</tbody>
</table>

¹⁵⁵ These particular parameters were not selected by myself, but by our faculty partner at the Indian Institute of Technology Madras, our partner institution in India on the AWSP project. This was determined before the primary research of this dissertation was designed or initiated. Hence, it is not part of the primary research of this dissertation.

¹⁵⁶ Error bars in the following figures represent standard deviations where several values were summarized to a mean (i.e. in the case of the ‘Lake’ and ‘All lanes’ data).
Of these eleven parameters, only five were found to be in excess of the permissible limits specified in Table 4-2. These are COD, BOD, total and fecal coliforms, and turbidity. Results for these five problematic parameters are reported in the following, with the results of the remaining parameters available in the AWSP Baseline Water Quality Monitoring Report (Appendix D).
Chemical oxygen demand (COD) is a proxy measure for the level of organic material present in the water. The desirable and permissible limits under IS-10500:1991 are 5 and 20 mg/L, respectively. As seen in Figure 4-19, it appears that the infiltration well reduced the organics content in the water such that lane (i.e. household) samples were generally within the permissible limit (20 mg/L), though still in excess of the desirable limit (5 mg/L). However, sporadic spikes in COD were observed over the course of the year. Even samples from the lanes and the infiltration well had COD values in excess of the permissible limit of 20 mg/L after May 2010. Organic matter washing into the lake during the monsoon season may be responsible for the observed spikes. Another possibility are breakages in the water pipes introducing sewage or other materials into the distribution water. Given the impact of organics on taste, odour, and the applicability of disinfection treatments, organics are considered a major water quality concern in the public water supply at Mylai Balaji Nagar. Similar trends were observed in the data for biochemical oxygen demand (BOD) (Figure 4-20). This was expected as BOD is a subset of COD and another proxy measure for organics. The level of BOD in the lake is
regularly in excess of the permissible limit (5 mg/L). Though the lane samples are generally within the permissible limit, they are often in excess of the desirable limit (2 mg/L). A spike is observed during the months of June, July and August 2010, during which time the lane samples and the infiltration well were in excess of the permissible level of 5 mg/L.

A parameter of more pressing concern is the microbiological quality of the water at Mylai Balaji Nagar. Most probable number (MPN) enumeration using the multiple tube fermentation method for both total and faecal coliforms revealed excessive levels of coliform bacteria in almost all samples, throughout the year. For total coliforms (Figure 4-21), several spikes can be observed, such as in the month of July, possibly linked to rain events washing in surface detritus and enriching nutrients in the water leading to blooms of bacteria. Throughout the year, almost all total coliform samples had greater than 10 coliform organisms per 100 mL, failing the third BIS permissibility condition. Faecal coliforms were assessed for a shorter period than total coliforms were; however, as
expected, the level of faecal coliforms was always above the desirable limit of zero (Figure 4-22). Similar trends following the rains in July are likewise observed. Though *E. coli* was not assessed as part of this study, the data indicate that the other three conditions of permissibility are routinely breached. Microbiological contamination is a major concern at Mylai Balaji Nagar.

**Figure 4-21** | Total coliform levels in water at various points at Mylai Balaji Nagar from August 2009 to December 2010.
The final parameter of concern observed at Mylai Balaji Nagar was excessive turbidity (Figure 4-23). Indeed such a thing was expected given the levels of organics, poor microbiological quality, and the complaints from community-members. The turbidity values were high in lake samples, exceeding the permissible limit of 10 NTU following the month of August until December. This was likely due to a precipitous decline in the water level in the lake leaving it a muddy puddle during the summer months of August to September, and due to high levels of surface runoff ending up in the lake in the monsoon months of October to December. Turbidity in the lane and infiltration well samples was generally low and within the permissible limit indicating that the infiltration well is effective at controlling turbidity. Turbidity is seen to be a concern in the lake water supply because of its regular seasonal spikes and community complaints.
Overall, it was found that the levels of total and faecal coliforms, COD, BOD and turbidity were regularly in excess of permissible limits set by the BIS. This indicates that the main water quality concerns with the tap water supply at Mylai Balaji Nagar are organic contamination, excessive turbidity, and microbiological contamination. A safe water system for the case study community should be able to handle these concerns. These results corroborate the earlier findings from Dutasta (2010), and confirm that microbiological contamination is the most pressing water quality concern at Mylai Balaji Nagar. Indeed, microbiological contamination of drinking water supplies is an ever-present threat for slums throughout India and the world (Kimani-Murage and Ngindu 2007; Dutta 2005; Swaminathan 1995; UNFPA 2007).
4.5.5.3 Existing water treatment practices

For poorer households that are constrained to drinking tap water (i.e. TWUs), a number of water treatment practices are utilized in the home to make the water more fit for consumption (Meunier-Marécal and David 2009). The baseline community survey looked into this matter as well (Appendix B). Amongst the most prevalent water treatment methods are boiling, alum (for clarification), bleaching powder (for disinfection), various kinds of household ceramic filters, and simple cloth filtration (Figure 4-24).\(^\text{157}\)

![Prevalent Water Treatment Methods Utilized by TWUs](chart)

**Figure 4-24** Longitudinal prevalence of various water treatment methods in TWU households.

From the time-series above it can be seen that, over the course of the year, between 26% and 79% of TWU households treat the tap water prior to drinking it. The prevalence of water treatment (by any method) appears to be greatest in the months leading up to the advent of the monsoon in Chennai. This corresponds to the period that the water quality in the lake drops to its worse of the year, as was described in section 4.5.5.2. Of the various treatments seen to be practised in the community, boiling water (with wood or household gas stoves) was the most prevalent, averaging at around 50% of all TWU households over the course of the year. Ceramic

\(^{157}\) In this graph, as it deals with only the sub-set of the population that uses tap water as their primary drinking water source (i.e. TWUs), the populations before and after the re-sampling event are the same—they are both representative of the TWU population (albeit that after the re-sampling there are more TWUs enrolled). Hence, trends can be followed across the re-sampling event and are still informative.
filters were a distant second with about 10% prevalence on average over the course of the year. Alum, bleaching powder, and cloth filtration were observed, but only rarely. As was discussed in section 4.5.5.1.1, water storage conditions observed in the community do not guarantee the preservation of acceptable water quality over time (Meunier-Marécal and David 2009).

Though a considerable proportion of TWU households reported practising some form of water treatment, the frequency with which treatment was done was found to be highly variable (Figure 4-25). Throughout the year, it was seen that there is a cohort averaging about half of all TWU households that regularly practise some form of household water treatment and treat all of the drinking water they consume. A smaller proportion of TWU households (averaging 6.7% over the course of year) practised water treatment only irregularly, and a small proportion—2.3% of TWUs over the course of the year—practised water treatment only when children were ill.

Ceramic filter use was however observed consistently over the course of the year likely owing to the fact that once purchased the ceramic filters can be used continuously.

As expected, the proportion of TWU households reporting ‘No treatment’ in Figure 4-25 follows the same trend as that seen in Figure 4-24, thereby triangulating the data on how many TWU households practise water treatment at all.

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159 As expected, the proportion of TWU households reporting ‘No treatment’ in Figure 4-25 follows the same trend as that seen in Figure 4-24, thereby triangulating the data on how many TWU households practise water treatment at all.

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162
4.5.5.4 Government development plans for water supply

Chennai has, for years, suffered from massive water scarcity, with millions facing water shortages every year (Brisset 2003; Janardhanan 2011; Karthikeyan 2011). In response, the city is undertaking aggressive plans to expand available supply. Previously, the city was served by diverting surface water resources from nearby rural locales, but with this option now mostly exhausted, the government is looking to the sea. Chennai opened its first seawater desalination facility in the north of the city in August 2010 (the Minjur plant). Another plant is currently under construction just south of Chennai (the Nemmeli plant) and is scheduled to come on line in 2012. This facility is slated to supply south Chennai, including all of Pallikaranai Panchayat and Mylai Balaji Nagar. When it will be connected into Mylai Balaji Nagar is presently unknown, though estimates range from one to seven years. This project is being developed under the auspices of the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) (INT16, INT17, FGD2, FGD3, Khosla 2009c; Dutasta 2010). As of August 2011, work had begun on laying a water main along Velachery Main Road to convey supply from the new desalination plant into the city (INT17).

At a more local level, the Panchayat has also announced plans to construct overhead water storage tanks, for a total capacity of 1500 m³, to serve the whole Panchayat. In Mylai Balaji Nagar itself, the Panchayat has plans to build a surface tank of 200 m³ and an overhead tank of 100 m³, both to be placed in the second sector. The Panchayat is also considering rehabilitating the water distribution network at Mylai Balaji Nagar (INT6, INT3, Dutasta 2010).

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160 Together, these two plants will have a combined capacity of 200,000 m³ per day (INT17, Dutasta 2010).
161 Metro Water is also used to refer to the CMWSSB.
162 When these interviews were done May 2011, the tender for this work had already been put out and a company was to be selected in the near future to begin the work (INT6, Dutasta 2010). As of August 2011, the tender had been accepted by a company, but they have not done any work saying that the tender amount is not sufficient to complete the project as proposed (INT16).
163 Another project is proposed to place two similarly-sized tanks in sector 3, to serve sectors 3 and 4, but this is only in the planning stages at present (INT16, Dutasta 2010).
164 The Panchayat’s plan is to simply replace the existing pipes with the same kind of pipe, without making any substantive system changes. Dutasta (2010) recommends against this proposal as it would not deal with the issue of pressure variations and water hammer which would ultimately result in the leakage/rupture of the network again. Instead, Dutasta recommends a more systemic approach to rehabilitating the water supply system be taken, including closing the open storage well, installing a slow sand filtration and a chlorination system, a backflow system as well as storage tanks, and then rehabilitating the pipes.
4.5.6 **Health services**

Health care services are inadequate at Mylai Balaji Nagar. There is no government hospital or clinic in the community or even nearby, however a number of charitable health services providers have been present in the community over the years. Periodically, health camps will visit the community, sometimes facilitated by the government or local charities (INT5). A nearby nursing college also used to send nursing students to conduct health outreach in the community, but this seems to be defunct as of August 2011. A small CBO called *CRAD Trust* used to operate a nursing station in sector 2, but this has since shut down as well (INF).\(^{165}\)

Presently, there are two main providers of health care in the community. Periodically, a mobile health clinic truck comes to the community and parks along the main road, where it can be visited by residents. More permanent is the health clinic in sector 2 established by the charitable organization St. John’s Ambulance. The clinic has a doctor that visits three days a week (INT2). Residents also utilize traditional and home medicine, or visit nearby private hospitals when cases are critical (FGD4). In recent years, a private hospital has opened up just to the south of the community (the *Kamakshi* Hospital).

4.5.6.1 **Diarrhoeal disease burden**

When discussing the tap water supply, residents complain of a host of maladies that it gives rise to including fever, diarrhoea, skin problems and allergies, stomach pains, and vomiting. Children and the elderly are especially vulnerable to these ailments (FGD1, FGD3, FGD4, INT12, Khosla 2009c). Given the state of water quality in the community, the limited medical records encountered, and residents’ complaints of frequent illness, the baseline community survey (Appendix B) also sought to investigate the diarrhoeal disease burden in the community. An add-on module to the baseline community survey served as a longitudinal diarrhoeal disease monitoring program (as introduced in section 3.2.2.4). Specifically, this program was designed to monitor the longitudinal prevalence of diarrhoeal disease amongst children five years and younger (Figure 4-26).

\(^{165}\) It was staffed by a volunteer nurse, dispensed basic medicines, and kept records of illnesses presented at the clinic. Most illnesses on record were water-related, and included diarrhoeal diseases, infectious hepatitis, typhoid fever, parasitic infections, and other gastro-intestinal disorders (INF).
From the representative sample, it was observed that between 0.26% to 3.39% of children aged five years and under in the community were suffering from diarrhoeal disease at any given time. This range was replicated in the post re-sampling data, but as the sample no longer represented the same population, they cannot be compared to one another. The variability apparent in both the original sampling and re-sampling frame is likely due to random error. Originally it was anticipated that the diarrhoeal disease and water quality monitoring data could be cross-compared in order to investigate possible seasonal co-variation. However, due to the relatively low diarrhoeal prevalence rate observed, no seasonal variation is apparent through the random error.

Compared to diarrhoeal disease prevalence rates published in the literature, that rate observed at Mylai Balaji Nagar is relatively low. Brown, Sobsey, and Loomis (2008) found the longitudinal prevalence of diarrhoea to be 23% amongst children less than five years in a rural village in

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166 The blue line in Figure 4-26 represents data collected from a representative sample of randomly selected households from across the community prior to the re-sampling event; the pink line represents data collected from a sample enriched with TWUs (which is no longer representative of the community as a whole).
Cambodia. In a study based in a slum in New Delhi, India, Marimuthu, Meitei, and Sharma (2009) found a diarrhoeal morbidity prevalence of 15% amongst the general population. Luby et al. (2006) found diarrhoeal prevalence to range from 2% to 10% depending on age bracket in a control group for a water treatment and hand-washing intervention in informal urban settlements in Karachi, Pakistan. Relatively high rates were documented in a slum community in Varanasi, India of 47.2% amongst children under five (Saran and Gaur 1981), and 51% amongst children less than three years in rural Sindh, Pakistan (Shah et al. 2003). Mishra et al. (1990) observed seasonal variability, with diarrhoeal prevalence ranging from 8.7% to 33% amongst children under five living in slums in urban Mirzapur, Uttar Pradesh, India.

The relatively low prevalence rates for diarrhoeal disease observed at Mylai Balaji may have arisen because of a number of factors. For one, as shown in Figure 4-13, the majority of residents drink bottled water which is relatively safe. Only a small minority consume the demonstrably contaminated tap water supply. This may have a protective effect, reducing the observed diarrhoeal prevalence at Mylai Balaji Nagar. Other factors such as improved nutritional status or reduced risk from other pathways of pathogen transmission (Figure 2-1) may also reduce the overall risk profile at Mylai Balaji Nagar compared to other communities documented in the literature.\(^{167}\)

When children are suffering from diarrhoeal illness, caregivers adopt a number of strategies for managing it. Amongst these are the use of oral rehydration therapy, visits to an allopathic physician (western medicine), in-home self-administration of allopathic medicines, or traditional and home medicine (Figure 4-27).

\(^{167}\) The method of self-reported prevalence may have mischaracterized the actual disease levels.
Prevalence of Various Strategies for the Treatment of Diarrhoeal Diseases

Figure 4-27 | Longitudinal prevalence of various strategies for the treatment of diarrhoeal disease amongst children as captured in baseline community survey (January 2010 to January 2011).

The vast majority of households rely upon allopathic medicine for the treatment of children’s diarrhoeal illnesses. At various points of the year, visits to the doctor are preferred or alternatively, the self-administration of allopathic medicines. Oral rehydration therapy is not observed to a significant extent at Mylai Balaji Nagar. Traditional and home remedies also appear on a few occasions, but generally take a backseat to western medicine.

The preceding sections have detailed the general inadequacy of basic services at Mylai Balaji Nagar. The community has only informal and intermittent connectivity to the electrical grid; unpaved, un-drained, and pot-holed roads; a total lack of effective solid waste management, and more troublingly, totally inadequate sanitation; faces persistent water scarcity and contamination of tap water; and lacks access to affordable health care services. Unfortunately, these conditions are not unique to Mylai Balaji Nagar, but are shared by unplanned, informal, or otherwise marginalized low-income urban and peri-urban settlements the world over (UNFPA 2007; UN-HABITAT 2011). Much of these conditions ultimately trace back to the issue of land tenure. Government authorities argue that because residents have not fulfilled the fiduciary obligations necessary to secure title to the land, they are absolved of responsibility to provide these basic services. Community underdevelopment—both in the sense of physical infrastructure as well as of social cohesion—at Mylai Balaji Nagar, as with informal settlements the world over, is
inextricably linked to insecurity of land tenure (Grant 2001). This is a major theme in the discussion on the appropriate level of application for a safe water system in the next chapter.

4.6 Participatory assessments of community development priorities

As was discussed in section, this research (in fact the larger project in which it is embedded) was preceded by a lengthy process of informal exploration and problem identification with residents and other stakeholders in order to identify community development priorities. This work began in 2007 when I visited Mylai Balaji Nagar for the first time with a local CBO (CRAD Trust) and a French-Indian NGO (Kynarou Association). During informal walkthroughs of the community, we had many conversations with residents who discussed their daily and most pressing challenges. Some of the challenges that came up included (INF):

- the struggle to get formal land tenure;
- the desire to improve their children’s educational opportunities;
- improving their family’s economic well-being through better livelihood opportunities;
- having the Panchayat and other government bodies improve the sorry state of basic services in the community;
- the indignity of the poor sanitation, lack of solid waste management, and the degraded environment in which they found themselves; and
- the struggle to get sufficient and regular access to safe water.

Previous participatory needs assessments had also been done by CRAD Trust and World Vision which had identified improved health services, safe drinking water, increased water supply, improved sanitation, solid waste management and improved drainage as community priorities (INF). As our research team (including our faculty partners at IITM) had expertise with environmental engineering, we were thus drawn to focus on improving the water and sanitation situation at Mylai Balaji Nagar.

The AWSP project was formally inaugurated on August 15, 2009. Since the project officially began, we have continued to learn more about community development priorities, both general

\[\text{\footnotesize\textsuperscript{168}}\]

\footnotesize\textsuperscript{168} The project was launched with a ceremony in the community on India’s national independence day on August 15th, 2009. In attendance were various government officials who pledged their support for the project. This day marked our official arrival in the community, though we have been engaging in an informal manner since the initial exploratory mission in 2007.
and those specific to water and sanitation, through a number of formal and informal activities. One of these (formal) activities was a workshop (the First All-Stakeholders’ Forum) held at IIT Madras on December 1, 2009. This event brought together stakeholders to discuss the water, environment, and public health challenges at Mylai Balaji Nagar (Figure 4-28). The first All-Stakeholders’ Forum was initiated in order to encourage discussion between the stakeholder groups, explore stakeholder perspectives and conflicts, encourage community and governmental support, articulate and discuss community development priorities, encourage community organization around these self-identified development priorities, and to refine and direct the objectives of our research project. Community representatives led a discussion on the water and sanitation challenges their community faced and generated a list of twenty-eight concerns (Figure 4-29).

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169 Present were some twenty-five residents (mostly women) from the community, including leaders of the women’s SHGs; representatives from government agencies including the TNSCB and the CMWSSB; elected representatives and officers from Pallikaranai Panchayat; faculty and students from IITM; our research team from IITM, the University of Guelph, and Queen’s University; and representatives from other NGOs active in the community, including CRAD Trust, the Kynarou Association and World Vision. Presentations were made by all stakeholders present including: community representatives; the MDs of the TNSCB and the CMWSSB; Panchayat representatives; by World Vision and Kynarou; and also by our research team. The presentation by the community representative was made by one of our field staff on the project who is also a resident of the Mylai Balaji Nagar, residing in the sector 1.

170 A social scientist on the research team, Dr. Jana Janakiram, invited all of the community-members and NGO representatives present to brainstorm a list on the community’s development priorities.
The community-members and NGO representatives ranked the ten most pressing concerns according to their perspective. These rankings were compiled and averaged in order to generate a ranked list of priorities:

1. The use of protected sources (borewell) for drinking water.
2. The need to have safe and clean water.
3. That tap water turns odorous within a few days of storage.
4. Connecting to the Chennai Metro Water network.
5. Mixing of wastewater in drinking water sources.
6. Increasing the presently insufficient quantities of water.
7. The lack of proper drainage and sanitation facilities.
8. The lack of 24-hour water availability.
9. Improving the quality of the presently turbid tap water.
10. The lack of proper solid waste management, leading to garbage being thrown in public places.

Water quality and quantity issues figure prominently in this list. In addition, drainage, sanitation and solid waste management are also issues for community-members. The focus on water quality issues resonated with the expertise and experience of the research team, and this was selected as the primary focus of the research project with the community-members and other stakeholders present. 171,172

Moreover, over the course of the present research as well, residents have voiced their concerns and priorities for their community as well. Some of the development priorities that have come up in the course of primary research include (FGD1, FGD2, FGD3, FGD4, INT1, INT2, INT3, INT4, INT5, INT 15, INT18, Khosla 2009b; Rajagopalan 2009):

- improving the quantity and quality of common public water supply;
- obtaining safe drinking water for their families;
- regularity and predictability of existing tap water supply;
- increasing the number of standpipes so that fewer families need to share a single one;
- faster response times from the government when the tap water network is damaged;

The meeting continued with building action plans to address these issues between the research team, community-members, external NGOs, and government officers. In fact, these exchanges became quite heated at times as the community confronted the MDs of the TNSCB and CMWSSB and Panchayat officials about the broken promises over the years and the failure to deliver basic services. This was one of the first occasion in years that the community had even seen representatives from the TNSCB and CMWSSB, let alone the MDs! The MDs made pledges to improve the situation at Mylai Balaji Nagar, but to date, not much has been done by either institution. From this and subsequent discussions with key stakeholders did the work-plan for the larger project emerge, which eventually fed into the present research work. 171,172
• preventing the contamination of the public water supply arising due to the uncontrolled discharge of medical waste and sewage from the nearby private hospital;
• improving water storage capacity in the community;
• formal household water connections from Metro Water (piped supply with household taps);
• diversifying the sources of water so residents are not so dependent on a single unreliable source (i.e. public tap water system)—for instance, by developing borewells for groundwater extraction;
• formal electrical connections from the state electricity board and quicker response times in the case of blackouts caused by equipment failure;
• traffic police presence at nearby intersections due to high rate of accidents along Velachery Main Road;
• a police station in the community to control crime and theft;
• closing down the wine shop in sector 2 due to rising alcoholism amongst the menfolk of the community;
• obtaining full patta to their plots;
• a (free) government hospital in the vicinity;
• improving solid waste management in the community; and
• improving sanitation facilities including regular cleaning of public latrine blocks by the government or an NGO.

4.6.1 Complementary community development activities

Working in the community and building relationships with residents presents the moral imperative to work with residents on the priorities identified above. As such, the project team has also been engaged in some complementary community development activities, over and above the research of the project. These included:

• WASH outreach workshops;
• youth sports clubs and tournaments;
• school children’s quiz and sports days;

\[173\] These are not detailed here but are included so as to contextualize the community engagement that has taken place over the course of this research.
• tree plantation drives;
• community clean-up and canal rehabilitation days;
• children’s health camps;
• improving solid waste management in the community; and
• improving educational facilities.

Further details on some of these activities are available in the AWSP Baseline Community Survey Report (Appendix B).

This section has attempted to describe, in as full a manner as is concisely possible, the history and present state of the case study community, Mylai Balaji Nagar. This was done in order to contextualize for the reader the setting in which the present decision-making support tool was developed and implemented, as well as to lay the foundations for the case study. This section has built up a picture of the case study community, Mylai Balaji Nagar, by discussing its location and physical layout, resettlement history, land tenure status, demographics and socio-economic characteristics, the status of basic services and coping strategies, and finally, its self-identified community development priorities. Now that this task has been accomplished, the next two chapters will present the results of the case study implementation of the decision-making support tool at Mylai Balaji Nagar.
CHAPTER 5: RESULTS & DISCUSSION I: APPROPRIATE LEVEL OF APPLICATION

Chapters 5 and 6 present the results of the case study application of the decision-making support tool at Mylai Balaji Nagar. The results are divided into two parts and are presented in two chapters corresponding to the two key design decisions (section 1.2). This chapter deals with the first key design question: *what is the appropriate level of application for a safe water system at Mylai Balaji Nagar?* Specifically, it reports the results from the application of the methodology detailed in section 3.4.1. The next chapter explores the second key design question on appropriate safe water technologies.

This chapter is divided into several sections, each one relating to each of the dimensions given in Table 2-3. Each section is composed of three parts: first there is a small table with the

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\(^{174}\) Of the dimensions given in this table, two are not included as unique sections in this chapter. Economies of scale is integrated into the discussion on availability of upkeep funding (section 5.7), and fostering of social cohesion is integrated into the discussion on propensity to collective action (horizontal social capital) (section 5.9). The content of these dimensions is subsumed in the discussion of other dimensions, so they do not require unique sections.
dimension (and the pertinent question associated with it) and the mapping of household and community level systems with respect to that dimension/question (for reference). Then, each section presents the qualitative and quantitative data from baseline and primary research that are pertinent to that dimension. Finally, on the basis of these data, an ‘expert’ assessment by the investigator is generated on which level of application—household or community level—may be more appropriate for a safe water system at Mylai Balaji Nagar with respect to that dimension. Data for the investigation into the first key design question was gathered primarily during FGDs 1 to 4, and from INT and INF events (Table 3-4). The raw data from the primary research—that is, the transcripts of the focus group and interview sessions—are available in Appendix S. To illustrate the analytical process, the coding analysis tables and memos are included in the appendices (Appendices ZA and ZB, respectively).175

A final ‘synthesis’ section collates the assessments for each dimension to generate a ‘total’ recommendation on which level of application may be, altogether, more appropriate for the case study community.176 As a note, though it is not the primary focus of this decision-making support tool, it is inevitable that—in looking to the potential roles of different stakeholders in a safe water system—the matter of appropriate O&M frameworks will arise. This chapter offers some comments in this regard as well. As before, attribution of data to primary and baseline sources here follows the conventions described in section 3.3.1.5.

175 The coding analysis tables (Appendix ZA) present the coding (“nodal” in NVivo 9) structure in the beginning and then present the primary and baseline transcript data that is coded to each dimension/node. The transcript data here are edited and processed following the description in Section 3.4.1, whereas the transcripts in Appendix S are raw and unedited.

176 As this chapter primarily features ‘expert’ assessments by a single investigator (that is, by the author), it could be criticized as being overly subjective. This risk must be duly acknowledged, but in response I would also say that the present work is the first attempt in the literature on the global safe water challenge to articulate the differences between household and community level safe water systems and to probe how a decision between them can be made. This matter is one that is presently not very well understood; as such, the present work attempts to do the most with what is presently known. Potentially, with further implementations at either level and as more is learned about how they function in the real world, the differences between the two approaches and how to discriminate between them in a more ‘objective’ fashion will come into better resolution. For the time being however, the present approach of gathering all of the relevant data from baseline, informal, and primary research and making an informed assessment on the basis of these data is the necessary first step. This was the same approach taken by Baffrey (2005), Sobsey (2002), and Sobsey et al. (2008) as they also tried to resolve how to grapple with uncertainty, local specificity, and limited information in making a decision on appropriate safe water technologies. I feel that this approach is the right first step for both aspects of the present decision-making support tool.
5.1 Treatment complexity

<table>
<thead>
<tr>
<th>Treatment complexity</th>
<th>Q: Are there water quality concerns that necessitate more complex treatment methods?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
<td>Water quality concerns must be simple and relatively straightforward to treat, as untrained lay-persons are operators at the household level. Only relatively basic water treatment techniques are applicable at the household level.</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>Water quality concerns can be more complex (as can the water treatment) as training of small systems operators is possible. If water quality concerns demand advanced treatment techniques (e.g. RO, UF, etc.), these may be more suited to a community level system.</td>
</tr>
</tbody>
</table>

The main source of water at Mylai Balaji Nagar is the tap water supply from nearby Lake Narayanapuram that is distributed via community standpipes. Its quality was discussed at length in section 4.5.5.2. Overall, it was found that the tap water contained excessive levels of total and faecal coliforms, COD and BOD, and turbidity, indicating that the major water quality concerns at Mylai Balaji Nagar are organic contamination, excessive turbidity, and microbiological contamination. These are common water quality concerns when dealing with surface water sources in the underdeveloped South. As such, a number of well-developed and relatively simple water treatment technologies are available for handling these contaminants at both the household and the community level (Table 2-4 and Table 2-5). Thus, with respect to this dimension, both household and community level systems are viable at Mylai Balaji Nagar.

5.2 Number of water supply sources

<table>
<thead>
<tr>
<th>Number of water supply sources</th>
<th>Q: Does drinking water come from several sources?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
<td>Household systems can take input from a number of different water sources, however, treatment effectiveness may be affected.</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>Community systems are typically built around a single source and are unable to handle different sources of water input.</td>
</tr>
</tbody>
</table>

A multiplicity of water supply sources are utilized at Mylai Balaji Nagar as was described in section 4.5.5. At present, the majority of residents use bottled water or lorry water as their

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177 Though not tested in the present study, lorry water and bottled water are assumed to be less problematic with respect to water quality than tap water due to their preferability and higher cost.
primary drinking water source (Figure 4-13).

It is only the poorest residents whom are constrained to using the tap water as their primary drinking water source. A community level system could be developed to treat the surface water resource that supplies the taps. Such an approach would not only directly serve the poorest households in the community, but the entire community would stand to benefit if the tap water supply was to be improved (i.e. it would encourage LWUs and BWUs to revert to drinking tap water).

However, as desirable as a community system may seem, there are some serious complications that arise when the seasonal availability of the surface water resource is considered. As discussed in Section 4.5.5, Lake Narayanapuram has become a seasonal lake and the tap water is not consistently available throughout the year. As such, lorry water and bottled water are used to supplement the water supply in the community, especially during the dry season. Given the multiplicity of sources, the seasonality of the tap water supply, the intermittent nature of the supply, and conflict arising due to water scarcity in the dry season, household level systems may actually be more appropriate. Household systems offer two important benefits relating to these concerns: 1) household systems can handle multiple inputs, something that is known to vary from household to household and over the course of the year (Figure 4-13); and 2) household systems allow individual households to control, manage, and ration their own safe water supply. The latter point is something that is especially important during periods of water scarcity. As one participant put it during the first focus group session:

\[ \text{During times of water shortage, we prefer doing the water treatment at the household level.} \]

\[ \text{(FGD1)} \]

Participants felt that during periods of water scarcity there is competition for water and conflict breaks out. As such, households prefer to control their own water supply instead of having to

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178 As discussed in section 4.2, a situation that is at least partly the result of the degradation of the quality of the tap water supply in recent years (INT9, FGD1).

