MES Research Project:

Review: Alkylated polycyclic aromatic hydrocarbons in fish and risk to human health: Implications for ecological and human health risk assessments in the Alberta oil sands

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Table of contents:

Tables and Figures

1.0 Abstract

The Alberta oil sands are one of the largest sources of naturally occurring bitumen in the world. Aromatics, specifically polycyclic aromatic hydrocarbons (PAHs), constitute the largest proportion of compounds found in bitumen. The risks of PAHs are well understood, they are known to contribute to cancer development in humans and alter early life stage development in fish inhabiting the Athabasca region, within the Alberta oil sands. However, the risks posed by alkyl substituted PAHs (A-PAHs) remain uncertain and are being neglected by decision makers like the Canadian Environmental Assessment Agency (CEAA). A-PAHs are potentially toxic to aquatic organisms, making them a concern in Ecological Risk Assessment (ERA) and are also potentially, mutagenic and carcinogenic, making them a particular concern in Human Health Risk Assessment (HHRA). Elevated loading of PAHs into ecosystems during snowmelt is a particular concern for fish within ecosystems, as snowmelt occurs during fish spawning periods. For these reasons the effects of A-PAHs derived from bitumen on fish health, and human health were targeted for this review paper. Though concrete evidence does not yet exist, information is becoming more available to evaluate the risks of A-PAH toxicity. Observations of retene provide evidence that A-PAHs can be more toxic and can potentially follow alternate metabolic pathways than parent compounds resulting in effects consistent with dioxin like compounds. The suggestion that A-PAHs may follow different metabolic pathways, and consequently, may have different toxic effects than parent compounds will potentially have implications in both HHRA and ERA. Human health effects associated with A-PAHs remain poorly understood.

2.0 Introduction

2.1 Alberta oil sands

The Alberta Oil Sands region is rich in deposits of bitumen and is considered one of the largest sources of naturally occurring bitumen in the world, estimated at 1.7 trillion barrels of crude oil (Jautzy et al., 2013; Wang et al., 2014). Bitumen is a viscous mixture of water, sand and crude oil (Kelly et al., 2009). Bitumen from the oil sands is released into the surrounding environment naturally and from anthropogenic activities. Naturally, tributaries that flow through the Athabasca Oil Sands region have eroded bitumen deposits distributing bitumen throughout the watershed (Colavecchia et al., 2004). In addition to natural sources, mining and processing of the Alberta Oil Sands produces wastewater containing residual bitumen (Giesy et al., 2010). The quantities of mining wastewater and natural bitumen entering the environment remain unknown due to the compounding issues of poorly monitored inputs and high seasonal variability of water flow (Giesy et al., 2010).

2.2 Petroleum Hydrocarbons

Petroleum hydrocarbons, found in high quantities within bitumen and wastewater commonly known as tailings, do not exist as a homogenous compound but as a mixture of hundreds of carbon based organic compounds (Wang et al., 2014). These petroleum based compounds are classified in four categories of hydrocarbons; (1) straight-chain alkanes (*n*-alkanes or *n*-paraffins), (2) branched alkanes (isoalkanes or isoparaffins), (3) cycloalkanes (cycloparaffins), and (4) aromatics (Albers, 2010). Aromatics, specifically polycyclic aromatic hydrocarbons (PAHs) constitute the largest proportion of compounds found in these mixtures (Albers, 2010).

2.3 Polycyclic aromatic hydrocarbons

PAHs are compounds that have two or more fused carbon rings that have hydrogen or an alkyl group attached to each carbon (C_nH_{2n+1}) (Albers, 2010; CCME, 1999a). Differences in the structure and size of individual PAHs result in substantial variability in physical and chemical properties (CCME, 1999a). PAHs are nonpolar, hydrophobic compounds that do not ionize (Albers, 2010; CCME, 1999b). The structure of these multiple, six carbon aromatic rings (benzene) can be arranged linearly, or in fused aromatic rings (Figure 1a). Fused rings innately form bays, referred to as bay like regions (Baird et al., 2007). These bay-like regions can also be formed on linear PAHs in the cases where hydrogen atoms on the linear parent PAH compound are substituted for by alkyl groups (Baird et al., 2007).

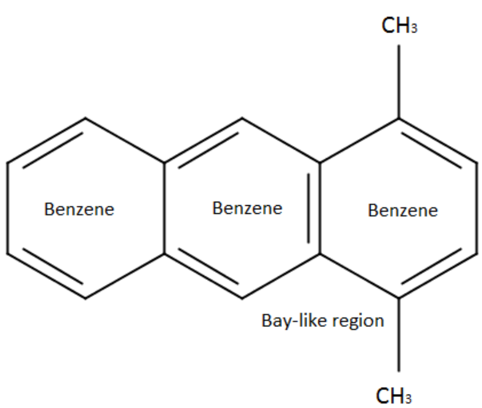

Figure 1a. Depicts a 3 ring linear PAH with alkyl substitutions on the first and fourth carbon. The structure is denoted by the formula, $C_{16}H_{14}$. It is commonly known as 1,4-dimethyl anthracene, or a C2-anthracene or a 3 ring A-PAH. Bay-like regions are formed on this linear structure due to the addition of alkyl groups. Chemical structure created in Scifinder.

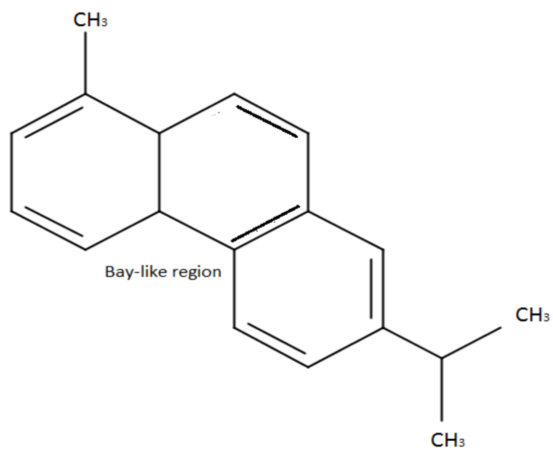

Figure 1b. Depicts a three ring A-PAH with alkyl substitutions on the first and seventh carbon. Denoted as 1-methyl-7-isopropyl phenanthrene commonly known as retene. Depicts a bay-like region naturally formed on a non-linear PAH. Chemical structure created in Scifinder.

2.4 Alkyl PAHs

Both linear and non-linear parent PAH compounds may be substituted with alkyl groups, and these substituted compounds are referred to as alkyl PAHs (A-PAHs) (Figure 1ab) (Baird et al., 2007). The structure of A-PAHs are made up of between 10 to 25 carbons (C10 to C25) (Wickliffe et al., 2014). Alkylation of these compounds refers to the number of methyl groups replacing hydrogen atoms in the structure represented by the notation (C_1, C_2, C_3, C_4, etc.) (Brandt et al., 2002). The number and position of alkyl substituents and subsequent bay-like regions may alter the metabolic pathway A-PAHs follow compared to parent compounds and consequently, may have additional implications in HHRA and ERA such as increased toxicity and carcinogenicity (CCME, 1999a).

2.5 Risk Assessment

ERA is the process used for evaluating how the environment will be impacted by any current or future change in conditions. Whereas, HHRA estimates any risks posed to human human health. Both risk assessments follow similar processes, HHRA is comprised of five stages- planning, hazard identification, dose-response and exposure assessments followed by a risk characterization. ERA is a similar four step process which also begins with planning, problem formulation, analysis and finally, risk characterizations. Human Health and Ecological Risk Assessments (HHERA) conducted to support the Environmental Impact Assessment (EIA) process are relied upon by decision makers, (e.g., the Alberta Energy Resources Conservation Board (ARCB) and the Canadian Environmental Assessment Agency (CEAA), to quantify risk associated with certain chemicals, pathways and receptors that may be implicated with proposed developmental projects (RSCEP, 2010). Yet in some cases, the risks of certain chemicals cannot be predicted conclusively (CCME, 1999a). Notably, there has been inadequate risk assessment of integrated and cumulative ecological impacts and the assessment of human health impacts (RSCEP, 2010). The risks posed by A-PAHs once released in to the environment due to the development of the Alberta oil sands have been neglected due to inconclusive toxicological information (Colavecchia et al., 2004; Jautzy et al., 2013). It is important to fully characterize the possible adverse health and environmental effects of oil sands projects in order for regulatory agencies to make informed decisions.

2.6 Literature Review

Analytical methods designed to determine the composition of individual PAHs in environmental and biological systems have progressed substantially in the past decade allowing for determination of risk for PAHs when paired with adequate toxicological health risk information (Wickliffe et al., 2014). A sediment quality guideline for the protection of aquatic life existed for one A-PAH, 2-methyl-naphthalene (2-MeN) (CCME, 1999b). Mortality of benthic organisms was used as the toxicological endpoint for this A-PAH however, the transferability of this protective guideline to fish or humans is non-existent. The update on PAH toxicity in 2010 did not include 2-MeN explaining that too little is currently known about the environmental fate and toxicity of A-PAHs to develop protective guidelines for any organisms (CCME, 2010).

The elevated loading of PAHs into aquatic ecosystems from snowmelt is a toxicological risk to fish in the Alberta Oil Sands. Snowmelt, containing large quantities of PAHs, occurs during the spawning period of 19 of the 24 fish species in the Athabasca River and tributaries, a concern because PAHs and A-PAHs have been linked to the early developmental toxicity of fish embryos (Giesy et al., 2010). Though government and industry relying on the Regional Aquatic Monitoring Program (RAMP), an aquatic ecosystem monitoring program guided by recommendations from Environment Canada in the oil sands region, report that the effects of PAH mixtures are minimal and human health and environment are not at risk, the reliability of RAMP findings have been questioned (Giesy et al., 2010; RSCEP, 2010). Some residents of Fort Chipewyan, Alberta are convinced that increased cancer rates within the community are related to the development of the Alberta oil sands, these rates were not specified (Giesy et al., 2010; RSCEP, 2010). Accordingly, a literature review was conducted to assess the scientific literature as it pertains to the toxicological risks of A-PAHs on fish and mutagenic and carcinogenic risks relevant to human health. A-PAHs may significantly contribute to the biological toxicity of PAH mixtures however they have not been evaluated in risk assessment. Risks to fish and human health from A-PAHs derived from natural and anthropogenic sources of bitumen leached into aquatic systems remain poorly understood and require review (Baird et al., 2007). Results of this literature review could be used to compliment future HHERAs dealing with A-PAHs.

3.0 Methods

3.1 Systematic Review

To assess the available literature on A-PAHs, fish and human health, a systematic review of the primary scientific literature was conducted. The sorting framework was based on the techniques developed in *The Cochrane Handbook for Systematic Reviews of Interventions* (Higgins, 2011) to reflect the best available knowledge on A-PAHs, humans and fish. More specifically, *The Handbook* provides a framework to describe selection bias, detection bias and reporting bias in output data confirming validity and reproducibility of the methods presented (Higgins, 2011). This literature review followed these judgement criteria to facilitate the selection of information pertinent to this study.

3.2 Databases

Three scientific databases were chosen to represent the body of scientific research: Scholars Portal, Web of Science (formerly known as Web of Knowledge) and Google Scholar. Initial searches revealed that information found in Scholars Portal overlapped with what was found in Web of Science, but the information in Web of Science was far more comprehensive. Google Scholar contained much information, however, Google Scholar does not possess the capability to restrict the search results to reputable scientific journals. Therefore, the risk of including information from unreliable sources was considered high. For these reasons, the Web of Science was relied upon as the sole credible database for the retrieval of scientific literature to be included in the results. The Web of Science database actively covers over 12,000 high-impact journals spanning many different areas of study and international proceeding coverage from over 160,000 conferences. The Web of Science comprises seven citation databases, one of which was specifically relevant to organic pollutants: the Science Citation Index Expanded (SCI-Expanded). The SCI Expanded includes over 8,500 leading journals across 150 scientific disciplines and includes all cited references captured from indexed articles. The Biosis Citation Index, a secondary index, also provided access to over 5,300 high quality journals dating back to 1926 and included access to over 90% of citation abstracts.

3.3 Search Results

Detailed search process:

- The terms Alkyl* PAH* were entered into the Web of Science database and 1260 articles were returned.
- To refine the results the search terms Alkyl* PAH* were combined with fish or human health which yielded 160 articles. Search results are attached in Section 1 of the Appendix.
- Looking through the titles it became apparent that many of the articles were not relevant to the topic of fish and human toxicity to A-PAHs.
- The following list of specific terms was generated to ensure only relevant studies from the 160 articles were included: environmental concentration, risk, oil/tar sands, exposure and consumption.
- A total of 50 articles contained at least two of these five listed terms and were included for further review.
- Even though many articles met the inclusion criteria, they were not related to the topic (e.g., A-PAH concentrations in house dust and aircraft fumes). Search results are attached in Section 2 of the Appendix.
- Of the 50 articles reviewed, 23 were included in this literature review and separated into the following three topics- Environmental Concentrations, Fish Health and Human Health.

