Ecological and Human Health Risk Assessment

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This literature review of the risk assessment process addresses both ecological and human receptors. The review covers the risk assessment literature including methodology, analysis, interpretation, uncertainty, and regulatory guidance. Companion reviews in this volume that address the effect of pollutants and their fate and transport processes in the aquatic environment overlap the discipline of risk assessment and, therefore, the reader is urged to review these sections as they will not be covered in this review. The focus of the review is on the risk assessment process as it is applied to human health and ecosystems, site remediation, and natural resources. The objective is to provide an overview of the scope of the literature published in 2006.

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General

In a topical mini-monograph that evaluated human health effects caused by climate change, Ebi et al. (2006a) proposed a method to assess impacts to human health and potential adaptation strategies, policies, and measures that could be used to reduce those impacts. The assessments are structured to be conducted at the country level, to provide information for policy makers, and to provide information to the United Nations Framework Convention on Climate Change. Campbell-Lendrum and Woodruff (2006) applied a standardized comparative risk assessment method to evaluate worldwide health consequences of climate change, to provide input to decision making with respect to greenhouse gas emissions, and in a regional assessment of an area of the Pacific Ocean. They concluded that risk assessment methods used to evaluate climate change need to include traditional epidemiologic approaches, but also need to consider the inherent characteristics of climate change, including the long-term and uncertain nature of the exposure and others. The effects of climate change on human health in Cuba

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were evaluated by Ortiz Bultó et al. (2006) and included a study of climate-dependent diseases, current adaptation strategies, and potential costs associated with continued climate change. Casimiro et al. (2006) conducted a study in Portugal that included an evaluation of heat-related mortality, health effects caused by air pollution, and specific vector borne diseases to investigate the effects of climate change on human health. The results predicted that the measured effects of climate change will increase in the absence of effective adaptation strategies. The effects of climate change in small island states was studied by Ebi et al. (2006b) in an effort to provide recommendations to anticipate and prepare for climate change in this area perceived to have significant vulnerability. Furgal and Seguin (2006) evaluated the effects of climate change and the vulnerability of the northern Aboriginal communities in Canada based on a review of two projects that used a community-based dialogue approach in two Inuit regions of the Canadian Arctic. The study concluded, as in general did the others in this monograph, that the evaluation of climate change-related health effects and the associated human health vulnerability should be further studies using a participatory framework that considers the ability for the local regions to develop adaptive strategies.

The effect of temperature extremes on mortality was studied by Medina-Ramon et al. (2006) using mortality and weather data from 50 U.S. cities over a period from 1989 to 2000. The researchers determined that there were several subpopulations and mortality causes that were particularly susceptible to effects of extreme temperature. Temperature extremes and related health effects also were examined by Filleul et al. (2006) based on an evaluation of mortality data, temperature and ozone levels recorded for nine cities in France during August 2003. The study results showed heterogeneous effects across the nine cities and confirmed that the concentrations of ozone had a non-neglible effect on human health.

The variability in physical constant parameter values (e.g. molecular weight, melting point, Henry's law constant) from multiple standard data sources was evaluated by Marino (2006). Both the identified disparity of constants between sources and the magnitude of these differences were significant and these variances could affect potential risk estimates.

Ecological

Problem Formulation and Methodology. Vyas et al. (2006) conducted two laboratory subacute dietary toxicity tests and one outdoor subacute dietary toxicity test to determine the effectiveness of the USEPA deterministic risk assessment model for evaluating the potential of adverse effects to birds in the field. Their overall objective was to further test the reliability of the USEPA assessment method for predicting adverse effects of insecticide applications to birds in the field. Vyas et al. (2006) concluded that the response of goslings in the laboratory and field illustrated the significant difference that can occur between a laboratory-derived estimate of risk and the observed response of birds in the field.

Eggs, nestlings, and adults of the eastern bluebird (*Sialia sialis*) and house wren (*Troglodytes aedon*) were collected at a polychlorinated biphenyl (PCB)–

contaminated site and a reference location on the Kalamazoo River (Neigh et al., 2006a). The exposures of the two species studied were different, which suggests that terrestrial-based insectivorous passerine species, foraging in the same area, may have differential exposure to PCBs depending on specific foraging techniques and the insect orders that are targeted (Neigh et al., 2006a).

Scheifler et al. (2006) evaluated the transfer of cadmium, copper, nickel, lead, and zinc in a soil–plant (lettuce, *Lactuca sativa*)–invertebrate (snail, *Helix aspersa*) food chain during a microcosm experiment using two agricultural soils, polluted and unpolluted. Their results suggest that a nonnegligible part of metals accumulated in snail tissues may come from the soil and not from the food, which usually is considered to be the major (if not the only) exposure source for terrestrial organisms (Scheifler et al., 2006).

