Ecological and Human Health Risk Assessment

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ABSTRACT: This literature review covers the risk assessment process and addresses both ecological and human receptors. The review covers the risk assessment literature including methodology, analysis, interpretation, management, uncertainty, policy, and regulatory guidance. The review is divided into ecological and human health sections. The focus of the review is on the risk assessment process as it is applied to ecological systems and human health, site investigation and remediation, and natural resources. The objective is to provide an overview of the scope of the literature published in 2008.

KEYWORDS: Ecological, human health, risk assessment, management, policy, regulatory

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Ecological

Problem Formulation and Methodology. Ecotoxicity issues associated with the use of the antiviral medicine, Tamiflu, during an influenza pandemic was the subject of an October 2007 meeting (Singer et al., 2008). As a result of the meeting, the following research priorities were established: a) publication of available data on oseltamivir ethylester-phosphate (OE-P) and oseltamivir carboxylate (OC), b) assessment of risk for OC-contaminated river water causing OC-resistant virus in waterfowl, c) investigation of sewage plant functioning and vulnerability as it may be affected by microbial inhibition during an influenza pandemic, and d) development of realistic worst-case exposure scenarios for OE-P and OC.

Baker et al. (2008) constructed a multigene cross-species fish microarray to use as a tool to evaluate the effect of environmental pollutants on aquatic environments using wild hornyhead turbot from both clean and polluted coastal waters and laboratory male zebrafish and studying exposure to estradiol and 4-nonylphenol and measuring gene expression in turbot liver. The results showed altered gene expression in the livers from turbot collected from polluted areas when compared to those from clean areas and also found agreement between the microarray data and

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the liver analyses indicating that the multispecies microarray can be used to measure endocrine function in other species of fish.

Barnthouse (2008) discussed the success of ecological risk assessment as a process for linking environmental science to decision making, using three recently published case studies involving establishment of baseline ecological risks at a contaminated site, probabilistic assessment of regional risks of pesticide use, and regulation of pharmaceutical product manufacture. The author also briefly discussed some promising future directions in ecological risk assessment, and identified three critical challenges to future success.

The limitations of the framework for ecological risk assessments to provide a way to analyze stressors in the environment to inform environmental management decisions are described under two categories, namely inherent and contrived (Kaputska, 2008). The author describes the inherent limitations, which are constraints of nature that need to be considered when studies are designed, and interpret studies and contrived limitations, which are impediments that have arisen in the practice through precedent or policy.

Suter (2008) presented a historical overview of the ecological risk assessment process in the US Environmental Protection Agency and noted that ecological risk assessment has been adapted by the Agency's program offices to fit their legal and policy contexts. The future of ecological risk assessment will inevitably include the incorporation of more complex and demanding methods; however, the biggest challenge for future risk assessors will be to make ecological risks more compelling to decision makers.

The Ecological Processes and Effects Committee of the US Environmental Protection Agency Science Advisory Board conducted a self-initiated study and convened a public workshop to characterize the state of the ecological risk assessment, with a view toward advancing the science and application of the process (Dale et al., 2008). The survey and analysis of ecological risk assessment in decision making shows that such assessments have been most effective when clear management goals were included in the problem formulation; translated into information needs; and, developed in collaboration with decision makers, assessors, scientists, and stakeholders.

Spencer et al. (2008) used a multitrophic level approach to evaluate current monitoring methods and to determine whether metal-mining activities had affected two otherwise pristine rivers that flow into the South Nahanni River, Northwest Territories, a World Heritage Site. Their results showed that although the effects of mining activities on riverine biota currently are limited, there is potential for effects to occur with proposed growth in mining activities.

The transfer of cadmium, methylmercury, and polonium in an estuarine food chain (from phytoplankton to zooplankton [*Daphnia pulex*] to killifish [*Fundulus heteroclitus*] and, finally, to juvenile striped bass [*Morone saxatilis*]) were examined by Mathews and Fisher (2008) to better understand both the extent to which these elements may biomagnify and the underlying mechanisms governing this biomagnification. In killifish feeding on *D. pulex*, the trophic transfer factor was consistently greater than one for

methylmercury, consistently less than one for cadmium, and from 0.1 to 1.4 for polonium, suggesting that both methylmercury and polonium have the potential to biomagnify at this trophic step.

Micheletti et al., (2008) estimated the ecological risk posed by 2,3,7,8-polychlorodibenzo-*p*-dioxins and furans (PCDD/Fs) and dioxin-like polychlorinated biphenyl (PCB) congeners to five edible fish species of the aquatic food web of Venice Lagoon, Italy, by applying a state-of the-art kinetic bioaccumulation model. Site-specific data were used to define a representative food web. Risk was estimated by applying the hazard quotient (HQ) approach, obtaining the ecological risk for each fish species on the basis of 90 and 99 percent protection levels, in six lagoon areas.

Spears et al. (2008) studied tree swallows (*Tachycineta bicolor*) at the Sangamo National Priorities List (NPL) site and a reference area within Crab Orchard National Wildlife Refuge, Illinois, USA, to evaluate the bioavailability of PCBs at the NPL site following remediation. There data demonstrated that tree swallows using the Sangamo site continued to accumulate significant quantities of PCBs seven years after remedial actions which prompted a reevaluation of remediation at the site and underscored the importance of postremediation monitoring of ecological receptors, particularly in cases involving persistent environmental contaminants.