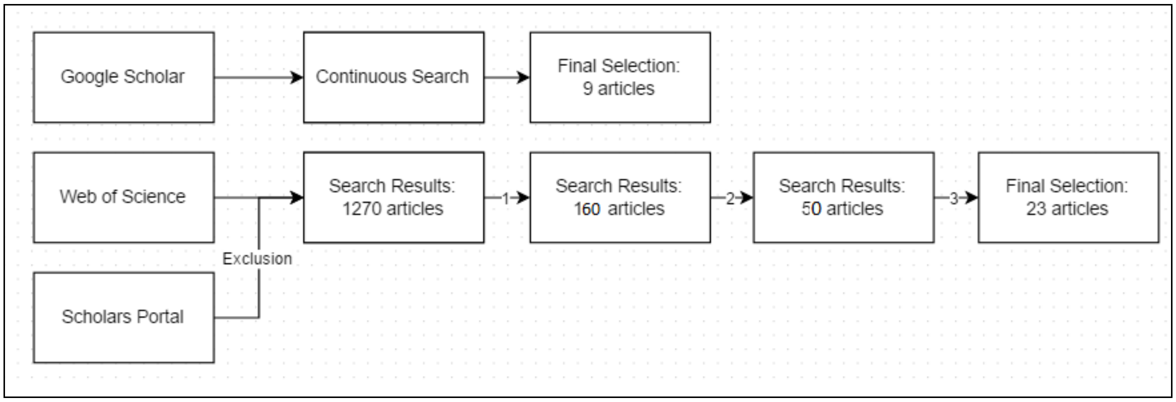

Figure 2. Conceptual map of screening process and results. 1- Alkyl* PAH* was entered into the database search engine which returned 1260 articles. 2- The search was refined to include the search terms human and fish health which yielded 160 articles. 3- 50 articles met the criteria of containing two of the five terms: environmental concentration, risk, oil sands, exposure and consumption in the abstract. These 50 articles were read in depth and excluded based on relevance to the topic resulting in a final selection of 23 scientific articles. Google scholar was used continuously to supplement scientific papers with context.

4.0 Results

4.1 Environmental Concentrations

In the environment, there exist multiple factors contributing to the observed concentrations of A-PAHs derived from bitumen. Releases of bitumen fall under the classification of petrogenic sources, these sources are considered releases of petroleum-derived compounds. Petrogenic sources are characterized by lower molecular weight compounds and dominated by A-PAHs (Danion et al., 2011a; Vignet et al., 2014). Depending on the type of petrogenic source the proportion and concentrations of PAHs will differ (Jautzy et al., 2013). Concentrations of PAHs in tailing pond sediment samples collected in the oil sands were five times higher than those found in natural bitumen samples (Colavecchia et al., 2004). In addition to being source dependant, the composition and concentrations of PAH mixtures are temporally dependant (Baird et al., 2007; Dsikowitzky et al., 2011; Murawski et al., 2014). Lighter, molecular weight, parent PAHs degrade quickly in the environment relative to heavy and highly alkylated PAHs (Dsikowitzky et al., 2011). For example, naphthalene and phenanthrene, two and three ring PAHs and have lower K_{OW} values than the larger PAHs they partition to surface water making them more available for uptake by biota (Baird et al., 2007).

It is assumed that A-PAHs, like PAHs, become available to fish and humans through sorption into exposed sediment particles in the water column or are deposited in sediment (Brandt et al., 2002). Using ion mass spectrometry researchers have been able to identify, quantify and differentiate parent and A-PAHs in environmental samples (Ramirez et al., 2014). A-PAHs and PAHs were evaluated river sediment samples, tailing pond sediment and bitumen samples collected from Ells River and Steepbank River, two tributaries of the Athabasca river basin. Bitumen deposits in this area are exposed along the bank of the river for approximately 100 km and from similar erosional inputs from tributaries (Colavecchia et al., 2004). The concentrations of A-PAHs in both natural oil sands and anthropogenic sediments dominated the chemical profile comprising between 93 to 99% of all PAHs measured in Athabasca samples (Colavecchia et al., 2004).

A historical record of PAHs has been collected from dated sediment cores from two headwater lakes located near major Athabasca open pit mines (Jautzy et al., 2013). In addition to the 16 commonly analysed PAHs in North America, retene along with 6 other A-PAHs were measured in the Athabasca oil sands region (CCME, 2010; Jautzy et al., 2013). According to the environmental protection agency (EPA) concentrations of A-PAHs and PAHs naturally present in the Athabasca oil sand bitumen, were found up to ~3.0×10^6 ng/g (Jautzy et al., 2013). Sediment cores in previous works have shown increases in PAHs while approaching the sediment surface (Jautzy et al., 2013). However, the presence of A-PAHs is not necessarily indicative of bitumen. For example, retene, an alkyl phenanthrene, is a known marker for coniferous wood combustion. However, recent fire records do not correlate with exponential increase in deposition of A-PAHs in the top 10 cm layer of soil (Jautzy et al., 2013). Upon further analysis of deeper (older) sediments, a significant proportion of pre-operations A-PAHs could not be attributed to oil sands mining activities, with forest fires being likely sources (Jautzy et al., 2013). Despite the improvements made in differentiating individual compounds from the environmental and biota, toxicity thresholds have not been developed for many A-PAHs (Ramirez et al., 2014).

Data specifically treating environmental concentrations of A-PAHs in the Alberta oil sands are limited, however there exists research examining petrogenic sources in freshwater and marine environments that may complement existing data. Common trends observed include that A-PAHs are abundant in crude oil, persist in the environment, diffuse across biological membranes and can potentially biomagnify up the food chain (Brandt et al., 2002; Dsikowitzky et al., 2011; Paruk et al., 2014). Near a crude well blowout in Trecate, Italy A-PAHs constituted more than 99.6% of total PAH dry mass. One month after the blowout, it was documented that heavy A-PAHs with high $K_{OW,}$ such as C_1-C_4 Chrysene, representing 5.1%,of PAH composition, were less prone to bioaccumulation than were lighter, lower molecular weight K_{OW} A-PAHs, specifically C_1-C_4 naphthalene representing 31.2% of measured PAHs in the soil (Brandt et al., 2002).

A study analysing Segara Anakan Lagoon water and sediment samples in Java, Indonesia marked sampling sites where PAH mixtures were composed entirely of A-PAHs (Dsikowitzky et al., 2011). A-PAH levels in these samples exceeded concentrations at which PAHs would cause adverse effects and lethal effects for benthic communities by up to ten fold, which may be a sublethal concern to fish (Dsikowitzky et al., 2011). It was also found near the crude well blowout in Italy that increasingly alkylated PAHs were found in higher concentrations in sediment, plants and organisms than expected based on both environmental concentrations and modelled K_{OW} values (Brandt et al., 2002). The likely cause of unexpectedly high values in the environment is attributed to the lower loss rates of A-PAHs versus PAHs (Brandt et al., 2002).

4.2 Fish Health

In fish, uptake of PAHs from water, takes place mainly as a passive diffusion process via the gills, other routes of exposure are not well documented (Jonsson et al., 2004). The uptake of A-PAHs in fish, like all chemical compounds, is governed by bioaccessibility and bioavailability. Bioaccessibility refers to the potential of a receptor to come in contact with a chemical whereas bioavailability refers to the potential of the chemical to transfer from media to exposed biota (Menzie & Coleman, 2007). Once absorbed, A-PAHs are biotransformed through metabolic processes. The biotransformation of retene appears to be divided into reactive metabolites and DNA or protein adducts in fish and can be measured by quantitative evaluation of selected metabolites excreted in bile (Jonsson et al., 2004). Oxygenation of retene in phase one metabolism may contribute to developmental toxicity (Mu et al, 2014). In this process, retene produces excess reactive oxygen species (ROS) through sustained induction of cytochrome P450 1A (CYP1A) enzymes (Mu et al., 2014). ROS can damage proteins, lipids and DNA when produced in large quantities (Mu et al., 2014). Retene is a high CYP1A activity inducer and a strong aryl hydroxyl receptor (AhR) agonist compared to parent phenanthrene. AhR is a cytosolic transcription factor involved with exposure response which ultimately results in gene transcription and expression of DNA (Le Bihanic et al., 2014). These effects could be the result of a co-reaction of retene metabolites and ROS action (Le Bihanic et al., 2014; Mu et al., 2014). Retene exhibited a mode of action similar to that of dioxin-like compounds, rather than PAHs (Mu et al, 2014). Retene also induced significant CYP1A activity consistent with effects of dioxin-like compounds (Mu et al., 2014). Retene caused blue sac disease (BSD) syndrome which is triggered by different nonspecific mechanisms similar to those attributed to dioxin-like compounds which include narcosis, or through interactions with specific receptors such as the AhR or cardiotoxicity (Le Bihanic et al., 2014). BSD is a common syndrome reported in fish embryos which is characterized by pericardial or peritoneal edemas, spinal curvature, craniofacial abnormalities or altered heart development (Le Bihanic et al., 2014).

A study was conducted on the effects of tailing pond and natural bitumen sediment samples collected from the Athabasca region on early life stages (ELS) of indigenous fathead minnows (*Pimphales promelas*). To determine composition, PAHs were extracted from sediment fractions while other compounds were discarded, as previously mentioned in Section 4.1 the proportion of A-PAHs within extracted PAHs ranged between 93% to 99% (Colavecchia et al., 2004). These samples included natural oil sands, reference sediments, and tailing pond sediment samples and were exposed to fish in sediment to water ratios (25.0, 12.5, 6.25, 3.12, 1.56, 0.78, 0.39, 0.19, 0.098, and 0.049 g) to 1 L of overlaying laboratory water with moderate aeration. At hatch, fathead minnow larvae were collected and later sampled for histology and CYP1A activity (Colavecchia et al., 2004). However, an increase in mortality, hatching malformations and CYP1A induction were observed in eggs and larvae exposed to concentrations between 0.05 to 25 g oil sand sediment per liter (Colavecchia et al., 2004). Both natural and wastewater sediments caused significant hatching alterations and exposure-related increases in ELS mortality, malformations, and reduced size consistent with dioxin induced BSD (Colavecchia et al., 2004). Larval deformities included edemas, hemorrhages, and spinal malformations. Exposure to reference sediments and controls showed negligible embryo mortality and malformations and excellent larval survival. Observed symptoms in the fathead minnows were consistent with toxicity associated with dioxin like compounds known to bind to the AhR (Colavecchia et al., 2004).

Though only one study has examined the effects of bitumen on growth and development of fish, many other studies outside of the oil sands have tested and observed effects from exposure to crude on a variety of fresh and marine fish species. The majority of these studies examine PAH mixtures dominated by similar composition of A-PAHs which allow for comparison to A-PAHs found in the oil sands (Danion et al., 2011a, 2011b; Grung et al., 2009; Heintz et al., 2000; Le Bihanic et al., 2014). Heintz et al., 2000 examines the effects of highly weathered oil, a source like bitumen known to be dominated by A-PAHs, on the growth and survival of Pink salmon (*Oncorhnchus gorbuscha*). Survival of fish exposed to PAHs was significantly reduced compared to control reaching 15% at concentrations of 5.4 µg/kg (Heintz et al., 2000). Growth was also significantly reduced, control fish averaged an increase in weight of 23.0 ± 0.9 grams compared with fish exposed which averaged a weight gain of 21.5 ± 0.6 grams (Heintz et al., 2000). In another study addressing increased incidence of skin lesions found on bottom dwelling species along the continental shelf north of the Deepwater Horizon oil spill concentrations of A-PAHs in liver, bile and muscle were measured in the dominant species, Red Snapper (*Lutjanus campechanus*) (Murawski et al., 2014). Effected Red Snapper concentration of A-PAHs in muscle and liver samples (84% and 85%, respectfully) were strongly correlated with the 1:10 ratio of parent to A-PAH composition of petroleum escaping the damaged well (Murawski et al., 2014).

4.3 Human Health

Human exposure to A-PAHs can occur from contaminated sediment and surface waters through ingestion and dermal contact, as well as indirectly from the ingestion of contaminated fish (Baird et al., 2007). Baird et al. (2007) reviewed literature concerning the risks posed by A-PAHs to human health in aquatic systems. There exists additional data on A-PAHs in humans since its review in 2007 however there does not exists published data analysing the effects of A-PAHs on humans health in the oil sands (Baird et al., 2007). However, data concerning A-PAHs metabolites and simulated exposure after crude oil spills have been published.

A recent study measuring A-PAHs and 11 A-PAH metabolites, methyl-napthols (Me-OHNs), of 1- methyl-naphthalene (1-MeN) and 2-methyl-naphthalene (2-MeN) in human urine samples was conducted (Li et al., 2014). Me-OHNs metabolites, the corresponding products of 2-MeN metabolism, were detected in 53% - 97% of non-smokers and in 100% of smokers. The geometric mean concentrations ranged from 34 to 453 pg/mL in non-smokers and 1608 to 6990 pg/mL in smokers, which corresponds to an average of 36.7 fold difference (Li et al., 2014). Correspondingly, the Me-OHN concentrations were 10.9–30.0 times higher in the smoker urine than the non-smoker urine SRM, whereas for the OH-PAHs, the differences were smaller (0.2-fold to 11.0-fold) (Li et al., 2014). Metabolites confirmed the presence of A-PAH exposure in humans after known exposure; these results could potentially be used in areas where humans are suspected of being exposed to A-PAHs.