Weight-of-evidence approaches have been used in ecological risk assessment for many years by integrating various types of data (e.g., from chemistry, bioassay, and field studies) to make an overall conclusion of risk (Hull and Swanson, 2006). Hull and Swanson (2006) developed a sequential analysis of lines of evidence (SALE) approach that advances the practice of weight-of-evidence and should assist risk managers by allowing their decisions to be based on a sequential, flexible, and transparent process that includes direct toxicity risks, indirect risks (via changes in habitat suitability), and the spatial and temporal factors that can influence the risk assessment.

Landis (2006) describes the need for selecting population-scale assessment endpoints rather than the current approach which focuses on population-level assessment endpoints. The benefits of population-scale assessment endpoints are a more descriptive endpoint, and one that incorporates spatial and temporal heterogeneity.

A spatial and temporal analysis was conducted by Mineau and Whiteside (2006) to investigate insecticide impacts on lethality to birds in the United States. A general decline in risks to avian fauna from insecticides was reported, and the highest measured risks to birds occurred in the southeastern United States with the highest risk crops being corn and cotton.

An evaluation of suitable statistical methods for calculating 95 percent upper confidence limits when chemical data contain 15 to 50 percent, or 50 to 80 percent, of the samples with concentrations that were qualified as nondetected samples was conducted by Sinha et al. (2006) using Monte Carlo simulations. The approach is a more statistically valid method for evaluation of chemicals of potential concern during the risk assessment process when site chemical data have nondetected samples in high percentages.

Saloranta et al. (2006) compare two models for the estimation of food web bioaccumulation of dioxins and furans, the power of size (POS) and Gobas, using concentrations in field contaminated biota from sediments of the Frierfjorden fjord in southern Norway. Comparisons between models and between each model and actual measured biota concentrations showed little variation, but the accuracy of models are highly dependent on accurate pore water concentration measurements.

Kapo and Burton (2006) developed a method for diagnosing aquatic ecosystem impairment based weights-of-evidence approach that used a Geographic Information System. A weighted logistic regression was used to determine the weight of impact from individual stressors in multiple stressor lotic environments using a model watershed in Ohio, United States.

Jansch et al. (2006) compared laboratory toxicity data to terrestrial model ecosystems (TME) and field data to estimate risks from pesticides to higher-tier effects concentrations. TME was recommended by Jansch et al. (2006) as a method to interpret and make higher-tier multispecies extrapolations as a complement to the 5 percent hazardous concentration approach used when toxicity data is abundant.

Rhomberg and Lewandowski (2006) looked at cross-species extrapolation factors to scale oral doses across species for non-carcinogenic endpoints as well as how metabolic data can be factored into the dose extrapolation process. This study shows that empirical and allometric approaches provide evidence that toxicological risks are equal when daily oral doses are proportional to body weight raised to the ¾ power.

Ahlers et al. (2006) investigated the validity of acute to chronic ratios (ACRs) used in the ecological risk assessment of organic contaminants. Findings indicate that the ACRs currently used in the European Union often exceed the accepted safety factor of 100 and can be as high as 4000, and that life-cycle tests are the best way to determine toxic effects on a long-term basis.

Babut et al. (2006) describe a method for evaluating risk to aquatic ecosystems from disposal of dredged materials. The methodology follows a multi-component four-tied approach. Step one involves a development of a hazard quotient based on probable effects concentrations and, depending on the magnitude of the quotient, the process stops (no risk), moves on to tier two that incorporates biotests, tier three that incorporates a battery of biotests, or to tier four where management options are chosen.

An in vitro study performed by Gong et al. (2006) was conducted using individual grains of the wheat *Triticum aestivum*, and using conventional seed germination and seedling growth toxicity tests to determine the acute phytotoxicities and genotoxicity of DDE either spiked to soil or added to hydrophonic cultures. By lowering bioavailability, the soil reduced the stress caused by the DDE on the wheat; inverse dose response relationships were detected between exogenous DDE levels and one of the following parameters: seed germination, seedling growth, and genotoxicity.

Simpson et al. (2006) reviewed various techniques used to predict metal toxicity in sediments that have progressed to the point where the basic benthic ecosystem health can be protected, but the single value sediment quality guidelines will be ineffective for predicting the toxicity of metals in sediments. This review illustrates that improvements are needed for measurements collected in the field and laboratory, recording of parameters that are influential for metal toxicity in sediments, as well as quantification of the metal exposure

routes and the relative contribution of dissolved and particulate sources to toxic effects which would improve the power of predictive models and the overall effectiveness of sediment quality guidelines for metals.

Blocksom and Winters (2006) studied comparisons of existing lists of macroinvertebrate tolerance values (TV) with their resulting Hilsenhoff Biotic Index, and compared TV derivation approaches and bioassessment metrics to help determine their repeatability and sensitivity to disturbance. It was determined that the methods used to develop the TVs are very difficult to repeat and therefore make the confidence in the TVs assigned to individual taxa to be limited.