179 Moreover, some water treatment technologies cannot handle intermittent flow and need to be operated continuously. One notable exception to this are slow sand filters (also known as biosand filters) which can be operated on a intermittent basis (Jenkins, Tiwari, and Darby 2011).
compete with other households (FGD1, INF). Thus, household systems appear to be better suited to the overall water supply situation encountered at Mylai Balaji Nagar.

5.3 Recontamination risk

<table>
<thead>
<tr>
<th>Recontamination risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q:</strong> Is there ambient contamination in the community that increases the risk of recontamination of treated water?</td>
</tr>
<tr>
<td><strong>Household</strong></td>
</tr>
<tr>
<td>Household systems may be preferable where there is considerable ambient contamination, as there are fewer opportunities for recontamination when treatment occurs closer in time and space to consumption. Safe storage is also critical for preventing recontamination.</td>
</tr>
</tbody>
</table>

The deplorable solid waste, sanitation, and drainage situation at Mylai Balaji Nagar was described in sections 4.5.3 and 4.5.4. The ambient environment at Mylai Balaji Nagar is extremely contaminated and presents countless opportunities for recontamination of treated water. As such, limiting the time and distance between treatment and consumption is an important concern at Mylai Balaji Nagar (INT18). Thus, household level systems are preferable with respect to this dimension. The risk of recontamination however can (and should) be mitigated in either scenario through the use of effective safe storage.

5.4 Quality control and monitoring

<table>
<thead>
<tr>
<th>Quality control and monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q:</strong> Is centralized water quality control and monitoring desired or mandated (by regulation)?</td>
</tr>
<tr>
<td><strong>Household</strong></td>
</tr>
<tr>
<td>Centralized water quality control and monitoring is not feasible with household level systems. As a result, end-users may not be confident in the quality of their drinking water. Decentralized methods of water quality testing may be applied to improve end-user confidence, however, this may not satisfy regulatory requirements for central authorities to monitor and assure water quality (if they exist).</td>
</tr>
</tbody>
</table>

In India, the primary responsibility for the provision of safe drinking water (and sanitation) rests with state governments. However, since 1994, when the 73rd Constitutional Amendment was ratified, state governments have been enabled to devolve responsibility for water supply to
Panchayat Raj Institutions (PRIs) and Urban Local Bodies (ULBs) (Khurana and Sen 2007). In Tamil Nadu state, indeed it is the case that PRIs/ULBs are now responsible for water supply. Regardless of which level of government may be responsible, regulations for drinking water quality are stipulated by the Bureau of Indian Standards in IS-10500:1991 (Bureau of Indian Standards 2003). Government authorities are required by law to monitor and assure that drinking water quality meets these standards. Community level systems are well-suited to facilitating this requirement.

There is another aspect to quality control and monitoring that was unforeseen prior to the outset of the research and which emerged during its course. When participants were asked during focus group sessions about why they preferred household or community level systems, some suggested that they had less confidence in the quality of water that is treated in the home:

*The result is assured [with a community level system]. We won’t know if the home-based method would be fruitful.*

(FGD3)

Similar statements were encountered during other research activities as well (c.f. FGD4). This feeling appears to come from a lack of confidence among residents that they can properly carry out water treatment tasks in the home themselves. Household water quality testing tools, such as H$_2$S strip test bottles, could conceivably improve end-user confidence in water treated in the home; however, the extent to which this is true is not presently known. Moreover, to date there has not been much experience integrating decentralized tools with the water quality monitoring program linking individual households to such authorities. This phase will take place after the completion of the primary research of this dissertation and thus is not part of the present work.

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180 The creation of PRI/ULBs was part of a larger project of the Government of India in the 73rd Constitutional Amendment of “democratizing” governance by devolving authority to more local levels (Ministry of Law and Justice 1992). PRIs and ULBs are now the most local level of governance in rural and urban India respectively.

181 In the present case, Pallikaranai Panchayat is the relevant PRI.

182 Unfortunately, as is often the case in India, what exists on paper is not what exists in practice. The overwhelming water quality crisis in India today attests to the fact that these regulations are seldom adhered to.

183 H$_2$S strip test bottles are a simple and inexpensive tool for detecting potential faecal contamination of water. These enable individual households to assess the bacteriological quality of their own drinking water in a simple, rapid, and cost-effective manner at the household level (Manja, Maurya, and Rao 1982; Pillai et al. 1999; Sobsey and Pfaender 2002; Venkobachar et al. 1994; McMahan et al. 2011). H$_2$S strip test bottles are part of a participatory water quality monitoring program that is part of the larger project in which this work is embedded. This phase will take place after the completion of the primary research of this dissertation and thus is not part of the present work.
programs of central authorities. Thus, in order to satisfy institutional requirements and assure households of safe water quality, community level systems may be more appropriate in the context of Mylai Balaji Nagar, though it must be acknowledged that monitoring at the community level will mean little if the distribution network remains as degraded as it is.

5.5 Rate of deployment

<table>
<thead>
<tr>
<th>Rate of deployment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q: How quickly must the water treatment system become operational?</td>
<td></td>
</tr>
<tr>
<td><strong>Household</strong></td>
<td><strong>Community</strong></td>
</tr>
<tr>
<td>Household systems can be rapidly deployed as no construction or infrastructure is required, although some mobilization of local people and institutions may be necessary.</td>
<td>Community systems have a longer horizon to become operational as construction of facilities and infrastructure is required. Moreover, mobilization of local people and institutions may be more complex and slow-moving.</td>
</tr>
</tbody>
</table>

This dimension pertains to how immediate the need for safe drinking water is in the case study community—and the situation at Mylai Balaji Nagar is somewhat equivocal in this regard. One pertinent feature here are the government’s water supply development plans. As discussed in section 4.5.5.4, the CMWSSB has indicated that Mylai Balaji Nagar will eventually be connected to the Metro Water supply—abrogating the need for a water treatment system to improve the quality of the surface water resource altogether. When this will happen remains to be seen, but the CMWSSB estimates it may take approximately five years (INT17). In this regard, there is likely a sufficient horizon in which to implement and enjoy the benefits of a community level system before the need is abrogated altogether. This is not to say that a community level system is more desirable with respect to this dimension, but just that it may still be worthwhile.

A clearer indication of which level of application may be more appropriate emerges when considering the current water supply situation in the community and the coping strategies that have emerged as a result (sections 4.2 and 4.5.5). On one hand, the fact that many residents have already shifted to drinking lorry or bottled water suggests that the situation has stabilized and that immediate intervention may not be necessary. On the other hand, approximately 5% to 20% of households still rely on the tap water as their primary drinking water source (Figure 4-13), and only about half of these households regularly practise some form of water treatment (Figure
This indicates that there is still a substantial population that lacks access to safe drinking water, and as such, are presently at risk of diarrheal and other water-related illnesses. Thus, with respect to just this dimension, household level systems, as a more rapidly deployable solution, may be preferable.

**ECONOMIC DIMENSIONS**

5.6 Availability of capital funding

A note is required before discussing the next two dimensions. *Availability of capital funding* and *availability of upkeep funding* are grouped as ‘economic’ dimensions in Table 2-3 because they have to do with the capital and O&M funding of a safe water system. These two dimensions connect to much larger contemporary debates on the role of private and public sector participation in the global water sector, and the status of water as a public good, a commodity, a human right, or part of the global commons. Specifically, these two dimensions inevitably raise the question of what sort of approach should be taken to financing and O&M on water projects; this is a deeply complex and contentious matter that indeed warrants great attention. The present work does not include a comprehensive analysis of financing and O&M approaches due to space restrictions. As such, the scope of discussion on these matters is limited here to: a) how they influence which level of application may be more appropriate; and b) some preliminary comments on what sort of financing and O&M approaches may be viable at Mylai Balaji Nagar. Such comments from this and other sections are parsed to elucidate possible financing and O&M approaches at Mylai Balaji Nagar in the final ‘synthesis’ section (section 5.14). Further details on scope limitations are indicated in the respective sections for each dimension. With that said, we proceed on to discuss the first economic dimension—availability of capital funding.

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184 And this is to say nothing about whether these treatments are effective or not.
185 The urgency of this concern however is somewhat diminished by the relatively low prevalence levels observed during the baseline diarrhoeal disease monitoring program (Figure 4-26).
186 For more on these debates, c.f. Gleick et al. (2002), Gleick (2007), and Bakker (2007).
Availability of capital funding

<table>
<thead>
<tr>
<th>Household</th>
<th>Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household systems may be preferable where start-up capital is limited as they have fewer up-front costs (due to the lack of infrastructure).</td>
<td>Community systems are only viable where start-up capital is sufficient to support the development of the necessary infrastructure.</td>
</tr>
</tbody>
</table>

The availability of capital funding to support investment in infrastructure is necessary for the development of a community level system. The scope of this section is limited to the availability of capital funding from various sources in the case study community with some limited discussion on the financing approaches these sources may entail. Capital funding can come from a number of sources including community-members themselves, government agencies, NGOs, the private sector, or a combination thereof.

**Community-members as a source of capital funding**

As was discussed in section 4.6, residents of Mylai Balaji Nagar see improving the quality of the public tap water supply as a priority and say they are ready to contribute to collectively solving it:

**SIA:** If it is at the community level, will people be contributing and participating in such an endeavour, for its building and its maintenance?

**P4:** Everybody’s participation and cooperation ought to be there. And I am sure everybody will contribute for it. People have to contribute if they want to drink more and good [water]. People will do whatever is possible from their means and their ends.

**P5:** Water is important, hence people will contribute for it.

**P4:** People will contribute their money towards reasonable expenses for such thing. They will contribute definitely for such thing.

(FGD1)

Over the course of the primary research, respondents have suggested a number strategies for implementing a safe water system in the community. Residents and NGO workers suggest that, with sufficient outreach and education, capital funds can be raised from across the community
(FGD1, FGD2, FGD3, FGD4, INT1, INT15). Others have also suggested mobilizing wealthier residents to subsidize a community level system (INT5).

Though many respondents insist that community-members would be prepared to contribute to financing a collective project in the community, when asked about previous experiences in this vein, there are no known examples.\(^{187}\) Moreover, previous experiences with residents contributing to smaller collective efforts are not encouraging. A community-based worker for World Vision, who has been involved in community development efforts for several years, relates this feeling:

_SIA:_ Given the experience with the latrine cleaning program, do you think people would contribute money to the collective construction of a community level water treatment system?\(^ {188}\)

_P:_ It is difficult to envisage that people will contribute funds. In the case of water, people are willing to immediately pay Rs. 20 to get a bottle of water, but they would not be willing to put money into a collective project for good water, even if the returns would be better eventually.

(INT3)

In addition, some respondents predict that problems may arise with funds being lost to graft; even if this does not happen, suspicions that funds are being misdirected will inevitably arise (FGD2, INT4, INT5). The only positive example of collective financing encountered during the research was of households collectively contributing small amounts (i.e. Rs. 100 per household) a few times a year for religious festivals and ceremonies in the community (INT4). Thus, the evidence is not encouraging that community-members themselves would be a viable source of capital funding for a community level system.

\(^{187}\) Even the position that residents would be prepared to contribute is not uncontroversial, as discussed in the next section.  
\(^{188}\) The latrine cleaning program mentioned here was discussed in the previous chapter in section 4.5.4. It is discussed further in the next section.
**Government agencies as a source of capital funding**

Government agencies are also another potential source of capital funding, however, the history of Mylai Balaji Nagar and its tempestuous relationship with government agencies is not encouraging (section 4.2). As documented in the section on land tenure of the previous chapter (section 4.3), a general ambiguity permeates the question of which government agency is responsible for basic services at Mylai Balaji Nagar. From the very outset of resettlement, the TNSCB did not have funds earmarked to support the delivery of even basic municipal services in the community. Now the agency says they are unable to contribute anything as they have moved on to resettlement projects elsewhere (INT7). In fact, the TNSCB had transferred all responsibilities for basic services provision to the Panchayat shortly after resettlement. However, to this day, the Panchayat is not able to draw any land tax revenue from Mylai Balaji Nagar (due to its unresolved tenure situation), and thus considers the community a low priority for basic services improvements (especially when compared to other areas in the jurisdiction that are formalized and from which the Panchayat regularly collects land taxes) (INT16, INT18, INT19, INT15, INT6, FGD1, FGD2, FGD4). The Executive Officer (E.O.) of Pallikaranai Panchayat says that the agency would take funds from an outside entity to support development efforts at Mylai Balaji Nagar, but there is little chance of the Panchayat mobilizing discretionary funds itself to build a community safe water system (or any other infrastructure) at Mylai Balaji Nagar (INT19).\(^\text{189}\) Thus, government agencies are unlikely to be a viable source of capital funding for a community level system. The Panchayat has also indicated that they are unable to provide benefits to individual households altogether (INT6).

**NGOs as a source of capital funding**

The primary NGO that has been working in Mylai Balaji Nagar is World Vision. In fact, World Vision is the agency to which the TNSCB has, in a way, ‘out-sourced’ its responsibility of providing resettlement services to residents of Mylai Balaji Nagar (INT7, INT1, Dutasta 2010). After having been involved in the community for more than fifteen years, World Vision is now ending its Area Development Program (ADP) and winding down its support of educational, child care, micro-finance and other services in the community. Community-based workers for World

\(^\text{189}\) The Panchayat does say however that, although it cannot support capital costs, it could potentially support upkeep (INT19). This is discussed further in the next section.
Vision see that there remain many outstanding needs to which World Vision could contribute, but say that it would require a new project being proposed and accepted by their head office, of which there is no guarantee (INT15). Thus, while World Vision, or any other new NGO, could be a potential source of capital funding, existing funding mechanisms have now expired and a new project would have to be initiated.

**Private sector as a source of capital funding**

Private sector financing of a community safe water system is also a possibility. As was discussed in section 2.2.2, one prominent example of this is the *iJal small water enterprise program* currently being field-tested in rural Andhra Pradesh (Safe Water Network 2010). It remains to be seen how successful this approach is in the rural setting, which is to say nothing of the considerably more complex circumstances that urban and peri-urban settings present, in which there have been, as yet, no test cases. The private sector, however, is already very much involved in water supply at Mylai Balaji Nagar. As documented in section 4.5.5, there is a well-developed retail network for bottled and lorry water supply in the community. These are proven business models for urban/peri-urban water supply, unlike community safe water systems which represent unknown (but possibly greater) financial risk to private sector investors. Finally, as was related in section 4.2, there have also been negative experiences with private firms carrying out charitable works in Mylai Balaji Nagar. Though this is not to say that all private sector involvement would end this way, it has set a negative precedent in the eyes of residents and raises questions about security of investment for private sector actors (INT9). Thus, while private sector funding is a possibility, because of the unknown risk it represents, a community system at Mylai Balaji Nagar is unlikely to attract capital funding from the private sector. A household level system may be introduced with private sector support, but a market-based approach entails that costs will eventually be borne by individual households, likely through user fees for the upkeep of the system. This is discussed in the next section.

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190 One prominent example of this is the case of the charitable wing of the private equity firm Sriram Chits Co. building a school on public land in sector 2, but then attempting to operate it as a private school (i.e. charging tuition to students) once it was completed. Following community outrage at this about-face, the Sriram Chits Co. ceased all educational and other services at the school, relinquished the building to the government (as it was on public land), and departed the community (INT9, INT15). This example says something quite interesting about the private sector, charity, and state responsibilities.
Multiple sources of capital funding

The possibility also exists, of course, of combining contributions from various sources together. There is, however, not much experience with this. The E.O. of Pallikaranai Panchayat notes that there are no previous examples of the Panchayat undertaking a cost-sharing agreement with an NGO on development projects in their jurisdiction (INT19). Likewise, the CMWSSB also has no experience with cooperating with NGOs on water supply projects (INT17). The TNSCB has a history of partnering with NGOs, but only insofar as ‘out-sourcing’ basic responsibilities to them without providing funding support (INT7). Though any number of partnerships between community-members, government agencies, NGOs, and/or the private sector are possible, there has been little experience with these at Mylai Balaji Nagar, and of what there has been unfortunately has been negative.

Summary of availability of capital funding

The possibility of obtaining capital funding from the various sources detailed above is summarized in schematic form in Figure 5-1.

![Figure 5-1](image-url)  
*Summary of the availability of capital funding from various sources at Mylai Balaji Nagar and associated implications to viable level of application. Coloured bars beneath either household or community level denote viability at that level, whereas a solid line denotes non-viability.*

Thus, altogether, the prospects of mobilizing sufficient capital funds for a community level system at Mylai Balaji Nagar seem remote. A household level system may be the only viable option with respect to this dimension.
5.7 Availability of upkeep funding

<table>
<thead>
<tr>
<th>Availability of upkeep funding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q</strong>: Is on-going funding available (from community, government, NGO, and/or private sector sources) for the O&amp;M of a safe water system once it has been implemented?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Household</th>
<th>Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household systems require upkeep funding for consumables, replacement parts, and repairs of household units. For household systems, upkeep can be done on a collective or an individual basis, though the latter is more common when a market- or NGO-based approach is taken.</td>
<td>Community systems require upkeep funding for consumables, replacement parts, and repairs of infrastructure. Economies of scale typically make costs lower than with household systems. For community systems, upkeep can be supported on a collective or an individual basis, with the former typical of NGO/CBO-based approaches and the latter typical of market-based approaches.</td>
</tr>
</tbody>
</table>

As per the note at the beginning of the previous section, this dimension is somewhat different than the others in this chapter. It is also different from the previous dimension in one important way: upkeep funding is necessary to support O&M for both household and community level systems (whereas capital funding was really only required for the latter). As such, the availability of upkeep funding does not in itself discriminate which level of application may be more appropriate in the case study community. This presents an additional level of complexity to the analysis here. What is pertinent here is the source of the upkeep funding and, also, whether this entails that households contribute (if at all) on an individual or a collective basis to the maintenance of the good. (This is distinct from the differentiation between household and community level systems as individual and collective upkeep approaches can conceivably be applied to either level of application.)

191 Economies of scale is included as a dimension in Table 2-3. However, as per the note at the beginning of this chapter, this dimension is integrated into the discussion on availability of upkeep funding.

192 This distinction between individual or collective engagement of households is something that was also relevant to the previous dimension (i.e. the availability of capital funding), but the particular nature of that dimension limited the extent to which this complexity became apparent. Basically, collective action is only required in the case that community-members collectively provide capital funding (and this was assessed as being unlikely to be a viable strategy at Mylai Balaji Nagar). Collective community action, as such, is not required in the case of capital funding being provided by government, NGO, or private sources, and thus it did not figure in that analysis any further. With respect to upkeep funding, this distinction remains relevant across different sources of funding because it is likely that households will have to support at least part of the O&M costs. As such, this distinction is given more prominence in this section.

193 To further clarify, this distinction between individual and collective approaches to upkeep financing has to do with how costs are borne for sustaining the production of safe water. For example, an individual upkeep approach for a household level system may entail that each family purchases materials to maintain the safe water system themselves (this is the status quo for HWTS products on the market). Alternatively, a collective upkeep approach for a household system may entail that all the families come together to pool resources and share the labour for regenerating all the household systems (via a community water committee, for instance). With respect to community level systems, an individual upkeep approach may entail that each family pays for each unit of safe water they
approaches that may be viable at Mylai Balaji Nagar, and some preliminary comments are made in this regard. To summarize then, the scope of discussion in this section is limited to:

1. Possible sources of upkeep funding;
2. The viable level of application these entail; and
3. Whether households should be engaged in upkeep (if at all) on an individual or a collective basis.

As with the previous dimension, upkeep funding can come from a number of sources including community-members, government agencies, NGOs, the private sector, or a combination thereof. This section is structured around these.

**Community-members as a source of upkeep funding**

As was discussed at the outset of the previous section, residents see improving water quality as a priority and say they are willing to contribute to collective efforts on it. However, as alluded to in the previous section, this is not an uncontroversial position. Respondents suggest that while some residents would be prepared to contribute, others would not be as forthcoming. An exchange between participants during the second focus group captures this tension:

**SIA:** Would you all be ready to spend money for such a common task?

**P1:** Yes, all of us will give.

**P2:** No. Some of them may refuse to give.

**P3:** They will give.

**P4:** They will not give.

**P5:** They will not.

**P6:** Generally when there is something in common, some people may not care about it as someone [else] is there to look after [it]. They will think: "Let them look after it...Why should I bother!"

(FGD2)

consume at a price that can sustain the operation of the system (this is the approach being tested in rural Andhra Pradesh in the CSWS and iJal projects that were discussed in section 2.2.2). A collective approach to a community level system may entail that all members of the community pay a flat rate or contribute labour/time to enjoy the shared benefit of a community level system regardless of individual levels of consumption (this is an experimental approach currently being tested in urban Jakarta with the CBWSS project that was discussed in section 2.1.2).
This tension applies equally to the availability of capital (FGD2). With perceptions amongst residents being equivocal as they are, it is important to look to actual experiences in the community’s history to shed some light on what is likely to happen if residents are asked to collectively support a public good.

Two illustrative examples of this are: a) the solid waste management program; and b) the public latrine block cleaning program. Both of these were mentioned in section 4.2. The solid waste management program was discussed at length in section 4.5.3 of the previous chapter. This program failed in large part due to the unreliability of the Panchayat (INT2, INT5), but there was also an element of non-cooperation from residents that played a role in program’s eventual collapse. One of the managers of the erstwhile program relates how many residents refused to pay the small fee for solid waste collection:

\textit{Income generation [for the workers] out of this solid waste management program was very important, however, in Balaji Nagar, there was no income [being generated]. The Panchayat has done nothing to support the program and even the people did not contribute anything. We wanted to collect a small contribution from every household to support our workers. We used to collect garbage door-to-door. But people refused to pay even the small contribution saying "We are not putting any garbage here, we are dumping somewhere else, not here!" and so on.}  

(INT2)

Though the baseline community survey indicated that the overwhelming majority of residents resort to open dumping of household solid waste (Figure 4-8), when residents were asked by workers to contribute for proper solid waste collection, many absolved themselves of responsibility and refused to contribute.

The public latrine block cleaning program met with a similar sort of end. As was described in section 4.5.4 of the previous chapter, World Vision paid for workers to come and clean the public latrine blocks on a regular basis from 1997 to 2005. As World Vision attempted to
progressively transfer the financial responsibility to individual households—first, at a subsidized rate, and then, to make it fully sustainable, the full cost—individual households refused to take on the responsibility for collectively maintaining the latrines, and the program collapsed (INT3).

Unlike residents’ perceptions, the actual historical experiences are unequivocal: no positive examples of the community collectively supporting a public good were encountered during the course of this research. What these two examples illustrate is a lack of willingness amongst individual households in Mylai Balaji Nagar to financially support collective efforts for the common good in the community.\(^{194}\) Thus, the prospects of individual households financially supporting the collective upkeep of either a community or household level system appear quite dim. This is not to conclude that a community level system is not possible with respect to this dimension, but rather that—if community-members are to be a key source of upkeep funding—this may be better done with individual households taking care of their own (FGD2, FGD3). As this is, in fact, the present status quo with water supply in the community, clearly residents are a viable source of upkeep funding. Both household and community level systems can be sustained in this manner and nothing in the data indicates one level over the other.

**Government agencies as a source of upkeep funding**

The role that government agencies, specifically the TNSCB and Pallikaranai Panchayat, play in financing basic services at Mylai Balaji Nagar was discussed in the previous section; much of that discussed there is pertinent to this dimension as well. With respect to the former, the TNSCB had fully transferred responsibility for sustaining basic services at Mylai Balaji Nagar to the Panchayat by 2000 (sections 4.2 and 4.3). As such, they no longer see themselves as the agency responsible for Mylai Balaji Nagar and have since moved on to resettlement projects elsewhere (INT7). With respect to the latter, the stated inability of the Panchayat to provide capital funds for improvising basic services at Mylai Balaji Nagar was documented in the previous section. However, the E.O. of the Panchayat indicated that the Panchayat is prepared to provide limited funding to support the O&M of a safe water system at Mylai Balaji Nagar, should another entity

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\(^{194}\) This is a classic example of what economists and political scientists refer to as a collective action problem (Rydin and Pennington 2000). This is discussed further in section 5.9.
(e.g. NGO/CBO/private sector) assume the capital costs (INT19). This position was corroborated by the de facto Ward Member representing Mylai Balaji Nagar at Pallikaranai Panchayat:

SIA:  If the NGO is financing it, how about [the Panchayat] managing the system?
C: He is asking, if an NGO contributes the money and builds a system at the community level, will the Panchayat do the maintenance?
P: Yes, the Town Panchayat always does the maintenance. Definitely.

(INT16)

The Panchayat has however indicated previously that they are unable to provide services to individual households; any services rendered by the Panchayat must be at the community level (INT6). Thus, the Panchayat may be a viable source of upkeep funding for a community level system only.195

NGOs as a source of upkeep funding
NGOs are also potential sources of upkeep funding. That detailed in the previous section—on the possibility of World Vision (or any other newcomer NGO) providing funding—applies here as well and need not be repeated beyond stating that NGOs could potentially support the upkeep for either a household and a community level system.196 Whether funding is in fact available at Mylai Balaji Nagar, with World Vision transitioning out of the community, is unknown however.

Private sector as a source of upkeep funding
The private sector taking on O&M responsibilities is also a possibility if a safe water system were to be deployed, in the case of household and community systems respectively, as a marketed product or a private safe water retailer. Of these two, only the former is a proven business model (as was discussed in the previous section). Private sector involvement however intimates that upkeep costs would ultimately be borne by individual households. Thus, in effect, there is no actual possibility of upkeep support being provided by the private sector.

195 Clearly, if the government is tapped to fully support the upkeep of a safe water system, the individual or collective engagement of households in the community becomes a moot point.
196 As above, with full NGO support for upkeep, the individual or collective engagement of households in the community becomes a moot point
Multiple sources of upkeep funding
As with the previous dimension, O&M partnerships between community-members, NGOs, and/or government agencies to sustain the upkeep of a safe water system are a possibility, though there is little positive experience with them at Mylai Balaji Nagar. From the preceding discussion it is seen that partnerships may be possible for either a community or a household level system.

Summary of availability of upkeep funding
The possibility of obtaining on-going upkeep funding for the O&M of a household or a community level system from the various sources detailed above is summarized in schematic form in Figure 5-2. Also stipulated is the appropriate level of engagement for households should such a community-member driven approach or a partnership with community-members be undertaken for O&M.

<table>
<thead>
<tr>
<th>Availability of Upkeep Funding</th>
<th>HOUSEHOLD</th>
<th>COMMUNITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community members</td>
<td>Engage on an individual basis only</td>
<td></td>
</tr>
<tr>
<td>Government agencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NGOs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private sector</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-2 | Summary of the availability of upkeep funding from various sources at Mylai Balaji Nagar and associated implications for viable level of application. Additionally, recommendations of individual or collective engagement are indicated where relevant. Coloured bars beneath either household or community level denote viability at that level, whereas a solid line denotes non-viability.

The outcome spaces for the availability of capital funding and the availability of upkeep funding have been summarized in Figure 5-1 and Figure 5-2 respectively. These are parsed together in the final ‘synthesis’ section (section 5.14) to generate some preliminary recommendations on appropriate financing and O&M frameworks for a safe water system at Mylai Balaji Nagar.
SOCIAL AND POLITICAL-INSTITUTIONAL DIMENSIONS

5.8 Local capacities

<table>
<thead>
<tr>
<th>Local capacities</th>
<th>Q: Which level of application is viable with the capacities available in the local community?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>Household systems are typically simple enough to be operated and maintained by lay-persons. As such, they do not demand many technical or managerial capacities from the local community aside from: a) widespread literacy; b) a basic level of education; and c) familiarity with technical tasks and devices. These enable the training of households in the use and maintenance of household devices. Additionally, demonstrated entrepreneurial/business capacities may be required for product distribution if a market-based approach is taken.</td>
</tr>
<tr>
<td>Community</td>
<td>Community systems are complex pieces of technical and institutional infrastructure. They require that a number of technical and managerial capacities be present in the community including: a) plumbing; b) concrete work/masonry; c) electrical; d) community organizing; and e) entrepreneurial/business (in addition to those three capacities required for household systems).</td>
</tr>
</tbody>
</table>

Three basic capacities are necessary for either level of application: a) widespread literacy; b) a basic level of education; and c) familiarity with technical tasks and devices. With respect to the first, literacy in the local language (Tamil) is widespread in Mylai Balaji Nagar, but some residents who could not read or write Tamil were encountered during the primary research activities. Informal estimates from World Vision workers, childcare centre staff, our project staff residing in the community, and community leaders all independently suggested an adult literacy rate of approximately 60% to 70% (INF). The baseline community survey (Appendix B) confirmed that the adult (i.e. eighteen years and over) literacy rate is 72.3% for women and 84.8% for men. Literacy and educational attainment also varies by age bracket (Figure 5-3).
As can be seen above, it is women and the elderly whom are disproportionately illiterate. Moreover, it was informally observed that those who were illiterate also tended to be poorer and more likely to be migrants from out of state (INF). Though literacy is not universal, most, if not all households had at least one member who could read and write as the baseline survey indicated that 86.2% of female and 88.2% of male children between the ages of five and seventeen years of age were enrolled in school. With respect to the third capacity of familiarity with technical tasks and devices, it was informally observed that most, if not all, households have a number of devices that all household members are familiar with including cell phones, refrigerators, motorcycles, rickshaws, and televisions. More importantly, as was discussed in section 4.5.5.3, a number of water treatment techniques are already widespread in the community. Knowledge of traditional water treatment practices commonly applied in rural south India such as ‘three-pot’ filtration or alum clarification is also widely spread (INT18). This represents a base of knowledge on which other water treatment systems can build. With respect to technical tasks, there was one important example documented in the primary research that demonstrates the ability of community-members to learn and self-manage technical tasks, albeit with some support. This example has to do with borewells that the government had drilled earlier on in the community’s history when the groundwater was thought to be a viable source to supplement local water supply:
The government dug deep bore-wells in many places [...] They gave us training for that. They taught us. We cannot bring mechanics from outside if there is any fault in the bore. Sometimes the chain may get cut. They made things ready; but they never turned back to repair things. Even after we reported to them that the pump broke down they did not bother to come and see what is wrong with that. There was no one to repair it. We tried our level best to repair it by ourselves as we were given a set of tools. The metal had become a waste as it was corroded by the salinity of water.