Another method of determining exposure was used in a series of exposure assessments conducted in South Korea on both residents and volunteers active in the Heibei-Spirit oil spill cleanup (Hyeon et al., 2011). Exposure through accidental ingestion and dermal contact was modelled based on residual oil at the Taean County at 1 month, 4 months, 1 year and 2 years after exposure (Hyeon et al., 2011). At the beginning of the accident the average exposures of residents and volunteers to A-PAHs were estimated to be .87 and .29 mg/kg/d, respectively (Hyeon et al., 2011). Exposure was estimated to decrease with time, reaching 220 and 13 ng/kg/d, respectively, within 2 years of the oil spill. The simulated ratio of A-PAHs to PAHs was 30:40 at the beginning and increased to 120:1 at the 2 year interval (Hyeon et al., 2011).

Mechanistic assays, reviewed by Baird et al. (2007) have shown that A-PAHs can pass through multiple extra and intracellular pathways of exposed cells. They may interfere with Gap Junction Intercellular Communication (GJIC). GJIC allows cells to maintain normal tissue structure in complex organisms. A-PAHs interfere by inhibiting cellular communication, which may lead to tumor-promoting steps in the carcinogenic process (Baird et al., 2007). *In vitro* assays have shown that inhibition occurs rapidly within the cell, within five minutes, and recovery occurs within 90 minutes following removal of A-PAHs (Baird et al., 2007). In addition to GJIC inhibition, A-PAHs stimulate extracellular response kinases (ERK). ERK is a protein associated with intracellular signalling, initiation of cell proliferation and, more specifically, nuclear transcription (Baird et al., 2007). GJIC inhibition preceded the onset of ERK and it was hypothesized that A-PAHs with bay-like regions stimulate GJIC inhibition which leads to the activation of ERK, resulting in increased cell proliferation and carcinogenesis (Baird et al., 2007). A-PAH toxicity can also be measured with AhR activity which is associated with toxic, biochemical and receptor responses that range from carcinogenicity to anti-estrogenic activity (Baird et al., 2007).

The availability of chronic animal studies for evaluating oral and dermal concentrations and resulting toxicity of A-PAHs in humans is limited (Baird et al., 2007; Li et al., 2014; Menzie & Coleman, 2007). Human health effects associated with parent PAHs have been well documented, however such information for A-PAHs remains limited to methyl naphthalene (MeN) (Baird et al., 2007). Baird et al. (2007) assembled chronic toxicity studies conducted with C2-MeN and C1-MeN, which resulted in a dose-dependent increase in the incidence of pulmonary alveolar proteinosis. Pulmonary alveolar proteinosis was considered relevant to human health and was used as the critical effect for the development of the 2-MeN in its inclusion in HHRA (Baird et al., 2007). Recently, cancer risks associated with the consumption of oysters were calculated using margin of exposure (MOE) approaches. This method is commonly used to quantify toxic equivalence of chemical compounds. At the average level of oyster consumption the cancer risks were estimated at $6.7x10^{-6}$ for 16 PAHs and $6.7x10^{-5}$ for A-PAHs (Jong-Hyeon et al., 2011). At the level of dietary exposure of humans to oyster the cancer risks were considered low (Jong-Hyeon et al., 2011). Due to constraints of the publication journal, Epidemiology, research data was limited and level of acceptable cancer risk was not provided.

5.0 Discussion:

5.1 Ecological Risk Assessment

PAH mixture toxicity is largely represented by PAHs in ERA leaving A-PAHs relatively uncharacterized (Dsikowitzky et al., 2011). The toxicological risks presented to fish are extremely important in ERA and are a good measure of ecological integrity (Menzie & Coleman, 2007). A-PAHs within PAH mixtures have been associated with fish abnormalities, however direct A-PAH toxicity remains undefined (Menzie & Coleman, 2007). Chemical fingerprinting of PAH mixtures has allowed for separation and preliminary measurements of A-PAHs in the environment (Brandt et al., 2002). One of the challenges to estimating exposure is that fish have the ability to quickly metabolize A-PAHs, original compounds are therefore not reliable indicators of exposure (Menzie & Coleman, 2007). The metabolism of PAHs is believed to be an essential factor in the development of various hepatic diseases, including neoplasia and liver tumors (Jonsson et al., 2004). The presence of A-PAHs metabolites have confirmed the role of metabolism in the expression of biological concentrations (Jonsson et al., 2004). The metabolic pathways A-PAHs follow within fish are relatively uncertain (Le Bihanic et al., 2014). The pathway of PAHs have been traced with varying degrees of success and it was assumed that due to the structural similarity of A-PAHs and PAHs, toxicological effects would be similar (Dsikowitzky et al., 2011). Contrarily, preliminary research supports that A-PAHs follow more complex metabolism pathways conforming more to dioxin-like toxicity than parent compounds but very little data exists to confirm or reject this hypothesis (Brandt et al., 2002). Additionally, A-PAHs were found in higher concentrations in all tested species than expected based on environmental concentrations and modelled octanol-water partitioning (Brandt et al., 2002). Bioaccumulation of A-PAH is highly dependent on both physical and chemical characteristics of chemicals and the environment, which in turn can influence observed concentrations (Menzie & Coleman, 2007). The elimination of A-PAHs from the environmental is due to volatilization and weathering (Brandt et al., 2002). Whereas metabolism governs the retention of A-PAHs in biological systems (Brandt et al., 2002; Uno et al., 2010).

The development of dose-response relationships for A-PAHs is a major interest for evaluating ecological responses of petrogenic exposure (Hellou et al., 2004). Despite the similarities of identified A-PAHs fish, concentrations do not translate across species (Uno et al., 2010). The distribution of A-PAH metabolites in shellfish were completely different than those of finfish (Uno et al., 2010). This difference is attributed to different uptake routes and metabolisms. Finfish are exposed to low molecular weight A-PAHs in water-soluble fractions of oil through passive diffusion as well as minimal ingestion of sediment. Shellfish are bottom feeders and ingest higher concentrations of contaminated sediment where heavy A-PAHs are more abundant (Uno et al., 2010). In addition to different levels of exposure and uptake routes, metabolism impacts the bioaccumulation of A-PAHs in organisms (Paruk et al., 2014; Uno et al., 2010). Shellfish have a much lower rate of metabolism compared to fish, concentrations in shellfish were very similar to that of the concentration of A-PAHs found in sediment, suggesting a very low elimination rate (Uno et al., 2010). It remains unclear whether or not the sensitivities of marine to freshwater fish are comparable, salinity potentially raises PAH sorption (Le Bihanic et al., 2014; Mu et al., 2014).

The sensitivity of aquatic organisms to toxic stress is affected by many factors including its environment, metabolic capacity, and stage development and therefore, comparisons between fish species would not be representative of ecological risk (Murawski et al., 2014). Fish are among the most diverse groups of vertebrates possessing large variations in physiology, anatomy and ecology (Menzie & Coleman, 2007). Consequently, the effects of PAH, and even less so A-PAHs, are not easily generalized (Menzie & Coleman, 2007). Much of the research on A-PAH toxicity has focused on acute exposure to marine fish species in response to the large scale oil spills (Carls et al., 2000; Danion et al., 2011a, 2011b; Heintz et al., 2000; Mu et al., 2014; Murawski et al., 2014). Evidence suggests that development of freshwater and marine fish is inhibited by PAH mixtures dominated by A-PAHs, but the degree of inhibition due to A-PAHs is uncertain (Vignet et al., 2014).

A comparative study analysing retene and its parent compound, phenanthrene, found that both compounds resulted in different expressions of developmental toxicity to marine medaka (Mu et al., 2014). Phenanthrene accumulated in the body and specifically affected the peripheral vascular system, which was consistent with anesthetic toxicity (Mu et al., 2014). Retene affected cardiac tissues which might be attributed to CYP1A mediated toxicity of metabolites (Mu et al., 2014). The lethal concentrations to 50% of the population (LC50) were compared between the two and were found to occur at >756 µg/L and 251 µg/L for phenanthrene and retene, respectively (Mu et al., 2014). Thus, retene toxicity was significantly higher than that of its parent.

The presence of A-PAHs is steadily increasing in the Alberta oil sands, yet assessing their potential ecological risk remains problematic (Jautzy et al., 2013; Le Bihanic et al., 2014). Recent studies suggests that toxicity of petrogenic exposure is driven by A-PAHs but due to limited data and limited transferability of existing data to fish species in the oil sands this cannot be confirmed or denied (Le Bihanic et al., 2014). A common finding among the studies was that toxicity and ecological impacts of A-PAHs in petrogenic pollution should not be ignored (Mu et al., 2014). If A-PAHs follow separate metabolic pathways than parent PAHs then PAH toxicity measured primarily with PAHs may not be protective of A-PAH toxicity within the mixture.

Though some evidence suggests that a main concern to fish is tumor development, in the context of risk assessment, growth and reproduction are more commonly used as the endpoints of species that have relatively short lifespans. One proposed method to grade A-PAH toxicity, known as the toxic equivalent factor (TEF), grades toxicity based on a well-known reference toxicant like Benzo(A)Pyrene (dioxin) (Le Bihanic et al., 2014). This method may be more effective in grading the toxicity of A-PAHs as A-PAHs are suspected to act similarly to dioxin like compounds as effects are associated with binding to the AhR (Le Bihanic et al., 2014). TEF values are summed and weighed for each PAH, to fully account for the risk TEF values of A-PAHs may need to be developed.

5.2 Human Health Risk Assessment

With increased emphasis on evaluating A-PAHs for ecological risk assessments there is now increased interest on the potential risks these may pose to human health (Menzie & Coleman, 2007). Direct exposure of A-PAHs to humans, like the environment and all other organisms, is also governed by bioaccessibility and bioavailability. Humans are likely to be exposed to A-PAHs from contaminated sediment and surface water through incidental ingestion, dermal contact and consuming fish contaminated with A-PAHs (Baird et al., 2007). It was found that in the top 10 cm of sediment in the Alberta oil sands, A-PAH concentrations were rising with decreasing depth, indicating that humans could potentially be in contact with high sediment concentrations of A-PAH. In terms of consumption, it is accepted that the transfer of un-metabolized A-PAH compounds from fish to humans is limited (Menzie & Coleman, 2007).

Additionally, there is very little information regarding the transfer of metabolites (Menzie & Coleman, 2007).

Recently, Li et al. (2014) published the first reported analysis of 11 metabolites of A-PAHs and 10 metabolites of parent PAHs in humans. The metabolites were measured in a group of smokers and non-smokers, two populations known to have different levels of PAH exposure. MeN and subsequent metabolites were found in large concentrations in the smoker urine samples. Considering MeNs are found in higher concentrations in petrogenic sources, shortly after exposure MeN metabolites would be expected to be measured in urine samples. Though the concentration of A-PAHs in petrogenic sources is higher than pyrogenic sources, A-PAH concentrations cannot be compared due to differences in pathways and the undescribed amount of A-PAHs inhaled by smokers. Quantification of these metabolites is difficult and thus rarely available for risk assessments (Menzie & Coleman, 2007). Even if the chemicals are quantified, it is difficult to translate these measures of exposure into levels of effects (Menzie & Coleman, 2007).

There is also concern that these metabolic products may be important in trophic transfer after PAH exposure. Thus, while it is generally acknowledged that trophic transfer of parent PAH compounds from fish to wildlife or humans is limited, uncertainty remains regarding transfer of metabolites (Menzie & Coleman, 2007). Exposure was simulated in residents and volunteers associated with the Heibei-Spirit oil spill in [South Korea, 2007]. Exposure was calculated using the residual oil and daily exposure was calculated for both sample groups at varying intervals after the spill (Jong-Hyeon et al., 2011). In the Hebei-Spirit oil spill study it was reported that the cancer risks of consuming oysters contaminated with A-PAHs were above the cancer threshold. It was briefly explained that due to the amount consumed that risks were not a cause for concern. The results gathered from the Hebei-Spirit oil spill could have been more useful if presented in greater detail.

6.0 Conclusion

The suspicions within the literature of whether or not A-PAHs are drivers of PAH toxicity in bitumen, or other petrogenic sources cannot be confirmed or disproved with amount of research presented. Observations of retene provide evidence that A-PAHs can be more toxic and can potentially follow alternate metabolic pathways than parent compounds resulting in effects consistent with dioxin like compounds. Additional research is necessary to determine if other A-PAH follow metabolic pathways similar to retene. A challenge presented to researchers is the accelerated rate A-PAHs metabolism in fish and humans. Once metabolized A-PAHs are not present in fish or humans, however A-PAH metabolites have been identified in fish bile and muscle as well as human urine. Quantification of these potentially harmful metabolites is currently very difficult and thus, rarely available for risk assessments. The suggestion that A-PAHs may follow different metabolic pathways, and consequently, may have different toxic effects than parent compounds will potentially have implications in both HHRA and ERA. Though toxicological risks of APAHs to humans and fish in the Alberta Oil Sands remain unclear, information is becoming more available. Additional data will be required to develop TEFs for A-PAHs so they may be included in future HHERA.