Ecological Effects and Exposure Assessment. Burkhard et al. (2006) present an approach for extrapolating field-measured biota–sediment accumulation factors (BSAFs) and bioaccumulation factors (BAFs) across species, time, and/or ecosystems. This approach, called the hybrid bioaccumulation modeling approach, uses mechanistic bioaccumulation models to extrapolate field-measured bioaccumulation data (i.e., BSAFs and BAFs) to new sets of ecological conditions.

Anderson and Lee (2006) reviewed different biomarker studies that were used to identify stress levels on marine organisms in order to determine an appropriate biomarker to be used in an oil spill risk assessment in the marine environment. The most useful biomarker of petroleum is the bile fluorescent compounds (FAC) response in fish; however, very few of the biomarkers currently being used are linked to any of the higher order biological effects such as reproductive failure or toxicity.

The factors influencing the bioavailability of nickel, including origin, localization and soil properties, were investigated by Echevarria et al. (2006) using 100 different soils from around the world. The authors show that pH is the single most important factor when determining nickel bioavailability and further conclude that the bioavailability can be closely estimated by diethylene triamine pentaacetic acid extraction of the soil as measured by the isotopic exchange kinetics method.

Antunes et al. (2006) describe the challenges in the implementation of the biotic ligand model (BLM) to predict bioavailability and uptake of metals to plants from soils. The authors conclude that the largest hurdle in developing a terrestrial BLM for plants is the ability to accurately calculate the amount of metal transferred to the shoots of the plant, but other factors such as kinetics, cationic competition, and metal speciation in soils also need to be considered in the model for the successful prediction of bioavailability.

Bradham et al. (2006) examined the effect of soil properties on the bioavailability and toxicity of lead to earthworms using field soils with a wide range of soil properties that were amended with the same total concentration of lead (2 000 mg/kg dry wt). The ranges of responses observed in the present study were the result of differences in lead bioavailability caused by lead interactions with the physicochemical matrix of the soil, and the authors noted that certain soil properties mitigated contaminant bioavailability and toxicity to ecological receptors (Bradham et al., 2006).

Bioavailability and desorption of five polycyclic aromatic hydrocarbons from freshwater sediments of the Anacostia River (Washington, DC) were measured by Liu et al. (2006). Biota-sediment accumulation factors were determined experimentally and compared with values available in the literature. Results of uptake and desorption experiments indicate steady state for uptake is governed by pore water equilibrium concentrations and field contaminated sediments were highly resistant to desorption.

Suedel et al. (2006) describe the implications for understanding and considering metal bioavailability and speciation when trying to characterize ecological risks from metals. A case study was completed using lead and chromium contaminated soils where a screening level assessment indicated ecological risks, but that assessing the bioavailable fraction of the metals permitted ecological protection while increasing cleanup concentrations levels.

The relationship between lead phytoavailability and phytotoxicity and soil properties was investigated by Dayton et al. (2005). Results of bioaccumulation and growth experiments involving soils spiked with 2 000 mg/kg lead on *Lactuca sativa* (lettuce) indicate that increasing organic carbon and cation-exchange capacity reduces metal bioavailability and bioaccumulation, and thus show the need for consideration of soil properties in risk management decisions.

Fuchsman et al. (2006) conducted an in-depth evaluation of polychlorinated biphyenyl (PCBs) aquatic toxicity and organic carbon partitioning to predict sediment effect concentrations using the equilibrium partitioning approach. Several lines of evidence were reviewed and the authors concluded that none of the lines of evidence support previously proposed, empirical sediment-quality guidelines for PCBs.

Phillips et al. (2006) conducted a solid-phase sediment toxicity identification evaluation on bulk sediments from Orcutt creek in the lower Santa Maria River Watershed, California, United States. The findings of the toxicity identification evaluation implicate pyrethroid insecticides; however, the organophosphate pesticide chlorpyrifos was also attributing to sediment toxicity.

Anderson, et al. (2006) assessed water and sediment quality in the Santa Maria River Watershed in California, United State. Toxicity testing of *Ceriodaphnia dubia* and *Hyalella azteca*, along with toxicity identification evaluation procedures, chemical analysis and benthic macroinvertebrate community analysis was used to determine impairment, which showed that significant impacts were caused by chlorpyrifos and pyrethroid pesticides from agricultural runoff.

Johnson et al. (2006) used a whole effluent toxicity based approach to determine environmental risks of sodium hypochlorite when combined with raw sewage, noting that increased halogenated organics were found to occur. However, differences in toxic effects were not observed between control and chlorinated treatments using various bacteria, algae, or invertebrate toxicity endpoints.