(INT5)

This example illustrates that community-members, with some training, were able to engage with technical tasks and diagnose problems successfully. Though the particular problem they faced in this example was ultimately too great for them to solve with the resources available to them (i.e. corrosion due to the salinity of the groundwater) and because the lack of support from the government was not enabling, it is nonetheless an encouraging example of the technical capacities of community-members. Thus, literacy, basic education, and familiarity with technical tasks and devices can be reasonably defined as available capacities in Mlyai Balaji Nagar.

In addition to the three basic capacities discussed above, community level systems also require a number of additional capacities. A rapid informal survey of skilled workers living in the community gives an indication of the technical capacities available in the community (Table 5-1).

<table>
<thead>
<tr>
<th>TECHNICAL SKILLS/CAPACITIES</th>
<th>NUMBER OF WORKERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plumbing</td>
<td>70</td>
</tr>
<tr>
<td>Concrete work/masonry</td>
<td>57</td>
</tr>
<tr>
<td>Electricians</td>
<td>18</td>
</tr>
</tbody>
</table>

This example of community-government relations is also pertinent to the discussion in section 5.10.
Community organizing is a capacity that is discussed at length later on in section 5.9. From the discussion in that section, it was found that community organizing tends to focus on protest rather than production, but regardless, there is substantial experience with the community organizing itself for a number of ends. Entrepreneurial/business capacities are also widespread in the community, as evidenced by the number and variety of small businesses in the community (Table 5-2).

<table>
<thead>
<tr>
<th>TYPE OF BUSINESS</th>
<th>NUMBER OF ESTABLISHMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water can supply</td>
<td>15</td>
</tr>
<tr>
<td>Tea shop</td>
<td>3</td>
</tr>
<tr>
<td>Provisional stores</td>
<td>31</td>
</tr>
<tr>
<td>Tiffin (lunch box catering) shop</td>
<td>12</td>
</tr>
<tr>
<td>Three wheeler (auto-rickshaw) workshop</td>
<td>2</td>
</tr>
<tr>
<td>Two wheeler (motorcycle) workshop</td>
<td>4</td>
</tr>
<tr>
<td>Four wheeler (car) workshop</td>
<td>2</td>
</tr>
<tr>
<td>Flour seller</td>
<td>10</td>
</tr>
<tr>
<td>Flour mill</td>
<td>28</td>
</tr>
<tr>
<td>Tailoring</td>
<td>9</td>
</tr>
<tr>
<td>Hardware shop</td>
<td>1</td>
</tr>
<tr>
<td>Electrical shop</td>
<td>1</td>
</tr>
<tr>
<td>Tiles and marble sellers</td>
<td>4</td>
</tr>
<tr>
<td>Cement workshop</td>
<td>2</td>
</tr>
<tr>
<td>Ration shop</td>
<td>2</td>
</tr>
<tr>
<td>Pawn broker shop</td>
<td>3</td>
</tr>
<tr>
<td>Transport company</td>
<td>1</td>
</tr>
<tr>
<td>Stationery store</td>
<td>2</td>
</tr>
<tr>
<td>Barber shop</td>
<td>3</td>
</tr>
<tr>
<td>Borewell shop</td>
<td>1</td>
</tr>
<tr>
<td>TV repair shop</td>
<td>1</td>
</tr>
</tbody>
</table>

Thus, because all of the basic, technical, and managerial capacities required for both household and community level systems are present in Mylai Balaji Nagar, either one of them may be viable in the community.
5.9 Propensity to collective action (horizontal social capital)

<table>
<thead>
<tr>
<th>Propensity to collective action (horizontal social capital)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q:</strong> What is the propensity toward cooperation, cohesion, and collective action in the community?</td>
</tr>
<tr>
<td><strong>Household</strong></td>
</tr>
<tr>
<td>In situations where horizontal social capital is lacking, household systems may be preferable as they rely primarily on individual households taking care of themselves.</td>
</tr>
</tbody>
</table>

This section looks to how well the community works together toward common goals. First, it discusses the perceptions that respondents hold on this matter, and then looks to the actual experiences with collective action in the community’s history. This dimension overlaps somewhat with the previous dimensions of availability of capital funding and availability of upkeep funding, but offers a more general look at collective action in the community. Furthermore, it builds on the concept of individual or collective engagement that was introduced in section 5.7. As such, this dimension too has implications for what kind of financing/O&M approach may be viable in the case study community.

**Perceptions of community-members on collective action**

When residents were asked to speak about whether they would prefer a community or a household level system in Mylai Balaji Nagar, a preference for the former was consistently voiced (c.f. section 5.13). One of the most common reasons given for this was that a community level system would be more egalitarian in that it would enable all households to gain access to safe water, whereas household systems would benefit only individual households, and thus, were less desirable:

*If it is at the community level it is beneficial to everyone, whereas if at the household level it serves only the household.*

(FGD1)
Similar statements were made during other research sessions as well (c.f. INT5, FGD2). This desire for egalitarianism drives residents’ assertions that they are ready to work collectively to improve access to safe water for all residents (INT5, INT4).

Unfortunately, such positive perceptions do not go much further than a desire for better cooperation in the community. When respondents were asked to elaborate on how collective action would likely play out, their responses were no longer so positive, with many expressing doubt that such a thing could even be possible in their community. One frequent response was that residents would be prone to shirking their part of the collective responsibility:

*If it is common and public, there will be a clash as to who will do it and everybody will try to shift [the responsibility] and point to others to do the task. If it [is at] the individual level, everybody ought to do it and they will not like to shift from their responsibility.*

(FGD1)

Similar statements were also made during other research sessions as well (cf. FGD4, INT3, INT2). Respondents cautioned that this would inevitably create conflict between households:

**SIA:**  *Will there be any problems if some come forward [to contribute] and some do not?*

**P1:**  *Yes. The ones who would be ready would start scolding the others who do not.*

**P2:**  *At the same time, those who do not like this would say: "If you want to, you go [ahead], don’t compel us!”*

**P3:**  *This would end up in a quarrel...*

(FGD2)

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198 These comments speak to the fostering of social cohesion dimension in Table 2-3. This dimension is subsumed in this section.

199 This, of course, resonates with the stated willingness of residents to contribute financially to a collective endeavour that was documented earlier (section 5.6).
Similar perceptions were documented during other research sessions as well (cf. FGD4). When respondents were asked to reflect on whether this individualistic attitude had always been prevalent in the community, or if it was something more recent, the responses were equivocal. Some responded in the affirmative:

**P1:** People are minding their own business only.

**P2:** People will not care for others, everyone is minding their own business.

**SIA:** Do you feel that things have changed over time? In the beginning, were people willing to work together and then, after you have been settled here for some time, have now become individualistic? Or has that been the case from the beginning?

**P3:** People are minding their own business from the beginning.

(FGD4)

Others suggested that this individualistic attitude has become entrenched only in recent years. A respected elder in the community, whom was a leader of the erstwhile solid waste management program and has also worked closely with the SHGs, related:

*People [here] are not taking any initiative for a common cause. People's attitude is becoming like taking loans and repaying loans from the SHGs. Even the [World Vision] ADP also does the same. [...]The ADP project only allotted people to receive loans and collect the money back. But they did not give any responsibility to individuals to take care of community resources. [...]Initially, people were together for joint action. Now they are focused on individual satisfaction. In the beginning, the [World Vision] ADP focused on community-building, but now they [have] just turned to giving loans alone.*

(INT2)

Thus, it is suggested that an individualistic attitude centred around household economic development has inadvertently been fostered by the emphasis on micro-finance on the part of the SHGs and the NGOs operating in the community, something that has displaced earlier
proclivities toward collective action. This individualistic attitude was encountered by the research team during the course of these investigations as well. Members of the research team relate that, when mobilizing residents to participate in action research activities or other collective action, many community-members were not forthcoming:

\[\text{P1: They will feel it is a waste of time...}\\ \text{P2: They would also ask how much money we would give [them] to participate.}\\ \text{P3: They would say: “We will get money if we go to work. We won't get anything [if we participate in collective action]. Will they give money to compensate for it?” They want to know what the [monetary] benefit is!}\\\]

(INT10)

Thus, there is a feeling held by many residents that unless an activity yields immediate financial gains, it was not worth the time or effort. The sum total of these perceptions leads one ultimately to a pessimistic view about the propensity to collective action in the community.

Respondents do however suggest that if an issue is large and pressing enough, such that it adversely affects many households at once, then it is something that people will collectively work on:

\text{If there is any emergency or an important need or a primary requirement, they would unite together. Otherwise, people will mind their own business.}\\

(INT5)

Similar statements were also made during other research sessions (cf. FGD3, FGD4, INT1). This raises two important questions:

\[\]
1. Is the degraded quality of the public tap water supply perceived as an “emergency or an important need” that warrants a collective response?; and

2. What manner of collective action does the community tend toward?

These two questions are elucidated by the actual experiences with collective action in the community, which is the subject of the next sub-section.

**Experiences with successful collective action**

Looking to the actual experiences with collective action in Mylai Balaji Nagar’s history—its successes and its failures—offers insight into which level of application would be more appropriate for a safe water system there. Throughout this section, an eye is kept to the two questions posed above: on which issues the community has previously mobilized, and the modes of collective action seen in the past.

There have been a number of instances of successful collective action in Mylai Balaji Nagar’s history. Five prominent examples are discussed below from which the main themes are extracted.

1. Collectively lobbying the Panchayat to improve various aspects of the community’s water supply situation, including:
   - Changing the timing of when the Panchayat agents turn on the public water standpipes to the daytime, so that women no longer had to wait up through the night to collect water (FGD1, Khosla 2009a).
   - Having more public standpipes installed so that fewer households had to share a single standpipe (Khosla 2009a).
   - Approaching the Panchayat with complaints about the degraded quality of the tap water supply or to remedy supply disruptions arising due to system breakages, as mentioned in

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203 It should be clarified here at the outset that ‘success’ here does not mean that the desired objective of the action was achieved *per se*, but just that the effort to collectively mobilize people was successful. ‘Failure’ then refers to instances where efforts to collectively mobilize the community fell apart.
section 4.2. The whole area (i.e. sector or lane) that is affected by the supply or quality issue would come together to address the problem (FGD1).

2. Emergent self-organization to improve basic services, specifically, the voluntary association that has recently been formed in sector 4. This voluntary association is a group of male volunteers residing in sector 4 who undertake various tasks to improve the state of basic services in their neighbourhood. It has arisen as an organic reaction to the inaction of the government over the years (INT4). The association collects Rs. 20/mo. from each household in sector 4 and provides the following services: connects households and responds to electrical system failures (section 4.5.1); augments water supply by purchasing lorry-loads of water and then retailing it to households in single pot units at a discounted rate (section 4.5.1.2); trims the trees in the sector (FGD2); and arranges for cleaners to come and take care of the public latrines on a regular basis (INT4). The leader of the group indicates that prior to the voluntary association, there was no other instance of collective action to improve basic services led by community-members themselves (INT4). The group may not be faring very well of late however as reports have been circulating (as of September 2011) that the voluntary association is winding down its activities due to growing conflict with residents who have been demanding more services for their Rs. 20 monthly fee (INF).

3. Mutual help and solidarity during times of crisis and disaster. As described section 4.2, several major fires have broken out in the community through its history. In the face of these events, residents have banded together to fight the fire together (FGD1, FGD2, FGD3, FGD4). A major flood also occurred in the community in 2004-5, as was described in section 4.2. In the wake of this event, the community showed great solidarity with residents giving one another material support and collectively engaging the Panchayat for relief (FGD4).

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204 Efforts relating to water quality however were not successful in the sense that the problem was actually resolved. Typically what would happen is that the Panchayat would ignore community complaints and the problem would persist. This is discussed further in section 5.10.

205 The voluntary association was introduced in section 4.2 and was referred to several times throughout the previous chapter.
4. Collective political action such as roadblocks, strikes, and petitions to pressure the Panchayat (or other government bodies) to provide critical services, including:

- As mentioned in section 4.2, residents conducted a roadblock of Velachery Main Rd. shortly after resettlement in order to protest the lack of local access to public transportation (the nearest bus stop was three km away). A local bus stop and a new route to Mylai Balaji Nagar was the outcome of this action.

- As described in section 4.2, it was only because residents carried out roadblocks that water supply was brought to the community itself. Initially, in the period immediately after resettlement, residents had to travel up to one km away to fetch water from other neighbourhoods. In response to the agitation, the TNSCB and the Panchayat arranged for regular lorry water deliveries directly to the community.

- As described in section 4.2, residents carried out a roadblock in order to get the newly opened wine shop in sector 2 to leave the community (as it is regarded as a social blight).\(^{206}\)

- Residents carried out roadblocks to pressure the government to repair the electrical system during excessively long blackouts in the area (INT10). Residents regularly collectively visit to pressure the Panchayat to repair the power supply when there are blackouts (FGD2).

- Residents carried out a roadblock to protest the dumping of solid waste by garbage workers along the roadside bordering sector 1, instead of within the landfill proper (i.e. the municipal landfill that borders the community, north of sector 1). Improper dumping by the landfill staff ceased after this action (INT2).

- As discussed in sections 4.2 and 4.5.4, the public latrine blocks in the community were built only after community agitation forced the TNSCB to ask an outside agency, World Vision, to fulfill its basic obligation and build sanitation facilities on its behalf.

- Residents organized petitions to have the ration shop returned to the community after it was displaced by the wine shop. It eventually was returned to a place nearby (i.e. Tay Nagar) (FGD4).

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\(^{206}\) Alcoholism among men is a major issue in Mylai Balaji Nagar as it is in many places in Tamil Nadu (INT10). This action was ultimately did not garner the desired outcome as the government did not force the wine shop to move because it is owned by members of local political parties (FGD4, INT1, INT10, INT4).
5. The SHGs, along with the associated Federation and Sangam, act as a community space for discussing and addressing shared problems. Though the SHGs themselves are primarily concerned with micro-finance, the Federation and Sangam have a more generalized function including: offering small business and cottage industry training; liaising with World Vision and other NGOs; assisting pensioners and BPL families with accessing government and NGO welfare schemes; and organizing community petitions on educational and water quality/supply improvements or against undesired development works affecting the community (INT15).

From the successful collective actions in the community’s history, four main themes can be drawn out:

I. Collective action in Mylai Balaji Nagar tends mostly toward lobbying government agencies to provide the services that residents are entitled to under the ‘sites and services’ scheme. Collective action ranges from petitions, to group visits to government offices, and, when the situation becomes critical, to direct action (i.e. roadblocks). Improving local water supply, including the tap water quality, is indeed a concern that mobilizes the whole community; however, lobbying is the only form of collective action undertaken in response to this service gap.

II. There is very limited experience with self-organizing community-members to provide basic services. The one example of this, the fourth sector voluntary association, may be faltering at present as well due to emergent problems with community cooperation.

III. The existing collective bodies in the community (i.e. SHGs, the Federation, and the Sangam) focus mostly on encouraging household economic development; identifying community needs for NGO interventions; and lobbying the government to provide services or benefits under public schemes. They have no experience with organizing residents to improve basic services themselves.

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207 The ‘Federation’ is a representative body of all the SHGs in the community, in which two members from each SHG represent their group to discuss matters relating to SHG activities. The ‘Sangam’ is a general representative body of the community, largely drawing its membership from the SHGs, but open to all residents of the community (including men) (INT15).

208 With reference to educational improvements, one example is the Sangam lobbying to have the Sriram private school converted to a public school, as described in sections 4.2. The undesired development work specifically referred to here is the sewage pumping station being built in the school grounds in sector 2 that was discussed in section 4.5.4.5.
IV. In the face of extreme crisis, such as fire or flood, residents will band together and support one another with everything they have.

The three community self-development strategies identified by Grant (2001)—community self-organization, informal links with powerful groups including clientelistic relations, and protest—were all observed at Mylai Balaji Nagar. The tendency toward protest and lobbying at Mylai Balaji Nagar, rather than self-organization, is likely linked to its insecure land tenure and insufficient horizontal social capital, as Grant demonstrated to be the case in her study of marginalized urban communities in Guatemala City. The emergent themes above shed light on the two questions posed earlier, especially on what the main modes of collective action in the community are.

Experiences with failed collective action

It is also instructive to look to instances of failed collective action in the community’s history. Six prominent examples are discussed in the following, from which the main themes are drawn out.

1. The public latrine cleaning program demonstrates several discouraging trends with respect to collective action to improve basic services, including:

   - As discussed at length in the previous chapter (section 4.5.4), as well as in earlier sections of this chapter (sections 5.6 and 5.7), once World Vision transferred full financial responsibility to the community, residents refused to fulfill their individual responsibilities to the collective good in paying their share of cleaners’ wages causing the program to eventually collapse.

   - Alleged graft by those collecting monies from households (while it was still subsidized by World Vision) may have also contributed to residents losing trust in the program (INT3).

   - Residents were not willing to contribute time or labour either when World Vision attempted to organize volunteers from within the community to clean the latrines (via SHGs) and this approach also failed (INT3).\(^{209}\)

\(^{209}\) This may be a caste-related issue. Traditionally in India, it is only certain sub-groups of the larger “untouchable” or “Dalit” caste groups that have contact with faeces. For others, faeces are considered categorically impure; to
Because of the degraded condition of the public latrine blocks and the demonstrated inability of the community to regularly maintain them, about three-quarters of the community have abandoned the public latrines altogether (Figure 4-9). Instead, they have shifted to using makeshift personal latrines or in-home toilets (INT12, INT14). Those still using the public latrine blocks periodically collect monies from neighbours in order to hire someone to clean the facilities on an one-off basis, but only once they have become unhygienic and totally unusable (section 4.5.4.1).

As described in section 4.5.4.1, the pumps that World Vision installed to provide groundwater for cleaning the public latrines were allegedly stolen once the latrine cleaning program began to fall apart (INT3).

2. The solid waste management program, discussed at length in the previous chapter (section 4.5.3), as well earlier in this chapter (section 5.7), likewise presents the same discouraging trend as above wherein residents refused to take on the financial burden from the sponsoring NGO (and fulfill their individual responsibilities to the collective good), leading to the eventual collapse of the program.

3. The experience with the community clean-up day in sector 4 also presents some disappointing lessons with respect to collective action in the community. Following from community meetings in which local development priorities were identified (section 4.6), the project team organized community-members and the Panchayat for a clean-up day in sector 4 on January 9, 2010 (section 4.6.1). The Panchayat provided manpower and vehicles, the project team hired a backhoe to clear the canal and also provided labour, and the residents were to provide additional labour. Even though the event arose because of several direct requests from residents themselves, and despite the fact that residents of sector 4 had indicated they would participate a week in advance and selected a day that was suitable to them, only a few residents actually turned up to work. When asked why they did not come to help, residents responded with a number of excuses come into contact with them is to be “polluted”. I did not explore caste issues directly in the primary research, however, this issue did come up once in an interview with an elder in the community who was the leader of the erstwhile solid waste management program. This person had requested that we help to improve the sanitation situation in the community by organizing the community to hire workers to come clean the public latrines as “there are tribals from Andhra living nearby, we can give them the responsibility to take care of the latrine” (INT2). This may have been a reference to caste.
(e.g. having to go out, having guests, having to take care of the family). Several respected elders who did come to assist and tried to mobilize other residents on the day of the event suggested that people did not come because they knew that they would not be paid for helping to clean the community (INF).²¹⁰

4. A lack of solidarity sometimes when residents attempt to mobilize the community to lobby the government to improve basic services. Though this was identified as a prominent example of successful community action above, it is not without its challenges. There are reports from several community leaders of residents dismissing their attempts to mobilize the community. For instance:

\[1.\text{SIA: What are the problems or hindrances you faced when you went to report to the authorities about the water problems?}
2.\text{PI: People both in the sector and in the Panchayat Board office said: "Why are you bringing this up as an issue when everybody in the sectors are drinking [the tap water]?"}
\]

(FGD1)

This lack of solidarity is exacerbated by a growing cynicism amongst residents of the futility of approaching the Panchayat with their concerns (FGD1). A lack of solidarity also manifests in other ways. For instance, during festival times when community events are planned, it is only a rare few people who involve themselves, generally young men who are unattached to familial responsibilities (INT10).

5. The representative bodies in the community, such as the Federation and the Sangam, though they could be a site for organizing collective action, have no such history. In fact, some respondents suggest that they may actually limit this possibility. As was discussed earlier on, a respected elder who is associated with the SHGs relates that the fixation of these groups on micro-finance has actually deepened the fragmentation of the community such that different

²¹⁰ This resonates with the perceptions documented earlier about residents being disinclined to participate unless an activity yields immediate financial gains.
SHGs are not willing to work with one another on collective issues (INT5). The respondent elaborates that the SHGs may have forestalled nascent collective action early on in the community’s history as people fragmented into many groups with the advent of the SHGs:

**SIA:** Can you tell me something about the times when people living in Balaji Nagar itself worked together? Did NGOs make them unite together?

**PI:** Once we tried. Before it could run in full swing, the small savings scheme [Self-Help Groups] was developed. So people spilt among many groups.

(INT5)

Thus, the fragmentation of the community into smaller groups focusing exclusively on micro-finance may have adversely affected the proclivity to collective action in the community.²¹¹

6. Issues related to gender as obstacles to collective action. Women of the community are generally more inclined than men to participate in collective efforts that may improve life in the community:

She is interested because she is maintaining the family. They need some help. When five women go, the sixth one follows. She thinks that things would be fruitful if they go as a group so that they can get some help. She also feels that she can learn something. They feel they can get some kind of benefit.

(INT10)

Similar statements were also encountered during other research sessions (cf. INT15).²¹² Though men often take the lead as community representatives during lobbying or other political actions, men are less inclined to participate in the on-the-ground work of collective action (INT10). This is for a number of reasons:

²¹¹ It is interesting to consider that the creation of self-help groups centred on household economic development by an external NGO may have encouraged individualism and the breakdown of community cohesion, thereby preventing the emergence of collective action in the community!

²¹² Notably, this was not the case for women who held employment outside the home—they were less inclined to participate due to time restrictions (INT10). Most women in the community have employment outside the community (INT15).
Most men work outside of the community six days a week and only have a single day off to relax. This is the same for working women (INT10).

As mentioned earlier, men are less inclined to participate in volunteer activities in which they may not be remunerated for their time (INT10).

On the weekends, many men drink, as alcoholism is rampant in the community (INT10, INT4).

Worse yet, oftentimes men actively create obstacles to prevent women from becoming involved in collective efforts:

**SIA:** Do you think that the men would take part in a community level system?

**P1:** No. Why participation… they would not even care for it. They won't give importance for it. They won't even allow our [women's] progress! That is the biggest hurdle for us. So we are scared to take effort and do things. The first opposition is from the gents to us. We took efforts and steps for building the toilet. The [sewage] pumping station… […] We thought that the smell would be horrible. We tried our level best to cancel it. But the first opposition arose from the gents of our own community! They ask me: “Who are you to do it? Why should you poke your nose in this matter!”

(INT15)

Similar stories were recounted during other research activities as well (cf. INT1, INT3, INT10). Men’s resistance to women’s involvement in collective action however becomes less pronounced as monetary or other benefits begin to flow from these activities:

**SIA:** Women have participated in other NGO groups too. How did men react after they achieved [benefits with] them?

**P1:** At first they [the men] were quarrelling [with the women]. After they saw the benefits of money and loans they became silent. Now they are supporting!

**P2:** Now they started believing them, as a tax [to the men] is also paid!

(INT10)
As a result of all that documented above, most NGOs that come to work in Mylai Balaji Nagar do so with the women only (INT10).

From the failed collective actions in the community’s history, five main themes can be drawn out:

I. The failure of the public latrine cleaning program and the solid waste management program are classic examples of what economists refer to as ‘collective action problems’ (Rydin and Pennington 2000). In these experiences, the unwillingness of some residents to fulfill their individual part of a collective responsibility (i.e. a share of the funds, time, or labour required for the maintenance of a public good) leads others to do the same, eventually leading to the collapse of the collective effort altogether.

II. Graft of collected monies or materials is a perennial concern, something that is a result of, but also engenders, a trust deficit in the community.

III. Individual households prefer services to be individualized (i.e. delivered as private goods) as the incentives and responsibilities are then clearly linked. Similarly, most community-members prefer direct financial remuneration for time and effort spent, rather than a shared non-monetary benefit. The historical emphasis on micro-finance by NGOs may have contributed to this.

IV. Repeated cycles of collective efforts ending in a disappointing manner vis-à-vis the government has engendered a cynicism amongst residents on the utility of collective action. This results in a lack of solidarity on day-to-day efforts to organize collective action.

V. Men often play an obstructionist role with respect to women participating in collective activities.

These themes shed light on the viable modes of collective action in the community.

**Summary of horizontal social capital**

As was discussed in section 2.2.3.7, social capital is one of the key determinants of whether a community can successfully cooperate on a community level water system. This section has examined the *horizontal* aspect of social capital in Mylai Balaji Nagar—that is, the nature and quality of the relationships between members of the community, and the propensity to collective
action. The two questions posed at the end of the perceptions sub-section above specifically speak to the link between horizontal social capital and which level of application may be more appropriate for a safe water system at Mylai Balaji Nagar.\textsuperscript{213} We return now to those two questions.

With respect to the first of these two questions, residents state that “big common problems” like land tenure warrant the community coming together as “everyone stands to benefit on something that is a pressing need” (INT1). Indeed, basic services like water and electricity qualify as large shared problems in the eyes of residents:

\begin{quote}
People will work together for the crisis arising out of water and electricity. But they will not come together for any other cause!"
\end{quote}

(FGD4)

More specifically, water quality concerns have engendered collective responses in the past, as was documented in the preceding.\textsuperscript{214}

This brings us back to the second question—what modes of collective action do water quality concerns engender? As was documented above, there have been occasions where the community has come together to lobby the Panchayat about the degraded quality of the public tap water supply. But action was limited to just that—lobbying.\textsuperscript{215} There are no examples of the community attempting to collectively improve the quality of basic services themselves:

\begin{quote}
\textsuperscript{213} To reiterate, those two questions are: 1) is the degraded quality of the public tap water supply perceived as an “emergency or an important need” that warrants a collective response?; and 2) what manner of collective action does the community tend toward?
\end{quote}

\begin{quote}
\textsuperscript{214} However, the degree to which water quality, and water supply more generally, are now perceived to be collective problems at Mylai Balaji Nagar is questionable. In 2007, when respondents report the tap water quality first began to decline, many households resorted to an individualized response to the collective problem by beginning to purchase lorry or bottled water to meet their household drinking water needs (section 4.2). Since this time forward, it seems that water quality has left the realm of the collective and become firmly entrenched at the individual level.
\end{quote}

\begin{quote}
\textsuperscript{215} Interestingly, declining tap water quality did not engender the strongest political response that the community has experience with, that is, roadblocks. This may be due to the more gradual and subtle onset of the water quality problem.
\end{quote}
**SIA:** The examples you gave were the ones which you went to the Panchayat Board and got them solved. Are there any examples of a common issue solved by you yourselves?

**P1:** No. Everything would be taken to the Panchayat Board!

**P2:** No, we don’t do them by ourselves.

(FGD3)

Effective collective action to improve water quality seems unlikely given the nature and quality of horizontal social capital documented in the preceding. Thus, with respect to this dimension, it appears that an individualized response in the form of a household level safe water system may be more appropriate at Mylai Balaji Nagar.

5.10 Relationships with local institutions (vertical social capital)

<table>
<thead>
<tr>
<th>Relationships with local institutions (vertical social capital) Q: What is the nature and quality of the relationships between the community and local institutions (government, NGOs, private sector)? What of the relationships between institutions? Are effective partnerships with local institutions for a safe water system at either level of application possible?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
</tr>
<tr>
<td>In cases where: a) local government neglects or is unable to fulfil its responsibilities (i.e. a good governance deficit) and thereby has a strained relationship with the community; and/or b) local NGOs have a poor relationship with the community or are unable or unwilling to provide support, household systems may be more feasible as they can rely on individual households taking the initiative themselves. Though governmental/non-governmental support can help, it is not required as household water treatment products are often widely available on the market (in urban areas at least).</td>
</tr>
</tbody>
</table>

This section looks to the vertical aspect of social capital, that is, how the community relates to local government and non-governmental institutions. As with the preceding section, this dimension overlaps somewhat with the previous dimensions of availability of capital funding and availability of upkeep funding, but offers a more general look rather than a narrow focus on funding. As with the two ‘economic’ dimensions, this one also has implications on the kind of financing/O&M approach that may be viable in the case study community.
**Relationships with local government**

The relationship between residents of Mylai Balaji Nagar and local government has been an ongoing motif throughout this and the previous chapter. Of the various government agencies that are involved with Mylai Balaji Nagar, the TNSCB and the Panchayat of Pallikaranai are the most pertinent.\(^{216}\) Without having to restate all that has been documented before, several themes on the community-government relationship can be abstracted from this chapter and the preceding one.

I. Antagonism between the community and the government was seeded early on by the people’s forcible eviction from their original location at Mylapore.

II. Few, if any, of the promised amenities of the ‘sites and services’ scheme were provided at Mylai Balaji Nagar by the government.\(^ {217}\) The government then out-sourced several of its basic responsibilities to the NGO World Vision without providing supporting funding. In the beginning, residents had to either agitate in order to get some basic services or improvise on their own with little or no outside support.\(^ {218,219}\)

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\(^{216}\) The TNSCB is responsible for the resettlement of impoverished peoples living in both ‘objectionable’ and ‘unobjectionable’ areas in the state of Tamil Nadu. For the latter, the TNSCB typically undertakes in situ rehabilitation by clearing the slum housing and putting up tenements in their place or providing necessary infrastructure facilities. For the former (including road margins, river margins, and places required for public purposes), the TNSCB typically constructs housing at an alternate location to which families are resettled. In addition, the TNSCB cooperates with civil society to provide employment training and other rehabilitation services (TNSCB 2010). It appears that the story of Mylai Balaji Nagar is a departure from standard practices for the TNSCB.