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8.0 Appendix

8.1 Preliminary Search Results

Title	Authors	Journal	Year	Volume	Issue
Developmental toxicity of PAH mixtures in fish early life stages. Part II: adverse effects in Japanese medaka	Le Bihanic, Florane; Clerandeau, Christelle; Le Menach, Karyn; Morin, Benedicte; Budzinski, Helene; Cousin, Xavier; Cachot, Jerome	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	2014	21	24
Prevalence of External Skin Lesions and Polycyclic Aromatic Hydrocarbon Concentrations in Gulf of Mexico Fishes, Post-Deepwater Horizon	Murawski, Steven A.; Hogarth, William T.; Peebles, Ernst B.; Barbeiri, Luiz	TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY	2014	143	4
Chronic dietary exposure to pyrolytic and petrogenic mixtures of PAHs causes physiological disruption in zebrafish - part I: Survival and growth	Vignet, Caroline; Le Menach, Karyn; Mazurais, David; Lucas, Julie; Perrichon, Prescilla; Le Bihanic, Florane; Devier, Marie-Helene; Lyphout, Laura; Frere, Laura; Begout, Marie-Laure; Zambonino-Infante, Jose-Luis; Budzinski, Helene; Cousin, Xavier	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	2014	21	24
In vitro and in vivo toxicities of sediment and surface water in an area near a major steel industry of Korea: Endocrine disruption, reproduction, or survival effects combined with instrumental analysis	Kim, Sunmi; Lee, Sangwoo; Kim, Cheolmin; Liu, Xiaoshan; Seo, Jihyun; Jung, Hyorin; Ji, Kyunghee; Hong, Seongjin; Park, Jinsoon; Khim, Jong Seong; Yoon, Seokmin; Lee, Woojin; Park, Jeongim; Choi, Kyungho	SCIENCE OF THE TOTAL ENVIRONMENT	2014	470	
Mutagenicity, dioxin-like activity and bioaccumulation of alkylated picene and chrysene derivatives in a German lignite	Meyer, Wiebke; Seiler, Thomas-Benjamin; Christ, Andreas; Redelstein, Regine; Puettmann, Wilhelm; Hollert, Henner; Achten, Christine	SCIENCE OF THE TOTAL ENVIRONMENT	2014	497	
Comparative embryotoxicity of phenanthrene and alkyl-phenanthrene to marine medaka (Oryzias melastigma)	Mu, Jingli; Wang, Juying; Jin, Fei; Wang, Xinhong; Hong, Huasheng	MARINE POLLUTION BULLETIN	2014	85	2
Polycyclic aromatic compounds (PAHs and oxygenated PAHs) and trace metals in fish species from Ghana (West Africa): Bioaccumulation and health risk assessment	Bandowe, Benjamin A. Musa; Bigalke, Moritz; Boamah, Linda; Nyarko, Elvis; Saalia, Firibu Kwesi; Wilcke, Wolfgang	ENVIRONMENT INTERNATIONAL	2014	65	
Source Apportionment and Distribution of Polycyclic Aromatic Hydrocarbons, Risk Considerations, and Management Implications for Urban Stormwater Pond Sediments in Minnesota, USA	Crane, Judy L.	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	2014	66	2
Heterocyclic Aromatic Hydrocarbons Show Estrogenic Activity upon Metabolization in a Recombinant Transactivation Assay	Brinkmann, Markus; Maletz, Sibylle; Krauss, Martin; Bluhm, Kerstin; Schiwy, Sabrina; Kuckelkorn, Jochen; Tiehm, Andreas; Brack,	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2014	48	10

	Werner; Hollert, Henner				
Polycyclic aromatic hydrocarbon exposure, obesity and childhood asthma in an urban cohort	Jung, Kyung Hwa; Perzanowski, Matthew; Rundle, Andrew; Moors, Kathleen; Yan, Beizhan; Chillrud, Steven N.; Whyatt, Robin; Camann, David; Perera, Frederica P.; Miller, Rachel L.	ENVIRONMENTAL RESEARCH	2014	128	
Evaluation of Polycyclic Aromatic Hydrocarbons Using Analytical Methods, Toxicology, and Risk Assessment Research: Seafood Safety after a Petroleum Spill as an Example	Wickliffe, Jeffrey; Overton, Edward; Frickel, Scott; Howard, Jessi; Wilson, Mark; Simon, Bridget; Echsner, Stephen; Nguyen, Daniel; Gauthe, David; Blake, Diane; Miller, Charles; Elferink, Cornelis; Ansari, Shakeel; Fernando, Harshica; Trapido, Edward; Kane, Andrew	ENVIRONMENTAL HEALTH PERSPECTIVES	2014	122	1
Does grazing on biosolids-treated pasture pose a pathophysiological risk associated with increased exposure to endocrine disrupting compounds?	Evans, N. P.; Bellingham, M.; Sharpe, R. M.; Cotinot, C.; Rhind, S. M.; Kyle, C.; Erhard, H.; Hombach-Klonisch, S.; Lind, P. M.; Fowler, P. A.	JOURNAL OF ANIMAL SCIENCE	2014	92	8
Polycyclic Aromatic Hydrocarbons Detected in Common Loons (Gavia immer) Wintering off Coastal Louisiana	Paruk, James D.; Long, Darwin; Perkins, Christopher; East, Andrew; Sigel, Bryan J.; Evers, David C.	WATERBIRDS	2014	37	
In vitro and in vivo toxicities of sediment and surface water in an area near a major steel industry of Korea: Endocrine disruption, reproduction, or survival effects combined with instrumental analysis	Kim, Sunmi; Lee, Sangwoo; Kim, Cheolmin; Liu, Xiaoshan; Seo, Jihyun; Jung, Hyorin; Ji, Kyunghee; Hong, Seongjin; Park, Jinsoon; Khim, Jong Seong; Yoon, Seokmin; Lee, Woojin; Park, Jeongim; Choi, Kyungho	SCIENCE OF THE TOTAL ENVIRONMENT	2014	470	
Human exposure to endocrine disruptors via ambient air: An unknown health risk	Moreau-Guigon, E.; Chevreuil, M.	ARCHIVES DES MALADIES PROFESSIONNELLES ET DE L ENVIRONNEMENT	2014	75	1
Metabolism of a representative alkylated petrogenic polycyclic aromatic hydrocarbon (PAH) 6-ethyl-chrysene associated with the Deepwater Horizon oil spill in human hepatoma (HepG2) cells	Huang, Meng; Blair, Ian A.; Penning, Trevor M.	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	2014	248	
Quantification of 21 metabolites of methylnaphthalenes and polycyclic aromatic hydrocarbons in human urine	Li, Zheng; Romanoff, Lovisa C.; Trinidad, Debra A.; Pittman, Erin N.; Hilton, Donald; Hubbard, Kendra; Carmichael, Hasan; Parker, Jonathan; Calafat, Antonia M.; Sjoedin, Andreas	ANALYTICAL AND BIOANALYTICAL CHEMISTRY	2014	406	13
Fully automated trace level determination of parent and alkylated PAHs in environmental waters by online SPE-LC-APPI-MS/MS	Ramirez, Cesar E.; Wang, Chengtao; Gardinali, Piero R.	ANALYTICAL AND BIOANALYTICAL CHEMISTRY	2014	406	1
Geologically distinct crude oils cause a common cardiotoxicity	Jung, Jee-Hyun; Hicken, Corinne E.; Boyd, Daryle; Anulacion, Bernadita	CHEMOSPHERE	2013	91	8

syndrome in developing zebrafish	F.; Carls, Mark G.; Shim, Won Joon; Incardona, John P.				
Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry	Bakke, Torgeir; Klungsoyr, Janie; Sanni, Steinar	MARINE ENVIRONMENTAL RESEARCH	2013	92	
Integrated chemical and biological analysis to explain estrogenic potency in bile extracts of red mullet (Mullus barbatus)	Martinez-Gomez, Concepcion; Lamoree, M.; Hamers, T.; van Velzen, M.; Kamstra, J. H.; Fernandez, B.; Benedicto, J.; Leon, V. M.; Vethaak, A. D.	AQUATIC TOXICOLOGY	2013	134	
Acute exposure to offshore produced water has an effect on stress- and secondary stress responses in three-spined stickleback Gasterosteus aculeatus	Knag, Anne Christine; Taugbol, Annette	COMPARATIVE BIOCHEMISTRY AND PHYSIOLOGY C-TOXICOLOGY & PHARMACOLOGY	2013	158	3
Silicone rubber passive samplers for measuring pore water and exchangeable concentrations of polycyclic aromatic hydrocarbons concentrations in sediments	Yates, Kyari; Pollard, Pat; Davies, Ian; Webster, Lynda; Moffat, Colin	SCIENCE OF THE TOTAL ENVIRONMENT	2013	463	
Century-Long Source Apportionment of PAHs in Athabasca Oil Sands Region Lakes Using Diagnostic Ratios and Compound-Specific Carbon Isotope Signatures	Jautzy, Josue; Ahad, Jason M. E.; Gobeil, Charles; Savard, Martine M.	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2013	47	12
Application of multiple geochemical markers to investigate organic pollution in a dynamic coastal zone	Liu, Liang-Ying; Wang, Ji-Zhong; Wong, Charles S.; Qiu, Jian-Wen; Zeng, Eddy Y.	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	2013	32	2
Composition and source identification of polycyclic aromatic hydrocarbons in mangrove sediments of Peninsular Malaysia: indication of anthropogenic input	Raza, Muhammad; Zakaria, Mohamad Pauzi; Hashim, Nor Rasidah; Yim, Un Hyuk; Kannan, Narayanan; Ha, Sung Yong	ENVIRONMENTAL EARTH SCIENCES	2013	70	6
Biomarker responses in Atlantic cod (Gadus morhua) exposed to produced water from a North Sea oil field: Laboratory and field assessments	Sundt, Rolf C.; Ruus, Anders; Jonsson, Henrik; Skarpheoinsdottir, Halldora; Meier, Sonnich; Grung, Merete; Beyer, Jonny; Pampanin, Daniela M.	MARINE POLLUTION BULLETIN	2012	64	1
Evaluation of tropical water sources and mollusks in southern Brazil using microbiological, biochemical, and chemical parameters	Marques Souza, Doris Sobral; Dores Ramos, Ana Paula; Nunes, Fabricio Flores; Moresco, Vanessa; Taniguchi, Satie; Guiguet Leal, Diego Averaldo; Sasaki, Silvio Tarou; Bicego, Marcia Caruso; Montone, Rosalinda Carmela; Durigan, Mauricio; Teixeira, Adriano Luiz; Pilotto, Mariana Range; Delfino, Nicesio; Bueno Franco, Regina Maura; Rodrigues de Melo, Claudio Manoel; Dias Bainy, Afonso Celso; Monte Barardi, Celia Regina	ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	2012	76	

Regional assessment of PAHs contamination in SE Brazil using brown mussels (Perna perna Linnaeus 1758)	Yoshimine, Renato V.; Carreira, Renato S.; Scofield, Arthur L.; Wagener, Angela L. R.	MARINE POLLUTION BULLETIN	2012	64	11
Data evaluation of tar oil degradation using comprehensive GC(2)/MS: individual compounds and principal component analysis	Vasilieva, Viktoriya; Janik, Les; Scherr, Kerstin E.; Edelmann, Eva; Loibner, Andreas P.	JOURNAL OF CHEMICAL TECHNOLOGY AND BIOTECHNOLOGY	2012	87	9
Effects of in vivo chronic hydrocarbons pollution on sanitary status and immune system in sea bass (Dicentrarchus labrax L.)	Danion, Morgane; Le Floch, Stephane; Kanan, Rami; Lamour, Francois; Quentel, Claire	AQUATIC TOXICOLOGY	2011	105	04-Mar
Alkylphenols and polycyclic aromatic hydrocarbons in eastern Mediterranean Spanish coastal marine bivalves	Bouzas, Alberto; Aguado, Daniel; Marti, Nuria; Manuel Pastor, Jose; Herraez, Rosa; Campins, Pilar; Seco, Aurora	ENVIRONMENTAL MONITORING AND ASSESSMENT	2011	176	04-Jan
Water Column Monitoring of the Biological Effects of Produced Water from the Ekofisk Offshore Oil Installation from 2006 to 2009	Brooks, Steven J.; Harman, Christopher; Grung, Merete; Farmen, Eivind; Ruus, Anders; Vingen, Sjur; Godal, Brit F.; Barsiene, Janina; Andreikenaite, Laura; Skarpheoinsdottir, Halldora; Liewenborg, Birgitta; Sundt, Rolf C.	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART A-CURRENT ISSUES	2011	74	09-Jul
Field comparison of passive sampling and biological approaches for measuring exposure to PAH and alkylphenols from offshore produced water discharges	Harman, Christopher; Brooks, Steven; Sundt, Rolf C.; Meier, Sonnich; Grung, Merete	MARINE POLLUTION BULLETIN	2011	63	12-May
Bioconcentration and immunotoxicity of an experimental oil spill in European sea bass (Dicentrarchus labrax L.)	Danion, Morgane; Le Floch, Stephane; Lamour, Francois; Guyomarch, Julien; Quentel, Claire	ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	2011	74	8
Repeated Sampling of Atlantic Cod (Gadus morhua) for Monitoring of Nondestructive Parameters During Exposure to a Synthetic Produced Water	Holth, T. F.; Beylich, B. A.; Camus, L.; Klobucar, G. I. V.; Hylland, K.	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART A-CURRENT ISSUES	2011	74	09-Jul
Organic Contamination of Settled House Dust, A Review for Exposure Assessment Purposes	Mercier, Fabien; Glorennec, Philippe; Thomas, Olivier; Le Bot, Barbara	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2011	45	16
Organic extracts of urban air pollution particulate matter (PM2.5)-induced genotoxicity and oxidative stress in human lung bronchial epithelial cells (BEAS-2B cells)	Oh, Seung Min; Kim, Ha Ryong; Park, Yong Joo; Lee, Soo Yeun; Chung, Kyu Hyuck	MUTATION RESEARCH-GENETIC TOXICOLOGY AND ENVIRONMENTAL MUTAGENESIS	2011	723	2
Effects of in vivo chronic hydrocarbons pollution on sanitary status and immune system in sea bass (Dicentrarchus labrax L.)	Danion, Morgane; Le Floch, Stephane; Kanan, Rami; Lamour, Francois; Quentel, Claire	AQUATIC TOXICOLOGY	2011	105	04-Mar
Alkylphenols and polycyclic aromatic hydrocarbons in eastern Mediterranean Spanish coastal	Bouzas, Alberto; Aguado, Daniel; Marti, Nuria; Manuel Pastor, Jose; Herraez, Rosa; Campins, Pilar; Seco,	ENVIRONMENTAL MONITORING AND ASSESSMENT	2011	176	04-Jan