The goal of the study by Hawthorne et al. (2006) was to evaluate the proposed methods to determine the 34 polyaromatic hydrocarbons in sediment samples and investigate the effects of common analytical approaches for both pyrogenic and petrogenic polyaromatic hydrocarbons

on the toxicity units predicted using the proposed U.S. EPA narcosis risk model. Although a high amount of uncertainty is associated with predicting the total polyaromatic hydrocarbons' toxicity units based on the measure sof only parent polyaromatic hydrocarbons for sediments, the study demonstrated that the uncertainty can be greatly reduced when the sediments are collected from areas containing primarily pyrogenic polyaromatic hydrocarbons, such as those associated with manufacture gas plant sites.

In order to determine whether artificial or natural soils are more relevant for evaluating risks to earthworms, springtails, and plants, Rombke et al. (2006) evaluated the reproduction and growth of three standard species in nine natural soils and Organization for Economic Cooperation and Development (OECD) artificial soil. The results varied based on the testing of natural soils, the OECD artificial soil, or the inclusion of an additional safety factor such as the EC50 in current risk assessment schemes focusing on no-observed-effect concentrations (Rombke et al. 2006).

Kapustka et al. (2006) conducted toxicity tests to set ecological soil screening levels for cobalt and nickel following the American Society for Testing and Materials international E1963-98 *Standard Guide for Conducting Terrestrial Plant Toxicity Tests.* Threshold responses interpreted as the EC20 for each species endpoint were calculated from regression analyses and the geometric mean of the EC20 values (excluding emergence, mortality, and nodule numbers) for each species, and resulted in values of 30.6 mg/kg for cobalt and 27.9 mg/kg for nickel.

Using laboratory-reared snails (*Helix aspersa aspersa*), Vaufleury et al. (2006) describe how the effects of contaminants on survival and growth of snails can be evaluated in laboratory bioassays. They conclude that snails are easy to handle even by nonspecialists and allow repeatable results if basic recommendations are respected, such as the size of snails or preparation of the test, and note that their work validates survival and growth inhibition of snails as endpoints to assess the effect of pollutants.

Frampton et al. (2006) conducted an analysis of species sensitivity distributions and 5 percent hazardous concentrations in an attempt to determine the reliability of pesticide data and test species used in the risk assessment process. Findings include major differences in the sensitivities to pesticides between the earthworn *Eisenia fetida* and the arthropod *Folsomia candida*, and recommend using *F. candida* as a regular test species when conducting toxicity tests for pesticides because the species is much more sensitive to this group of toxicants.

Kuperman et al. (2006) investigated the effects of the metals antimony, barium and beryllium on reproduction of *Folsomia candida, Eisenia fetida* and *Enchytraeus crypticus* to fill data gaps necessary for the development of US EPA Eco-SSL values, which are used in soil screening during ecological risk assessments. Implications of the study include the necessity of multiple species testing for the development of ecotoxicological benchmarks as shown by the variation in toxicity between metals and species in this study.

Hagger et al. (2006) describe the utility of the integration of biomarkers into the risk assessment process, and describe the controversial history of biomarkers and the significance of biomarkers relevant to contaminant exposure. They address the need for use of biomarkers as a line-of-evidence when considering a weight-of-evidence approach to risk assessment rather than a stand alone tool for assessment.

Forbes et al. (2006) give a critical review of ecotoxicogenomics, the use of genetic biomarkers for ecotoxicological assessment, and describe the practical uses in the field of risk assessment. The authors conclude that although significant advances have been made in the field, the assessment of ecological impairment cannot be determined by biomarkers alone and that research should focus on other methods for diagnosing ecosystem impairment at higher levels of biological organization.

Using an arsenic bioaccumulation database, Williams et al. (2006) identified 12 studies of arsenic bioaccumulation in freshwater fishes to explore the differences between field generated bioaccumulation factors (BAFs) and laboratory generated bioconcentration factors (BCFs) along with how they relate to arsenic concentrations in water. It was indicated that concentrations in tissue and BAFs could be power functions of the arsenic in water which may show that high BCF values occur at low background levels and could decrease when environmental concentrations rise above the ambient range.

Along the Kalamazoo River, Michigan, Neigh et al. (2006b) studied the dietary exposures of passerine birds exposed to polychlorinated biphenyls (PCBs) in the terrestrial and aquatic food webs to evaluate the risk of PCBs causing population level adverse effects on the birds. Birds that consumed primarily terrestrial insects had a lower exposure to PCBs compared to birds that consumed primarily aquatic insects; however, it was concluded that by considering the multiple lines of evidence approach, the current concentration of PCBs in the various food chains were not the cause of population-level adverse effects on the birds in this study.