\(^{217}\) The *National Rehabilitation and Resettlement Policy, 2007* promulgated by the Land Reforms Division of the Department of Land Resources in the Ministry of Rural Development specifies the compensation and support that evictees are entitled to during and after a government-mandated resettlement (Ministry of Rural Development 2007). The 2007 policy replaced an earlier one, from 2003, called the *National Policy on Resettlement and Rehabilitation for Project Affected Families* (Ministry of Rural Development 2003). This was the first national policy for rehabilitation and resettlement of development-displaced peoples. Prior to the 2003 national policy, some states and Central Ministries/Departments had their own policies and guidelines for resettlement and rehabilitation of peoples affected by their specific works. I was not able to ascertain which policy was in play when the residents of Mylai Balaji Nagar were resettled in 1993-4, but the current policies are quite progressive, on paper at least. It is likely that earlier policies shared many of these traits, being only generalized to higher levels of government with the 2003 and 2007 policies. Many community-members reported that few of the obligations of the rehabilitation/resettlement policy relevant to them had been met.

\(^{218}\) One important matter that came up several times in the research was that permanent water supply only came to the community after several fires over three years culminated in a major blaze in 1998 that destroyed much of the community and took the lives of a child and an elderly woman. This appears to be what it took before the government was inclined to provide a basic service they were already obligated to provide under the resettlement scheme.

\(^{219}\) The resettlement of Mylai Balaji Nagar was, in fact, a sort of experiment by the TNSCB—a *laissez-faire* approach to resettlement in which the evictees were resettled without any governmental support (i.e. basic shelter or any other amenities), and expected to develop their own community with limited support from non-governmental agents to whom basic responsibilities were ‘out-sourced’ (mostly in the form of micro-finance and childcare to support economic development). Officers from the TNSCB expressed remorse and admitted, in retrospect, that the resettlement of Mylai Balaji Nagar has been an unparalleled disaster. Mylai Balaji Nagar was the second and the last
III. Residents’ livelihoods were disrupted by their displacement to the unconnected urban periphery. Without income or services, residents were unable or unwilling to pay the leasing fees. Few, if any, families met their leasing obligations under the ‘sites and services’ scheme.

IV. The involvement of different agencies across three levels of government in the resettlement and rehabilitation of Mylai Balaji Nagar has resulted in a lack of clarity on governmental roles, responsibilities, and jurisdiction. This has complicated the resolution of the land tenure situation in particular, which in turn has had consequences for leasing fees and basic services.

V. A ‘vicious cycle’ has emerged in which the government and residents blame one another for failing to meet their respective obligations under the ‘sites and services’ scheme. Owing to the lack of revenue being drawn from the community, basic services at Mylai Balaji Nagar have suffered for a lack of investment, resulting in the environmental degradation the community presently faces. When confronted with complaints, the government seldom responds positively and instead deflects or ignores them altogether. Additionally, on several occasions the Panchayat has failed to deliver promised support on community development efforts (e.g. the erstwhile solid waste management program). This behaviour, in turn, entrenches non-compliance on the part of residents. This sort of cycle is typical of communities lacking secure land tenure (Grant 2001).

VI. The situation appears intractable as the key issue is the resolution of the land tenure problem, but this has also become extremely confused because of informal land transfers, accumulating interest and penalties on undefined leasing fees, and intra-government conflict over jurisdiction and land ownership.

These themes illuminate the nature of the relationship between the community and the government which, to summarize, cannot be described as anything other than antagonistic.

Governmental support of community development efforts was identified by respondents as a prerequisite for their success:

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resettlement of this kind in Chennai, and the TNSCB has committed to not visiting this mistake on any other unfortunate people in the future (INT7, Khosla 2009b).
**SIA:** I wanted to discuss with you an important aspect about a water treatment system—whether community level or household level system would be appropriate [for Balaji Nagar]? As you told us about the Exnora project, people did not want to pay to run the project. Do you think people would contribute some money to maintain a community level system or do they want to take care of it at the household level?

**P:** Yes, people can contribute money and also they can cooperate to run the system at the community level. But it needs cooperation from the Panchayat, at the very least, cooperation from the local Ward Member to encourage people to cooperate. However, the Panchayat here is not cooperating for any of the projects.

(INT2)

However, as seen even in the quote above, given the poor history of community-government relations, the prospects for this were seen to be limited. With reference to the failed solid waste management program, one of the program workers had this to say:

**SIA:** Given this experience would you think that working with the Panchayat or other government agencies would give a good outcome? Would you say that you would want to work with the government in future? Would you trust the government that they would give what they promise?

**P:** No. I would not want to. Government is eyewash. At first they would convince us and take us to their side. They would make us work hard. But finally we would not be [supported].

(INT5)

Similar statements were also encountered during other research activities (c.f. FGD2, INT2). Generally, respondents felt that government agencies are unreliable in keeping to their commitments (FGD1, INT5, INT4, INT3, INT2, INT7); unresponsive to community concerns (FGD1, FGD2, FGD4, INT1, INT15); view the community as little more than a vote bank (FGD2, FGD4, INT17, INT18); constantly deflect responsibility between agencies (INT1, INT2,
INT4, INT6, INT7, INT15); and that its officers are only interested in enriching themselves (through corruption or other means) (INT1, INT4, INT9, INT10, INT11, INT15, FGD4). There was only a single instance of residents speaking positively of the government (and this was only with respect to the Panchayat responding to recurring problems with the water and electrical supply in a satisfactory and timely manner) (FGD3).

It is also very interesting to note that the Panchayat has, in the past, actively obstructed infrastructural development efforts coming from NGOs. Community-based workers for World Vision report:

World Vision told us that they would build a [water storage] tank for us. But the Panchayat wouldn’t agree to that! Our NGO was ready to take up the responsibility and complete the job. They [World Vision] said that they would build an overhead [water supply] tank so that the entire area [of Mylai Balaji Nagar] can get water every day [24-hour supply]. But the Panchayat said that World Vision should hand over the money to them and they said only they will build it and World Vision would not be allowed to do it! […] That is why the [Sintex water storage] tanks were bought. […] The major problem is that the government does not help us at all sir… to date!

(INT15)

With this it appears that the Panchayat desires or is required to be the sole agent of infrastructural development in the community, requiring that other agents transfer the funds to the Panchayat so that they can carry out the work themselves.220

The negative feelings also went in the other direction. The Panchayat is at present, and has been for some time, maintaining a minimal level of services in the community, including paying the electrical bills and providing water, and more recently, beginning to pave the roads. As discussed

220 This was encountered by the research team during the course of these investigations as well. When we were interviewing the E.O. of the Panchayat, he requested that we provide him with the funds to develop a community level system and the Panchayat would take care of it from there (INT19).
previously, the Panchayat is providing these services without drawing any revenue from the community. Though this is at least partially due to the legal/institutional obstacles documented in section 4.3, some government officers say that the residents abuse the Panchayat’s goodwill and do not contribute because they are irresponsible and do not care for their community (INT6). Additionally, some government officers question the actuality of residents’ poverty by pointing to the means they must in fact have to be able to build pucca and, in some cases, multi-storey homes (INT15).\(^{221}\) The officers feel that the Panchayat is going above and beyond its duty and are satisfied with their work in Mylai Balaji Nagar (INT6, INT19).

As was discussed earlier in sections 5.6 and 5.7, the Panchayat says that it would support a community level system (INT16, INT19); however, given the poor history of community-government relations, it is highly unlikely that such a partnership would be fruitful.

**Relationships with non-governmental institutions (NGOs and the private sector)**

A number of NGOs have been involved at Mylai Balaji Nagar over the years, the most prominent of which is World Vision.\(^{222}\) The important and multi-faceted role it has played in Mylai Balaji Nagar was highlighted in sections 4.2 and 4.5 of the previous chapter, and sections 5.6, 5.7, and 5.9 of this chapter. In fact, as has been described previously, World Vision was the institution to which the TNSCB ‘out-sourced’ many of its basic development and service responsibilities. This was done without providing supporting funding to the NGO, so it had to rely on its own sources of private charitable funding.\(^{223}\) World Vision has, amongst many other

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\(^{221}\) In a way, residents also sometimes recognize the Panchayat’s predicament: “Even a poor family here has a fridge, washing machine and rice cooker! Let them cut the power and talk to us. In a way they are correct as some people here are arrogant and create problems. Let them come and ask. We will pay” (INT15).

\(^{222}\) Other NGOs that have been involved in some capacity at Mylai Balaji Nagar include: Hand-in-Hand, Growing Opportunity, Janalakshmi, L&T, Five Star Welfare Residents Association, Kuupa, Exnora, CRAD Trust, Christ Foundation, and YWAM (INT2, INT5, FGD1). Most of these NGOs offer micro-finance to residents and some are linked to commercial banks, but some also provide educational support, vocational training, and other kinds of non-credit support (INT11). Micro-finance loans offer the advantage of having a lower rate of interest compared to traditional moneylenders. They also keep capital within the community (INT15).

\(^{223}\) It is interesting to note that with this policy of out-sourcing the responsibility to provide basic services to a third party, the government essentially absolves itself of one of its basic duties. Without government funding, the level of service quality is entirely dependent on the largesse of the contractor NGO. In the (inevitable) event of service deficits, the government can deflect community complaints to the contractor NGO. However, since the contractor NGO is providing the service as a charity, the scope for remedy is limited. Essentially, the right of citizens to basic services is converted into an act of charitable giving, undermining accountability and transparency in the provision
things, initiated the SHGs and the allied Federation and Sangam which were discussed in section 5.9. Although some residents are critical of their focus on micro-finance activities, the SHGs and its allied bodies remain an excellent avenue by which to mobilize the community for a household or community safe water system (INT2). Generally, the residents of Mylai Balaji Nagar have a very long-standing positive relationship with World Vision (FGD1, FGD4, INT1). A partnership with World Vision could potentially support a safe water system at Mylai Balaji Nagar, though as mentioned before, World Vision is presently winding down its ADP so it is not clear whether they will be in the community for very much longer. Other NGOs, with which the community has a positive relationship, such as Hand in Hand, could also be approached for a partnership.\textsuperscript{224} When their community-based workers were asked whether a household or a community level system would be more suitable for Mylai Balaji Nagar they replied that—given the experiences that World Vision has had in Mylai Balaji Nagar, and in spite of the organization’s preference for community level interventions—World Vision is increasingly focusing on household interventions at Mylai Balaji Nagar. They explained that with household level interventions each family will take care of the development good. Moreover, with respect to water, each household is then enabled to control and wisely manage their own water supply. This is in contrast to community level interventions, with which NGO workers anticipate that conflicts over shared responsibilities would ultimately derail the effort (INT3). Thus, a partnership with World Vision (or another NGO) to support a household level system at Mylai Balaji Nagar is a possibility.

With respect to the private sector, there is a thriving private sector in the community itself constituted of a wide array and number of many small businesses (Table 5-2). This represents a body of entrepreneurial experience that is authochthonous to the community and could potentially be mobilized to support the delivery of safe water from a household or a community level system. As for external private sector agents, there have been some negative experiences in the community’s history especially when they become involved in community development efforts. One example is that of the school in sector 2 built by the Sriram Chits Co. This was

\begin{itemize}
\item of services and the rights of the citizen \textit{vis-à-vis} the government. Here we see a rather insidious side to the role of NGOs in development.
\item Hand in Hand has been involved in offering educational support for several years at Mylai Balaji Nagar (INT11). In fact, as of December 2011, the larger project in which the present work is embedded is seeking to establish a partnership with Hand in Hand to support a water cooperative for a household filter that the project has developed and implemented in the community.
\end{itemize}

218
discussed in sections 4.2 and 5.6. With the preponderance of NGOs and banks offering micro-finance in the community, there have also been some negative experiences with predatory lending:

*So many exploitation happened […] Yeah, the government says, and some few NGOs came. But their only purpose was, they will say micro-finance and this that, but their only purpose is [collecting] interest. […] Yeah, so they will came and give money and get some times that back in extra money [interest]. […] So their only motive is the interest, not for the community, not for the family, not for the individual.*

(INT1)

The officer for World Vision’s ADP at Mylai Balaji expands that this negative experience has made residents somewhat suspicious of outside agents entering the community, and that if a community level system is to be undertaken, it must proceed slowly with a great deal of outreach to get everyone on board (INT1). Thus, with respect to this dimension, private sector participation in a household or a community level may be possible, albeit with some reservations.

**Summary**

As this section deals with a number of stakeholders, a schematic, similar to that used in sections 5.6 and 5.7, is used to summarize the assessments (Figure 5-4).

![Figure 5-4](image-url) | Summary of the relationships with local institutions at Mylai Balaji Nagar and associated implications for viable level of application. Coloured bars beneath either household or community level denote viability at that level, whereas a solid line denotes non-viability.
5.11 Land tenure

<table>
<thead>
<tr>
<th><strong>Land tenure</strong></th>
<th><strong>Q: How secure is land tenure in the community?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
<td>Household systems are more feasible in places that have low tenure security as they are portable and do not require community mobilization for infrastructural development.</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>High tenure security is necessary for community systems. This is to assure community-members of a return when investing time, labour, or money in a collective endeavour to develop community infrastructure and organization. Substantial community mobilization may be required for this.</td>
</tr>
</tbody>
</table>

The land tenure situation at Mylai Balaji Nagar was discussed at length in section 4.3. Suffice it to say, land tenure at Mylai Balaji Nagar is complex, controversial, and, in the end, ambiguous. Though the community has been present there for some time, the lack of clear legal title and the antagonistic footing the community and the government have vis-à-vis one another raises the spectre of repeated displacement in the eyes of residents. This has the consequence of forestalling collective constructive action to improve life in the community:

**P5/1/3:** [Lack of patta] is the primary reason why there is no collective and constructive efforts from the people. People fear that they could be displaced at any time for lack of patta or land documents, and hence, [they are] not ready for any joint efforts. Even if people come together and build an overhead water tank for solving the water [storage/supply] problem, they [still] fear that they could be displaced at anytime, hence even though they have the desire to have such [things], [they] are not ready to do it because of the fear of displacement!

**C:** You want to do many things, but fear of displacement prevents you from undertaking such tasks, like overhead tank back in your villages? You are not ready to do it for fear of displacement?

**P5/1/3:** What is the use of such efforts? People say, even if we come together, we have the fear of displacement! We are even ready to do something about the dumping of garbage near Balaji Nagar, but the lack of patta prevents us from undertaking any collective efforts! Hence, people fear contributing anything towards the common cause...

**C:** You fear being displaced after doing such community efforts?
**P5/1/3:** With patta, we can do everything and we will be assured our efforts [will not go to waste] and nobody will question us [our rights].

(FGD1)

Similar statements were encountered during other research activates as well (cf. FGD2, INT18). Thus, there is a feeling that without patta in hand, residents cannot be assured that they would not be moved in the future, and thereby lose any collective investments they make in improving their community. This helps us to understand the proclivity to protest rather than to production documented in section 5.9.

However, this is not the whole story. As documented in Section 4.3, many residents have already paid into obtaining an NOC from the TNSCB. Though not quite full patta, the NOC does function as a sort of acknowledgement that residents have paid into obtaining title to the land (INT16, INT7). As such, residents have somewhat mixed perceptions of how insecure their tenure really is. Following from this, residents also voiced a contrary opinion to that above, saying that they are here for now so they may as well undertake whatever effort they can to improve their conditions. Sometimes these exchanges became heated as respondents argued with one another as to what might happen with community projects given their ambiguous land tenure status:

**SIA:** Do you think that it [a community system] is a waste of money and effort when you don’t have patta?

**P:** No one will think that way. When it is common we have to cooperate as long as we are here.

**P:** We use the [tap] water. So we have to cooperate with them [the rest of the community]. Nothing wrong in it.

**P:** Otherwise we are going to pay our own money and get things done [in the household anyway].

**SIA:** Do you think that patta is not a problem at all?

**P:** Not at all. Whether we have patta or don’t have patta, we will pay and do it.[…]
**SIA:** After paying money, you could build a big water tank here. After that time, you may be asked to quit [by the government] due to the patta problem. Do you have a feeling or fear about wasting money in this? Do you think that when we are not sure of staying here, how can we spend money?

**P:** Yes! When we are not sure about staying here how I can invest money here!

**P:** We are ready to give money even though we don’t have patta.

**SIA:** What are your reasons for saying that?

**P:** As long as we are here, we can have good water.

**P:** Worry and concern about water will not be there.

**P:** We want to have good water at least as long as we stay here.

(FGD2)

Similar statements saying that, regardless of patta, people need good water and will be living together even if they are resettled elsewhere so they may as well work together on it now were encountered during other research sessions as well (cf. FGD3, FGD4). Though such statements were verbalized, they seem to contradict the considerable history of failed collective action in the community discussed in section 5.9.

Altogether, the outlook is mixed. Though residents technically do not have proper legal title to their plots, some residents have at least partial claim to the land by virtue of having paid into the TNSCB’s NOC. Threats and rumours of future displacement on one hand contend with statements from the government that the residents are now the *de facto* owners of the land and will not be displaced. But whether residents will or will not be displaced is perhaps not so relevant here; perhaps the more pertinent question is instead *do residents perceive they are secure enough in their location to invest in their community?* Feelings on this matter were seen to be ambivalent as well, as documented in the preceding. However, that there is a strong perception amongst residents that because of their insecure land tenure they cannot be assured of a return on collective investment is perhaps enough to forestall collective action on a community level system. As such, with respect to this dimension, household level systems may be more appropriate for Mylai Balaji Nagar.
5.12 Government development plans

<table>
<thead>
<tr>
<th>Government development plans</th>
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</thead>
<tbody>
<tr>
<td>Q: What are government development plans for water supply in the community and do they conflict with either level of application?</td>
<td></td>
</tr>
<tr>
<td><strong>Household</strong></td>
<td><strong>Community</strong></td>
</tr>
<tr>
<td>Household systems are not affected by government development plans as they are individual units that are located within each household. Whether or not the government has development plans for water supply lined up in the near future affects household level systems less. It should be noted however that household systems may reduce the political and social impetus to provide public goods however by displacing governmental responsibilities to provide safe water.</td>
<td>Community systems may conflict with government development plans. If the government is going to develop new water supply infrastructure in the near future, it may not be preferable to go to the considerable expense and effort of developing a community level system. Community systems, if they do not involve local authorities, risk displacing governmental responsibilities for the provision of safe water.</td>
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</tbody>
</table>

Government development plans for water supply in the community were documented in section 4.5.5.4. Piped water from the CMWSSB’s new southern desalination plant will eventually connect into Mylai Balaji Nagar, though when this will happen is not presently known; estimates range from one to seven years and more likely later rather than earlier. Additionally, the Panchayat is undertaking a number of water storage projects in Mylai Balaji Nagar itself in the near future.

The Metro Water connection would basically abrogate the need for either a household or a community level safe water system; however, it is not so imminent that investing in either would be without value. With respect to the water storage proposed for the community, a community level system could easily be built around such a development, and a household level system would not be affected at all. Thus, with respect to this dimension, either level of application would be viable at Mylai Balaji Nagar.

5.13 Local perceptions

The dimensions above were drawn from the literature review in Chapter Chapter 2:.. In addition, further dimensions that were not foreseen prior to the primary research emerged during its course as we learned from participants. These are detailed in this section.
When respondents were asked directly whether they would prefer a household or a community level safe water system in their community, a preference for the latter was consistently voiced (FGD1, FGD2, FGD3, FGD4, INT1, INT4). A number of reasons for this were given including:

- The convenience and time savings of having water treatment handled at a central location so that residents would generally just have to collect the treated water (FGD1, FGD3, FGD4, INT4).
- The relative ease for households if potentially complex treatment tasks could be handled by trained operators at the community level (FGD3).
- A community level system would imply that safe water supply would be consistently available throughout the year, and could be collected at any time. Access to sufficient quantities of water was seen as being as important as quality of water (FGD1, INT5, INT18).
- The potential efficiency of placing a filter right at the infiltration well intake in the Lake Narayananapuram (INT18).
- The possibility of getting bottled water from a community level system for less than the market price (INT4).

Though these and the features already discussed were seen as compelling positive points that a community level system offered, after discussing the history of collective action in the community, respondents suggested that though it might be desirable, a community level approach might not be as viable as a household level system at Mylai Balaji Nagar (FGD1, FGD2, FGD4, INT1, INT5). Advantages offered by household level systems that were identified by respondents (and that have not already been discussed above) included:

- More security and less risk of vandalism and breakage (FGD2).
- Greater sense of family ownership of the system leading to a proclivity to care for it (FGD2, INT3, INT18).
- Individuals households can produce water at their own pace and manage their own supply better (FGD3, INT3).

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225 This was a particular hope of residents as the current supply is seasonal, intermittent, and limited, as described in section 4.5.5. Whether a community level system utilizing the same source would actually be able to improve these conditions is another matter altogether.
· Ability to protect and improve children’s health in caregivers’ own hands (INT1).

Thus, respondents identified a number of features for both household and community level systems that were not foreseen prior to beginning the primary research. The preferability of a community level system, primarily for the perception that it would increase the total supply and make it more convenient, was emphasized throughout the research.\textsuperscript{226} The relative desirability of a community system was however balanced by respondents’ own assessment of the challenges that it would entail, as well as the unique benefits that household level systems also had to offer. In this way, local perceptions were ambivalent toward both household and community level systems.

5.14 Synthesis

The preceding sections each generated an assessment with respect to each dimension in Table 2-3 on whether a household or a community level system would be more appropriate at Mylai Balaji Nagar. The purpose of this final section is to parse all of these assessments together in order to arrive at a ‘total’ recommendation of which level of application to pursue in the case study community. A graphical representation in the form of a ‘pseudo-nomogram’ is used to facilitate this.\textsuperscript{227} In addition, some of the comments that have been made throughout this chapter on appropriate O&M approaches will also be synthesized here to generate some preliminary recommendations.

The assessment of which level of application is most appropriate is an exercise in dominance testing (section 2.3.6). As was described earlier, evaluation factors (i.e. the dimensions) are

\textsuperscript{226} Even when we pointed out that supply restrictions would likely remain because the lake source remains the same, the respondents still cited the possibility of this advantage as a major point of desirability for a community level system.

\textsuperscript{227} A nomogram is a general term for the graphical representation of a mathematical or conceptual relationship. In a nomogram (also referred to as a nomograph), a conceptual relationship is “represented graphically and allows the user to plot the known variables on provided scales, and ‘read off’ the resulting value from the remaining scale” (McCullough 2011). In the present case, we are not working with a mathematical relationship \textit{per se}, but rather a conceptual one linking the dimensions given in Table 2-3 to the outcome space of a household or community level system. I refer to it as a ‘pseudo’ nomogram because discrete variables are not plotted to yield an outcome, for there is no clear analytical solution proposed here, just an intuited understanding of how ‘things fit together’ in the case study community. The nomogram form is applied here because it is useful for summarizing each dimension’s assessment and then illustrating how each assessment is parsed with the others to inform the overall total recommendation.
inevitably of variable importance. How important they are has to do with “how things fit together” in the unique locale and is an assessment that cannot be made on *a priori* basis. An ‘expert’ assessment has been made by the investigator on which dimensions emerged as the most important during the course of the research. Those dimensions that were assessed as being of relatively high importance in the case study community have emboldened bars with a solid black line in Figure 5-5, whereas those that were assessed as being of relatively low importance are not bold. Similarly, dominance testing results with respect to high and low importance dimensions are presented separately in Table 5-3.
Figure 5-5 | Summary of assessments of appropriateness of household or community level systems. Coloured bars beneath either household or community level denote viability at that level, whereas a solid line denotes non-viability. Bars with a black border were assessed as being more influential factors locally, whereas bars that were not bold were less important locally.
Dominance testing results are presented in Table 5-3. Dominance results for high and low importance dimensions are reported separately. The numbers in each column indicate the number of dimensions in which household level systems dominate community level systems, or vice versa, or there is a draw between the two (i.e. the dimension is ambivalent).

<table>
<thead>
<tr>
<th>RELATIVE IMPORTANCE</th>
<th>DOMINANCE COUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Household level</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>3%</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>5%</td>
</tr>
</tbody>
</table>

It appears that the household level, in consistently dominating the community level, is the appropriate level of application for a safe water system at Mylai Balaji Nagar.

However, the reality can be made a bit more complex. For the purpose of making the decision-making process clearer and more intuitive, household and community level systems have been treated as the only two possible options. The reality is, of course, far more gradational than that assumed here—dual level systems are also a possibility. These are arrangements in which some of the treatment is handled at the community level (typically clarification), and further treatment takes places at the household level (usually disinfection to ensure safety at the point of consumption). Most community level clarification systems are demanding in the ways detailed in this chapter, so there needs to be sufficient reason to believe that the community level component

---

228 A note is required as to how the dominance count was done as the use of fractions in the table may appear at first to be rather strange. The dimensions of availability of capital funding, availability of upkeep funding, and relationships with local institutions were divided into four, four, and three sub-categories, respectively. If a simple tally of dominance was done, these dimensions would contribute more than the other dimensions as there were more bars presenting them. To compensate for this, counts from these dimensions were made a fraction by the number of sub-categories, such that if all the bars were summed in a given dimension, it would contribute unity, just as the other dimensions. This introduced fractions to the dominance count—which admittedly is unusual—but it kept the relative contribution of these dimensions the same as the others.
of a dual level system would be viable in a given setting. One exception to this is the use of a passive clarification method at the community level, such as bank-side or subsurface infiltration wells. Though these still require O&M support, they are considerably simpler and less expensive when compared to other community level options, given their passive utilization of natural subsurface filtration processes. These systems may be viable in situations where, on the balance, a household level approach is primarily indicated, but there is still some support for a community level. Where this balance lies is difficult to say, so a contextual assessment must be made. In the present case, there is some support for a dual level system with community level clarification, given the number of draws on the high importance dimensions (Table 5-3). This is something that is, in fact, already borne out in that there is a passive subsurface infiltration well at the tap water intake in Lake Narayanapuram (section 4.5.5). On the other hand, the consistent mismanagement of pumping and the degradation of the distribution system, also highlighted in Chapter 4, bears out much of the failures of local governance described in section 5.10. For a dual-level system to be viable at Mylai Balaji Nagar, there would have to be a sound distribution system such that water, once clarified at the infiltration well, would not be subject to further contamination during distribution; this of course entails that there be good governance to correctly operate and maintain the distribution system. A dual level system is already in place at Mylai Balaji Nagar but because of a good governance deficit, the distribution system is ineffective and further clarification is still required; thus, the possibility for a dual level system is left here and not considered any further in the next chapter.

Reflecting on some of the discussion earlier in this chapter also enables us to make some preliminary statements about the O&M approach that may be viable at Mylai Balaji Nagar. Sections 5.7 and 5.9 demonstrate that households are best engaged on an individual basis rather than a collective one. The Panchayat (or any other government agency) is unlikely to be an effective partner in a safe water system, particularly not at the household level, as demonstrated in sections 5.6, 5.9, and 5.10. As such, a household system would have to be deployed with support from only community-members, NGOs, and/or the private sector. One possible mode by which this could be accomplished is having individual households, supported by NGOs, create, or purchase from the market, household water treatment systems. NGOs could then support their on-going operation at the household level.
This chapter has presented the results of the analysis on the first of the two key design questions—*which is the appropriate level of application for a safe water system at Mylai Balaji Nagar?* This case study application of the decision-making support tool analyzed focus group and interview data from the primary research, along with water quality monitoring and community survey data from the baseline research, and demonstrated that a household level system is more appropriate for application at Mylai Balaji Nagar. Now that the level of application has been elucidated, we move on to the second of the two key design questions—*what are appropriate water treatment technologies for application at Mylai Balaji Nagar?*—in the next chapter.
CHAPTER 6: RESULTS & DISCUSSION II: APPROPRIATE TECHNOLOGY

This chapter presents the second part of the case study application of the decision-making support tool. It looks to the second key design question posed at the beginning of the thesis (section 1.2): what are appropriate water treatment technologies for application at Mylai Balaji Nagar? Specifically, this chapter reports the results of the methodology detailed in sections 3.4.2 (Technology feasibility flowchart), 3.4.3 (Assessment of technological alternatives), and 3.4.4 (Multi-factor analysis).

6.1 Selection of viable technologies via the feasibility flowchart

As described in Section 3.4.2, the first step in the process of selecting appropriate water treatment technologies is to identify those options that are viable, and to eliminate those that are not, on the basis of source water quality. This section presents the results of the application of the technology feasibility flowchart. Each box of the flowchart is discussed in an independent subsection, with the outcomes collated at the end.
Preliminary step: Source water quality assessment

- Assess source water quality (including seasonal variation).
- Identify water quality parameters of concern that are in excess of local (BIS) or international (WHO) drinking water quality guidelines.

The quality of public water supply at Mylai Balaji Nagar, and its relation to BIS drinking water standards, was discussed in section 4.5.5.2.

Step 1: Water quality concerns requiring specialized treatment

Are the permissible limits for common heavy metals including arsenic (0.05 mg/l), lead (0.05 mg/l), and mercury (0.001 mg/l) exceeded?

Is the water observed to have or is likely to have (due to heavy pesticide use in surrounding agricultural fields, if present) excessive levels of pesticides?

Is the water salty or brackish?

- If any of these conditions are met, it may be necessary to utilize advanced water treatment systems (e.g. reverse osmosis) or seek another water source. This is not the focus of the present work.

Prior to the initiation of the baseline water quality monitoring program, as part of the larger project in which the present work is embedded, grab samples were taken from Lake Narayananapuram to test for heavy metals. These preliminary tests indicated that heavy metals were not a concern with the tap water supply at Mylai Balaji Nagar. With respect to pesticides, no testing was done, but there is little reason to believe there are any in the water as the surrounding area is totally residential with no agricultural activity in the immediate surroundings.\(^2\) Finally, with respect to salinity, the baseline water quality monitoring program (Appendix D) indicated that the water of Lake Narayananapuram is not salty nor brackish, hence its present use as a drinking water source.\(^3\) As none of the conditions indicating specialized treatment were encountered, we may proceed with the flowchart.