marine bivalves	Aurora				
Anthropogenic organic contaminants in water, sediments and benthic organisms of the mangrove-fringed Segara Anakan Lagoon, Java, Indonesia	Dsikowitzky, Larissa; Nordhaus, Inga; Jennerjahn, Tim C.; Khrycheva, Polina; Sivatharshan, Yoganathan; Yuwono, Edy; Schwarzbauer, Jan	MARINE POLLUTION BULLETIN	2011	62	4
Bioconcentration and immunotoxicity of an experimental oil spill in European sea bass (Dicentrarchus labrax L.)	Danion, Morgane; Le Floch, Stephane; Lamour, Francois; Guyomarch, Julien; Quentel, Claire	ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	2011	74	8
Contamination of cheese by polycyclic aromatic hydrocarbons in traditional smoking. Influence of the position in the smokehouse on the contamination level of smoked cheese	Guillen, M. D.; Palencia, G.; Ibargoitia, M. L.; Fresno, M.; Sopelana, P.	JOURNAL OF DAIRY SCIENCE	2011	94	4
Optimisation of pressurised liquid extraction for the ultra-trace quantification of 20 priority substances from the European Water Framework Directive in atmospheric particles by GC-MS and LC-FLD-MS/MS	Becouze, Celine; Wiest, Laure; Baudot, Robert; Bertrand-Krajewski, Jean-Luc; Cren-Olive, Cecile	ANALYTICA CHIMICA ACTA	2011	693	02-Jan
Effect-Directed Analysis of Mutagens in Ambient Airborne Particles	Durant, John L.; Lafleur, Arthur L.	Effect-Directed Analysis of Complex Environmental Contamination	2011	15	
Contamination of cheese by polycyclic aromatic hydrocarbons in traditional smoking. Influence of the position in the smokehouse on the contamination level of smoked cheese.	Gullen, M. D.; Palencia, G.; Ibargoitia, M. L.; Fresno, M.; Sopelana, P.	Journal of Dairy Science	2011	94	4
Human Health Risk Assessment From Exposure to Polycyclic Aromatic Hydrocarbons and Alkylated PAHs in the Hebei-Spirit Oil Spill Area	Lee, Jong-Hyeon; Kim, Chan-Kook; Shim, Won-Joon; Yim, Un-Hyuk	EPIDEMIOLOGY	2011	22	1
Bioanalytical characterisation of multiple endocrine- and dioxin-like activities in sediments from reference and impacted small rivers	Kinani, Said; Bouchonnet, Stephane; Creusot, Nicolas; Bourcier, Sophie; Balaguer, Patrick; Porcher, Jean-Marc; Ait-Aissa, Selim	ENVIRONMENTAL POLLUTION	2010	158	1
Development of Atlantic cod (Gadus morhua) exposed to produced water during early life stages Effects on embryos, larvae, and juvenile fish	Meier, Sonnich; Morton, H. Craig; Nyhammer, Gunnar; Grosvik, Bjorn Einar; Makhotin, Valeri; Geffen, Audrey; Boitsov, Stepan; Kvestad, Karen Anita; Bohne-Kjersem, Anneli; Goksoyr, Anders; Folkvord, Arild; Klungsoyr, Jarle; Svardal, Asbjorn	MARINE ENVIRONMENTAL RESEARCH	2010	70	5
Monitoring North Sea oil production discharges using passive sampling devices coupled with in vitro bioassay techniques	Harman, Christopher; Farmen, Eivind; Tollefsen, Knut Erik	JOURNAL OF ENVIRONMENTAL MONITORING	2010	12	9

Monitoring of PAHs and alkylated PAHs in aquatic organisms after 1 month from the Solar I oil spill off the coast of Guimaras Island, Philippines	Uno, Seiichi; Koyama, Jiro; Kokushi, Emiko; Monteclaro, Harold; Santander, Sheryll; Cheikyula, J. Orkuma; Miki, Shizuho; Anasco, Nathaniel; Pahila, Ida G.; Taberna, Hilario S., Jr.; Matsuoka, Tatsuro	ENVIRONMENTAL MONITORING AND ASSESSMENT	2010	165	04-Jan
Synergistic Ecotoxicity of APEOs-PAHs in Rivers and Sediments: Is there a Potential Health Risk?	Zoller, Uri; Hushan, Marwan	Reviews on Environmental Health	2010	25	4
The possibility of removal of endocrine disrupters from paper mill waste waters using anaerobic and aerobic biological treatment, membrane bioreactor, ultra-filtration, reverse osmosis and advanced oxidation processes	Balabanic, D.; Hermosilla, D.; Blanco, A.; Merayo, N.; Klemencic, A. Krivograd	ENVIRONMENTAL TOXICOLOGY III	2010	132	
Ecosystem health of the Baltic Sea: HELCOM Initial Holistic Assessment.		Baltic Sea Environment Proceedings	2010	122	
Effect-related monitoring: estrogen-like substances in groundwater	Kuch, Bertram; Kern, Frieder; Metzger, Joerg W.; von der Trenck, Karl Theo	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	2010	17	2
Comparison of Alkylnitronaphthalenes Formed in NO3 and OH Radical-Initiated Chamber Reactions with those Observed in Ambient Air	Wang, Lin; Atkinson, Roger; Arey, Janet	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2010	44	8
Polycyclic Aromatic Hydrocarbons in Soil of the Canadian River Floodplain in Oklahoma	Sartori, Fabio; Wade, Terry L.; Sericano, Jose L.; Mohanty, Binayak P.; Smith, Kevin A.	JOURNAL OF ENVIRONMENTAL QUALITY	2010	39	2
Synergistic Ecotoxicity of APEOs-PAHs in Rivers and Sediments: Is there a Potential Health Risk?	Zoller, Uri; Hushan, Marwan	Reviews on Environmental Health	2010	25	4
The possibility of removal of endocrine disrupters from paper mill waste waters using anaerobic and aerobic biological treatment, membrane bioreactor, ultra-filtration, reverse osmosis and advanced oxidation processes	Balabanic, D.; Hermosilla, D.; Blanco, A.; Merayo, N.; Klemencic, A. Krivograd	ENVIRONMENTAL TOXICOLOGY III	2010	132	
Ecosystem health of the Baltic Sea: HELCOM Initial Holistic Assessment.		Baltic Sea Environment Proceedings	2010	122	
Biomagnification profiles of polycyclic aromatic hydrocarbons, alkylphenols and polychlorinated biphenyls in Tokyo Bay elucidated by delta C-13 and delta N-15 isotope ratios as guides to trophic web structure	Takeuchi, Ichiro; Miyoshi, Noriko; Mizukawa, Kaoruko; Takada, Hideshige; Ikemoto, Tokutaka; Omori, Koji; Tsuchiya, Kotaro	MARINE POLLUTION BULLETIN	2009	58	5
Genotoxicity of Environmentally Relevant Concentrations of Water-	Holth, Tor F.; Beylich, Bjornar A.; Skarphedinsdottir, Halldora;	ENVIRONMENTAL SCIENCE &	2009	43	9

Soluble Oil Components in Cod (Gadus morhua)	Liewenborg, Birgitta; Grung, Merete; Hylland, Ketil	TECHNOLOGY			
Polycyclic Aromatic Hydrocarbon (PAH) Metabolites in Atlantic Cod Exposed via Water or Diet to a Synthetic Produced Water	Grung, Merete; Holth, Tor Fredrik; Jacobsen, Marte Rindal; Hylland, Ketil	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART A-CURRENT ISSUES	2009	72	04-Mar
Development of a laboratory exposure system using marine fish to carry out realistic effect studies with produced water discharged from offshore oil production	Sundt, Rolf C.; Meier, Sonnich; Jonsson, Grete; Sanni, Steinar; Beyer, Jonny	MARINE POLLUTION BULLETIN	2009	58	9
Task 5: integrated biomonitoring and bioaccumulation of contaminants in biota of the cANIMIDA study area: Final report. 2004-2006 field seasons consolidated report.	Neff, Jerry M.; Trefry, John H.; Durrell, Gregory	OCS Study Report MMS	2009	2009-037	
Monitoring and Reducing Exposure of Infants to Pollutants in House Dust	Roberts, John W.; Wallace, Lance A.; Camann, David P.; Dickey, Philip; Gilbert, Steven G.; Lewis, Robert G.; Takaro, Tim K.	REVIEWS OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY, VOL 201	2009	201	
Searching for anthropogenic contaminants in human breast adipose tissues using gas chromatography-time-of-flight mass spectrometry	Hernandez, Felix; Portoles, Tania; Pitarch, Elena; Lopez, Francisco J.	JOURNAL OF MASS SPECTROMETRY	2009	44	1
Occupational exposure to potential endocrine disruptors: further development of a job exposure matrix	Brouwers, M. M.; van Tongeren, M.; Hirst, A. A.; Bretveld, R. W.; Roeleveld, N.	OCCUPATIONAL AND ENVIRONMENTAL MEDICINE	2009	66	9
Contamination profiles of heavy metals, organochlorine pesticides, polycyclic aromatic hydrocarbons and alkylphenols in sediment and oyster collected from marsh/estuarine Savannah GA, USA	Kumar, Kurunthachalarn Senthil; Sajwan, Kenneth S.; Richardson, Joseph P.; Kannan, Kurunthachalam	MARINE POLLUTION BULLETIN	2008	56	1
Chemical and biochemical tools to assess pollution exposure in cultured fish	Fernandes, Denise; Zanuy, Silvia; Bebianno, Maria Joao; Porte, Cinta	ENVIRONMENTAL POLLUTION	2008	152	1
Assessment of pollution along the Northern Iberian shelf by the combined use of chemical and biochemical markers in two representative fish species	Fernandes, Denise; Andreu-Sanchez, Oscar; Bebianno, Maria Joao; Porte, Cinta	ENVIRONMENTAL POLLUTION	2008	155	2
Distribution profiles of endocrine disrupting PAHs/APEOs in river sediments: is there a potential ecotoxicological problem?	Zoller, Uri	WATER SCIENCE AND TECHNOLOGY	2008	57	2
Contamination profiles of heavy metals, organochlorine pesticides, polycyclic aromatic hydrocarbons	Kumar, Kurunthachalarn Senthil; Sajwan, Kenneth S.; Richardson, Joseph P.; Kannan, Kurunthachalam	MARINE POLLUTION BULLETIN	2008	56	1