Modeling and Probability Simulations. Jian-Ying Hu and Yao (2006) introduced a probabilistic method for quantitatively evaluating the effects of chemical pollutants in the environment on a wildlife population, and applied that method to assess the ecological risk to a night heron (*Nycticorax nycticorax*) population exposed to dichlorodiphenyltrichloroethane (DDE) in Tai Lake, China. The authors used the magnitude of the difference between the intrinsic rates of increase under contaminant-free and contaminated conditions to reflect the exact extent of chemical effects at the population level (Jian-Ying Hu and Yao 2006).

Mokhtari and Frey (2006) focused on six sampling-based sensitivity analysis methods that were applicable to risk assessment models with two-dimensional probabilistic frameworks, using a microbial food safety process risk model. They found that two-dimensional risk models may be confounded by uncertainty but can differentiate between important inputs and unimportant inputs, and that rank-based methods give greater insights by producing clear distinctions and smaller uncertainty; and

regression-based methods are capable of providing insight to interactions and nonlinearities in the model.

Chiu and White (2006) compare the results of a physiologically-based pharmacokinetic (PBPK) model and a steady-state analysis for volatile organic compounds to determine if a simplified steady-state solution reproduces similar outcomes as the complex, multi-component PBPK model for route-to-route extrapolation in EPA's 2000 risk assessment for vinyl chloride. This study, as well as other more specific studies, indicated that the steady-state solution exactly reproduces the PBPK model and either reproduces or closely approximates the solutions of other PBPK models; cross-species extrapolation and intraspecies will be evaluated in subsequent evaluations.

Monte Carlo techniques are increasingly used in pesticide exposure modeling to evaluate the uncertainty in predictions arising from uncertainty in input parameters, and to estimate the confidence that should be assigned to the modeling results. Using these techniques, Beulke et al. (2006) conducted a study in which six modelers made choices regarding the type and parameterization of distributions assigned to degradation and sorption data for an example pesticide, the correlation between the parameters, the tool and method used for sampling, and the number of samples generated, and demonstrated that subjective choices made in Monte Carlo modeling introduce variability into probabilistic modeling.

Using a GIS approach, Pfleeger et al. (2006) were able to identify those areas in the United States having the greatest potential risk for exposure from the movement of herbicides off-target based on current patterns of herbicide use. They additionally noted that risk assessors could use this approach for evaluating risks associated with a new pesticide by locating those areas in the country where the pesticide is expected to be used on specific crops. This approach constitutes a major departure from current registration practices because it advocates test flexibility and a reduced need for extrapolating data to untested species or stages of development. It emphasizes the problem formulation phase of risk assessment to generate data pertaining to biota common to a particular region of interest.

Supplement 1 to the April 2006 *Environmental Health Perspectives* included a monograph introduced by Jobling and Tyler (2006) focusing on the ecological relevance of wildlife endocrine disruption brought on by exposure to various chemicals. The monograph includes research on the effects of endocrine disruption in wildlife, an examination of multicausality and the effects of mixtures, articles describing new approaches to assessing the effects of endocrine disruptors, discussion of low-dose effects, and research on protection of wildlife from further exposure.

According to Etterson and Bennett (2006), the popularity of using population models for wildlife risk assessment has increased, and due to the high cost of demographic data to collect, researchers are using surrogate data from published scientific literature to fill the data gap. By using surrogate data inferential errors have the potential to be present, but it is believed that by using methods from other disciplines such as life-history theory, meta-analysis,

and Bayesian statistics, the inferential errors can be reduced.

Risk Characterization and Management. Wenning et al. (2006) review the importance of linking risk assessment to a cost-benefit analysis and discuss two types of risk, engineering and biological, that deserve careful consideration when evaluating sediment remedy alternatives. The evaluation of remedy implementation risks addresses predominantly short-term engineering issues, such as worker and community health and safety, equipment failures, and accident rates, while the evaluation of residual risks addresses predominantly longer-term biological and environmental issues, such as ecological recovery, bioaccumulation, and relative changes in exposure and effects to humans, aquatic biota, and wildlife.

Scott-Fordsmand and Damgaard (2006) examined whether it is possible to estimate the magnitude of probable effects (with uncertainty estimates) on all species when only single treatment data are known. They concluded that the proposed species effect distribution approach introduced uncertainty estimates into the risk assessment of data from single treatment scenarios and can estimate the maximum effect (e.g., % mortality) on, for example, 95% of all species with a given certainty (Scott-Fordsmand and Damgaard, 2006).

Human Health

Methodology. Ofungwu and Eget (2006) presented a methodology for applying existing models to estimate emissions of residual landfill hazardous compounds, and to quantify associated health risks. They describe an approach that includes estimating post-development airborne contaminant concentrations from residual landfill emissions.