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\(^2\) Whether there is agricultural activity in more distant parts of the watershed that affect the lake is unknown, but we have no reason to believe there is at present.

\(^3\) Referring back to section 4.5.5.2., chloride was included as one of the eleven parameters monitored in the baseline water quality monitoring program (Appendix D). Chloride at all sampling locations was always well below the BIS permissible limit of 1000 mg/L. These findings corroborate the earlier grab samples taken from the lake (Table 4-1).
Step 2: Is a clarification stage required?

<table>
<thead>
<tr>
<th>Is turbidity &gt; 10 NTU often or do community-members complain that the water is murky or cloudy?</th>
</tr>
</thead>
<tbody>
<tr>
<td>· If so, then a <strong>CLARIFICATION stage is required</strong>.</td>
</tr>
<tr>
<td>Consider the following clarification options at the appropriate level of application:</td>
</tr>
<tr>
<td>· <strong>Household</strong>: sedimentation, ceramic filtration, biosand filtration, rapid granular media filtration, cloth filtration, alum or moringa coagulation, combined coagulant-disinfectant products</td>
</tr>
<tr>
<td>· <strong>Community</strong>: rapid granular media filtration, slow sand filtration, alum or moringa coagulation, bank-side/subsurface infiltration</td>
</tr>
</tbody>
</table>

Turbidity results from the baseline water quality monitoring program were presented in Figure 4-23. The raw lake water was shown to regularly exceed the permissible limit of 10 NTU during the period of August to December. However, lane and well samples were consistently within both desirable (5 NTU) and permissible limits, suggesting that the infiltration well effectively controls turbidity.

These findings indicate two things. First, the raw lake water does in fact require clarification, and second, that the existing subsurface infiltration well functions as a community level clarification system. If it were the case that a community or a dual level system was assessed as being viable at Mylai Balaji Nagar, this need would already be (at least partially) met by the existing infiltration well. As per the discussion at the end of Chapter 5, there is some support for a dual level system (although not for a full community level system). This ambivalence is reflected in the fact that though it exists, the community level clarification and distribution system suffers from consistent mismanagement, as was documented in section 4.5.5. Regardless, as the infiltration well is already present at Mylai Balaji Nagar, the possibility for a dual level system is not considered any further.

With the infiltration well successfully reducing turbidity levels, it would appear that a further clarification process is not necessary at the household level, at least with respect to the water quality data. However, community-members repeatedly identified particulate and suspended matter in the tap water as a leading concern during the primary research:

**P5**: *We don’t like to drink this [tap] water. […] Layers of sediment form after a couple of days, even worms are forming in the stored [tap] water.*
P3: Lots of layers and deposits form and there is a lot of cloudiness [in the tap water]. Even the colour of the [tap] water is not good—the water that comes now is yellow in colour.

(FGD1)

Similar concerns were voiced during other research sessions as well (c.f. FGD2, FGD3, FGD4, INT3). As such, though the tap water meets BIS turbidity standards (according to the baseline water quality monitoring results documented in Figure 4-23), residents identify particulate and suspended material in the water, including insect larvae, as something that negatively affects their willingness to consume the stored tap water in the home. For this reason, it is advisable to include a further clarification stage at the household level. Options for this include:

- sedimentation,
- ceramic filtration,
- biosand filtration,
- rapid granular media filtration,
- cloth filtration,
- alum or moringa coagulation, and
- combined coagulant-disinfectant products (e.g. Proctor and Gamble’s PuR sachets).

Step 3: Is a disinfection stage required?

Is the water microbiologically contaminated? Remedial action is necessary if the following conditions, stipulated by the BIS, are not met:

a) Throughout any year, 95 percent of samples should not contain any coliform organisms in 100 ml;

b) No sample should contain E. coli in 100 ml;

c) No sample should contain more than 10 coliform organisms per 100 ml; and

d) Coliform organisms should not be detectable in 100 ml of any two consecutive samples;

or do local people complain about waterborne/G.I. illnesses affecting their families and is there open sewage in the environs?

- If so, then a DISINFECTION stage is required.

Consider the following disinfection options at the appropriate level of application:

- Household: chlorination, UV lamp irradiation, SODIS, boiling, combined coagulant-disinfectants, ceramic filtration, biosand filtration
- Community: chlorination, UV lamp irradiation

231 Speaking of particulate matter, the World Vision workers report that, around the time of the interview, a snake had come out of one of the standpipes in sector 2 when the water had just been turned on (INT3)!
Monitoring results for total and faecal coliforms were presented in Figure 4-21 and Figure 4-22 respectively. The baseline monitoring program demonstrated that the public water supply, irrespective of sampling location or season, contains excessive levels of both total and faecal coliforms. Though *E. coli* was not analyzed directly, the other three BIS conditions were not met. With respect to the proxy indicators given above, residents complain of a host of waterborne/gastrointestinal illnesses affecting their families, as discussed in section 4.5.6.1, and open sewage is ubiquitous throughout the community, as discussed in section 4.5.4. Thus, a disinfection process is required at the household level. Options for this include:

- chlorination,
- UV lamp irradiation,
- SODIS,
- boiling,
- combined coagulant-disinfectants,
- ceramic filtration, and
- biosand filtration.\(^{232}\)

**Step 4: Special considerations**

<table>
<thead>
<tr>
<th>Question</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is iron &gt; 1.0 mg/l often or do community-members complain of a metallic taste and/or rust-colour staining of laundry/vessels?</td>
<td>If so, it may be preferable to use coagulation (for suspended insoluble form only) or biosand/slow filtration at either level of application to treat these metals.</td>
</tr>
<tr>
<td>Is manganese &gt; 0.3 mg/l often or do community-members complain of blackish staining of laundry/food?</td>
<td></td>
</tr>
</tbody>
</table>

Iron was included in the baseline water quality monitoring program; full data are available in Appendix D. To summarize, iron content in lane and well samples fell within the BIS permissible limit (1.0 mg/l). Though periodically the lake samples exceeded the permissible limit, generally levels were within an acceptable range. Previous water quality tests by Dutasta (2010) similarly indicate negligible levels of iron in the water at all locations (Table 4-1). With respect to the proxy indicator, only on a single occasion (c.f. FGD3) did a respondent indicate a “smell of rust” as a water quality complaint. There was no further corroboration of this, either in the baseline or the primary research. This instance may have been an incidental finding (possibly

\(^{232}\) Though ceramic and biosand filtration options are not disinfection methods *per se*, high quality filters of these two types can effectively control microbiological contamination, reducing the need for an additional disinfection stage.

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due to rust in water storage vessels or the standpipe at that particular location). There is no strong evidence to believe that iron is a significant concern here.

Manganese was not included in the baseline water quality monitoring program. Though there are no explicit data, there were no complaints encountered during the primary research of black staining of food, laundry, or vessels that might suggest excessive manganese. Thus, as neither iron nor manganese were seen to be concerns, this advisory need not be applied.

<table>
<thead>
<tr>
<th>Is pH outside the range of 6.5 – 8.5 often?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• If so, there are two courses of action:</td>
</tr>
<tr>
<td>1) pH levels outside the normal range may reduce the effectiveness of some treatment options which may need to be precluded from consideration including:</td>
</tr>
<tr>
<td>o Clarification via alum or moringa coagulation-flocculation</td>
</tr>
<tr>
<td>o Disinfection via chlorination</td>
</tr>
<tr>
<td>2) If these treatments are desired, may need to include a preceding pH CONTROL step via lime or acid addition.</td>
</tr>
</tbody>
</table>

Although pH was not monitored as part of the baseline monitoring program, previous water quality tests by Dutasta (2010) indicate that the pH is 8 at all locations (Table 4-1). As this is within the normal range, this advisory need not be applied.

<table>
<thead>
<tr>
<th>Is nitrate &gt; 45 mg/l often or is the area highly agricultural with substantial levels of fertilizer use in the vicinity and/or is there open animal or human sewage in the surrounding environment?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• If so, there are two courses of action:</td>
</tr>
<tr>
<td>1) Preclude boiling, ceramic, or slow sand filtration due to an increased risk of methaemoglobinemia</td>
</tr>
<tr>
<td>2) Alternatively, it may be preferable to use chlorine (or other chemical oxidant) to convert nitrite to less-harmful nitrate and reduce this risk.</td>
</tr>
</tbody>
</table>

Nitrate was monitored as part of the baseline water quality monitoring program. The data for this parameter are available in Appendix D. To summarize, nitrate in lake, well, and lane samples ranged from 2.0 mg/l to 10.0 mg/l over the course of the monitoring period; at no time did it approach or exceed the desirable limit of 45 mg/l. As such, this advisory need not be applied.

<table>
<thead>
<tr>
<th>Are organics excessive (i.e. COD &gt; 20 mg/l) often or do community-members complain of taste, odour, or colour issues associated with excessive organic matter?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• If so, then may need to include a charcoal/coal or granular activated carbon adsorption filtration component or alum coagulation to remove organics.</td>
</tr>
</tbody>
</table>

Community-members often complain of colour, taste, and odour issues with the tap water, as was documented in section 4.5.5.2. This suggests that there may be excessive levels of organic
matter in the water. This is corroborated by the baseline water quality monitoring program. Figure 4-19 illustrated that the public water supply, at times, exceeded the BIS permissible limit of 20 mg/L, but was almost always in excess of the desirable limit of 5 mg/l. As excessive organics are a concern, this advisory should be applied. Referring back to the suggested evaluation in Table 3-10, a merit/demerit factor of +10% for alum coagulation or charcoal/coal/granular activated carbon filtration should be applied in the MWA.

Fluoride was included in the baseline monitoring program; results for this parameter are included in Appendix D. To summarize, fluoride was found to be consistently below both the desirable limit of 1 mg/l and permissible limit of 1.5 mg/l, in all samples from all locations. As fluoride is not a water quality concern, this advisory need not be applied.

**Step 5: Exceptions and counter-indications**

<table>
<thead>
<tr>
<th>Exception: if utilizing boiling for disinfection, clarification may not be necessary; this may not be in accordance with local WQ standards, but the output water may still be safe(r).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exception: if using a high-performance type of clarification (i.e. ceramic filtration), further disinfection may not be necessary.</td>
</tr>
<tr>
<td>Exception: if influent turbidity is &gt;50 NTU exclude slow sand filters as they are subject to rapid fouling when influent turbidity is high.</td>
</tr>
<tr>
<td>Exception: if influent turbidity is &lt;10 NTU, alum coagulation may be ineffective and should be excluded.</td>
</tr>
<tr>
<td>Exception: if influent turbidity is &lt;50 NTU, moringa coagulation may be ineffective and should be excluded.</td>
</tr>
<tr>
<td>Counter-indication: moringa coagulation is not compatible with chlorine disinfection (because of organics enrichment and excessive chlorine demand with moringa addition). When using moringa, SODIS or UV lamp irradiation may be preferable means of disinfection.</td>
</tr>
</tbody>
</table>

These exceptions and counter-indications indicate what combinations of the required treatment stages are viable and should proceed for further analysis.

**Summary of outcomes from the technology feasibility flowchart**

The application of the flowchart generates the following recommendations on viable technologies for further analysis (Table 6-1).
Table 6-1 | Technological alternatives for further analysis for application at Mylai Balaji Nagar.

<table>
<thead>
<tr>
<th>Clarity Options (Household Level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification</td>
</tr>
<tr>
<td>sedimentation</td>
</tr>
<tr>
<td>ceramic filtration</td>
</tr>
<tr>
<td>biosand filtration</td>
</tr>
<tr>
<td>rapid granular media filtration</td>
</tr>
<tr>
<td>cloth filtration</td>
</tr>
<tr>
<td>alum coagulation</td>
</tr>
<tr>
<td>moringa coagulation</td>
</tr>
<tr>
<td>combined coagulant-disinfectants</td>
</tr>
</tbody>
</table>

As both clarification and disinfection stages are required, quite a number of system combinations are possible (i.e. more than thirty). Applying the exceptions and counterindications identified above limits the possible combinations somewhat, but there remain many to consider. For the present purpose of designing the decision-making support tool and demonstrating its application, it is not necessary to analyze all possible permutations. Instead, a subset of six combinations were selected for further analysis on the basis of an informed understanding of the case study application site and/or because the systems represent interesting possibilities. These are:

1. **Alum coagulation + chlorination.** Alum coagulation (followed by flocculation, settling, and decanting) is widely practiced as a traditional technique for clarifying surface water in rural India. Chlorination using chlorine bleach (NaOCl) powder is also a common practice. This system has been selected on the basis of the widespread existing use of its constituent technologies in India.

2. **Moringa coagulation + SODIS.** Recent years have seen many studies assessing the potential of moringa coagulation (with flocculation, settling, and decanting) as an appropriate water treatment technology. Likewise, research on SODIS as an appropriate water treatment technology, especially in dense urban and peri-urban areas, has greatly

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233 Furthermore, as discussed in 3.3.1.7, because the present case study could only be done in an ‘academic’ manner, it was not necessary to assess all the options for possible application in the field—there was no need for a real recommendation for subsequent community action. Only a subset was required to demonstrate the application of the decision-making support tool. For this reason and to put a limit on the length of this dissertation, other options having significant potential, such as biosand or ceramic filtration, were not analyzed any further.

234 A number of chlorination agents are available that have been widely applied in the field, including liquid bleach, chlorine bleach powder tablets, and NaDCC tablets.
expanded in recent years. The potential of this combination for application in a peri-urban area is considerable.  

3. **Cloth filtration + SODIS.** Cloth filtration has been identified as a simple pre-treatment for SODIS. The combination of these technologies represents a simple and low-cost possibility for application in peri-urban areas.

4. **Boiling.** In many ways, boiling is the ‘standard’ method of water treatment. Boiling figures as an important benchmark against which other technologies are compared.

5. **Rapid granular media filtration.** A range of technologies utilizing rapid granular media filtration have been developed and implemented in the field. Two alternatives of this type were selected for further analysis here.
   a. **AWSP dual-media bucket filter + chlorination.** The AWSP filter was developed as part of the larger project in which the present work is embedded. The filter features rapid sand and charcoal carbon filtration to handle turbidity, microbiological contamination, and organics. Post-filtration disinfection is achieved through the use of chlorine bleach tablets. This system has been included as it was developed specifically for the case study site and it is interesting to see how it performs with respect to other options. Further details on this filter are available in the AWSP Filter Summary Report (Appendix Q).
   b. **TATA Swach filter.** From one of India’s leading industrial houses, the Swach filter is a much-anticipated low-cost water purifier that is being promoted as the innovation which will bring “clean drinking water to millions of Indian families” (Rodrigues 2010). The filter features a rice husk ash (containing silica and carbon) for clarification purposes, which also acts as a substrate for the key innovation that sets it apart from other granular media filters—silver nanoparticles for microbiological control (Rautaray 2011). As such, it doesn’t require any further disinfection. It has been included here as it is interesting to assess how this filter performs relative to other alternatives with respect to appropriateness.

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235 Although one of the exceptions from Step 5 is that with low turbidity water moringa should be excluded, it was still considered here because some research was done with this option as part of the larger project.
This preliminary analysis has identified potential alternatives which now proceed for assessment against the appropriate technology criteria (Table 2-9).

6.2 Assessment of technological alternatives

This section presents the results of the assessment/ranking procedure outlined in section 3.4.3. Each appropriate technology criteria in Table 2-9 is discussed in a sub-section here in which relevant information on the performance of each alternative (with respect to that criterion) was gathered and a ranking generated. The ranking was done on a non-parametric (simple relational) basis, with the best performance assigned a rank of 1 and then descending in rank order to 6. Ties were assigned the average of the shared ranks. The assessment strategies utilized for each criterion varied following Table 3-9.

**END-USER PREFERENCE CRITERIA**

6.2.1 Cost (capital)

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Cost (INR)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>Nil</td>
<td>2.5</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>Nil</td>
<td>2.5</td>
</tr>
<tr>
<td>Cloth filtration + SODIS</td>
<td>Nil</td>
<td>2.5</td>
</tr>
<tr>
<td>Boiling</td>
<td>Nil</td>
<td>2.5</td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>760 (Appendix Q)</td>
<td>5</td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>1199 (TATA Chemicals Ltd. 2012a)</td>
<td>6</td>
</tr>
</tbody>
</table>

Some notes and assumptions on the table above:

- No start-up subsidies are available at the present time for any alternatives at Mylai Balaji Nagar.
- Alum coagulation, chlorination, moringa coagulation, cloth filtration, SODIS, and boiling are assumed to utilize common household items (e.g. buckets, spoons, empty soft drink bottles, mortar and pestles, pots, stoves, old cloth, etc.) that are available in most households in Mylai Balaji Nagar. As such, it is assumed that no further up-front items are required.
• The value given for the AWSP dual-media bucket filter + chlorination is the sum total of labour and materials for prototype filter construction (Appendix Q). This figure is conservative as these were handmade prototypes; with mass production costs would likely be much lower. Chlorination costs are not included here as per the note above.

• The value given for the TATA Swach filter is the MSRP from the manufacturer’s online store as of January 2012.

6.2.2 Cost (on-going)

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Cost (INR)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>756</td>
<td>3.5</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>66</td>
<td>2</td>
</tr>
<tr>
<td>Cloth filtration + SODIS</td>
<td>Nil</td>
<td>1</td>
</tr>
<tr>
<td>Boiling</td>
<td>3240</td>
<td>6</td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>775</td>
<td>3.5</td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>1750</td>
<td>5</td>
</tr>
</tbody>
</table>

Some notes and assumptions on the table above:

• No on-going subsidies are available at the present time for any alternatives at Mylai Balaji Nagar.

• Household labour costs were not included in the above estimates.

• Calculations above are based on an average annual water requirement for drinking and cooking purposes of 13,500 litres per household. This figure is based on an average family size of 4.7 members (section 4.4) and an average daily water requirement (for drinking and cooking purposes) of 7.8 litres per capita.236

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236 Data for the average daily water requirement was gathered from the representative period of the baseline community survey, from January to February 2010, prior to the re-sampling event (Appendix B). This period corresponds to the time directly following the monsoons when water availability is at its greatest at Mylai Balaji Nagar. Thus, the annual requirement represents the maximum annual demand at the best level of availability currently possible in the community. 7.8 litres per capita per day for cooking and drinking purposes (and again, this is during the best time of the year) is very close to the minimum drinking water requirement of 5 litres per day per capita (Gleick 1996). This highlights the scenario of general water scarcity at Mylai Balaji Nagar.
The value for chlorination was derived from laboratory studies that were part of the larger project. In these studies, a single chlorine bleach tablet, costing INR 0.50 each, was required for treating ten litres of filtered lake water.\(^{237}\)

Appropriate dose for both alum and moringa coagulation is dependent on the characteristics of the influent water (Letterman, Amirtharajah, and O’Melia 1999). No formal alum dosing tests were conducted with lake or lane water samples as part of this research. General recommendations for alum powder dosage in the literature range from 0.05 g·L\(^{-1}\) (for initial turbidity of between 10 and 30 NTU) (Preston et al. 2010) to 0.1 g·L\(^{-1}\) (Arnoldsson et al. 2008).\(^{238}\) For present purposes, the latter figure was used as it represents a more conservative estimate.\(^{239}\) An informal survey of several shops in Chennai in January 2012 indicated an average price of Rs. 60/kg for alum. For the yearly household requirement of 13,500 L, approximately 1.35 kg of alum would be required annually, for a total yearly cost of INR 81 per household.

With respect to moringa, some laboratory-based testing was done with lake water as part of the larger project (Ali et al. 2011). Here it was found an appropriate dose was 100 mg·L\(^{-1}\) (by dry sieved weight) for influent water with an average turbidity of approximately 35 NTU.\(^{240}\) An informal survey of several shops in Chennai in January 2012 indicated an average price of Rs. 20/kg for moringa seeds. Thus, for a yearly household requirement of 13,500 L, approximately 3.3 kg of full moringa seeds would be required, for a yearly cost of INR 66 per household.

The amount of fuel required for boiling water was not directly measured at the case study site. Instead, the value given above comes from a cost analysis of boiling water as a water treatment method conducted in another peri-urban community in India by Clasen et al.

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\(^{237}\) As all forms of chlorination are paired with clarification pre-treatments in the safe water systems being investigated here, this chlorine dosage, specifically for clarified waters, is appropriate.

\(^{238}\) It should be noted that Preston et al. (2010) also demonstrated that at relative low turbidity (i.e. 10 NTU), alum at all dosage levels performed worse—actually increasing turbidity rather than lowering it—than settling/decanting controls. This may well also be the case with the low turbidity water available at the household level at Mylai Balaji Nagar that is under discussion here, highlighting the need for pilot testing any recommended outputs of this decision making support tool!

\(^{239}\) Our faculty partner at IIT, on the basis of previous experience in the region, also recommended a dose of 0.1 g·L\(^{-1}\) for informal alum powder dosing tests on the lake water that were part of the larger project.

\(^{240}\) This is within the recommended dosage range of 50 to 100 mg·L\(^{-1}\) for water with turbidity <50 to 150 NTU (Lea 2010). As with alum, Lea (2010) points out the potential unsuitability of moringa coagulation with low-turbidity water (i.e. < 50 NTU) (Dorea 2006).
Only the direct cost of fuel consumed was considered for the value here; indirect costs such as time were not accounted for here as it is considered elsewhere (section 6.2.5).

- SODIS requires only plastic bottles which are widely available from recyclers or by re-using soft drink bottles. The cost for these are negligible.
- Cloth filtration just requires that the cloth be washed periodically. When replacement is required, used cloth scraps are desirable, as it is used cotton cloth that has smaller pores (Colwell et al. 2003). The costs for these are considered to be negligible.
- The only upkeep the dual-media bucket filter requires is that the media needs to be washed with water every two to three months. This can be handled at the household level without any other inputs. However, the absorptive capacity of the carbon layer eventually becomes exhausted, at which time, the carbon media must be replaced. At the water consumption levels prevalent in the community, this may need to be done once a year. As such, an annual cost of INR 100 for materials and labour to replace the charcoal layer is assumed. The sand layer does not need to be regenerated. Chlorination is as above.
- The TATA *Swach* filter bulb is designed to last a maximum of 3000 litres and costs INR 350 for a replacement (TATA Chemicals Ltd. 2012a). For the yearly water requirement, five replacement bulbs would be consumed totalling a yearly cost of INR 1750.
- Though alum coagulation + chlorination and the AWSP filter are technically different prices (INR 756 and 775, respectively), the difference is nominal, so they were ranked as a tie.

### 6.2.3 Health impact

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Comparative risk</th>
<th>Average</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alum coagulation + chlorination</strong></td>
<td>OR = 0.77 (Clasen et al. 2007) · RR = 0.59 (Hunter 2009)</td>
<td>0.68</td>
<td>3</td>
</tr>
<tr>
<td><strong>Moringa coagulation + SODIS</strong></td>
<td>OR = 0.69 (Clasen et al. 2007) · RR = 0.69 (Hunter 2009)</td>
<td>0.69</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Cloth filtration + SODIS</strong></td>
<td>OR = 0.69 (Clasen et al. 2007) · RR = 0.69 (Hunter 2009)</td>
<td>0.69</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Boiling</strong></td>
<td>RR = 0.38 (Fewtrell et al. 2005 after Xiao, Lin, and Chen 1997)</td>
<td>0.38</td>
<td>2</td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>OR = 0.77 (Clasen et al. 2007)</td>
<td>Pooled RR (in children) = 0.71 (Arnold and Colford Jr. 2007)</td>
<td>RR = 0.64 (Hunter 2009)</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>---------------------------------</td>
<td>-----------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>OR = 0.37 (Clasen et al. 2007)</td>
<td>0.37</td>
<td>1</td>
</tr>
</tbody>
</table>

Some notes on the above table follow:

- An attempt was made to gather data from as many relevant sources as possible, but it should be noted that the present effort did not constitute a systematic review of the literature. The search strategy here focused on Google Scholar searches of key terms with respect to each alternative. Systematic reviews and meta-analyses were sought out first for data to populate the table. If data were not available there, then individual studies were sought.

- OR refers to the odds ratio which is the odds of disease among exposed individuals divided by the odds of disease among unexposed individuals. RR is the relative risk or risk ratio and represents the probability that a member of the exposed group will develop a disease relative to the probability that a member of an unexposed group will develop the same disease (Merrill and Timmreck 2006). In either case, the lower the ratio is, the better the alternative performs (i.e. the lower the OR or RR, the better/higher it ranks). Under specific circumstances, the OR and the RR are approximately equal (Webb, Bain, and Pirozzo 2005). In order to simplify the present analysis, they were treated as the same measure and aggregated to generate a simple average.

- Diarrhoeal disease reductions pertain to all age groups unless otherwise stated.

- Epidemiological assessments are not available for moringa coagulation, cloth filtration, or either in combination with SODIS. As such, health impact data for the disinfection method alone (SODIS) were utilized.

- No systematic review included boiling. The data for this was taken from an individual study of boiling for controlling diarrhoea in rural China (Xiao, Lin, and Chen 1997).

- The AWSP dual-media bucket filter and the TATA Swach filter are recent developments which have not yet been examined in epidemiological studies. As technology specific data is not available, meta-analysis results for chlorination and general household filtration have been utilized for either respectively.
6.2.4 Ease of use/difficulty

**Ease of use/difficulty**

*How technically easy or difficult is the alternative to use and maintain? This includes:*
- the need to make difficult subjective decisions;
- whether procedural errors can lead to treatment failures;
- the time required to train people in the use and maintenance of the alternative;
- whether on-going technical support would be required; and
- whether children can also use the alternative.

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| **Alum coagulation + chlorination** | *Alum dosage needs to be optimized periodically using jar tests to adapt to changing influent water characteristics.*  
*Excessive stirring speed can break up flocs during flocculation. Both flocculation and decanting must be conducted precisely otherwise re-suspension can occur.*  
*Alum addition can lower the pH excessively which may affect the effectiveness of chlorination (though acidification boasts its own germicidal effect).*  
*Coagulation stage may be difficult for children to perform.*  
*Chlorination stage is relatively straightforward.* | 5 |
| **Moringa coagulation + SODIS** | *Moringa coagulation faces the same challenges as alum coagulation above.*  
*Required exposure time for complete disinfection with SODIS is sensitive to weather conditions and requires subjective decisions to be made.* | 6 |
| **Cloth filtration + SODIS** | *Cloth filtration is very straightforward.*  
*SODIS is more complex as above.* | 4 |
| **Boiling** | *Basic treatment with which all households have experience.*  
*Some experience is required to ensure that the water comes to a full boil for a sufficient length of time.* | 2 |
| **AWSP dual-media bucket filter + chlorination** | *The use of the filter typically involves just pouring water in the top and collecting it from the tap at the bottom and adding chlorine tablets to the storage container.*  
*However, a subjective judgment is required as to when the filter needs to be cleaned. The actual procedure for cleaning the media is itself no more technically difficult than washing rice.*  
*Chlorination stage is relatively straightforward.* | 3 |
| **TATA Swach filter** | *The use of the filter just involves pouring water in the top and collecting it from the bottom.*  
*When the filter bulb is exhausted it automatically shuts off preventing further water from passing through so that users need not make a subjective decision on when to replace it.*  
*Periodic cleaning of the unit and pre-filters is required, but the required steps are simple and clearly articulated in the user manual (TATA Chemicals Ltd. 2010).* | 1 |

Some comments on the above table:

- The qualitative assessment here was made on the basis of an informed understanding of the use and maintenance of the alternatives.
6.2.5 Time and effort required (convenience)

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>• Alum prep and floculation: ~10 minutes active.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>• Settling and decanting: ~30 min passive.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Chlorination: ~30 min passive.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Periodic cleaning of vessels only.</td>
<td></td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>• Moringa powder prep and floculation: ~30 min active.</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>• Settling and decanting: ~30 min passive.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• SODIS: 3 to 6 hours passive.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Periodic cleaning of vessels and replacement of SODIS bottles.</td>
<td></td>
</tr>
<tr>
<td>Cloth filtration + SODIS</td>
<td>• Filtering: ~5 min active.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>• SODIS: 3 to 6 hours passive.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Washing the cloth after every use and periodic replacement of SODIS bottles.</td>
<td></td>
</tr>
<tr>
<td>Boiling</td>
<td>• Boiling: ~10 min active.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>• Periodic cleaning of vessels only.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increased need to replace fuel bottles for stove more often.</td>
<td></td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>• Filtering: ~15 min passive (Appendix R).</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>• Chlorination: ~30 min passive.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Maintenance involves periodic removal of filter media, washing and regeneration of media, cleaning of filter vessel and storage containers. May need to crush charcoal if it needs to be replaced (labour intensive tasks).</td>
<td></td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>• Purifying: ~1 hour passive.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>• Maintenance involves disassembling unit, washing pre-filters, and installing a replacement filter bulb. These are active tasks but not very labour intensive.</td>
<td></td>
</tr>
</tbody>
</table>

Some comments on the above table:

- The above estimates of the time and effort required were made on the basis of an informed understanding of the operation and maintenance of the alternatives.
- The differentiation between active and passive involvement reflects whether the user has to be involved actively in the process, or whether they can leave the process to proceed on its own.
- Timing data for the AWSP filter is included in the raw data spreadsheet from its lab pilot testing (Appendix R).
### 6.2.6 Production rate

How much time does the alternative take to produce enough water to meet the daily drinking requirements of a single family?