and alkylphenols in sediment and oyster collected from marsh/estuarine Savannah GA, USA					
A comparison of concentrations of polycyclic aromatic compounds detected in dust samples from various regions of the world	Naspinski, Christine; Lingenfelter, Rebecca; Cizmas, Leslie; Naufal, Ziad; He, Ling Yu; Islamzadeh, Arif; Li, Zhiwen; Li, Zhu; McDonald, Thomas; Donnelly, K. C.	ENVIRONMENT INTERNATIONAL	2008	34	7
Mercury, trace elements and organic constituents in atmospheric fine particulate matter, Shenandoah National Park, Virginia, USA: A combined approach to sampling and analysis	Kolker, Allan; Engle, Mark A.; Orem, William H.; Bunnell, Joseph E.; Lerch, Harry E.; Krabbenhoft, David P.; Olson, Mark L.; McCord, Jamey D.	GEOSTANDARDS AND GEOANALYTICAL RESEARCH	2008	32	3
Effects-directed analysis of organic toxicants in wastewater effluent from Zagreb, Croatia	Grung, Merete; Lichtenthaler, Rainer; Ahel, Marijan; Tollefsen, Knut-Erik; Langford, Katherine; Thomas, Kevin V.	CHEMOSPHERE	2007	67	1
Distribution and sources of aliphatic and polycyclic aromatic hydrocarbons in surface sediments, fish and bivalves of Abu Qir Bay (Egyptian Mediterranean Sea)	El Deeb, Kamal Z.; Said, Tarek O.; El Naggar, Mohamed H.; Shreadah, Mohamed A.	BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	2007	78	5
Evaluating human risk from exposure to alkylated PAHs in an aquatic system	Baird, Sandra J. S.; Bailey, Elisabeth A.; Vorhees, Donna J.	HUMAN AND ECOLOGICAL RISK ASSESSMENT	2007	13	2
Human biomonitoring: State of the art	Angerer, Juergen; Ewers, Ulrich; Wilhelm, Michael	INTERNATIONAL JOURNAL OF HYGIENE AND ENVIRONMENTAL HEALTH	2007	210	04-Mar
Organic contaminants from sewage sludge applied to agricultural soils - False alarm regarding possible problems for food safety?	Laturnus, Frank; von Arnold, Karin; Gron, Christian	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	2007	14	1
1,2-Dimethylimidazole-4-sulfonyl chloride, a novel derivatization reagent for the analysis of phenolic compounds by liquid chromatography electrospray tandem mass spectrometry: Application to 1-hydroxypyrene in human urine	Xu, Li; Spink, David C.	JOURNAL OF CHROMATOGRAP HY B-ANALYTICAL TECHNOLOGIES IN THE BIOMEDICAL AND LIFE SCIENCES	2007	855	2
Development of a house dust standard reference material for the determination of organic contaminants	Poster, Dianne L.; Kucklick, John R.; Schantz, Michele M.; Vander Pol, Stacy S.; Leigh, Stefan D.; Wiset, Stephen A.	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2007	41	8
Evaluating human risk from exposure to alkylated PAHs in an aquatic system	Baird, Sandra J. S.; Bailey, Elisabeth A.; Vorhees, Donna J.	HUMAN AND ECOLOGICAL RISK ASSESSMENT	2007	13	2
Investigation of the solvent extracts of humic organic matter (HOM) isolated from the Ravenna Lagoon to study environmental pollution and	Poerschmann, Juergen; Fabbri, Daniele; Gorecki, Tadeusz	CHEMOSPHERE	2007	70	2

microbial communities					
Polycyclic aromatic hydrocarbons in sediments: An overview of risk-related issues	Menzie, Cbarles A.; Coleman, Andrew J.	HUMAN AND ECOLOGICAL RISK ASSESSMENT	2007	13	2
Organic Contaminants from Sewage Sludge Applied to Agricultural Soils. False Alarm Regarding Possible Problems for Food Safety? (8 pp).	Gron, Christian	Environmental science and pollution research international	2007	14 Suppl 1	
Magnitude and extent of contaminated sediment and toxicity in Chesapeake Bay.	Hartwell, S. Ian; Hameedi, Jawed	NOAA Technical Memorandum NOS NCCOS	2007	47	
Investigation of micronuclei and other nuclear abnormalities in peripheral blood and kidney of marine fish treated with crude oil	Barsiene, J; Dedonyte, V; Rybakovas, A; Andreikenaite, L; Andersen, OK	AQUATIC TOXICOLOGY	2006	78	
Effects of North Sea oil and alkylphenols on biomarker responses in juvenile Atlantic cod (Gadus morhua)	Sturve, Joachim; Hasselberg, Linda; Falth, Herman; Celander, Malin; Forlin, Lars	AQUATIC TOXICOLOGY	2006	78	
May organic pollutants affect fish populations in the North Sea?	Hylland, K; Beyer, J; Berntssen, M; Klungsoyr, J; Lang, T; Balk, L	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART A-CURRENT ISSUES	2006	69	02-Jan
Expression of cytoskeletal proteins, cross-reacting with anti-CYP1A, in Mytilus sp exposed to organic contaminants	Jonsson, H; Schiedek, D; Goksoyr, A; Grosvik, BE	AQUATIC TOXICOLOGY	2006	78	
The BEEP Stavanger Workshop: Mesocosm exposures	Sundt, RC; Pampanin, DM; Larsen, BK; Brede, C; Herzke, D; Bjornstad, A; Andersen, OK	AQUATIC TOXICOLOGY	2006	78	
Biomarkers detected in Chub (Leuciscus cephalus L.) to evaluate contamination of the Elbe and Vltava rivers, Czech Republic	Randak, T; Zlabek, V; Kolarova, J; Svobodova, Z; Hajslova, J; Siroka, Z; Janska, M; Pulkrabova, J; Cajka, T; Jarkovsky, J	BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	2006	76	2
Specificity of the peroxisome proliferation response in mussels exposed to environmental pollutants	Cajaraville, Miren P.; Ortiz-Zarragoitia, Maren	AQUATIC TOXICOLOGY	2006	78	
An overview of the BEEP Stavanger workshop	Pampanin, DM; Viarengo, A; Garrigues, P; Andersen, OK	AQUATIC TOXICOLOGY	2006	78	
Simultaneous determination of urinary hydroxylated metabolites of naphthalene, fluorene, phenanthrene, fluoranthene and pyrene as multiple biomarkers of exposure to polycyclic aromatic hydrocarbons	Chetiyanukornkul, Thaneeya; Toriba, Akira; Kameda, Takayuki; Tang, Ning; Hayakawa, Kazuichi	ANALYTICAL AND BIOANALYTICAL CHEMISTRY	2006	386	3
Organic/inorganic hybrid filters based on dendritic and cyclodextrin nanosponges for the removal of organic pollutants from water	Arkas, M; Allabashi, R; Tsiourvas, D; Mattausch, EM; Perfler, R	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2006	40	8

Characterization of trace organic contaminants in marine sediment from Yeongil Bay, Korea: 1. Instrumental analyses	Koh, CH; Khim, JS; Villeneuve, DL; Kannan, K; Giesy, JP	ENVIRONMENTAL POLLUTION	2006	142	1
Determination of selective quinones and quinoid radicals in airborne particulate matter and vehicular exhaust particles	Valavanidis, A; Fiotakis, K; Vlahogianni, T; Papadimitriou, V; Pantikaki, V	ENVIRONMENTAL CHEMISTRY	2006	3	2
Molecular and stable carbon isotopic characterization of PAH contaminants at McMurdo Station, Antarctica	Kim, Moonkoo; Kennicutt, Mahlon C., II; Qian, Yaorong	MARINE POLLUTION BULLETIN	2006	52	12
Determination of selective quinones and quinoid radicals in airborne particulate matter and vehicular exhaust particles (vol 3, pg 118, 2006)	Valavanidis, Athanasios; Fiotakis, Konstantinos; Vlahogianni, Thomais; Papadimitriou, Vasilios; Pantikaki, Vayia	ENVIRONMENTAL CHEMISTRY	2006	3	3
Presence and distribution of PAHs, PCBs and DDE in feed and sediments under salmon aquaculture cages in the Bay of Fundy, New Brunswick, Canada	Hellou, J; Haya, K; Steller, S; Burridge, L	AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS	2005	15	4
Pressurized liquid extraction using water/isopropanol coupled with solid-phase extraction cleanup for semivolatile organic compounds, polycyclic aromatic hydrocarbons (PAH), and alkylated PAH homolog groups in sediment	Burkhardt, MR; Zaugg, SD; Burbank, TL; Olson, MC; Iverson, JL	ANALYTICA CHIMICA ACTA	2005	549	02-Jan
Analytical investigations on a releasing agent application in aluminium diecasting	Wichmann, H; Sprenger, R; Ehlers, N; Bahadir, MA	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	2005	12	4
Toxicity of oil sands to early life stages of fathead minnows (Pimephales promelas)	Colavecchia, MV; Backus, SM; Hodson, PV; Parrott, JL	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	2004	23	7
Bioconcentration, biotransformation, and elimination of polycyclic aromatic hydrocarbons in sheepshead minnows (Cyprinodon variegatus) exposed to contaminated seawater	Jonsson, G; Bechmann, RK; Bamber, SD; Baussant, T	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	2004	23	6
The identification of readily bioavailable pollutants in Lake Shkodra/Skadar using semipermeable membrane devices (SPMDs), bioassays and chemical analysis	Rastall, AC; Neziri, A; Vukovic, Z; Jung, C; Mijovic, S; Hollert, H; Nikcevic, S; Erdinger, L	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	2004	11	4
The polycyclic aromatic hydrocarbon and geochemical biomarker composition of sediments from sea lochs on the west coast of Scotland	Webster, L; Fryer, RJ; Megginson, C; Dalgarno, EJ; McIntosh, AD; Moffat, CF	JOURNAL OF ENVIRONMENTAL MONITORING	2004	6	3
Protein expression in chronic	Andersen, Odd Ketil; Bjornstad,	Marine	2004	58	05-Feb

exposure field samples compared to controlled laboratory exposures	Anne; Monsinjon, Tiphaine; Knigge, Thomas; Larsen, Bodil Katrine	Environmental Research			
Identification and characterization of novel stable deoxyguanosine and deoxyadenosine adducts of benzo[alpha]pyrene-7,8-quinone from reactions at physiological pH	Balu, N; Padgett, WT; Lambert, GR; Swank, AE; Richard, AM; Nesnow, S	CHEMICAL RESEARCH IN TOXICOLOGY	2004	17	6
Toxicity assessment of complex mixtures remains a goal	Donnelly, KC; Lingenfelter, R; Cizmas, L; Falahatpisheh, MH; Qian, YC; Tang, Y; Garcia, S; Ramos, K; Tiffany-Castiglioni, E; Mumtaz, MM	ENVIRONMENTAL TOXICOLOGY AND PHARMACOLOGY	2004	18	2
Comparison of immunoassay and gas chromatography-mass spectrometry for measurement of polycyclic aromatic hydrocarbons in contaminated soil	Chuang, JC; Van Emon, JM; Chou, YL; Junod, N; Finegold, JK; Wilson, NK	ANALYTICA CHIMICA ACTA	2003	486	1
Analytical and environmental chemistry in the framework of risk assessment and management: The lagoon of Venice as a case study	Pojana, G; Critto, A; Micheletti, C; Carlon, C; Busetti, F; Marcomini, A	CHIMIA	2003	57	9
Persistent toxic substances (PTS) in fats: state of the art according to the report of the United nations environment programme (UNEP)	Narbonne, JFO	OCL-OLEAGINEUX CORPS GRAS LIPIDES	2003	10	4
Sources and significance of alkane and PAH hydrocarbons in Canadian arctic rivers	Yunker, MB; Backus, SM; Graf Pannatier, E; Jeffries, DS; Macdonald, RW	ESTUARINE COASTAL AND SHELF SCIENCE	2002	55	1
Bitumen fumes: review of work on the potential risk to workers and the present knowledge on its origin	Binet, S; Pfohl-Leszkowicz, A; Brandt, H; Lafontaine, M; Castegnaro, M	SCIENCE OF THE TOTAL ENVIRONMENT	2002	300	03-Jan
Distribution of polycyclic aromatic hydrocarbons in soils and terrestrial biota after a spill of crude oil in Trecate, Italy	Brandt, CA; Becker, JM; Porta, A	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	2002	21	8
PAHs and petroleum markers in the atmospheric environment of Alexandria City, Egypt	Barakat, AO	WATER AIR AND SOIL POLLUTION	2002	139	04-Jan
Application of P450 reporter gene system (RGS) in the analysis of sediments near pulp and paper mills	Jones, JM; Anderson, JW; Wiegel, JV; Tukey, RH	BIOMARKERS	2001	6	6
Identification of selected hormonally active agents and animal mammary carcinogens in commercial and residential air and dust samples	Rudel, RA; Brody, JG; Spengler, JC; Vallarino, J; Geno, PW; Sun, G; Yau, A	JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION	2001	51	4
Application of P450 reporter gene system (RGS) in the analysis of sediments near pulp and paper mills	Jones, JM; Anderson, JW; Wiegel, JV; Tukey, RH	BIOMARKERS	2001	6	6
Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development	Heintz, RA; Rice, SD; Wertheimer, AC; Bradshaw, RF; Thrower, FP; Joyce, JE; Short, JW	MARINE ECOLOGY PROGRESS SERIES	2000	208	