Bright et al. (2006) studied human health risk estimates for sites with contaminated soils with biases in the distribution of contaminants across soil particle sizes, the size range of particles in soils and dusts that are environmentally available, and factors that influence desorption from particles and uptake into humans. The studies show that the distribution across particle sizes of contaminants of concern should be observed along with the size fractions most critical to human exposure.

Reasonable worst-case risk assessment methods were applied by Peterson et al. (2006) to evaluate the potential population risks due to outbreaks of West Nile Virus and due to exposure to insecticides used to managed the disease-carrying mosquitos. The results determined that the potential risk associated with exposure to West Nile Virus was higher than the potential health risks associated with exposure to the insecticides noting that the insecticides risk was low and not likely to exceed a level of concern. Gulson and Wong (2006) propose the use of stable isotopic tracers to evaluate the absorption of nanoparticles such as zinc and titanium, common ingredients in sunscreen products, as a method to measure exposure to nanoparticles in personal care products.

Using a cohort of workers determined to be highly exposed to polychlorinated biphenyls (PCBs), Prince et al. (2006) studied mortality due to specific cancers as a means of evaluating the response to exposure. The study confirmed a previously established link between

PCB exposure and liver cancer mortality and also demonstrated a link between PCB exposure and prostate cancer mortality.

The maximum likelihood estimation and bootstrap simulation was used by Zhao and Frey (2006) and applied to various cases of censored air toxic emission factors. Censored values in the emission factor data ranged from 4 to 80 percent and sample size as well as inter-unit variability were factors that influenced the estimated uncertainty in the mean of censored data.

Vasquez et al. (2006) applied a mental model and created four influence diagrams for the Mayer Ranch area of the Tar Creek Superfund site in Ottawa County, Oklahoma in order to determine the health risks from exposure to heavy metals. This research came to the conclusion that the site has a high level of complexity and that the most influential transport pathways include ground and surface water pathways by either becoming exposed to the water directly or by ingesting plants or animals that have consumed the contaminated water.

Samaniac et al. (2006) evaluated the incidence of cancer among a cohort of pesticide applicators in North Carolina and Iowa that were exposed to dicamba. It was determined that there was no association between exposure and the overall incidence of cancer and no strong association with a specific type of cancer.

The cancer risk for two groups of teenagers, one in New York city and one in Los Angeles, associated with exposure to urban air pollutants was studied by Sax et al. (2006) who determined that the median upper-bound lifetime cancer risks for volatile organic compounds (VOCs), chromium, arsenic, and nickel exceeded the U.S. Environmental Protection Agency (USEPA) benchmark of 1×10^{-6}. The study also found that the USEPA tended to underestimate the potential cancer risk for nickel and arsenic.

Catelinois et al. (2006) used the well documented relationship between radon exposure and lung cancer to evaluate the population risk in France and studied the effect of various risk models and uncertainty analysis on the outcome. The study was based on cohorts of miners and analyses of residential case-control studies and relied on different exposure-response relationships from different epidemiological studies to conclude that the number of deaths due to lung cancer caused by exposure to radon was relatively stable across the study groups.

Johnson (2006) conducted a screening level evaluation to monitor fine particulates surrounding an outdoor wood boiler (OWB) because of escalating public concerns over residential wood smoke exposure. In the pilot study, an increasing problem of potential health risk is identified especially in view of patients with cardiac and respiratory health risks.

Toxicity and Exposure Assessment. Dietert and Piepenbrink (2006) reviewed the relevant literature to address a perceived data gap in exposure assessment – that of applying adult exposure assessment research and models to infants, both pre- and post-natal, to predict risk. The article defends and confirms the importance of developing age-based exposure assessment methodologies that will address the potential for risk in the rapidly developing immune systems of newborns.

Various home water use activities were evaluated by Gordon et al. (2006) as a means of determining exposure to trihalomethanes which result from the water treatment and disinfection process. The study involved collection of water, indoor air, blood, and breath samples and described positive associations between some water use activities and the concentrations of chlorinated compounds in breath or blood.

Due to concern that the U.S. Environmental Protection Agency's (EPA) 2005 calculation method for cancer slope factors was overly conservative, Subramaniam et al. (2006) compared slope factors calculated using the EPA's 2005 default method to previous calculation methods using cancer bioassay information from 60 chemicals listed in the EPA's Integrated Risk Information System. The comparison indicated that the EPA method for the cancer slope factor did not increase or decrease risk estimates.

The ExpoFacts database is a compilation of exposure factor data, including food intake, time use, physiology, and demographic parameters, from 30 European countries (Vuori 2006). Using both non-parametric and variance techniques, Borgonovo (2006) investigated the impact that assumptions of input variance have on the output variance. The results of numerical examples indicate that output variance is not necessarily influenced by the inputs with the most variance.

