Design of a Natural Pool

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Abstract — Current regulations do not allow public pool water to be treated with methods other than using chlorine or bromine compounds, but the use of these chemicals have been inconclusively shown to correlate with respiratory problems such as asthma in pool users. A UV disinfection unit is proposed in this paper to be able to sufficiently treat the proposed outdoor public pool at the University of Soeville to the water quality standards outlined by Ontario regulations. As the pool is a seasonal facility and utilizes solar thermal collectors as the main source of water heating, the design actually helps conserve energy as well. It is shown in this design that UV disinfection is just as capable as chlorine or bromine in treating pool water, and is actually less harmful than using chemicals for treatment.

Index Terms — Ultraviolet disinfection, solar pool heating, pool water treatment

I. INTRODUCTION

THE University of Soeville is in need of an outdoor pool design that meets criteria centered around respiratory health. It has been found that chronic respiratory conditions, such as asthma, may be correlated to the use of chlorinated pools. To show their commitment to the environment, the University of Soeville also wants their pool to be heated using a renewable source of energy. The design of the public pool will be in accordance with Ontario Regulation 565, Public Pools, excepting the clauses that make direct reference to using chlorine or bromine chemical water treatments. The pool must also fit into the area of existing parking lot P12, have a large sundeck, and use a renewable energy source for heating. The design must minimize cost, maintenance, and energy use, while at the same time maximize quality of water, seasonal use, clarity, sustainability and esthetics. It has been assumed that the facility will be connected to the university water supply and power grid with no restriction in use and that the pool is to be seasonal, used from May 1 to September 30 of each year.

There are many different water treatment solutions available to the market, but ultraviolet treatment of water was chosen as it has many advantages over other options. UV disinfection is perhaps the safest pool water treatment method because it does not involve the use of any chemicals. There is no danger of an overdose, no chemical residue in the water, and no by-products are produced. The UV system put in place for the pool has the capacity to destroy 99% of the bacteria in the pool water. The design presented in the following paper is new, as UV isn't currently used in public pools due to Ontario regulations and as it will combine a unique treatment form with a renewable energy heating system.

In designing the requested pool, ENV07 used different approaches to determine the parameters needed in the design to meet all requirements for water temperature and quality. In designing the solar heating system, the available radiation at the University of Soeville was calculated, as was the natural temperature of water year round. Once those initial measurements were known, the energy needed to supplement the natural temperature was determined and the heat loss from the pool by convection and radiation were determined to provide an amount of energy that had to be collected from the solar thermal panels. In designing the UV system, the effective intensity of the mercury lamp, the dimensions of the chamber, and the retention time were all determined to calculate an ultimate dosage that would destroy 99% of contaminants present in the water.

To produce a milestone that was usable to the client, a calculation simulation, simulating the contamination load of a loose-stool accident in the pool, will describe how the system will respond to the contamination.

II. CONCEPTUAL DESIGN

A. Overall Design

The overall design is based on the principles of ultraviolet disinfection for maintaining the water quality of the pool and on the principles of open-loop solar collection for keeping the water temperature of the pool between 25 and 28°C [2].

For circulation of the water through the UV disinfection unit, there are three skimmers on the sides of the pool and one main drain on the pool bottom that will drain the water into a sand filter. From the filter, the water will be pumped into the UV disinfection unit where it will undergo disinfection, and then re-enter the pool through two inlets.

For the heating system of the pool water, an automatic controller will determine if there is a significant temperature difference of 5°C between the temperature of the pool water and the temperature of the thermal collectors. If the difference is significant, water will be pumped from the pool, through a sand filter, and through banks of solar collector panels that will be mounted on the roof of the health center adjacent to P12.

B. Major Components

The design work was split up into two major components. The first major component was the actual water treatment portion of the design, treating the water to an appropriate level by only using ultraviolet radiation. The fluence, intensity, dosage, and flow rate through the unit were all calculated as integral parts of the treatment design.

The second main component of the design was to determine the system for heating the pool water using solar thermal col-
lectors. Heat losses from the pool, solar radiation incident on the pool surface, and supplementary energy needed to heat the pool were all integral calculations of this component.

III. DETAILED DESIGN

A. UV Disinfection Unit

The contamination load of an outdoor pool, with an assumed number of bathers that produced a certain amount of biological contaminants, was the basis for determining what needed to be removed from the water by the disinfection unit. It was determined that a complete pool-water turnover of 8 hours would be sufficient to keep water quality healthy for users. Based on the volume of the pool and the turnover time, a flow rate was able to be calculated for the disinfection unit.

It was very important when integrating an industrial-size UV disinfection unit into the pool treatment system that the amount of radiation be enough to kill even the hardiest bacteria. The following system of equations was used to determine the effective UV radiation dosage needed [3]:

\[
\Phi_{\text{net}} = V_v - V_a = \text{net radiation from the water, } \text{W/m}^2
\]

The final dosage that the UV disinfection unit will provide for a complete pool-water turnover of 8 hours would be enough to kill 99% of all microorganisms in the water.

B. Solar Water Heating

Water loses heat through convection from the water surface, radiation from the water surface, and evaporation.

The following set of equations was used to determine the radiation incident on the water, and the convection, evaporation, and radiation that cause the pool to lose water, heat and energy. Equations and methodology for heating equations were taken from Almanza and Lara [1].

\[
\Phi_{\text{sol}} = 1.076 \times 10^{-3} H_x \quad \text{(equation 7)}
\]

where:
- \(I_v = \text{effective average intensity, } \text{mW/cm}^2\)
- \(I = \text{average intensity, } \text{mW/cm}^2\)
- \(\Phi_{\text{conv}} = \text{heat loss by convection, } \text{W/m}^2\)
- \(\Phi_{\text{e}} = \text{loss of heat by evaporation, } \text{W/m}^2\)

The energy required to keep the pool heated, above the natural temperature, is then determined by:

\[
Q(W/m^2) = \Phi_{\text{water}} + \Phi_{\text{conv}} + \Phi_{\text{e}} - \Phi_{\text{sol}} - \Phi_{\text{am}} \quad \text{(equation 12)}
\]

By using the manufacturer-recommended flow rate of 15L/m, an energy balance was calculated on the solar collectors utilizing the volume of water in the pool to determine how much time is needed to heat the pool at the beginning of the season.

IV. DISCUSSION

The design tackled for the University of Soeville considered a method of water treatment that is not currently used in treating recreational-sized public pools and made it specific to the current site of parking lot P12. The main limitation with the design is the fact that Ontario regulations specify that chlorine or bromine compounds must be used to treat public pool water and that there must be a residual of chlorine left in the water. It was shown through this design process that contaminants that are in the water due to environmental factors and bather contaminant loading are effectively removed using UV disinfection. The milestone gives a detailed calculation that shows the system response to contaminant loading such as vomit, which is one of the heaviest contaminant loads a pool might encounter. Through the design calculations performed, it was determined that simply manipulating areas of the UV disinfection process such as the dosage can allow the system to deal with either light or heavy contaminant loading.

In using solar thermal heating, using such a large surface area of solar collectors was a challenge because of pumping restrictions due to the high flow rates and head needed throughout the system. Performing a finite element analysis (FEA) or experimental testing on the piping joints to ensure that the joints are strong enough to handle the high flow rates and pressure would be needed in future work on the design. Although these values were researched for the design, there was very limited information available for strength of joints, sudden expansions, and sudden contractions in PVC piping. Design errors may occur where flow rates would have to be changed due to the FEA, where the pump was unable to provide sufficient head for the entire system, or where heavier dosages of UV radiation may be needed in times of extreme catastrophe.

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REFERENCES