Exposure of Pacific herring to weathered crude oil: Assessing effects on ova	Carls, MG; Hose, JE; Thomas, RE; Rice, SD	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	2000	19	6
Chemical characterization and bioactivity of polycyclic aromatic hydrocarbons from non-oxidative thermal treatment of pyrene-contaminated soil at 250-1.000 degrees C	Richter, H; Risoul, V; Lafleur, AL; Plummer, EF; Howard, JB; Peters, WA	ENVIRONMENTAL HEALTH PERSPECTIVES	2000	108	8
The impact of environmental epidemiology/toxicology and public health practice in the Great Lakes	Hicks, Heraline E.; Cibulas, William; De Rosa, Christopher T.	Environmental Epidemiology and Toxicology	2000	2	1
Real-time and integrated measurement of potential human exposure to particle-bound polycyclic aromatic hydrocarbons (PAHs) from aircraft exhaust	Childers, Jeffrey W.; Witherspoon, Carlton L.; Smith, Leslie B.; Pleil, Joachim D.	Environmental Health Perspectives	2000	108	9
Polynuclear aromatic hydrocarbons in American oysters Crassostrea virginica from the Terminos Lagoon, Campeche, Mexico	Norena-Barroso, E; Gold-Bouchot, G; Zapata-Perez, O; Sericano, JL	MARINE POLLUTION BULLETIN	1999	38	8
Levels, persistence and bioavailability of organic contaminants present in marine harbor sediments impacted by raw sewage	Hellou, J; Mackay, D; Banoub, J	CHEMOSPHERE	1999	38	2
The occurrence and bioavailability of retene and resin acids in sediments of a lake receiving BKME (bleached kraft mill effluent)	Leppanen, HJT; Oikari, AOJ	WATER SCIENCE AND TECHNOLOGY	1999	40	12-Nov
Alkylphenols, polycyclic aromatic hydrocarbons, and organochlorines in sediment from Lake Shihwa, Korea: Instrumental and bioanalytical characterization	Khim, JS; Villeneuve, DL; Kannan, K; Lee, KT; Snyder, SA; Koh, CH; Giesy, JP	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	1999	18	11
Polynuclear aromatic hydrocarbons in American oysters Crassostrea virginica from the Terminos Lagoon, Campeche, Mexico	Norena-Barroso, E; Gold-Bouchot, G; Zapata-Perez, O; Sericano, JL	MARINE POLLUTION BULLETIN	1999	38	8
Compound-specific gas chromatographic mass spectrometric analysis of alkylated and parent polycyclic aromatic hydrocarbons in waters, sediments, and aquatic organisms	Means, JC	JOURNAL OF AOAC INTERNATIONAL	1998	81	3
Selected non-heterocyclic polycyclic aromatic hydrocarbons.		Environmental Health Criteria	1998	ISBN 92-4-157202-7	No. 202
Organochlorine contaminants in fish and polycyclic aromatic hydrocarbons in sediments from the Barents Sea	Stange, K; Klungsoyr, J	ICES JOURNAL OF MARINE SCIENCE	1997	54	3
Polynuclear aromatic hydrocarbons (PAHs) in fish from the Red Sea	Douabul, AAZ; Heba, HMA; Fareed,	HYDROBIOLOGIA	1997	352	

Coast of Yemen	KH				
Occurrence and concentrations of polycyclic aromatic hydrocarbons in semipermeable membrane devices and clams in three urban streams of the Dallas-Fort Worth Metropolitan Area, Texas	Moring, JB; Rose, DR	CHEMOSPHERE	1997	34	3
Polynuclear aromatic hydrocarbons (PAHs) in fish from the Red Sea Coast of Yemen	Douabul, AAZ; Heba, HMA; Fareed, KH	HYDROBIOLOGIA	1997	352	
Human DNA adduct measurements: State of the art	Poirier, MC; Weston, A	ENVIRONMENTAL HEALTH PERSPECTIVES	1996	104	
Biomonitoring human exposure to environmental carcinogenic chemicals	Farmer, PB; Sepai, O; Lawrence, R; Autrup, H; Nielsen, PS; Vestergard, AB; Waters, R; Leuratti, C; Jones, NJ; Stone, J; Baan, RA; vanDelft, JHM; Steenwinkel, MJST; Kyrtopoulos, SA; Souliotis, VL; Theodorakopoulos, N; Bacalis, NC; Natarajan, AT; Tates, AD; Haugen, A; Andreassen, A; Ovrebo, S; Shuker, DEG; Amaning, KS; Schouft, A; Ellul, A; Garner, RC; Dingley, KH; Abbondandolo, A; Merlo, F; Cole, J; Aldrich, K; Beare, D; Capulas, E; Rowley, G; Waugh, APW; Povey, AC; Haque, K; KirschVolders, M; VanHummelen, P; Castelain, P	MUTAGENESIS	1996	11	4
BIOCONCENTRATION OF POLYCYCLIC AROMATIC-COMPOUNDS FROM SEDIMENTS TO MUSCLE OF FINFISH	HELLOU, J; MACKAY, D; FOWLER, B	ENVIRONMENTAL SCIENCE & TECHNOLOGY	1995	29	10
GAS CHROMATOGRAPHIC-MASS SPECTROMETRIC ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBON METABOLITES IN ANTARCTIC FISH (NOTOTHENIA GIBBERIFRONS) INJECTED WITH DIESEL FUEL ARCTIC	YU, Y; WADE, TL; FANG, J; MCDONALD, S; BROOKS, JM	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	1995	29	2
Human exposure and dosimetry of polycyclic aromatic hydrocarbons in urine from Xuan Wei, China with high lung cancer mortality associated with exposure to unvented coal smoke	Mumford, JL; Li, XM; Hu, FD; Lu, XB; Chuang, JC	CARCINOGENESIS	1995	16	12
COMPOSITION AND ORIGINS OF POLYCYCLIC AROMATIC-HYDROCARBONS IN THE MACKENZIE RIVER AND ON THE BEAUFORT SEA SHELF	YUNKER, MB; MACDONALD, RW	ARCTIC	1995	48	2
BIOACCUMULATION OF AROMATIC-HYDROCARBONS	HELLOU, J; PAYNE, JF; UPSHALL, C; FANCEY, LL;	ARCHIVES OF ENVIRONMENTAL	1994	27	4

FROM SEDIMENTS - A DOSE-RESPONSE STUDY WITH FLOUNDER (PSEUDOPLEURONECTES-AMERICANUS)	HAMILTON, C	CONTAMINATION AND TOXICOLOGY			
POLYCYCLIC AROMATIC-COMPOUNDS IN NORTHWEST ATLANTIC COD (GADUS-MORHUA)	HELLOU, J; PAYNE, JF; HAMILTON, C	ENVIRONMENTAL POLLUTION	1994	84	2
POLYCYCLIC AROMATIC-HYDROCARBONS (PAH) - PROBLEMS AND PROGRESS IN SAMPLING, ANALYSIS AND INTERPRETATION	LAW, RJ; BISCAYA, JL	MARINE POLLUTION BULLETIN	1994	29	05-Apr
COMBUSTION OF DIESEL FUEL FROM A TOXICOLOGICAL PERSPECTIVE .2. TOXICITY	SCHEEPERS, PTJ; BOS, RP	INTERNATIONAL ARCHIVES OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH	1992	64	3
COMBUSTION OF DIESEL FUEL FROM A TOXICOLOGICAL PERSPECTIVE .1. ORIGIN OF INCOMPLETE COMBUSTION PRODUCTS	SCHEEPERS, PTJ; BOS, RP	INTERNATIONAL ARCHIVES OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH	1992	64	3
CHEMICAL CHARACTERIZATION OF MUTAGENIC FRACTIONS OF PARTICLES FROM INDOOR COAL COMBUSTION - A STUDY OF LUNG-CANCER IN XUAN-WEI, CHINA	CHUANG, JC; WISE, SA; CAO, S; MUMFORD, JL	ENVIRONMENTAL SCIENCE & TECHNOLOGY	1992	26	5
HYDROCARBON AND COPROSTANOL LEVELS IN SEAWATER, SEA-ICE ALGAE AND SEDIMENTS NEAR DAVIS-STATION IN EASTERN ANTARCTICA - A REGIONAL SURVEY AND PRELIMINARY-RESULTS FOR A FIELD FUEL SPILL EXPERIMENT	GREEN, G; SKERRATT, JH; LEEMING, R; NICHOLS, PD	MARINE POLLUTION BULLETIN	1992	25	12-Sep
XENOBIOTIC COMPOUNDS IN BLUE CRABS FROM A HIGHLY CONTAMINATED URBAN SUBESTUARY	MOTHERSHEAD R F II; HALE R C; GREAVES J	Environmental Toxicology and Chemistry	1991	10	10
DISTRIBUTION AND SOURCES OF POLYCYCLIC AROMATIC-HYDROCARBONS (PAHS) IN STREET DUST FROM THE TOKYO METROPOLITAN-AREA	TAKADA, H; ONDA, T; HARADA, M; OGURA, N	SCIENCE OF THE TOTAL ENVIRONMENT	1991	107	
S9-ACTIVATED AMES ASSAYS OF DIESEL-PARTICLE EXTRACTS - DETECTING INDIRECT-ACTING MUTAGENS IN SAMPLES THAT ARE	BALL, JC; GREENE, B; YOUNG, WC; RICHERT, JFO; SALMEEN, IT	ENVIRONMENTAL SCIENCE & TECHNOLOGY	1990	24	6

DIRECT-ACTING					
BEHAVIOR OF MICROORGANIC POLLUTANTS IN RISING RIVER	ITO M; TAKADA H; OGURA N	Chikyukagaku	1990	24	2
ACUTE TOXICITY TO DAPHNIA-PULEX OF 6 CLASSES OF CHEMICAL-COMPOUNDS POTENTIALLY HAZARDOUS TO GREAT-LAKES AQUATIC BIOTA	SMITH, SB; SAVINO, JF; BLOUIN, MA	JOURNAL OF GREAT LAKES RESEARCH	1988	14	4
ACUTE BIOASSAYS AND HAZARD EVALUATION OF REPRESENTATIVE CONTAMINANTS DETECTED IN GREAT-LAKES FISH	PASSINO, DRM; SMITH, SB	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	1987	6	11
DETERMINATION OF GENOTOXIC POLYCYCLIC AROMATIC-HYDROCARBONS IN A SEDIMENT FROM THE BLACK RIVER (OHIO)	WEST, WR; SMITH, PA; BOOTH, GM; WISE, SA; LEE, ML	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	1986	15	3
CAPILLARY GC ANALYSIS OF DIESEL FUELS USING SIMULTANEOUS PARALLEL TRIPLE DETECTION	WILLIAMS, PT; BARTLE, KD; MILLS, DG; ANDREWS, GE	JOURNAL OF HIGH RESOLUTION CHROMATOGRAPHY & CHROMATOGRAPHY COMMUNICATIONS	1986	9	1
AZAARENES IN RECENT LAKE-SEDIMENTS	WAKEHAM, SG	ENVIRONMENTAL SCIENCE & TECHNOLOGY	1979	13	9
POLYCYCLIC AROMATIC-HYDROCARBONS IN SOILS OF A MOUNTAIN VALLEY - CORRELATION WITH HIGHWAY TRAFFIC AND CANCER INCIDENCE	BLUMER, M; BLUMER, W; REICH, T	ENVIRONMENTAL SCIENCE & TECHNOLOGY	1977	11	12

8.2 Secondary Search Results

Author	Title	Journal	Volume	Issue	Year
Li, Zheng; Romanoff, Lovisa C.; Trinidad, Debra A.; Pittman, Erin N.; Hilton, Donald; Hubbard, Kendra; Carmichael, Hasan; Parker, Jonathan; Calafat, Antonia M.; Sjoedin, Andreas	Quantification of 21 metabolites of methylnaphthalenes and polycyclYunic aromatic hydrocarbons in human urine	ANALYTICAL AND BIOANALYTICAL CHEMISTRY	406	13	2014
Paruk, James D.; Long, Darwin; Perkins, Christopher; East, Andrew; Sigel, Bryan J.; Evers, David C.	Polycyclic Aromatic Hydrocarbons Detected in Common Loons (Gavia immer) Wintering off Coastal Louisiana	WATERBIRDS	37		2014
Crane, Judy L.	Source Apportionment and Distribution of Polycyclic Aromatic Hydrocarbons, Risk Considerations, and Management Implications for Urban Stormwater Pond Sediments in Minnesota, USA	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	66	2	2014
Wickliffe, Jeffrey; Overton, Edward; Frickel, Scott; Howard, Jessi; Wilson, Mark; Simon, Bridget; Echsner, Stephen; Nguyen, Daniel; Gauthe, David; Blake, Diane; Miller, Charles; Elferink, Cornelis; Ansari, Shakeel; Fernando, Harshica; Trapido, Edward; Kane, Andrew	Evaluation of Polycyclic Aromatic Hydrocarbons Using Analytical Methods, Toxicology, and Risk Assessment Research: Seafood Safety after a Petroleum Spill as an Example	ENVIRONMENTAL HEALTH PERSPECTIVES	122	1	2014
Ramirez, Cesar E.; Wang, Chengtao; Gardinali, Piero R.	Fully automated trace level determination of parent and alkylated PAHs in environmental waters by online SPE-LC-APPI-MS/MS	ANALYTICAL AND BIOANALYTICAL CHEMISTRY	406	1	2014
Le Bihanic, Florane; Clerandeau, Christelle; Le Menach, Karyn; Morin, Benedicte; Budzinski, Helene; Cousin, Xavier; Cachot, Jerome	Developmental toxicity of PAH mixtures in fish early life stages. Part II: adverse effects in Japanese medaka	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	21	24	2014
Vignet, Caroline; Le Menach, Karyn; Mazurais, David; Lucas, Julie; Perrichon, Prescilla; Le Bihanic, Florane; Devier, Marie-Helene; Lyphout, Laura; Frere, Laura; Begout, Marie-Laure; Zambonino-Infante, Jose-Luis; Budzinski, Helene; Cousin, Xavier	Chronic dietary exposure to pyrolytic and petrogenic mixtures of PAHs causes physiological disruption in zebrafish - part I: Survival and growth	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	21	24	2014
Meyer, Wiebke; Seiler, Thomas-Benjamin; Christ, Andreas	Mutagenicity, dioxin-like activity and bioaccumulation of alkylated picene and chrysene derivatives in a German lignite	SCIENCE OF THE TOTAL ENVIRONMENT	497		2014
Mu, Jingli; Wang, Juying; Jin, Fei; Wang, Xinhong; Hong, Huasheng	Comparative embryotoxicity of phenanthrene and alkyl-phenanthrene to marine medaka (Oryzias melastigma)	MARINE POLLUTION BULLETIN	85	2	2014
Murawski, Steven A.; Hogarth, William T.; Peebles, Ernst B.;	Prevalence of External Skin Lesions and Polycyclic Aromatic	TRANSACTIONS OF THE	143	4	2014