Mirabelli et al. (2006) studied the population characteristics of race and socioeconomic status in conjunction with the exposure of middle-school aged children to emissions from confined swine feeding operations in North Carolina. The researchers determined that race and socioeconomic factors played a key role in the proximity of schools to concentrated animal feed operations thus creating a higher potential for in-school exposure for children in certain population groups.

Nanoscale materials are of increasing interest to science and industry and Hardman (2006) focused on the available literature regarding potential toxicity associated with exposure to quantum dots, an engineered nanoscale product. Hardman concluded that there are a number of potential factors associated with quantum dots, e.g., variability in size, charge, concentration, and outer coating bioactivity, among a number of others, that affect toxicity and may pose a risk to human health and the environment.

Crawford-Brown et al. (2006) reviewed data published in 2005 by the National Research Council to analyze variability of risk resulting from perchlorate exposure for pregnant women and their unborn children. The results of the review suggested that a Maximum Contaminant Level of 24.5 micrograms per liter would protect the most sensitive subpopulations evaluated in the study.

The causal link between exposure to diesel exhaust and chronic obstructive pulmonary disease (COPD) was examined by Hart et al. (2006) in a case-control study of railroad worker deaths in 1981 and 1982. The study concluded that there was a relationship between diesel exhaust exposure and COPD mortality sufficient to warrant additional study.

Measurements of serum immunoglobulins was used by Williamson et al. (2006) to evaluate the potential

health effects of people living near six Superfund sites in Kentucky, Texas, California, Nebraska, Massachusetts, and North Carolina. The results of the study suggest a potential increase in IgA levels and the study concluded that further investigation should be conducted using more functional immunotoxicity testing in conjunction with individual exposure data.

Yu et al. (2006) measured the bioaccessibilty of lead in house dust vacuumed from typical urban households employing a method currently used for heavy metals in contaminated soils to determine a more accurate dose for lead in gastric fluid (52.4 percent to 77.2 percent) and intestinal fluid (4.9 percent to 30 percent). The bioaccessibility data of the two biofluids were then compared to the IEUBK default model inputs: the intestinal bioaccessibility data reasonably approximated the model default of 30 percent; however, the gastric bioaccessibility appeared to provide an upper bound that overcomes limitations in the model when child-specific data is not available.

Hryhorczuk et al. (2006) studied the relationship between human exposure to mercury (using air monitoring data) as a result of spills during replacement of residential natural gas mercury regulators and urine mercury concentrations in homes in the Chicago area. The results demonstrated a relationship between exposure to higher air concentrations of mercury and a positive bioassay response and confirmed that there was a risk of residential mercury exposure due to improper work procedures during regulator replacement.

The relationship between air pollution caused by traffic and the incidence of otitis media in children was evaluated by Brauer et al. (2006) using data from the Netherlands and Germany. The results indicated an association between traffic-related air pollution, including nitrogen dioxide, fine particles, and elemental carbon, and the incidence of otitis media.

Chiu et al. (2006a) introduced a mini-monograph discussing the various scientific concerns regarding the human health risk assessment of trichloroethene (TCE). The research articles in the monograph included key scientific issues for TCE including the pharmacokinetics of TCE and its metabolites (Chiu et al., 2006b), TCE modes of action and effects with respect to tumor promotion in the liver and kidney (Caldwell and Keshava, 2006), TCE toxicity and the role of peroxisome proliferator-activated receptor agonism (Keshava and Caldwell, 2006), cancer epidemiology issues (Scott and Chiu, 2006). The series provides an important update on the status of TCE toxicity and the future research needs.

The effects of arsenic exposure on DNA repair, specifically nucleotide excision repair, were evaluated by Andrew et al. (2006) using two study populations in New Hampshire and Mexico with input data including individual exposure levels from drinking water and biological samples. The study results, which included corroborative laboratory studies, showed an inhibition of DNA repair related to arsenic exposure.

Chang et al. (2006) determined that occupational exposure to toluene exacerbated the effect of hearing loss in an environmental with elevated noise levels based on a

study of workers in an adhesive plant in the U.S. with exposure to both toluene and noise.

The use of biomonitoring data to evaluate human exposure in the risk assessment process was the subject of a mini-monograph introduced by Albertini et al. (2006). The monograph included six case studies that focused on the pesticides chlorpyrifos and malathion (Barr and Angerer, 2006), polybrominated diphenyl ethers (Birnbaum and Cohen Hubal, 2006), perfluorooctanesulfonate (Butenhoff et al., 2006), diethyl phthalate and di (2-ethylhexyl) phthalate (Calafat and McKee, 2006), inorganic arsenic (Hughes, 2006), and methyl eugenol (Robison and Barr, 2006). The case studies discussed the applicability of using biomarkers to study the effects of exposure and included and evaluation of the public health uses of the biomonitoring data.