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alum coagulation + chlorination</em></td>
<td><em>The daily requirement could be produced in a single treatment operation: ~70 min.</em></td>
<td>3</td>
</tr>
<tr>
<td><em>Moringa coagulation + SODIS</em></td>
<td><em>The daily requirement could be clarified in a single operation: ~60 min.</em></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td><em>Eighteen 2 litre bottles would be required to treat 36 litres of water with SODIS, but this could all be done at once in the morning, provided sufficient space on the rooftop. It would still take up to 6 hours to treat the water so water would likely have to be produced the day before. Treatment could only be done during the day, so all treatment work would have to be done regularly in the mornings.</em></td>
<td></td>
</tr>
<tr>
<td><em>Cloth filtration + SODIS</em></td>
<td><em>The daily requirement could be clarified in a single operation: ~5 min.</em></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>SODIS as above.</em></td>
<td></td>
</tr>
<tr>
<td><em>Boiling</em></td>
<td><em>Boiling takes 10 minutes approximately to be brought to a rolling boil for a minute. Boiling would be done with available stoves and pots. Since the largest pots are typically ~10 litres, it would take four boiling operations to meet the daily requirement: ~40 min.</em></td>
<td>1</td>
</tr>
<tr>
<td><em>AWSP dual-media bucket filter + chlorination</em></td>
<td><em>The flow rate for the filter is ~80 litres per hour (Appendix R), so it would take ~30 min to filter the daily requirement.</em></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><em>Chlorination could be done on the full volume at once: ~30 min.</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Total ~60 min to get daily requirement.</em></td>
<td></td>
</tr>
<tr>
<td><em>TATA Swach filter</em></td>
<td><em>The flow rate for the filter is 3 to 4 litres per hour (TATA Chemicals Ltd. 2010). At this rate, it could take up to 12 hours to meet the daily requirement.</em></td>
<td>6</td>
</tr>
</tbody>
</table>

Some comments on the above table:

- A daily household water requirement for drinking and cooking purposes of 36.6 litres is assumed (section 6.2.2).
- Some of the values above were estimates made on the basis of an informed understanding of the operation and maintenance of the alternatives while others were taken from published or laboratory data.
6.2.7 Appearance of product water

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| Alum coagulation + chlorination | · Coagulation is effective for controlling colour and turbidity (Farahbakhsh 2009). If it is done correctly, it can clarify water almost completely, but there is a risk of increasing the turbidity if flocculation or decanting is improperly performed, or if the influent turbidity is too low (i.e. <10 NTU) (Preston et al. 2010).  
· Chlorination has little effect on appearance, so long as there are few dissolved solids in the water that can be oxidized. | 2 |
| Moringa coagulation + SODIS | · As above, coagulation is effective for controlling turbidity and colour, however, it is a sensitive procedure. Moringa may be more sensitive to influent turbidity than alum as it has a more restrictive range of effectiveness (i.e. >30 NTU) (Dorea 2006; Lea 2010).  
· SODIS has no effect on the appearance of the product water. The effectiveness of SODIS is however limited by turbidity and colour in the water. | 3 |
| Cloth filtration + SODIS | · Cloth filtration is only marginally effective at reducing turbidity and colour in water.  
· As above, SODIS has no effect on the appearance of the product water. However, as cloth filtration does little to control turbidity and colour, the effectiveness of SODIS may be negatively affected. | 5 |
| Boiling | · Boiling does little to nothing to affect appearance. | 6 |
| AWSP dual-media bucket filter + chlorination | · The sand layer of the dual-media filter can control turbidity.  
· A properly selected carbon layer can remove the organic compounds that contribute to colour (Farahbakhsh 2009). The carbon used in the AWSP filter is finely ground charcoal wood. Laboratory assessments, though informal, demonstrate that the carbon layer is effective at controlling colour and odour compounds.  
· Chlorination has little effect on appearance, so long as there are few dissolved solids in the water that can be oxidized. | 4 |
| TATA Swach filter | · The Swach filter bulb is composed of a base of rice husk ash that contains activated silica and carbon that can effectively control turbidity and organic compounds that contribute to colour (Rautaray 2011). | 1 |

Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives, and in light of the turbidity control assessment in section 6.2.12.
### 6.2.8 Taste, odour, and palpability of product water

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| **Alum coagulation + chlorination** | - Coagulation is not effective at removing dissolved organic compounds that contribute to odour and taste issues (Farahbakhsh 2009). It can at least partially improve taste and odour by removing the suspended organic fraction.  
- Acidification arising due to alum usage may cause palpability issues.  
- Chlorine taste and odour itself may be objectionable to some users, especially children.  
- In fact, chlorination can worsen existing taste and odour issues of water when chlorine reacts with organic matter. | 6       |
| **Moringa coagulation + SODIS** | - As above, coagulation is not effective at removing dissolved organic compounds that contribute to odour and taste issues (Farahbakhsh 2009). It can at least partially improve taste and odour by removing the suspended organic fraction.  
- In fact, moringa can enrich the dissolved organic content of the water which may create their own taste and odour issues (Ali et al. 2011).  
- Moringa does not lower pH as alum does (Yongabi, Lewis, and Harris 2011; Ndabigengesere and Narasiah 1998), evading palpability issues associated with acidification.  
- SODIS may limit the palpability of water by increasing its temperature and decreasing the dissolved oxygen content. | 3       |
| **Cloth filtration + SODIS** | - Cloth filtration will not effectively remove dissolved or suspended organics contributing to taste and odour issues.  
- SODIS is as above. | 4.5     |
| **Boiling** | - Boiling will not effectively remove organic compounds contributing to taste and odour issues, beyond evaporating volatile compounds if they are present.  
- Boiling may affect the taste of water by increasing the temperature and reducing the dissolved oxygen content if it is consumed immediately. | 4.5     |
| **AWSP dual-media bucket filter + chlorination** | - Carbon filter layer can remove dissolved organic matter contributing to taste and odour issues (Farahbakhsh 2009). The carbon used in the AWSP filter is finely ground charcoal wood. Laboratory assessments, though informal, confirm that the carbon layer is effective at controlling colour, taste, and odour compounds.  
- Chlorination may introduce its own palpability issues, as above, although, because organics are removed, new disinfection by-products (DBPs) are less likely to form than with alum coagulation + chlorination. | 2       |
The activated carbon of the rice husk ash in the filter can adsorb organic compounds contributing to taste and odour issues. The silver nano-particles for microbiological control do not impart any objectionable palpability issues as chlorination does.

Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.

6.2.9 Aspirational appeal

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>• Uses only household materials.</td>
<td>3.5</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>• Uses only household materials. • May be unsightly to have 18 used soft drink bottles on the roof for SODIS.</td>
<td>5.5</td>
</tr>
<tr>
<td>Cloth filtration + SODIS</td>
<td>• Uses only household materials. • May be unsightly to have 18 used soft drink bottles on the roof for SODIS.</td>
<td>5.5</td>
</tr>
<tr>
<td>Boiling</td>
<td>• Uses only household materials.</td>
<td>3.5</td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>• Clean and simple bucket houses filter.</td>
<td>2</td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>• Sleek and modern appearance is highly appealing.</td>
<td>1</td>
</tr>
</tbody>
</table>

Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.

6.2.10 Durability

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>• Requires no hardware beyond common household utensils that are highly durable (i.e. metal pots).</td>
<td>1.5</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>• Moringa coagulation requires no hardware beyond common household utensils (i.e. metal pots). • Used soft drink bottles for SODIS are easily scratched and scuffed, limiting their translucence and negatively affecting performance.</td>
<td>5</td>
</tr>
</tbody>
</table>
Cloth filtration + SODIS · Cloth filters have to be washed after use and eventually have to be replaced if they become worn. · SODIS is as above. 6

Boiling · Requires no hardware beyond common household utensils that are highly durable (i.e. metal pots). 1.5

AWSP dual-media bucket filter + chlorination · The plastic drum that houses the filter is made of the highest density plastic available widely on the market. · There is still a risk of the base cracking because of the weight of the media (especially when wet) when being shifted about the house or being transported. 4

TATA Swach filter · Engineering-grade plastic used in this durable good, but it is plastic nonetheless. 3

Some comments on the above table:

· The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.

6.2.11 Fit in the home environment

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>· Uses existing household utensils that can have other functions when not being used for treating water. · May take a bit of space while flocculation and settling is being done. · No other requirement beyond safe storage containers.</td>
<td>2</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>· Moringa coagulation uses existing household utensils that can have other functions when not being used for treating water, as above. · May take a bit of space while flocculation and settling is being done. · 18 soft drink bottles can take up quite a lot of room on the roof or in the home when full and awaiting use or empty.</td>
<td>5</td>
</tr>
<tr>
<td>Cloth filtration + SODIS</td>
<td>· Cloth filtration requires no additional space beyond the existing household utensils it requires, and an existing clothes line to hang from when it is washed. · SODIS as above.</td>
<td>4</td>
</tr>
<tr>
<td>Boiling</td>
<td>· Uses existing household utensils that can have other functions when not being used for treating water. · Takes up limited cooking space on the stove while being treated. · No other requirement beyond safe storage containers.</td>
<td>3</td>
</tr>
</tbody>
</table>
Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives and the case study site.

### TECHNICAL CRITERIA

#### 6.2.12 Technical effectiveness (turbidity control)

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Log Reduction Values</th>
<th>Weighted average</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alum coagulation + chlorination</strong>&lt;sup&gt;241&lt;/sup&gt;</td>
<td>2.2 (Arnoldsson et al. 2008)</td>
<td>1.1 (Crump et al. 2005)&lt;sup&gt;242&lt;/sup&gt;</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>0.5 (Preston et al. 2010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 (Ndabigengesere and Narasiah 1998)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2 (Sarpong and Richardson 2010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Moringa coagulation + SODIS</strong>&lt;sup&gt;243&lt;/sup&gt;</td>
<td>0.9 (Preston et al. 2010)</td>
<td>n/a</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1.0 (Ndabigengesere, Narasiah, and Talbot 1995)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.8 (Arnoldsson et al. 2008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 (Ndabigengesere and Narasiah 1998)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2 (Asrafuzzaman, Fakruddin, and Hossain 2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2 (Sarpong and Richardson 2010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cloth filtration + SODIS</strong>&lt;sup&gt;244&lt;/sup&gt;</td>
<td>0.3 (Kotlarz et al. 2009)</td>
<td>n/a</td>
<td>5</td>
</tr>
<tr>
<td><strong>Boiling</strong></td>
<td>Nil</td>
<td>Nil</td>
<td>6</td>
</tr>
</tbody>
</table>

---

<sup>241</sup> Studies that were found but not included as the influent turbidity was not within the specified range (~100 NTU) were, from the lab, Crump et al. (2004) and Diaz et al. (1999), and from the field, Marimax (2011).

<sup>242</sup> This is a performance report of a combined coagulant-disinfectant product; this was utilized to build the information base for alum coagulation + chlorination in the field.

<sup>243</sup> Studies found, but excluded for reason of varying influent turbidity, included Madsen, Schlundt, and Omer (1987), Babu and Chaudhuri (2005), Muyibi and Evison (1996), Ali et al. (2010), Lea (2010), and Ali et al. (2011) for the lab; and for the field, Marimax (2011).

<sup>244</sup> Ali et al. (2011) was excluded from providing lab data for reason of different influent water turbidity.
Some notes on the above table:

- Turbidity control is inherently linked to influent levels. Greater apparent reductions are possible when the influent water has a relatively high turbidity. Hence, influent water conditions must be similar in order to intelligibly compare alternative effectiveness. This ideally would be achieved by carrying out lab and field experiments with all the alternatives using the same influent water from a single real world source; however, this was beyond the scope of the present work. Instead, the strategy here was to search the literature and gather data from previous experiences. In order to make the most informative comparisons, data was taken only from treatment effectiveness studies where the influent water had a turbidity of ~100 NTU. If the influent water used in the study had a different turbidity, it was not included. Outcome measures were converted to equivalent log reduction values in order to facilitate comparison.
- A limitation here was that other water quality parameters were not considered, though they too may relate to treatment effectiveness.
- An attempt was made to gather data from as many relevant sources as possible, but it should be noted that the present effort did not constitute a systematic review of the literature. The search strategy here focused on Google Scholar searches of key terms with respect to each alternative. First, systematic reviews and meta-analyses were sought and if data was not available, then data was abstracted from individual studies.
- Where accounts of multiple dosages were provided, the most effective dosage was used.
- A weighted average of the field and lab data was generated wherein field data contributed 70% and lab data contributed 30%.
- For the four combined systems, it is the clarification component that offers turbidity control only. Data for these systems was taken from studies of the clarification component alone, not of the combined system.
- It should be noted that both moringa and alum coagulation are less effective at controlling turbidity at lower influent turbidity levels (Preston et al. 2010; Lea 2010; Dorea 2006).
- No field reports were available of the effectiveness of cloth filtration at controlling turbidity. Likewise, none were available for moringa coagulation either.
- The AWSP study filter was assessed in the lab for turbidity control with raw lake water as part of the larger project. On no occasion was the influent water source from the lake in the vicinity of ~100 NTU. However, this is the only available data for this filter. As such, the trial data from the replicate experiment where the turbidity was the greatest (Replicate #6: 42.7 NTU) was used to populate this field. This influent value is less than the standard applied to others which makes this an underestimate of the effectiveness of the AWSP filter. However, some data was necessary for comparison, so this had to be done. The results of pilot testing are appended (Appendix R). No data is available yet for its effectiveness in the field.
- Independent reports of the turbidity control capabilities of the TATA Swach filter are not available. The reported value is based on manufacturer claims in which the influent water quality was not identified. This was the only available data, so it was taken to populate the field, however it should be regarded with some scepticism. No reports are available from field assessments at present.

### 6.2.13 Technical effectiveness (microbiological control)

#### Technical effectiveness (microbiological control)

*How effective is the alternative at reducing microbiological contamination? Consider both 1) field-effectiveness and 2) lab-efficacy, if data are available. (Applicable only if a disinfection stage is required.)*

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Log Reduction Values</th>
<th>Weighted average</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alum coagulation + chlorination</strong></td>
<td>4.4 (Crump et al. 2004) 7.0 (Souter et al. 2003)</td>
<td>3.2 (Rangel et al. 2003)</td>
<td>3.95</td>
</tr>
<tr>
<td><strong>Moringa coagulation + SODIS</strong></td>
<td>1.0 (Ali et al. 2011) 3.9 (Wilson and Andrews 2011)</td>
<td>n/a</td>
<td>2.45</td>
</tr>
<tr>
<td><strong>Cloth filtration + SODIS</strong></td>
<td>5+ (WHO 2008) 5.5+ (Sobsey et al. 2008) 1.0 (Ali et al. 2011)</td>
<td>3.0 (WHO 2008) 3.0 (Sobsey et al. 2008)</td>
<td>3.25</td>
</tr>
<tr>
<td><strong>Boiling</strong></td>
<td>9+ (WHO 2008)</td>
<td>6.0 (WHO 2008)</td>
<td>6.90</td>
</tr>
<tr>
<td><strong>AWSP dual-media bucket filter + chlorination</strong></td>
<td>1.1 (Appendix Q)</td>
<td>n/a</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>TATA Swach filter</strong></td>
<td>6.0 (TATA Chemicals Ltd. 2012b)</td>
<td>n/a</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Some comments on the above table:

- An attempt was made to gather data from as many relevant sources as possible, but it should be noted that the present effort did not constitute a systematic review of the literature. The search strategy here focused on Google Scholar searches of key terms with respect to each relevant alternative. First, systematic reviews and meta-analyses were sought, if available, and if not available, then data was abstracted from individual studies.
- A weighted average of the field and lab data was generated wherein field data contributed 70% and lab data contributed 30%.
- Many studies reported treatment effect on three classes of microbiological organisms (bacteria, viruses, and protozoa). To simplify the present analysis, only bacterial LRVs are presented here, as this was the primary microbiological concern assessed at Mylai Balaji Nagar.
- Performance reports of combined coagulant-disinfectant products were also utilized to build the information base for alum coagulation + chlorination.
- A notable exception for chlorination are the oocysts of the protozoan Cryptosporidium parvum (WHO 2008).
- The performance of coagulation is highly dependent on the type of coagulant, dose, pH, temperature, alkalinity, and turbidity of the water (WHO 2008). This highlights the importance of pilot testing recommendations emerging from this tool.
- SODIS-only data was not included to supplement the moringa coagulation + SODIS information base. This is because moringa coagulation has been observed to be associated with secondary re-growth of bacteria (Ali et al. 2011; Wilson and Andrews 2011; Madsen, Schlundt, and Omer 1987; Jahn and Dirar 1979). As such, these two treatment systems behave differently and should not be aggregated. No field assessments of moringa coagulation + SODIS were found.
- Performance reports of SODIS alone were also utilized to build the information base for cloth filtration + SODIS. Rather than a multiplicity of individual studies, the values here were primarily collected from two systematic reviews. The only individual study included here is one that was done with specific relevance to the case study site (Ali et al. 2011).
The AWSP study filter was assessed for microbiological control in the lab with raw lake water as part of the larger project. The filter report is appended (Appendix Q). No data is available yet for its effectiveness in the field.

Independent reports of the microbiological control capabilities of the TATA Swach filter are not available. The reported value is based on the manufacturer’s claim that the filter meets US Environmental Protection Agency (EPA) standards for water purifiers (TATA Chemicals Ltd. 2012b). Moreover, no reports are available from field assessments at present.

6.2.14 Availability

**Availability**

*How easily can parts and materials be obtained locally? Considerations here include:*

* whether there is an existing supply chain for parts and materials, or whether one can be established easily;
* whether parts and materials are produced locally or need to be imported;
* whether materials are fragile, heavy or otherwise problematic to transport; and
* whether materials locally have other competing uses which may be impinged upon or limit their availability for water treatment purposes.

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| **Alum coagulation + chlorination**| • Alum and chlorine bleach tablets are established products available widely in urban and rural marketplaces throughout India.  
• Both are produced locally throughout India.  
• Both are light-weight, easy to transport, and not particularly fragile.  
• Both are intended for water treatment purposes primarily (although alum is also used as an aftershave), so no other major uses are impinged upon. | 2       |
| **Moringa coagulation + SODIS**    | • Moringa trees grow widely throughout India, however, in South India, its young fruit (the ‘drumstick’) is a popular foodstuff. As such, the fruit is mostly harvested before the seeds reach maturity and it is the mature seed that is required for water treatment purposes. Because of this competing use, the mature seed is relatively difficult to obtain in South India. In Mylai Balaji Nagar specifically, there are a few moringa trees, but being a peri-urban community, there are hardly enough to sustain continuous and widespread water treatment. Moringa had to be obtained from special suppliers (i.e. agricultural research stations) for research that was part of the larger project.  
• SODIS requires only used plastic soft drink bottles which are available in great quantities from recyclers in Mylai Balaji Nagar itself, or nearby. Almost all homes in the community have flat or shallow pitched roofs upon which SODIS bottles can be exposed to the sun, with the exception of the few steeply pitched thatched roofs of | 6       |
the very poor in the community. These households can likely find other locations to place the bottles.

**Cloth filtration + SODIS**
- Used cotton sari cloth is a prime material for this purpose. This is something that is available in great quantities in all homes.
- SODIS is as above.

**Boiling**
- Boiling requires just a pot, stove, and fuel, but it is the latter that presents problems of availability. The government subsidizes and rations the supply of cooking fuel. Using cooking gas for boiling water can substantially increase household consumption, impinging on other uses. Though additional cooking gas can be purchased on the black market, it is substantially more expensive. Supply chains are already well-established in the community for cooking gas, but the quantities are generally limited.
- Biomass or other natural fuel sources are not available in significant quantities in the community given its peri-urban location.

**AWSP dual-media bucket filter + chlorination**
- The AWSP filter requires materials that are widely available in any urban or rural marketplace (e.g. plastic buckets, PVC piping, charcoal, construction sand).
- Its manufacture does require some basic tools however (e.g. drill press).
- Chlorination is as above.

**TATA Swach filter**
- The TATA Swach filter has just come on to the market in India.
- It is a locally produced good.
- Units and replacement parts are available at most household goods retailer in the urban marketplace. Market penetration in rural areas may be limited however.

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Some comments on the above table:
- The qualitative assessments above were made on the basis of an informed understanding of the local context at Mylai Balaji Nagar and experience with the alternatives.

### 6.2.15 Reliability

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Can the alternative consistently treat water effectively (with respect to the required treatment stages), or is its performance contingent on external or environmental factors?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technological alternative</strong></td>
<td><strong>Assessment</strong></td>
</tr>
</tbody>
</table>
| Alum coagulation + chlorination | - Quality of alum available locally varies such that clarification may be affected.  
- Chlorine tablets become less effective with age and exposure to air such that disinfection may become less effective with time. | 4 |
<table>
<thead>
<tr>
<th>System</th>
<th>Characteristics</th>
<th>Note</th>
</tr>
</thead>
</table>
| Moringa coagulation + SODIS                 | · Quality of seeds is naturally variable; level of active agent in seeds (polyelectrolyte) is substantially less during the rainy season, so seeds should be harvested during the dry season (Fuglie 2000). This may affect clarification.  
· The effectiveness of SODIS disinfection is entirely contingent on exposure time and intensity of sunlight. During the rainy season, this method may be entirely unreliable. | 6    |
| Cloth filtration + SODIS                    | · Cloth filtration is not affected by external/environmental factors.  
· SODIS is as above. | 5    |
| Boiling                                     | · Not affected by external/environmental factors. | 1    |
| AWSP dual-media bucket filter + chlorination| · Does not appear to be affected by external/environmental factors, however, it is a prototype filter still undergoing refinement. | 3    |
| TATA Swach filter                          | · Not affected by external/environmental factors.  
· Product of 10+ years of field and laboratory development; extensive product testing  
· Filter effectiveness does decrease with time. Disinfection potential may become impaired with clogging of the filter matrix. | 2    |

Some comments on the above table:

· The reliability of both system components (i.e. clarification for turbidity control and disinfection for microbiological contamination control) was assessed separately where applicable.
· The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.
### Robustness

**Robustness**

*How well can the alternative handle varying quality of influent water (with respect to the required treatment stages)?*

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| Alum coagulation + chlorination       | • Alum dosage needs to be calibrated to specific influent turbidity; if influent water quality changes, alum coagulation is liable to become less effective. At low influent turbidity, alum coagulation becomes ineffective and may in fact increase turbidity.  
  • Alum also changes the pH of the water which in turn may affect chlorine disinfection effectiveness.  
  • Chlorination also needs to be calibrated to influent water characteristics. Its effectiveness is contingent on turbidity and organics removal, so if the preceding clarification stage becomes less effective, disinfection too is likely to suffer. Varying dissolved organic content in the water can also affect chlorination effectiveness. | 5       |
| Moringa coagulation + SODIS           | • As with alum coagulation, moringa coagulation must be calibrated to the specific influent turbidity and is vulnerable to quality changes. In fact, moringa is more sensitive than alum with respect to this feature.  
  • SODIS is less effective if the water is cloudy or coloured, making it totally contingent on how well the preceding clarification stage is functioning. | 4       |
| Cloth filtration + SODIS              | • Cloth filtration can only remove the larger fraction (>20 µm) of suspended material in water (Colwell et al. 2003).  
  • SODIS is as above. With cloth filtration, SODIS is liable to be affected as the cloth filtration is not as effective as other clarification methods (section 6.2.12). | 6       |
| Boiling                               | • The disinfection effectiveness of boiling is generally unaffected by changing influent water quality.                                                                                                                                                                                                                                  | 1       |
| AWSP dual-media bucket filter + chlorination | • The dual sand and charcoal filter layers can robustly remove varying levels of turbidity and organic—until the capacity is exhausted. When this occurs may be unclear to some users as it is a somewhat subjective call.  
  • Chlorination can be negatively affected if the organic content becomes elevated because of undetected filter breakthrough. | 3       |
Some comments on the above table:
  · The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.

6.2.17 Absence of environmental impacts and hazards

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alum coagulation + chlorination</strong></td>
<td>· Alum coagulation produces hazardous aluminum-containing sludge that must be disposed of safely. Given the lack of effective waste management at Mylai Balaji Nagar (section 4.5.4), waste sludge is likely to wind up in the canals and the immediate environment, presenting a long-term toxicity hazard to residents.</td>
<td>6</td>
</tr>
</tbody>
</table>
| **Moringa coagulation + SODIS** | · If moringa were locally supplied, there may be a risk of over-harvesting, but this is not the case at Mylai Balaji Nagar as it has to be obtained from outside.  
  · The waste sludge is biodegradable.                                                                 | 2       |
| **Cloth filtration + SODIS** | · No hazards or impacts. Environmentally friendly as it uses only waste items (i.e. scrap cloth and old plastic bottles).                                                                                 | 1       |
| **Boiling** | · Irrespective of fuel source, leads to greenhouse gas emissions. If using biomass, could lead to stripping of local forest cover. Some water boiling at Mylai Balaji Nagar is done with wood, but mostly it is cooking gas. | 4       |
| **AWSP dual-media bucket filter + chlorination** | · The filter requires manufactured plastic goods, so there are indirect industrial impacts.  
  · Wash waters from cleaning media may be contaminated.  
  · Disposing of exhausted charcoal media may present environmental hazards.                                                                 | 3       |
TATA Swach filter

- Filter is a manufactured plastic good, so industrial impacts are inescapable, as above.
- Filter bulbs need to be regularly replaced and properly disposed. Throw away filter bulbs represent a significant volume of non-biodegradable waste. Exhausted filter bulbs may also present environmental hazards because of the contaminants they contain. Accumulation of waste bulbs is especially a concern at Mylai Balaji Nagar given the lack of effective solid waste management there (section 4.5.4).

Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of the local context at Mylai Balaji Nagar and experience with the alternatives.

### 6.2.18 Risk of recontamination

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| Alum coagulation + chlorination | - Alum coagulation takes place in an open buckets that may be contaminated, but afterward it is decanted to a safe storage jar in which chlorination is done.  
- If done currently, a chlorine residual protects the water from recontamination.  
- Safe storage is necessary to prevent the introduction of foreign materials that can consume the chlorine residual. | 1       |
| Moringa coagulation + SODIS | - Moringa coagulation has been observed to be associated with the secondary re-growth of some bacterial species (Ali et al. 2011; Wilson and Andrews 2011; Madsen, Schlundt, and Omer 1987; Jahn and Dirar 1979). This may be due to enrichment of organics in the treated water. If SODIS disinfection is not complete, there may be re-growth of bacteria in the water.  
- SODIS itself takes place in narrow-mouth soft drink bottles from which the water is directly consumed limiting the opportunity for re-contamination by the introduction of foreign materials. | 5       |
| Cloth filtration + SODIS | - Cloth filtration occurs between two open containers, but from there the water is placed in SODIS bottles, which offer the advantages given above. | 4       |
| Boiling | - Boiling takes place in open pots and offers no residual protection. Often, the boiled water is kept in the same pot into which glasses are dipped, or foreign materials may fall into, increasing the risk for recontamination.  
- This can only be ameliorated by transferring boiled water immediately to narrow-mouthed safe storage containers. | 6       |
Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.

### 6.2.19 Absence of hazards to users

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Ranking</th>
</tr>
</thead>
</table>
| **Alum coagulation + chlorination** | - Chlorine bleach tablets are hazardous to keep in the home because of the risk of children swallowing them.  
- Chlorine is a strong oxidant which may react violently with flammable household liquids. | 4       |
| **Moringa coagulation + SODIS** | - No foreseeable hazards.                                                 | 2       |
| **Cloth filtration + SODIS** | - No foreseeable hazards.                                                 | 2       |
| **Boiling** | - Indoor air pollution because of the burning of fuels for cooking or boiling water is a leading health concern (Kulshreshtha, Khare, and Seetharaman 2008).  
- Use of small stoves are a leading cause of fires in slum settings (Jayaraman, Ramakrishnan, and Davies 1993; Marsh et al. 1996) | 6       |
| **AWSP dual-media bucket filter + chlorination** | - The filter is large and bulky and needs to be placed at a height above the safe storage receptacle. This presents a crushing hazard if not securely placed.  
- Chlorination presents hazards as above. | 5       |
| **TATA Swach filter** | - No foreseeable hazards.                                                 | 2       |

Some comments on the above table:

- The qualitative assessments above were made on the basis of an informed understanding of, and experience with, the alternatives.
Criteria relating to socio-cultural and local appropriateness

6.2.20 Traditional knowledge, practices, and perceptions

As was discussed in section 3.4.3, the criteria relating to socio-cultural and local appropriateness were not treated in the same way as the criteria of the previous two suites. As was the case with several of the criteria above, a qualitative assessment was made on the basis of an informed understanding of the case study site and experience with the alternatives; however, instead of ranking the alternatives, here the strategy was to apply merit/demerit points reflecting the promoting or inhibiting nature of the qualitative assessments (Table 3-9).

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Merit/ Demerit Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>· Clarifying water with alum blocks is a widespread traditional practice throughout rural India. Knowledge of alum coagulation, although it is not widely practised, is already present in Mylai Balaji Nagar as well (Figure 4-24). (+2%)&lt;br&gt;· Chlorination using bleaching tablets is a widespread practice in both rural and urban India. Limited use of this method was also documented during the baseline community survey (Figure 4-24). (+2%)&lt;br&gt;· Though not common, there was a perception amongst community-members that using chlorine bleach powder could lead to negative health effects, particularly for those with heart conditions (FGD7). (-1%)</td>
<td>+3%</td>
</tr>
</tbody>
</table>
| **Moringa coagulation + SODIS** | - Moringa is a common foodstuff in south India and is, itself, not widely used as a water treatment agent. However, the use of other plant-based materials (notably the seeds of *Strychnos potatorum*—also known as the *clearing nut* tree, or the *nirmali* tree in Hindi) for water treatment purposes stretches back to ancient *ayurvedic* literature, and is still widely practiced in rural Maharashtra and Tamil Nadu (Babu and Chaudhuri 2005). Moringa could build upon this traditional knowledge, but it is not presently known to the residents of Mylai Balaji Nagar. (+1%)  
- Likewise, the practice of exposing water to sunlight (i.e. combined effect of heat and UV radiation) for purification purposes is also documented in ancient *ayurvedic* literature (Baker 1949). Applications of the modern form of SODIS are not widespread in India however, and there was little pre-existing knowledge, and no pre-existing use, of solar UV disinfection observed in Mylai Balaji Nagar. (+1%) | +2% |
| **Cloth filtration + SODIS** | - Cloth filtration is a technique already used by women in Mylai Balaji Nagar when collecting water from the taps (FGD4). (+2%)  
- SODIS is as above. (+1%) | +3% |
| **Boiling** | - Boiling is the leading pre-existing water treatment method utilized in Mylai Balaji Nagar (Figure 4-24). (+4%) | +4% |
| **AWSP dual-media bucket filter + chlorination** | - Rapid sand filtration and the use of charcoal were both novel treatment methods to many residents of Mylai Balaji Nagar, though both have traditional precedents in the rural south India. (+1%)  
- On the other hand, during some filter design sessions (a part of the larger project), some residents raised the concern that the sand would be unclean as construction sand is often taken from the banks of sewage-polluted rivers. This perception led to some resistance to the idea of using sand to filter water (INF). (-1%)  
- Chlorination is as above (+2% and -1% = +1%). | +1% |
| **TATA Swach filter** | - Ceramic filters were also amongst the common water treatment methods already utilized at Mylai Balaji Nagar (Figure 4-24). Though the *Swach* filter is technically not a ceramic filter, it is similar in both form and effect. (+2%)  
- Silver nano-technology is novel and unknown to the Indian public.  
- Consumer products from TATA are seen as highly desirable and reliable products amongst the emerging consumer class in India. (+1%) | +3% |

Some comments on the above table:

- The qualitative assessment of each alternative and the assignment of merit/demerit factors was made on the basis of an informed understanding of, and experience with, the alternatives and the field-site, drawing on field and/or literature data wherever possible.
- Some comments on the assignment of merit/demerit factors: If an alternative was already known and utilized in the case study community, a merit factor of +2% was applied. If no pre-existing practice of an alternative was observed, but the alternative had some basis in traditional knowledge, a merit factor of 1% was applied. A merit or demerit of 1% to 2% was applied if there was a pre-existing perception about an alternative, depending on its
positive or negative significance. Boiling was assigned a positive merit factor of 4% because of its widespread use and to compensate for the skewing resulting from it having only a single component whereas the others had two components.