Barbeiri, Luiz	Hydrocarbon Concentrations in Gulf of Mexico Fishes, Post-Deepwater Horizon	AMERICAN FISHERIES SOCIETY			
Raza, Muhammad; Zakaria, Mohamad Pauzi; Hashim, Nor Rasidah; Yim, Un Hyuk; Kannan, Narayanan; Ha, Sung Yong	Composition and source identification of polycyclic aromatic hydrocarbons in mangrove sediments of Peninsular Malaysia: indication of anthropogenic input	ENVIRONMENTAL EARTH SCIENCES	70	6	2013
Jautzy, Josue; Ahad, Jason M. E.; Gobeil, Charles; Savard, Martine M.	Century-Long Source Apportionment of PAHs in Athabasca Oil Sands Region Lakes Using Diagnostic Ratios and Compound-Specific Carbon Isotope Signatures	ENVIRONMENTAL SCIENCE & TECHNOLOGY	47	12	2013
Yates, Kyari; Pollard, Pat; Davies, Ian; Webster, Lynda; Moffat, Colin	Silicone rubber passive samplers for measuring pore water and exchangeable concentrations of polycyclic aromatic hydrocarbons concentrations in sediments	SCIENCE OF THE TOTAL ENVIRONMENT	463		2013
Jung, Jee-Hyun; Hicken, Corinne E.; Boyd, Daryle; Anulacion, Bernadita F.; Carls, Mark G.; Shim, Won Joon; Incardona, John P.	Geologically distinct crude oils cause a common cardiotoxicity syndrome in developing zebrafish	CHEMOSPHERE	91	8	2013
Yoshimine, Renato V.; Carreira, Renato S.; Scofield, Arthur L.; Wagener, Angela L. R.	Regional assessment of PAHs contamination in SE Brazil using brown mussels (Perna perna Linnaeus 1758)	MARINE POLLUTION BULLETIN	64	11	2012
Vasilieva, Viktoriya; Janik, Les; Scherr, Kerstin E.; Edelmann, Eva; Loibner, Andreas P.	Data evaluation of tar oil degradation using comprehensive GC(2)/MS: individual compounds and principal component analysis	JOURNAL OF CHEMICAL TECHNOLOGY AND BIOTECHNOLOGY	87	9	2012
Danion, Morgane; Le Floch, Stephane; Kanan, et al	Bioconcentration and immunotoxicity of an experimental oil spill in European sea bass (Dicentrarchus labrax L.)	ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	74	8	2011
Danion, Morgane; Le Floch, Stephane; Kanan, Rami; Lamour, Francois; Quentel, Claire	Effects of in vivo chronic hydrocarbons pollution on sanitary status and immune system in sea bass (Dicentrarchus labrax L.)	AQUATIC TOXICOLOGY	105	42067	2011
Oh, Seung Min; Kim, Ha Ryong; Park, Yong Joo; Lee, Soo Yeun; Chung, Kyu Hyuck	Organic extracts of urban air pollution particulate matter (PM2.5)-induced genotoxicity and oxidative stress in human lung bronchial epithelial cells (BEAS-2B cells)	MUTATION RESEARCH-GENETIC TOXICOLOGY AND ENVIRONMENTAL MUTAGENESIS	723	2	2011
Dsikowitzky, Larissa; Nordhaus, Inga; Jennerjahn, Tim C.; Khrycheva, Polina; Sivatharshan, Yoganathan; Yuwono, Edy; Schwarzbauer, Jan	Anthropogenic organic contaminants in water, sediments and benthic organisms of the mangrove-fringed Segara Anakan Lagoon, Java, Indonesia	MARINE POLLUTION BULLETIN	62	4	2011
Lee, Jong-Hyeon; Kim, Chan-Kook;	Human Health Risk Assessment	EPIDEMIOLOGY	22	1	2011

Shim, Won-Joon; Yim, Un-Hyuk	From Exposure to Polycyclic Aromatic Hydrocarbons and Alkylated PAHs in the Hebei-Spirit Oil Spill Area				
Lee, Jong-Hyeon; Kim, Chan-Kook; Shim, Won-Joon; et al.	Human Health Risk Assessment From Exposure to Polycyclic Aromatic Hydrocarbons and Alkylated PAHs in the Hebei-Spirit Oil Spill Area	Joint Conference of International-Society-of-Exposure-Science/International-Society-for-Environmental-Epidemiology	22	1	2010
Uno, Seiichi; Koyama, Jiro; Kokushi, Emiko; Monteclaro, Harold; Santander, Sheryll; Cheikyula, J. Orkuma; Miki, Shizuho; Anasco, Nathaniel; Pahila, Ida G.; Taberna, Hilario S., Jr.; Matsuoka, Tatsuro	Monitoring of PAHs and alkylated PAHs in aquatic organisms after 1 month from the Solar I oil spill off the coast of Guimaras Island, Philippines	ENVIRONMENTAL MONITORING AND ASSESSMENT	165	04-Jan	2010
Neff, Jerry M.; Trefry, John H.; Durrell, Gregory	Task 5: integrated biomonitoring and bioaccumulation of contaminants in biota of the cANIMIDA study area: Final report. 2004-2006 field seasons consolidated report.	OCS Study Report MMS	2009-037		2009
Grung, Merete; Holth, Tor Fredrik; Jacobsen, Marte Rindal; Hylland, Ketil	Polycyclic Aromatic Hydrocarbon (PAH) Metabolites in Atlantic Cod Exposed via Water or Diet to a Synthetic Produced Water	JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH-PART A-CURRENT ISSUES	72	04-Mar	2009
Naspinski, Christine; Lingenfelter, Rebecca; Cizmas, Leslie; et al.	A comparison of concentrations of polycyclic aromatic compounds detected in dust samples from various regions of the world	Environmental International	34	7	2008
Dianne L.; Kucklick, John R.; Schantz, Michele M.	Development of a house dust standard reference material for the determination of organic contaminants	ENVIRONMENTAL SCIENCE & TECHNOLOGY	41	8	2007
Menzie, Cbarles A.; Coleman, Andrew J.	Polycyclic aromatic hydrocarbons in sediments: An overview of risk-related issues	HUMAN AND ECOLOGICAL RISK ASSESSMENT	13	2	2007
Baird, Sandra J. S.; Bailey, Elisabeth A.; Vorhees, Donna J.	Evaluating human risk from exposure to alkylated PAHs in an aquatic system	HUMAN AND ECOLOGICAL RISK ASSESSMENT	13	2	2007
El Deeb, Kamal Z.; Said, Tarek O.; El Naggar, Mohamed H.; Shreadah, Mohamed A.	Distribution and sources of aliphatic and polycyclic aromatic hydrocarbons in surface sediments, fish and bivalves of Abu Qir Bay (Egyptian Mediterranean Sea)	BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	78	5	2007
Burkhardt, MR; Zaugg, SD; Burbank, T	Pressurized liquid extraction using water/isopropanol coupled with solid-phase extraction cleanup for semivolatile organic compounds,	ANALYTICA CHIMICA ACTA	549	02-Jan	2005

	polycyclic aromatic hydrocarbons (PAH), and alkylated PAH homolog groups in sediment				
Hellou, J; Haya, K; Steller, S; Burridge, L	Presence and distribution of PAHs, PCBs and DDE in feed and sediments under salmon aquaculture cages in the Bay of Fundy, New Brunswick, Canada	AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS	15	4	2005
Donnelly, KC; Lingenfelter, R; Cizmas, L; Falahatpisheh, MH; Qian, YC; Tang, Y; Garcia, S; Ramos, K; Tiffany-Castiglioni, E; Mumtaz, MM	Toxicity assessment of complex mixtures remains a goal	ENVIRONMENTAL TOXICOLOGY AND PHARMACOLOGY	18	2	2004
Colavecchia, MV; Backus, SM; Hodson, PV; Parrott, JL	Toxicity of oil sands to early life stages of fathead minnows (Pimephales promelas)	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	23	7	2004
Jonsson, G; Bechmann, RK; Bamber, SD; Baussant, T	Bioconcentration, biotransformation, and elimination of polycyclic aromatic hydrocarbons in sheepshead minnows (Cyprinodon variegatus) exposed to contaminated seawater	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	23	6	2004
Rastall, AC; Neziri, A; Vukovic, Z; Jung, C; Mijovic, S; Hollert, H; Nikcevic, S; Erdinger, L	The identification of readily bioavailable pollutants in Lake Shkodra/Skadar using semipermeable membrane devices (SPMDs), bioassays and chemical analysis	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	11	4	2004
Chuang, JC; Van Emon, JM; Chou, YL; Junod, N; Finegold, JK; Wilson, NK	Comparison of immunoassay and gas chromatography-mass spectrometry for measurement of polycyclic aromatic hydrocarbons in contaminated soil	ANALYTICA CHIMICA ACTA	486	1	2003
Binet, S; Pfohl-Leszkowicz, A; Brandt, H; Lafontaine, M; Castegnaro, M	Bitumen fumes: review of work on the potential risk to workers and the present knowledge on its origin	SCIENCE OF THE TOTAL ENVIRONMENT	300	42007	2002
Brandt, CA; Becker, JM; Porta, A	Distribution of polycyclic aromatic hydrocarbons in soils and terrestrial biota after a spill of crude oil in Trecate, Italy	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	21	8	2002
Yunker, MB; Backus, SM; Graf Pannatier, E; Jeffries, DS; Macdonald, RW	Sources and significance of alkane and PAH hydrocarbons in Canadian arctic rivers	ESTUARINE COASTAL AND SHELF SCIENCE	55	1	2002
Childers, Jeffrey W.; Witherspoon, Carlton L.; Smith, Leslie B	Real-time and integrated measurement of potential human exposure to particle-bound polycyclic aromatic hydrocarbons (PAHs) from aircraft exhaust	Environmental Health Perspectives	108	9	2000
Carls, MG; Hose, JE; Thomas, RE; Rice, SD	Exposure of Pacific herring to weathered crude oil: Assessing effects on ova	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	19	6	2000
Norena-Barroso, E; Gold-Bouchot, G; Zapata-Perez, O; Sericano, JL	Polynuclear aromatic hydrocarbons in American oysters Crassostrea virginica from the	MARINE POLLUTION	38	8	1999

	Terminos Lagoon, Campeche, Mexico	BULLETIN			
International Programme on Chemical Safety	Selected non-heterocyclic polycyclic aromatic hydrocarbons. book	Environmental Health Criteria	ISBN 92-4-157202-7	No. 202	1998
Douabul, AAZ; Heba, HMA; Fareed, KH	Polynuclear aromatic hydrocarbons (PAHs) in fish from the Red Sea Coast of Yemen	HYDROBIOLOGIA	352		1997
Moring, JB; Rose, DR	Occurrence and concentrations of polycyclic aromatic hydrocarbons in semipermeable membrane devices and clams in three urban streams of the Dallas-Fort Worth Metropolitan Area, Texas	CHEMOSPHERE	34	3	1997
YUNKER, MB; MACDONALD, RW	COMPOSITION AND ORIGINS OF POLYCYCLIC AROMATIC-HYDROCARBONS IN THE MACKENZIE RIVER AND ON THE BEAUFORT SEA SHELF	ARCTIC	48	2	1995
YU, Y; WADE, TL; FANG, J; MCDONALD, S; BROOKS, JM	GAS CHROMATOGRAPHIC-MASS SPECTROMETRIC ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBON METABOLITES IN ANTARCTIC FISH (NOTOTHENIA GIBBERIFRONS) INJECTED WITH DIESEL FUEL ARCTIC	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	29	2	1995
LAW, RJ; BISCAYA, JL	POLYCYCLIC AROMATIC-HYDROCARBONS (PAH) - PROBLEMS AND PROGRESS IN SAMPLING, ANALYSIS AND INTERPRETATION	MARINE POLLUTION BULLETIN	29	42099	1994
HELLOU, J; PAYNE, JF; UPSHALL, C; FANCEY, LL; HAMILTON, et al.	BIOACCUMULATION OF AROMATIC-HYDROCARBONS FROM SEDIMENTS - A DOSE-RESPONSE STUDY WITH FLOUNDER (PSEUDOPLEURONECTES-AMERICANUS)	ARCHIVES OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	27	4	1994