Dose-Response. Using statistical models to evaluate air pollution, weather, and mortality data across 98 urban communities in the U.S. from 1987 to 2000, Bell et al. (2006) studies the effects of low concentrations of ozone on premature mortality. The study demonstrated that exposure to ozone at low concentrations resulted in an increased risk of premature death and opined that steps were warranted to further reduce ozone concentrations in the U.S.

Manassaram et al. (2006) conducted a literature review to evaluate available data on the relationship between concentrations of nitrates in drinking water with various health effects to evaluate the body of evidence in support of the current drinking water standard in the U.S. The study identified a lack of individual exposure data and resulting uncertainties in epidemiological studies, particularly for private well users, which were determined to be the population at highest risk of exposure to nitrates.

The link between exposure to pesticides and the onset of Parkinson's disease was studies by Brown et al. (2006) based on a review of published literature focusing on epidemiological evidence and toxicological evidence. The researchers determined that the existing weight of evidence supported a finding that there is a general relationship between pesticide exposure and Parkinson's disease, but that the available research did not support the existence of a direct causal link or a link to exposure to a specific pesticide or class of pesticides.

A study by Lu et al. (2006) used urinary biomonitoring combined with total organic food diets to evaluate pesticide exposure in elementary school-aged children in Seattle, Washington. The results showed that consumption of an organic diet resulted in a immediate and substantial reduction in urinary concentrations of organophosphorus pesticides in the participating children and the concentrations of pesticides increased following the return of the children to their normal diets. Child exposure to pesticides in a child care center setting were evaluated by Cohen Hubal et al. (2006) by studying the potential for dermal transfer from various surfaces. The results indicated a wide variability in measurements of dermal loading from the different surfaces and that the upper-range values were consistent with the default value that was used by the U.S. EPA to assess child exposure to pesticides from contact with indoor surfaces.

Ruder et al. (2006) conducted an update of a previous study that examined mortality response to polychlorinated biphenyl (PCB) exposure in a cohort of capacitor manufacturing workers in Indiana where the original study showed an increased incidence in mortality related to melanoma and brain cancer. The update confirmed the finding of the original study regarding the incidence of mortality and also determined that the incidence of melanoma did not have a relationship with estimated cumulative exposure and that there was not an obvious dose-response relationship for brain cancer and estimated cumulative exposure.

Lamm et al. (2006) evaluated the effect of township as a confounding factor on the cancer risk related to arsenic exposure in drinking water in the blackfoot disease-endemic area of southwest Taiwan. The researchers concluded that only three of the six townships studied showed significant bladder and lung cancer risks related to arsenic exposure, the other three had elevated incidences of bladder and lung cancer that were independent of the exposure to arsenic, thus demonstrating that township was a confounding factor in assessing the dose response relationship.

The polychlorinated biphenyl (PCB) concentrations in cord serum of infants born to mothers living near a Massachusetts Superfund site were assessed by Choi et al. (2006) to study the effects of maternal exposure to PCBs over a 5-year period. The results indicated several factors that affected the infant PCB levels including proximity, time of birth relative to the site remediation activities, and maternal habits such as consumption of meat and local dairy products, among others.

A public health goal (PHG) for perchlorate of 0.6 ppb was calculated by Ting et al. (2006) based on a review of animal and human toxicity data focusing on reduction of thyroidal iodide uptake as the endpoint for protection of human health as a result of drinking water exposures. The PHG will be used by the California Department of Health Services in its efforts to develop a reasonable Maximum Contaminant Level for perchlorate in drinking water. Buffler et al. (2006) studied the effect of perchlorate exposure in drinking water on thyroid function in newborns using data from 287 California communities with average perchlorate concentrations less than or equal to 5 µg/l and 24 communities with average perchlorate concentrations greater than 5 µg/l. The researches did not demonstrate an association between measured thyroid effects and exposure at concentrations greater than 5 µg/l.

Using a cohort of 175 children in Mexico City, Schnaas et al. (2006) examined the effects of prenatal exposure to lead on intellectual development. The study showed a link between prenatal exposure to lead and a decrease in the tested IQ level; exposure at approximately 28 weeks of gestation appeared to be the critical point.

Mathematical models used in the quantification of risks associated with contaminated lands potentially underestimate the uncertainty related to the model inputs. Sander et al. (2006) states that rounding errors and distribution assumptions impact the outcome of a risk evaluation; that the magnitude of uncertainty may be greater than initially believed; and suggests that full

disclosure of uncertainties will help facilitate the decision making process.

Risk Characterization, Management, and Perception. The effects of extremely low-frequency (ELF) electromagnetic fields on human health were studied by Kheifets et al. (2006) using ELF exposure distributions from different countries and dose-response data from two pooled studies, focusing on the incidence of childhood leukemia. The researchers concluded that only a small fraction of childhood cases of leukemia could be attributable to ELF exposure worldwide, but that there were uncertainties in the ELF exposure estimates.

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