### 6.2.21 Local taste preferences

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Merit/ Demerit Factor</th>
</tr>
</thead>
</table>
| **Alum coagulation + chlorination** | · There was no preference or concern regarding alum observed during the field research, but this alternative was not actually implemented on a large scale in the community so this is not to say there are no possible concerns that may arise with experience.  
· Chlorination was associated with a number of palpability concerns amongst users. As part of the field application of the AWSP filter in the larger project, some filter-users reported that excessive chlorine caused throat irritation (FGD2). A common report during focus groups on appropriate technology options was that children (and even some adults) would be resistant to consuming water that had a chlorine odour or taste to it (FGD5, FGD6, FGD7, FGD8, FGD9). Though excessive chlorine taste and odour are caused by improper dosing of chlorine bleach tablets—something that experience would eventually rectify—it remains an inescapable concern. (-3%) | -3% |
| **Moringa coagulation + SODIS** | · There was no preference or concern regarding moringa or SODIS observed during the field research, but this alternative was not actually implemented in the community so this is not to say there are no possible concerns that may arise with experience. | Nil |
| **Cloth filtration + SODIS** | · There was no preference or concern regarding cloth filtration or SODIS observed during the field research, but this alternative was not actually implemented in the community so this is not to say there are no possible concerns that may arise with experience. | Nil |
| **Boiling** | · In other parts of south India, for instance, in rural Andhra Pradesh, some people feel that boiling makes water tasteless and undesirable (PATH 2008; PATH 2011). Despite this, there were still no such complaints observed during the field research when discussing this leading method of water treatment in the community. | Nil |
| **AWSP dual-media bucket filter + chlorination** | · During field assessments of the AWSP filter, some users reported the growth of algae in the filter leading to an unpleasant musty odour in the treated water (FRM1). (-1%)  
· Chlorination as above. (-3%) | -4% |
There was no preference or concern regarding the TATA Swach filter observed during the field research, but this alternative was not actually implemented in the community so this is not to say there are no possible concerns that may arise with experience.

Some comments on the above table:

- The qualitative assessment and the assignment of merit/demerit factors for each alternative was made on the basis of an informed understanding of, and experience with, the alternatives and the field-site, and drew on field and/or literature data wherever possible.

6.2.22 Perception of treatment by users

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Merit/Demerit Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>No such concerns observed.</td>
<td>Nil</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>No such concerns observed.</td>
<td>Nil</td>
</tr>
<tr>
<td>Cloth filtration + SODIS</td>
<td>No such concerns observed.</td>
<td>Nil</td>
</tr>
<tr>
<td>Boiling</td>
<td>No such concerns observed.</td>
<td>Nil</td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>No such concerns observed.</td>
<td>Nil</td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>No such concerns observed.</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Some comments on the above table:

- This criteria did not emerge as a concern during the course of the field research at the case study site, though it may be a concern in other communities. It is retained here to demonstrate the logic of the decision-making support tool.
- Community-members did raise concerns about being assured of water quality when undertaking treatment at the household level, as was discussed in section 5.4. This concern was already handled there, and would be equally applicable to all of the alternatives here, so it is not considered any further.

6.2.23 Relation to institutional environment

<table>
<thead>
<tr>
<th>Technological alternative</th>
<th>Assessment</th>
<th>Merit/Demerit Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum coagulation + chlorination</td>
<td>No known opportunities.</td>
<td>Nil</td>
</tr>
<tr>
<td>Moringa coagulation + SODIS</td>
<td>No known opportunities.</td>
<td>Nil</td>
</tr>
</tbody>
</table>
### Table 6.2: Performance of Alternate Water Treatments

<table>
<thead>
<tr>
<th>Technology</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloth filtration + SODIS</td>
<td>No known opportunities.</td>
</tr>
<tr>
<td>Boiling</td>
<td>No known opportunities.</td>
</tr>
<tr>
<td>AWSP dual-media bucket filter + chlorination</td>
<td>No known opportunities.</td>
</tr>
<tr>
<td>TATA Swach filter</td>
<td>No known opportunities.</td>
</tr>
</tbody>
</table>

Some comments on the above table:

- All of the materials required for the first five alternatives are household products already widely available on the market.
- Subsidies and other support from NGOs is always a possibility at Mylai Balaji Nagar, but as was documented in Chapter 5, with World Vision on its way out, there is presently no active NGO program in the community. Any such program would have to begin at the project proposal stage.
- As was documented in section 5.7, the Panchayat has previously indicated that they are unable to provide services to individual households: any services rendered by the Panchayat must be at the community level (INT6). Thus, there is no known potential for governmental support of any of the above household alternatives.
- The TATA *Swach* filter emerged from a decade-long corporate social responsibility initiative in which TATA supported field research and implementation of its precursor, the *Sujal* filter (Rodrigues 2010). The *Swach* filter is now being deployed as a commercial product, not as part of a corporate social responsibility initiative, so no further subsidies are expected.

With this, all of the appropriate technology criteria given in Table 2-9 have been applied to the selected alternatives and ranking assessments of their performance have been generated. This represents one of the key informational inputs (Figure 3-1) for the multi-factor analysis which is discussed in the next section.

### 6.3 Multi-factor analysis

As described in section 3.4.4, the multi-factor analysis integrates two informational components to develop an outcome space of appropriate water treatment technology(-ies). There are:

1. The performance assessment of technological alternatives with respect to the appropriate technology criteria (Table 2-9).
2. The weightings of the appropriate technology criteria.

The first of the informational components has been developed in the preceding section (section 6.2). Before moving on to the multi-factor analysis, the second must also be developed.

6.3.1 Weightings of appropriate technology criteria

Assessing the relative importance of appropriate technology criteria constituted the second part of the community-based field research (section 3.3.3). This section presents the results of these field investigations and how the data was processed in order to integrate it into the MWA.

End-user preference criteria

Weightings for the end-user preference criteria suite were generated via a ranking game carried out during focus group sessions (Figure 6-1, Figure 6-2, and Figure 6-3).

Figure 6-1 | Focus group discussion (FGD 9) on end-user preferences (appropriate technology criteria) in Sector 4 of Mylai Balaji Nagar in May 2011.
Investigations into this question were done during FGDs 5 to 10, INT18, and INF events (Table 3-4). Transcripts from these sessions are appended (Appendix S). A total of thirty-one unique rankings from thirty-one individual respondents (identified by the code Rx-y, where x is the FGD
number and y is the respondent number) were gathered over the course of five focus group sessions (FGD #x, where x = 5 to 10). A summary ranking (Table 6-2) was generated by taking the mean ranking of the thirty-one unique results for each criteria (Table 6-3).

Table 6-2 | Summary of ranking results for end-user preference criteria from community-member rankings.

<table>
<thead>
<tr>
<th>Rank position</th>
<th>Criteria</th>
<th>Mean ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Health impact</td>
<td>1.55</td>
</tr>
<tr>
<td>2</td>
<td>Appearance of product water</td>
<td>3.16</td>
</tr>
<tr>
<td>3</td>
<td>Taste, odour, and palpability of product water</td>
<td>4.35</td>
</tr>
<tr>
<td>4</td>
<td>Durability</td>
<td>5.39</td>
</tr>
<tr>
<td>5</td>
<td>Production rate</td>
<td>5.84</td>
</tr>
<tr>
<td>6</td>
<td>Time and effort required (convenience)</td>
<td>6.48</td>
</tr>
<tr>
<td>7</td>
<td>Aspirational appeal</td>
<td>6.68</td>
</tr>
<tr>
<td>8</td>
<td>Costs</td>
<td>6.81</td>
</tr>
<tr>
<td>9</td>
<td>Ease of use/difficulty</td>
<td>7.13</td>
</tr>
<tr>
<td>10</td>
<td>Fit in the home environment</td>
<td>7.61</td>
</tr>
</tbody>
</table>

The mean ranking in Table 6-2 was used in the MWA to generate general recommendations on appropriate technology options (Scenario A). Each unique respondent ranking (Table 6-3) was used to perform sensitivity analyses (Scenario B). This will be elaborated upon more fully in section 6.3.3. Please note that Table 6-2 presents the mean ranking, in which 1 is high and 10 is low.
Table 6-3 | Individual rankings of end-user preference criteria by community-members during focus group sessions.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>END-USER PREFERENCE CRITERIA</th>
<th>FGD #5</th>
<th>FGD #6</th>
<th>FGD #7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R5-1</td>
<td>R5-2</td>
<td>R5-3</td>
</tr>
<tr>
<td>1</td>
<td>Costs (1a and 1b)</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Health impact</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Ease of use/difficulty</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Time and effort required</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Production rate</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Appearance of product water</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Taste, odour, and palpability</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Aspirational appeal</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Durability</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Fit in the home environment</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 6-3 cont’d

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>CRITERIA</th>
<th>FGD #8</th>
<th>FGD #9</th>
<th>MEAN RANKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Costs (1a and 1b)</td>
<td>2</td>
<td>10</td>
<td>5.61</td>
</tr>
<tr>
<td>2</td>
<td>Health impact</td>
<td>1</td>
<td>1</td>
<td>1.55</td>
</tr>
<tr>
<td>3</td>
<td>Ease of use/difficulty</td>
<td>6</td>
<td>8</td>
<td>7.13</td>
</tr>
<tr>
<td>4</td>
<td>Time and effort</td>
<td>8</td>
<td>7</td>
<td>6.48</td>
</tr>
<tr>
<td>5</td>
<td>Production rate</td>
<td>9</td>
<td>5</td>
<td>5.84</td>
</tr>
<tr>
<td>6</td>
<td>Appearance of product</td>
<td>4</td>
<td>2</td>
<td>3.16</td>
</tr>
<tr>
<td>7</td>
<td>Taste, odour, and</td>
<td>7</td>
<td>4</td>
<td>4.35</td>
</tr>
<tr>
<td>8</td>
<td>Aspirational appeal</td>
<td>3</td>
<td>6</td>
<td>6.68</td>
</tr>
<tr>
<td>9</td>
<td>Durability</td>
<td>5</td>
<td>3</td>
<td>5.39</td>
</tr>
<tr>
<td>10</td>
<td>Fit in the home environment</td>
<td>10</td>
<td>9</td>
<td>7.61</td>
</tr>
</tbody>
</table>
**Technical criteria**

For the technical criteria, a weighting activity was undertaken with the nine subject matter ‘experts’ (Tech-x) in a focus group setting (Table 3-6). These experts were my staff from the larger project as well as engineering faculty members at IIT-M. A summary weighting (Table 6-4) was generated by taking the mean of the nine unique results (Table 6-5).

<table>
<thead>
<tr>
<th>Rank position</th>
<th>Criteria</th>
<th>Mean weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical effectiveness (turbidity and microbiological)</td>
<td>21.78</td>
</tr>
<tr>
<td>2</td>
<td>Reliability</td>
<td>17.39</td>
</tr>
<tr>
<td>3</td>
<td>Absence of environmental impacts and hazards</td>
<td>14.94</td>
</tr>
<tr>
<td>4</td>
<td>Availability</td>
<td>13.00</td>
</tr>
<tr>
<td>5</td>
<td>Absence of hazards to users</td>
<td>12.94</td>
</tr>
<tr>
<td>6</td>
<td>Robustness</td>
<td>11.11</td>
</tr>
<tr>
<td>7</td>
<td>Risk of recontamination</td>
<td>8.83</td>
</tr>
</tbody>
</table>

The summary weightings in Table 6-4 were used in the MWA to generate the general recommendation (Scenario A). Please note that Table 6-4 does not feature a mean ranking, but rather a mean weighting. This is the inverse of ranking, such that the greater the weighting, the more important it is.\(^{245}\)

\(^{245}\) There were 100 points for respondents to distribute on the basis of how important each criterion was in their perspective.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>TECHNICAL CRITERIA</th>
<th>Tech-1</th>
<th>Tech-2</th>
<th>Tech-3</th>
<th>Tech-4</th>
<th>Tech-5</th>
<th>Tech-6</th>
<th>Tech-7</th>
<th>Tech-8</th>
<th>Tech-9</th>
<th>MEAN WTG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical effectiveness</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>18</td>
<td>25</td>
<td>21.78</td>
</tr>
<tr>
<td>2</td>
<td>Reliability</td>
<td>15</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>27</td>
<td>10</td>
<td>20</td>
<td>13.00</td>
</tr>
<tr>
<td>3</td>
<td>Absence of environmental impacts</td>
<td>20</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>25</td>
<td>22</td>
<td>19.5</td>
<td>15</td>
<td>17.39</td>
</tr>
<tr>
<td>4</td>
<td>Availability</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>18.5</td>
<td>12.5</td>
<td>11.11</td>
</tr>
<tr>
<td>5</td>
<td>Absence of hazards to users</td>
<td>12.5</td>
<td>20</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>18</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>14.94</td>
</tr>
<tr>
<td>6</td>
<td>Robustness</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>16</td>
<td>7.5</td>
<td>8.83</td>
</tr>
<tr>
<td>7</td>
<td>Risk of recontamination</td>
<td>12.5</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>9</td>
<td>10</td>
<td>15</td>
<td></td>
<td>12.94</td>
</tr>
</tbody>
</table>
Assessment of criteria relating to socio-cultural and local appropriateness

This criteria suite was not ranked but assessed as merit/demerit factors. Values for these have already been developed in section 6.2 (specifically, in sections 6.2.20, 6.2.21, 6.2.22, and 6.2.23).

Now that the two informational components have been developed, we proceed on to integrating them into the matrix-weighting array in order to generate outcome spaces.

6.3.2 General recommendation (Scenario A)

This section reports the overall general recommendation on appropriate water treatment technologies for application at Mylai Balaji Nagar (Scenario A). The matrix-weighting array of the selection tool was built into Microsoft Excel 2003 as a spreadsheet (Appendix T). The variable input component identities for the multi-factor analysis for Scenario A are given in Table 6-6.

<table>
<thead>
<tr>
<th>No.</th>
<th>INPUT COMPONENT</th>
<th>IDENTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Appropriate technology criteria weight: end-user preference criteria</td>
<td>Summary ranking from community-members (Table 6-2)</td>
</tr>
<tr>
<td>1b</td>
<td>Appropriate technology criteria weight: technical criteria</td>
<td>Summary ranking from subject matter experts (Table 6-4)</td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
<td>Assume as 1 following discussion in section 3.4.4.1</td>
</tr>
<tr>
<td>4a</td>
<td>Merit/demerit factors: socio-cultural and local appropriateness criteria</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>4b</td>
<td>Merit/demerit factors: special considerations from technology feasibility flowchart</td>
<td>From application of flowchart (section 6.1), following from Table 3-10</td>
</tr>
</tbody>
</table>

The MWA output for Scenario A is included in the appendices (Appendix U). The outcome space for Scenario A, presenting the final alternative scores, is given in Figure 6-4.
General recommendations on appropriate safe water technologies for Mylai Balaji Nagar can be drawn from Figure 6-4. The TATA *Swach* filter demonstrated the greatest performance under Scenario A, with a final score of 10.21. If the single ‘best’ alternative was sought for implementation across Mylai Balaji Nagar, the TATA *Swach* filter would be that alternative. It led by a large margin over the rest of the alternatives, the performances of which were more evenly distributed. The next ranking alternative was alum coagulation + chlorination (7.77), indicating that this alternative may have unrealized potential for application at Mylai Balaji Nagar given its presently low level of existing use in the community (Figure 4-24). Only slightly behind alum coagulation + chlorination was boiling (7.60), corroborating its status as the ‘status quo’ treatment method in the community and its potential for further promotion (Figure 4-24). Further behind, though not by a large margin, was the AWSP filter + chlorination (7.14), followed at some distance by cloth filtration + SODIS (6.28) and finally by moringa coagulation + SODIS (5.74), indicating the relatively limited suitability of these alternatives.

Of course, the utility of making a general recommendation is limited in that it collapses a great deal of diversity by virtue of using summary inputs for end-user preference and technical criteria...
rankings/weightings. Assessing the stability of the outcome space under different input conditions can improve our confidence in the decision model and the recommendations generated. This possibility is explored in the next section.

### 6.3.3 Sensitivity analyses (Scenarios B, C, D, E, and F)

**Scenario B: Customized responses**

As was discussed in the Chapter 2, Lantagne et al. (2009) and Murphy (2010) caution against the “silver bullet” approach of trying to find the single “best” safe water technology—something that is as true at the community level as it is at the global level. Even at the community level, there is a diversity of circumstances amongst the multiplicity of households in the community. Some of this diversity was captured in the thirty-one unique rankings of the end-user preference criteria that each respondent made (Table 6-3). With these unique rankings, it was possible to generate customized recommendations for every respondent. This constituted Scenario B.

The input component identities for Scenario B are given in Table 6-7. The input component that is the subject of the sensitivity analysis here is given in bold type.

<table>
<thead>
<tr>
<th>No.</th>
<th>INPUT COMPONENT</th>
<th>IDENTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Appropriate technology criteria weight: end-user preference criteria</td>
<td>Individual ranking from each respondent (Table 6-3)</td>
</tr>
<tr>
<td>1b</td>
<td>Appropriate technology criteria weight: technical criteria</td>
<td>Summary ranking from subject matter experts (Table 6-4)</td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
<td>Assume as 1 following discussion in section 3.4.4.1</td>
</tr>
<tr>
<td>4a</td>
<td>Merit/demerit factors: socio-cultural and local appropriateness criteria</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>4b</td>
<td>Merit/demerit factors: special considerations from technology feasibility flowchart</td>
<td>From application of flowchart (section 6.1), following from Table 3-10</td>
</tr>
</tbody>
</table>

The outcome space of the MWA, representing customized recommendations for each respondent, are given in Table 6-8.
Table 6-8 | Unique outcome spaces for each respondent ranking of end-user preference criteria (Scenario B).

<table>
<thead>
<tr>
<th>No.</th>
<th>FGD ID</th>
<th>RESPONDENT ID</th>
<th>ALTERNATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>AC+C</td>
</tr>
<tr>
<td>1</td>
<td>R5-1</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>2</td>
<td>R5-2</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>3</td>
<td>R5-3</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>4</td>
<td>R5-4</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>5</td>
<td>R5-5</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>6</td>
<td>R6-1</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>7</td>
<td>R6-2</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>8</td>
<td>R6-3</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>9</td>
<td>R6-4</td>
<td>3 6 5 4 2 1</td>
<td>3 6 5 4 2 1</td>
</tr>
<tr>
<td>10</td>
<td>R7-1</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>11</td>
<td>R7-2</td>
<td>3 6 5 4 2 1</td>
<td>3 6 5 4 2 1</td>
</tr>
<tr>
<td>12</td>
<td>R7-3</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>13</td>
<td>R7-4</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>14</td>
<td>R7-5</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>15</td>
<td>R7-6</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>16</td>
<td>R8-1</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>17</td>
<td>R8-2</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>18</td>
<td>R8-3</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>19</td>
<td>R8-4</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>20</td>
<td>R8-5</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>21</td>
<td>R9-1</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>22</td>
<td>R9-2</td>
<td>3 6 5 2 4 1</td>
<td>3 6 5 2 4 1</td>
</tr>
<tr>
<td>23</td>
<td>R9-3</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>24</td>
<td>R9-4</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>25</td>
<td>R9-5</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>26</td>
<td>R9-6</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>27</td>
<td>R9-7</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>28</td>
<td>R9-8</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>29</td>
<td>R9-9</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>30</td>
<td>R9-10</td>
<td>2 6 5 3 4 1</td>
<td>2 6 5 3 4 1</td>
</tr>
<tr>
<td>31</td>
<td>R9-11</td>
<td>3 6 5 2 4 1</td>
<td>3 6 5 2 4 1</td>
</tr>
</tbody>
</table>

Average of rankings: 2.1 6.0 5.0 2.87 4.0 1.0

As seen in Table 6-8, the TATA Swach filter consistently out-performed the other alternatives, with unanimous first-place ranking for all unique respondents. Likewise, moringa coagulation + SODIS consistently ranked as the least suitable alternative (sixth place) across all respondent rankings, while cloth filtration + SODIS consistently ranked as fifth and the AWSP filter + chlorination held the fourth. Variability across respondent rankings was only observed with respect to the second and third positions. Generally, alum coagulation + chlorination held the second position, but periodically it traded places with boiling, which typically held the third position. Hence, varying end-user preference criteria rankings registered an impact on the second
and third positions, but generally the rank ordering was relatively stable across all respondent rankings.

In Scenario B, the TATA Swach filter consistently emerged as the highest scoring alternative. This is a testament to how well it performed with respect to the appropriate technology criteria, as assessed in section 6.2, and therefore, its potential suitability to the specific context of Mylai Balaji Nagar. However, let us consider for a moment a situation in which there was no single leading option, for instance, if the TATA Swach filter was unavailable at Mylai Balaji Nagar. Under Scenario B, though alum coagulation + chlorination, boiling, and the AWSP filter + chlorination typically held the second, third, and fourth positions respectively, their scores were relatively close to one another (c.f. Sheet ‘B Summary’ in Appendix T). For some respondents, the order changed, but more often, they came very close to one another without changing positions. These three alternatives had more evenly distributed scores between them, while the TATA Swach filter had a runaway lead, and cloth filtration + SODIS and moringa coagulation + SODIS trailed far behind. Harris (2005), in his study of the challenges facing the commercial viability of PoU water treatment systems in low-income settings, identifies offering a ‘smorgasbord’ of PoU options to potential end-users as a key strategy to improve uptake and sustained usage in low-income communities. He recommends “offer[ing] the two or three best products to consumers rather than a more expanded selection” so that individuals can “choose between the various interventions according to their needs”. This decision-making support tool can perform such a role in generating a preliminary assessment of which alternatives amongst the multiplicity available may be best suited to the specific community. Once the analysis has been carried out and a ranked list of potential appropriate technologies generated, a ‘smorgasbord’ of the two or three highest scoring technologies can then be presented to community-members. Community-members can try the options out and then, on the basis of this experience, decide for themselves which they most prefer to use. In the present case, if the TATA Swach filter was not available at Mylai Balaji Nagar, alum coagulation + chlorination, boiling, and the AWSP filter +

\[246\] This can be done in an individualized manner wherein each respondent gets her or his own specific ranked recommendations list, or in a summarized manner wherein a general ranked recommendation list is developed for the whole community. It is not so important which route is taken as ultimately the highest-scoring technologies can all be placed before respondents so that they can make their own decision as to which is best for them with some further guidance and product trials.
chlorination, as the three next highest scoring alternatives, could be presented to the community as part of a water treatment ‘smorgasbord’. Households could then be supported in making an informed decision about which alternative is best for them. This approach returns decision-making control to individual households and positions external actors as facilitators, bearing out the precepts of a participatory approach in a post-normal scientific context (section 2.3).

 Scenario C: Cost and convenience as controlling factors
The summary ranking of the end-user preference criteria (Table 6-2) has cost and time and effort required figuring as relatively unimportant. The ranking game conducted with community-members during the focus groups was an abstract-reasoning activity—respondents were asked to suggest what they thought was most important to them. What may actually be the most important in practice may well be different from what is assumed in abstract. This is something that is of specific importance to the two criteria identified above. Follow-up on field implementations of household safe water systems have demonstrated that excessive cost and inconvenience are the leading reasons why households discontinue use (Luby et al. 2008). For this reason, it is important to assess what the outcome space may be under conditions where cost and convenience are controlling factors. This is Scenario C and it is detailed in Table 6-9 and Table 6-10.

<table>
<thead>
<tr>
<th>No.</th>
<th>INPUT COMPONENT</th>
<th>IDENTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Appropriate technology criteria weight: end-user preference criteria</td>
<td>Constructed ranking wherein criteria relating to cost and convenience rank high (Table 6-10)</td>
</tr>
<tr>
<td></td>
<td>Appropriate technology criteria weight: technical criteria</td>
<td>Summary ranking from subject matter experts (Table 6-4)</td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
<td>Assume as 1 following discussion in section 3.4.4.1</td>
</tr>
</tbody>
</table>

247 This process can be facilitated via community forums and using tools such as product trials or informed choice catalogues (for instance, c.f. BORDA Indonesia (2006) for a good example of the use of an informed choice catalogue in an urban services project).

248 There may have also been an element of research participants ‘gaming’ the process. Seeing us as outside agents who have come to deliver some type of development good, the respondents may have ranked cost as less important than it truly is because they may have assumed that we or some other external agency would be bearing the costs of any development intervention, hence, they need not account for it.
4 a Merit/demerk factors:
socio-cultural and local
appropriateness criteria

General assessment (section 6.2)

b Merit/demerk factors:
special considerations from
technology feasibility flowchart

From application of flowchart (section 6.1), following
from Table 3-10

Table 6-10 | Constructed ranking of end-user preference criteria for Scenario C.

<table>
<thead>
<tr>
<th>Rank position</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cost</td>
</tr>
<tr>
<td>2</td>
<td>Time and effort required (convenience)</td>
</tr>
<tr>
<td>3</td>
<td>Ease of use/difficulty</td>
</tr>
<tr>
<td>4</td>
<td>Health impact</td>
</tr>
<tr>
<td>5</td>
<td>Durability</td>
</tr>
<tr>
<td>6</td>
<td>Appearance of product water</td>
</tr>
<tr>
<td>7</td>
<td>Taste, odour, and palpability of product water</td>
</tr>
<tr>
<td>8</td>
<td>Production rate</td>
</tr>
<tr>
<td>9</td>
<td>Fit in the home environment</td>
</tr>
<tr>
<td>10</td>
<td>Aspirational appeal</td>
</tr>
</tbody>
</table>

The outcome space of Scenario C, along with the general solution of Scenario A for comparison, is presented in Table 6-11.

Table 6-11 | Comparative assessment of alternative scores under input scenarios A and C.

<table>
<thead>
<tr>
<th></th>
<th>AC+C</th>
<th>MC+S</th>
<th>CF+S</th>
<th>BOIL</th>
<th>AWSP</th>
<th>TATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario A</td>
<td>7.77</td>
<td>5.74</td>
<td>6.28</td>
<td>7.60</td>
<td>7.14</td>
<td>10.21</td>
</tr>
<tr>
<td>Scenario C</td>
<td>7.64</td>
<td>5.68</td>
<td>6.61</td>
<td>7.77</td>
<td>7.11</td>
<td>9.91</td>
</tr>
</tbody>
</table>

Increasing the importance of cost and convenience engenders a shift in the scores of alternatives reflecting their relative performance with respect to these criteria. Boiling and cloth filtration + SODIS increase their scores, reflecting the cost and convenience strengths these alternatives offer, whereas the others decrease to varying degrees. The TATA Swach filter suffers a considerable loss in score, but still leads the others by a large margin. A shift in rank order does occur with respect to the second and third positions, with boiling taking second while alum coagulation + chlorination falls to the third position under Scenario C. The other rank positions remain the same.
Scenario D: Cost as a separate suite

Given the importance of cost, it is interesting to consider increasing the sensitivity of the decision model to this criteria even further. This can be achieved by removing the cost criterion from the suite of end-user preference criteria and treating it as its own suite (which can then also be modified by a suite weight). The input identities for this scenario, Scenario D, are given in Table 6-12.

<table>
<thead>
<tr>
<th>No.</th>
<th>INPUT COMPONENT</th>
<th>IDENTIFY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 a</td>
<td>Appropriate technology criteria weight: end-user preference criteria</td>
<td>Summary ranking order (Table 6-2) with cost extracted and treated as its own suite of equal weight (1.00)</td>
</tr>
<tr>
<td>1 b</td>
<td>Appropriate technology criteria weight: technical criteria</td>
<td>Summary ranking from subject matter experts (Table 6-4)</td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
<td>Assume as 1 following discussion in section 3.4.4.1</td>
</tr>
<tr>
<td>4 a</td>
<td>Merit/demerit factors: socio-cultural and local appropriateness criteria</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>4 b</td>
<td>Merit/demerit factors: special considerations from technology feasibility flowchart</td>
<td>From application of flowchart (section 6.1), following from Table 3-10</td>
</tr>
</tbody>
</table>

The MWA output for Scenario D is included in the appendices (Appendix V). The output table is presented below (Figure 6-5).
In Figure 6-5, as the cost criterion was treated as an independent suite, the total points available was greater here than with previous scenarios. Even in this case, the TATA Swach filter outperformed the rest of the alternatives (12.35), although now the gap has considerably narrowed. Alum coagulation + chlorination trailed closely behind in second with 12.11 points. A change did occur in this scenario for cloth filtration + SODIS (which was in the fifth position for all of the previous scenarios) now rising to third (11.35), owing to its considerable cost advantage (i.e. it has no costs!). Likewise moringa coagulation + SODIS also rose from the sixth position to the fourth because of its relatively low cost, just edging out boiling. The big losers in this scenario were boiling (10.52) and the AWSP filter + chlorination (10.23) which fell to the fifth and sixth positions respectively owing to their relatively high cost and lack of performance in other dimensions. Thus, this analysis confirms that the TATA Swach filter, despite its relatively high capital and on-going costs, offers significant advantages in other respects that more than compensate for its relative expense.
Scenario E: Outlier technical criteria rankings

A summary ranking was developed for the technical criteria (Table 6-4) and utilized for generating the outcome spaces for the previous scenarios. Scenario E looked at the impact of outlier rankings of the technical criteria on the outcome space. Outlier rankings of the technical criteria were identified by assessing divergence from the mean beyond a single standard deviation (c.f. Technical criteria rankings summary in Appendix W). A single one of the nine expert rankings of the technical criteria was identified as an outlier: Tech-8. The input identity for Scenario E is given in Table 6-13.

Table 6-13 | Variable input component identities for Scenario E.

<table>
<thead>
<tr>
<th>No.</th>
<th>INPUT COMPONENT</th>
<th>IDENTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a Appropriate technology criteria weight: end-user preference criteria</td>
<td>Summary ranking from community-members (Table 6-2)</td>
</tr>
<tr>
<td></td>
<td>b Appropriate technology criteria weight: technical criteria</td>
<td>Using outlier ranking of Tech-8 (Table 6-5)</td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
<td>Assume as 1 following discussion in section 3.4.4.1</td>
</tr>
<tr>
<td>4</td>
<td>a Merit/demerit factors: socio-cultural and local appropriateness criteria</td>
<td>General assessment (section 6.2)</td>
</tr>
<tr>
<td></td>
<td>b Merit/demerit factors: special considerations from technology feasibility flowchart</td>
<td>From application of flowchart (section 6.2), following from Table 3-10</td>
</tr>
</tbody>
</table>

The MWA output for scenario E is included in the appendices (Appendix X). The outcome space of Scenario E, along with the general solution of Scenario A, is presented in Table 6-14.

Table 6-14 | Comparative assessment of alternative scores under input scenarios A and C.

<table>
<thead>
<tr>
<th>FINAL ALTERNATIVE SCORES</th>
<th>Scenario A</th>
<th>Scenario E</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC+C</td>
<td>7.77</td>
<td>7.73</td>
</tr>
<tr>
<td>MC+S</td>
<td>5.74</td>
<td>5.74</td>
</tr>
<tr>
<td>CF+S</td>
<td>6.28</td>
<td>6.48</td>
</tr>
<tr>
<td>BOIL</td>
<td>7.60</td>
<td>7.53</td>
</tr>
<tr>
<td>AWSP</td>
<td>7.14</td>
<td>7.32</td>
</tr>
<tr>
<td>TATA</td>
<td>10.21</td>
<td>9.93</td>
</tr>
</tbody>
</table>

Modifying the technical criteria weightings to the outlier ranking of Tech-8 does modify the alternative scores, but not enough to change the rank ordering of the outcome space. The outcome space is stable even with the outlier ranking for the technical criteria.
**Scenario F: Increasing the impact of the special considerations**

The percentage merit/demerit factors for the special considerations from the technology feasibility flowchart were arbitrarily assigned as 10%. Scenario F sought to assess the affect on the outcome space if the percentage was increased (Table 6-15). This reflects a scenario in which the water quality special considerations from the technology feasibility flowchart are given greater prominence in the model (Section 3.4.2).

<table>
<thead>
<tr>
<th>Table 6-15</th>
<th>Variable input component identities for Scenario F.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario F: Modifying influence of the special considerations</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No.</strong></td>
<td><strong>INPUT COMPONENT</strong></td>
</tr>
<tr>
<td>1</td>
<td>a Appropriate technology criteria weight: <em>end-user preference criteria</em></td>
</tr>
<tr>
<td>1</td>
<td>b Appropriate technology criteria weight: <em>technical criteria</em></td>
</tr>
<tr>
<td>2</td>
<td>Alternative performance rankings</td>
</tr>
<tr>
<td>3</td>
<td>Appropriate technology criteria suite weights</td>
</tr>
<tr>
<td>4</td>
<td>a Merit/demerit factors: <em>socio-cultural and local appropriateness criteria</em></td>
</tr>
<tr>
<td>4</td>
<td>b Merit/demerit factors: <em>special considerations from technology feasibility flowchart</em></td>
</tr>
</tbody>
</table>

The MWA output for scenario F is included in the appendices (Appendix Y). The outcome space of Scenario F, along with the general solution of Scenario A, is presented in Table 6-16.

<table>
<thead>
<tr>
<th>Table 6-16</th>
<th>Comparative assessment of alternative scores under input scenarios A and F.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FINAL ALTERNATIVE SCORES</strong></td>
<td>AC+C</td>
</tr>
<tr>
<td>Scenario A</td>
<td>7.77</td>
</tr>
<tr>
<td>Scenario F</td>
<td>8.47</td>
</tr>
</tbody>
</table>

As predicted, increasing the influence of the special considerations increases the scoring for those alternatives that can handle organics (i.e. those that feature carbon filtration or alum coagulation). This modification may be used to better portray the need for organics control. In this case, the TATA Swach filter still outscores all of the other alternatives, this time by an even larger margin (10.91). Alum coagulation + chlorination also increases (8.47) and retains its second place. The third place position now goes to the AWSP filter (7.84) as it is capable of
handling organics, whereas boiling falls to fourth position (though it keeps the same score at 7.60) because it cannot improve organics. The last two, not affected by this shift, have the same scores and remain in the same position. In this case, the leading option remains the TATA Swach filter, however, alum coagulation + chlorination and the AWSP filter also rise in suitability.

The preceding sections have subjected the decision model to a number of tests to explore the sensitivity of the outcome space to variable input identities. From the preceding it can be seen that the decision model, though responsive to changing user input, generates a stable outcome space: throughout all of the preceding sensitivity analyses, the TATA Swach filter consistently emerged as the leading alternative. If a single household water treatment technology was sought for implementation at Mylai Balaji Nagar, the TATA Swach filter would be that alternative. However, a ‘smorgasbord’ approach, following Harris’ (2005) recommendation, may be taken in order to increase HWTS uptake, in which case the top two or three alternatives could be selected from the ranked outcome space of the decision model to present to individual households whom could then select the alternative that best suits them (either on the basis of their own criteria rankings or after product trials). This approach would be especially relevant if the TATA Swach filter was not available at the case study site, as the rest of alternatives demonstrated more variability in their rankings and may be differentially preferable to different households.

With this, the two key questions that the present decision-making support tool has been designed to handle have been addressed. Given the conditions observed during the course of this research, the decision-making support tool indicates that a household level approach to safe water would be more appropriate at Mylai Balaji Nagar (Chapter 5). This chapter has explored the most appropriate household level technologies for the case study community. It has identified the most appropriate safe water technologies for Mylai Balaji Nagar, in order of suitability, as the TATA Swach filter, then alum coagulation + chlorination, and finally, boiling. Now that the case study application of the decision-making support tool has been completed, the next chapter concludes this dissertation.
CHAPTER 7: CONCLUSION

This dissertation has designed and carried out a case study application of a participatory
decision-making support tool for appropriate safe water systems development in marginalized
low-income communities of the global South. This work was undertaken to meet the need for
complex decision-making support tools to assist project implementers as decentralized safe water
systems begin to be scaled up around the world (Lantagne et al. 2009; Murphy 2010;
Palaniappan, Lang, and Gleick 2008). The support tool centres local people in the development
process and brings together several theoretical and methodological threads including
humanitarian engineering, post-normal science, appropriate technology, participatory
development, engineering decision-making, and water treatment engineering. This final section
will briefly recap the structure of the tool itself; the ways in which it advances the state of the art
over previous support tools; and the case study application at Mylai Balaji Nagar. It will also
draw upon the case study application to identify refinements to the decision model for
7.1 Summary of dissertation

This section briefly summarizes the structure of the decision-making support tool developed in the present work, the ways in which it improves over previous decision-making support tools, and the main findings from the case study application at Mylai Balaji Nagar.

7.1.1 Overview of decision-making support tool

The decision-making support tool was designed to assist implementing organizations resolve two key design decisions in the development of decentralized safe water systems:

1. Selecting the appropriate level of application (i.e. household or community level); and
2. Selecting an appropriate water treatment technology (or technologies).

The task of safe water systems design is treated in four parts in this tool. First are the pre-implementation steps which aim to set the stage for the design and planning of an appropriate safe water system by developing a contextualized understanding of the community of implementation. Following these are the primary community-based field investigations into the two key design questions. Here, focus group discussions and key informant/informal interviews with local community-members, government officers, NGO workers, and other stakeholders are utilized to identify stakeholder preferences and community capacities and circumstances. In the third stage, information gathered from baseline, informal, and primary field research is analyzed to determine appropriate strategies for safe water systems development in the local community. This includes:

- An assessment of which level of application (household vs. community level) is most appropriate for a safe water system in the local community on basis of technical, economic, and social and political-institutional dimensions;
- A technology feasibility flowchart that identifies viable suites of technological alternatives at the household and/or community level on the basis of water quality data;
- An ‘expert’ assessment by the investigator on the performance of selected technological alternatives with respect to appropriate technology criteria including end-user preference, technical, and socio-cultural/local appropriateness criteria; and
· Integration of technological performance assessments and stakeholder preferences in a matrix-weighting array in order to identify appropriate water treatment technology option(s).

The fourth and final stage of the decision-making support tool are community PAR forums in which further action and research on safe water systems development and implementation, informed by the recommendations emerging from the previous steps, takes place. Through these steps, the decision-making support tool guides implementing organizations through the stages of safe water systems design and planning in a manner that centres local people in the process.

7.1.2 Added value of the present decision-making support tool

The previous work on decision-making support tools in the WASH literature was reviewed in order to inform the present development (section 2.2.6). The present decision-making support tool improves on previous tools and advances the state of the art in several ways:

· Instead of limiting the present development to a single tool type, a more articulated and comprehensive approach would be to integrate different tool types to meet the various goals subsumed in the larger task of appropriate safe water systems development. The present decision-making support tool deploys different tool types to accomplish the various tasks of safe water systems design.

· It considers both household and community level safe water systems, whereas previous tools focused almost exclusively on the former only.

· It features an explicit additive model in the form of a matrix-weighting array to make the integration of technology performance information and appropriate technology criteria preference information transparent. Bias can be observed and tested in the decision-model via sensitivity analyses.

· It centres local people in the development process, positioning them as the ultimate decision-making authority in community PAR forums. Various informational inputs are gathered from participatory research, creating opportunities for local stakeholders to guide and lead the process. It details specific methods by which to pursue participatory development and involve local peoples in investigatory and decision-making processes. It is designed to not be a ‘black box’ by focusing on engagement with local community-
members on desired outcomes, necessary tradeoffs, and preferred solutions—critical matters that are better handled through open discussion.

- It has a clear and comprehensive ranking system for technological performance assessments.
- It draws on previous experiences documented in the literature with household and community level systems utilizing various safe water technologies to drive appropriate technology selection.
- It centres consumer preferences in the process, as well as gives consideration to social implications of technology and equity factors.
- Local water quality is an important controlling input. It considers water quality issues that are prominent with surface water sources in the developing world including excessive turbidity, organics, and microbiological contamination, but also includes consideration of important chemical water quality parameters including iron, manganese, pH, fluoride, nitrate, and others that are relevant for both surface and ground water sources.
- It can be scaled up as an accessible online platform with a user-friendly interface to encourage usage. This online platform can also tie into and build up databases that will make future applications all the more informed by experience.
- The tool has been designed to be as open-ended as possible so as to facilitate adaptation to unique local circumstances.
- The tool is designed to generate a ranked list of recommendations that can then feed into subsequent participatory processes instead of generating a deterministic outcome.
- The tool is built around two sets of dimensions/criteria on a) the factors affecting the relative contextual appropriateness of household and community level systems; and b) factors relating to appropriate safe water technology. Both of these have been drawn from an exhaustive review of monitoring and evaluation studies of previous safe water interventions, studies of consumer preferences, and previous decision-making tools. These two sets of criteria develop a comprehensive taxonomy of appropriate safe water systems and technologies.

In all of the ways identified above, the present work advances the state of the art and improves on what has thus far been available to guide decision-making on safe water systems development.
7.1.3 Summary of the case study application at Mylai Balaji Nagar

The present work also included a case study application of the decision-making support tool. A full-scale implementation of the tool was not possible due to the constraints imposed by the larger project in which the present work was embedded. As such, the present case study application was restricted to the second (community-based field research) and the third (analyses) stages discussed in section 7.1.1. The first stage—the pre-implementation steps—were completed as part of the larger project prior to the initiation of the primary research for this dissertation and served as background for the present work. The fourth stage—the post-implementation steps of community PAR forums—could not be implemented due to an on-going field study of another safe water technology at the case study site.249

The case study application of the decision-making support tool at Mylai Balaji Nagar indicated that a household level system would be more appropriate there, although there was limited support for a community level system as well, raising the possibility of a dual level approach. The application of the technology feasibility flowchart generated a wide range of potential water treatment technologies, from which a subset of six systems (i.e. unique combinations of clarification and disinfection stages) was selected for further analysis. These six alternatives were:

1. Alum coagulation + chlorination;
2. Moringa coagulation + SODIS;
3. Cloth filtration + SODIS;
4. Boiling;
5. AWSP dual media bucket filter + chlorination; and
6. TATA Swach filter.

A general outcome space utilizing summary inputs of stakeholder preferences identified the TATA Swach filter as the leading alternative.

Sensitivity analyses utilizing various input identities were also conducted in order to assess the stability of the outcome space. Through all of the sensitivity scenarios, the first position of the

249 In place of this, and to fulfill the ethical requirements for the research, a community research-sharing forum was carried out (FRM1). For more details, please refer to Appendix S.
outcome space remained stable. Even for the scenario in which cost was extra-influential (Scenario D), the TATA Swach filter remained the leading option. There was greater variability in the second and third positions through the sensitivity analyses; however, the ranked order was generally stable as the TATA Swach filter > alum coagulation + chlorination > boiling. It is for these reasons that the household level safe water system of the TATA Swach filter is recommended as the most appropriate alternative for Mylai Balaji Nagar (if a single option was sought). The AWSP filter + chlorination generally remained in the fourth position across all sensitivity analyses, with the exception of the scenario wherein water quality special considerations were emphasized (Scenario F), in which it rose to third. Cloth filtration + SODIS and moringa coagulation + SODIS typically remained in fifth and sixth positions respectively.

If the TATA Swach filter were not available, or in other situations where there is not a clearly preferable alternative, it may be advisable to utilize, as Harris (2005) suggests, a ‘smorgasbord’ approach in which end-users select from amongst the top two or three alternatives the one that best suits their needs, in order to improve uptake and sustained usage. In generating a ranked list with discrete performance scores, the present decision-making support tool enables implementers to compare the relative performance of alternatives and identify several leading options around which to build a ‘smorgasbord’ approach. These are aspects that could be discussed in community PAR forums (i.e. the post-implementation step of the decision-making support tool). Though it was not possible to implement the community PAR forums in the present case study application due to constraints from the larger project, a smaller research sharing forum (FRM1) was conducted with research participants to share the results on the appropriate level of application. The transcript from this session is available in the appendices (Appendix S).

7.2 Refining the decision-making support tool

From the case study implementation of the decision-making support tool at Mylai Balaji Nagar, some ways in which to improve the support tool emerged. Future applications of the decision-making support tool may seek to incorporate these refinements.
7.2.1 Enhancing the participatory nature of the support tool

The present work was limited in the degree to which a fully participatory effort could be implemented due to constraints posed by the larger project in which it was embedded. However, the case study implementation did indicate potential places for improvement in the decision-making support tool that may serve to make it more participatory for future applications. These are some of the ways in which I would, in retrospect, revise my approach were I to do this research again (or more importantly, how I would do similar work in the future).

Central to affecting a more fully-fledged participatory approach would have been to form, earlier on, a core group of community members and informal leaders (including elders) to guide the investigations and decisions-making processes of the support tool. Such a group would form what Kelly and Farahbakhsh (2008) refer to as a core learning alliance group. For this group I would seek out those people who were the key informants in my research because of their knowledge and experience, credibility with the community, and desire to improve its situation. The group would include representatives from each sector/neighbourhood, such that by just one or two degrees of separation everyone in the community would be connected to the core group. The learning alliance group could also be sub-divided on the basis of gender to reduce male domination of the platform, and also to better identify and target specific gendered priorities and perceptions on safe water supply. The two sub-groups could come together when necessary for shared tasks. The core learning alliance would have several important roles:

- Encouraging community dialogue in order to affect sustainable behavioural change in the community by changing attitudes, perceptions of risk, and social norms (Figueroa and Kincaid 2010).
- I would go back to this group more regularly with the intermediate outcomes of the research in order to guide subsequent steps.
- Developing the necessary inter-language, as Kelly and Farahbakhsh (2008) put it, to effectively communicate between the different stakeholders on the project (including the researchers).

250 Understanding how men perceive and relate their priorities to water and sanitation is a significant gap in the research (Figueroa 2012; PATH 2012). The approach detailed here would help to cast light on this question as well.
• Direct involvement in the assessment of dimensions relating to the first key design question on the appropriate level of application (household vs. community). This is an aspect of the support tool that is presently very much expert-driven, and could stand to be improved upon.

• Another important place for deepening community participation in the support tool would be to have the core learning alliance group lead the task of technology assessment/ranking with respect to the appropriate technology criteria. This could be done by having the suite of possible technologies available for the core learning alliance to try out and familiarize themselves with at home over the course of several weeks. I would then help to facilitate the core learning alliance group in assessing and ranking the technologies with respect to the appropriate technology criteria. This would dramatically improve the quality of technology assessments, and subsequently, the recommendations—moving it away from its presently very much expert-driven approach. This would capture locally relevant perceptions of the technologies and greatly improve the quality of the recommendations.

All of these aspects would help to better lay the groundwork for safe water systems implementation in a given community. The learning alliance group could help to refine the recommendations of the support tool, communicate them to the community at large, and then initiate community PAR forums to discuss how to go about implementing safe water solutions in the community. The ranked list of technologies from the support tool could feed into product demonstrations at the neighbourhood level led by learning alliance group members from which individual households could choose the technology that best suits their preferences and circumstances, following the ‘smorgasbord’ approach (Harris 2005). Deepening the participatory

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251 This would help to draw locally important perceptions of the technologies into the decision-making process. Presently, the expert-driven assessment of technologies with respect to appropriate technology criteria partially treat this, for instance, in the appropriate technology criterion of traditional knowledge, practices, and perceptions (section 6.2.20). But this is something that would be better handled altogether if local people were doing the ranking themselves. An important gap that was identified in the present expert-driven assessment highlights this. With respect to the appropriate technology criterion of production rate (section 6.2.6), I had assessed boiling to have the fastest production rate. However, I did not take into account the time it takes to let the boiled water cool! This is something that I missed that may not have been missed if the ranking was done by local people after having had some experience with the alternatives in their homes. Though such oversights could be captured and corrected on a one-by-one basis, an altogether more robust approach is to have local people lead the assigning of ranks themselves, thereby capturing more rich and locally relevant information. Assessment of end-user preferences criteria regarding cost, ease of use, time and effort required, appearance of water, taste, smell and others may be most valuable when they come from actual or potential users (Figueroa 2012).
aspect of the research following these strategies would improve uptake and sustained usage of a safe water system in a given community.

This matter brings up an important disclaimer for future applications. As with any model, the participatory decision-making model here is only as good as the information that feeds into it. What this means for future applications is that implementers must be committed to deep, intensive, and long-term engagement on the participatory development of a safe water system in a given locale. Rushing the process to quickly carry out research before relationships with local stakeholders are sufficiently mature carries with it the risk of generating superficial and/or inaccurate data, which in turn would generate inappropriate recommendations. Commitment to the participatory process and to the specific place is necessary in order to obtain a contextualized understanding of the community, as well as to have the benefit of multiple research relationships by which to triangulate the information received. An example from the present case study illustrates this. Referring to the discussion in section 5.9 on the propensity to collective action in the case study community, what I found during my investigations was that earlier on in the research process, before I had developed strong relationships with local research participants, participants would uniformly tell me that a community level system was what they preferred and what would be the best strategy for safe water systems development in the community. By better understanding the community’s history and context, I was able to probe more deeply into this matter; there were many layers behind it. Bolstered too by a growing trust with research participants, subsequent investigations exposed significant contradictions between the stated preferences of community-members and their own assessments of what was actually possible in the community, as was detailed in section 5.9. What this example illustrates is that one must “go deep” and be committed to the principles and precepts of the participatory approach (section 2.3.4) in order to get through all the intervening layers to accurate and meaningful information. This is a pre-requisite for the use of the present decision-making support tool.

### 7.2.2 Improving the treatment of the cost appropriate technology criterion

An interesting feature was observed in the ranking of the end-user preference suite of the appropriate technology criteria by local community-members (section 6.3.1). In Table 6-3, it was noted that respondents living in sector 4, whom were poorer and were more often TWUs, tended
to rank the cost of a safe water system as being relatively unimportant, when compared to respondents from the other wealthier sectors. This finding is somewhat counter-intuitive as one would assume that those who have less income would be more concerned about the cost of a safe water system. Cost was more often ranked as being of greater importance during FGDs taking place in sectors 1, 2, or 3, which are relatively wealthy compared to sector 4. This may have been because of residents perceived us, the researchers, as external actors who may be bringing development goods to the community in the near future. This may have led respondents to “game the system”, so to speak, by prioritizing other appropriate technology criteria over cost, in the belief that we, the external actors, would be bearing the costs of a future safe water intervention. In sector 4, there has been greater NGO involvement given the larger proportion of impoverished households in that sector; this may have contributed to NGO dependency and/or a tradition of free goods in sector 4 vis-à-vis the other sectors which have had less NGO involvement because they are wealthier and more self-sufficient. This may have led to possible “gaming” of the development process in sector 4.

What this means then is that perhaps ranking cost amongst the other end-user preference criteria may be subject to misreporting or bias. In response to this possibility, it may be preferable to remove the cost criterion from the suite of end-user preference criteria. Instead, it may be included in the technical criteria which are weighed by subject matter ‘experts’ in the present model (i.e. my staff from the larger project and engineering faculty at IIT-M). Alternatively, economic research tools such as willingness-to-pay or auction studies may be useful for determining the relative cost-benefit tradeoffs of various safe water technologies from the perspective of different groups (i.e. socio-economic) of potential end-users. Moreover, such an approach could develop cut-off prices which appropriate safe water systems would have to beat in order to be viable for certain socio-economic groups. These are some possibilities by which the influence of cost on appropriate safe water technology may be more thoroughly investigated.

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252 Though we made clear in the preamble to all of our research activities, that no such intervention would be proceeding from the investigations.
7.2.3 Handling variable quality of input data on technical effectiveness

What was seen in the present case study implementation was that the TATA Swach filter benefitted from its high performance with respect to the two appropriate technology criteria relating to technical effectiveness (i.e. turbidity control and microbiological control in sections 6.2.12 and 6.2.13 respectively). This is in contrast to the AWSP filter which had limited data available for it as well; the little data available however did not indicate a strong performance with respect to these two criteria. The data used to represent the performance of the TATA filter came from manufacturer literature and not from independent testing. Moreover, most of the studies of the other technologies used simulated water samples generated in the lab for their assessments, where as the data for the AWSP filter came from research of the larger project that was conducted using real-world water samples (i.e. from Narayanpuram Lake). This may have influenced the performance of the AWSP filter in the lab compared to those other studies using simulated waters. While performance data coming from laboratory and field studies have already been differentiated in the decision model, it may be desirable to further qualify the input data on the basis of its quality—along axes such as the use of real-world or simulated water, or between self-reported or independent testing. Efforts should also be made to ensure that technical effectiveness data from the literature come from studies which replicate conditions as closely as possible in order to strengthen the legitimacy of cross-comparison. These may be important refinements for the decision model in subsequent applications.

7.3 Future work

The decision-making support tool developed here focused on the hardware side of safe water systems design and planning. Though it does partially look at appropriate O&M approaches in which to deploy a safe water system, and begins to build up appropriate technology transfer mechanisms, developing these two software aspects is the next step in safe water systems development. Further work on the design, implementation, and evaluation of O&M and implementation frameworks, as well as mechanisms for appropriate technology transfer are required in the future. Interesting possibilities for these have been discussed by, just to name a few, Kelly and Farahbakhsh (2008), Brikké and Bredero (2003), Harris (2005), Ahmed and Ali (2006), and Prabaharyaka and Pooroe (2010). In fact, what is required is another decision-making support tool that can consolidate these experiences and do for software what this tool did
for hardware. Moreover, the present work did not constitute a calibration or validation of the present decision-making support tool. This is also an important stream for future work.

7.4 Scaling up

A demand for decision-making support tools has arisen alongside efforts to scale up decentralized safe water systems across the global South. As such, there is considerable potential to scale up this tool in order to better support the research community and NGOs working on the global safe water challenge. Palaniappan, Lang, and Gleick (2008) identify a number of needs which the present decision-making support tool could be scaled up to meet.

The decision-making support tool developed in this thesis could potentially be built into an accessible online platform. Such an online platform would be positioned to support decentralized safe water system implementations around the world. This thesis has developed the “back of the shop” of the tool, and an online platform featuring a user-friendly graphical interface could function as the front-end to guide project implementers though the stages of safe water systems development.

Making the tool universally available, easy to use, and intuitive would encourage its use by project implementers. This would create many opportunities to calibrate and validate the tool on the basis of further field experiences. Expert use and evaluations of the tool would also help to refine it. Carrying out field applications of the tool in a structured manner would also help to better understand matters that are presently somewhat obscure—for instance, how important the different dimensions/criteria affecting the suitability of household or community level systems or appropriate technology are. These investigations would also help to make the tool more robust. The online platform could be built into multiple languages in order to increase its accessibility. Additionally, it could be developed into a simple Java program (or any other computer code) to be downloaded and used offline, or even as a paper and spreadsheet booklet for places where computers are not available.

For the purposes of the present case study application, an informal literature review was carried out in order to build databases on the technical efficacy/effectiveness (e.g. turbidity control,
microbiological control, and health impact) of the selected technological alternatives. Another advantage of an online platform would be its ability to key into a centralized global database which could accumulate such information. To begin, formal systematic reviews would have to be carried out for each technological alternative, but once this was done, information from new studies could constantly be updated into the database.  

Additionally, the other informational inputs could also be developed into databases that could be tapped by users of the tool on demand. For instance, rankings of technical appropriate technology criteria were done by a group of local subject matter experts in the present work (i.e. my staff from the larger project and engineering faculty at the IIT-M). This suite of rankings could be utilized in summary form by other users around the world. New rankings could be done by individuals around the world which could then be inputted into a database and eventually used to develop global/regional/contextual summary measures which could also then be tapped on demand. Thus, the online platform could be designed to allow users to tap into central databases and utilize summary measures for any of the informational inputs, or customize whichever inputs they like themselves to suit their particular application. This applies to other inputs of the decision-making support tool, such as the ‘expert’ assessment by the investigator of alternatives with respect to the appropriate technology criteria. Having these databases available would also serve to reduce the workload on the implementer if desired. Building databases of these inputs is an important stream for future work.

In the present work, the assessment of the performance of technological alternatives with respect to the appropriate technology criteria was structured in a very open-ended way that relied on the user to assess the context themselves. Baffrey (2005) took a different approach on this and specifically spelled out the parameters which affect each the performance of alternatives with respect to the appropriate technology criteria he identifies. Though this approach is inflexible and potentially inaccurate when compared to that taken in the present work, it has the advantage of being less demanding on the implementer. The online platform could also be designed to offer

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253 This could be structured as a decentralized wiki-type community that enables researchers and practitioners from around the world to directly update the database themselves, or it could be done in a more centralized manner, with periodic systematic reviews done by a central body.
both strategies to users so that they can pick which suits them best. (Additionally, this would create an interesting opportunity to see how the outcomes following from open-ended assessments and directed assessments correlate.)

Scaling up the decision-making support tool could be done as a collaboration with organizations in the global safe water community that have identified the need for such a tool including the Pacific Institute or the WHO International Network to Promote HWTS. The next step is to discuss with these groups the gaps they see today, and if and how the present decision-making support tool could be adapted and scaled up to meet these needs. There is great potential there, and the next step is to explore it.
CHAPTER 8: REFERENCES


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CHAPTER 9: APPENDICES

As the present work reports over three years of research, the appendices are quite voluminous. For this reason, they have not been included within this document, but rather, as separate files on the University of Guelph Atrium ETD submission (they can also be obtained by emailing me at ali.s.imran@gmail.com). Below is a list of the appendices:

A Critical appraisal of previous decision-making support tools
B AWSP Baseline Community Survey Report
C AWSP Baseline Health Monitoring Status Report
D AWSP Baseline Water Quality Monitoring Report
E Tamil Ethics Consent Form
F English Ethics Consent Form
G University of Guelph REB Certificate
H FGD I session guide
I FGD I visual aid (household systems)
J FGD II visual aid (community systems)
K FGD II session guide
L FGD II criteria information cards (Tamil + English)
M FGD II ranking sheet
N Technical criteria information cards
O Technical criteria ranking sheet
P TNSCB-Sogreah schematic map of MBN with water distribution network
Q AWSP Filter Summary Report
R AWSP Filter lab pilot testing raw data spreadsheet
S Primary research (FGD and INT) transcripts
T Selection tool matrix-weighting array
U MWA output (Scenario A)
V MWA output (Scenario D)
W Technical criteria rankings summary
X MWA output (Scenario E)
Y  MWA output (Scenario F)
ZA  Coding analysis tables (from NVivo 9)
ZB  Memos from analytical process