Using geographic information system methodology, data layers describing or integrating contamination (impaired waters, fish or wildlife consumption advisories, toxic release inventory sites, and estimates of pesticide use) were overlaid on buffered Important Bird Area boundaries, and the relative threat at each site was ranked to analyze potential contaminant threats at 52 Important Bird Areas within the northeastern Atlantic coast drainage (Rattner and Ackerson, 2008). Based upon this screening level risk assessment, it was concluded that contaminant biomonitoring of birds was warranted at such sites, and data generated from these efforts could foster natural resource management activities.

Estimates of toxicity reference values (TRVs) derived from laboratory studies with individual PCDDs/PCDFs and PCB congeners or mixtures of those congeners, as well as application of toxicity equivalent factors, were compared to site-specific measures of mink exposure in sediments and floodplain soils of the Tittabawassee River (Zwiernik et al., 2008). Based on the lack of negative outcomes for any measurement endpoints examined, including jaw lesions, a sentinel indicator of possible adverse effects, and direct measures of effects on individual mink and their population, it was concluded that current concentrations of PCDDs/PCDFs were not causing adverse effects on resident mink of the Tittabawassee River.

Leonards et al. (2008) classified two main approaches (diet based and tissue based) to make more direct, accurate, and site-specific methods of assessing the risks of secondary poisoning of top predator by persistent organic pollutants (POPs), as opposed to traditional approaches to exposure assessment based on POPs in abiotic compartments or organisms low in the food chain. They illustrated and evaluated the potential of diet-based

and tissue-based risk assessment approaches with case studies and demonstrated that appropriate methodologies significantly reduce the uncertainty in risk assessments of POPs.

Smit et al. (2008) described an approach to environmental risk assessment of drilling discharges to the sea, because these discharges might lead to concentrations of toxic compounds and suspended clay particles in the water compartment and concentrations of toxic compounds, burial of biota, change in sediment structure, and oxygen depletion in marine sediments. The approach was based on species sensitivity distributions (SSDs) and incorporated precautionary principles from the European Union Technical Guidance Document to assure that the method was acceptable in a regulatory context.

Dagnino et al., (2008) presented a reliable and effective decision support system (DSS) for contaminated site assessment and management that may be useful to environmental managers and scientists for objectively interpreting the complex results obtained during a Triad-based ecological risk assessment. The DSS assigned different weights to the results obtained from Triad disciplines by employing the following parameters: 1) chemical soil analyses, 2) ecotoxicological bioassays, 3) biomarkers, and 4) ecological parameters.

Hickey et al. (2008) described and analyzed several models from a Bayesian perspective to construct SSDs from data derived using rapid toxicity testing, combining both rapid test data and expert opinion top try and accurately predict the proportion of species in a community that are at hazard from environmental contaminants. They recommended that rapid tests, expert judgements, and novel Bayesian statistical methods are used so that SSDs reflect communities of organisms found in nature.

A SSD for elevated temperatures was developed on the basis of temperature sensitivity data (mortality) of 50 aquatic species, and applies to risk assessment of heat discharges that are localized in space or time (Vries et al., 2008). Data from a thermal discharge in The Netherlands were then used to show the applicability of the developed SSD in environmental risk assessment.

Raimondo et al. (2008) comprehensively evaluated the protectiveness of SSD first and fifth percentile hazard concentrations (HC1, HC5) relative to the application of safety factors using 68 SSDs generated from 1,482 acute (lethal concentration of 50%, or LC50) toxicity records for 291 species, including 24 endangered species (20 fish, four mussels). The authors recommended the use of SSDs as a distribution-based risk assessment approach that is generally protective of listed species.

Efroymson et al. (2008) conducted a multiple stressor ecological risk assessment using the military Apache Longbow helicopter firing Hellfire missiles that studied the effects of helicopter overflight, missile firing, and tracked vehicle movement on woody desert wash communities and desert mule deer populations. The primary stressors were sound for overflight and missile firing, and soil disturbance/hydrological change/water loss to desert washes for tracked vehicle movement.

Ecological Effects and Exposure Assessment. Danovaro et al. (2008) studied the potential effect of

sunscreen on corals and symbiotic algae through laboratory testing and in situ experiments in the Atlantic, Indian, and Pacific Oceans and the Red Sea using aliquots of sunscreen and typical ultraviolet filters commonly found in sunscreen and checking for evidence of viral infection. The team determined that the ultraviolet filters caused bleaching of the hard corals and promoted viral infection concluding that suncreens were a key contributor to coral bleaching in aquatic environments used extensively by humans for recreation.

The potential for carbon nanotubes to be absorbed into organism tissues was evaluated by Petersen et al. (2008a) who measured the uptake of radioactively labeled nanotubes by the oligochaete, *Lumbriculus variegatus*, in spiked sediment samples. The results indicated that the nanotubes were not readily absorbed into the cellular tissues. Petersen et al. (2008b) also examined bioaccumulation of radioactively labeled nanotubes in *Eisenia foetida* and found bioaccumulation factors almost two orders of magnitude smaller than those measured for pyrene. These results suggest that purified nanotubes, unlike pyrene, are neither readily absorbed into organism tissues nor manifest equilibrium partitioning.

Reeves et al. (2008) conducted a study of the relationship between anthropogenic influences (approximated by proximity to a road) and the development of eye or skeletal abnormalities in wood frogs in five National Wildlife Refuges in Alaska. The researchers concluded that proximity to a road increases the prevalence of skeletal abnormalities, but has not effect on the rate of eye abnormalities.

Klaine et al. (2008) introduced the key aspects pertaining to nanomaterials in the environment and discussed what is known concerning their fate, behavior, disposition, and toxicity, with a particular focus on those that make up manufactured nanomaterials. The review critiqued existing nanomaterial research in freshwater, marine, and soil environments, illustrated the paucity of existing research, and demonstrated the need for additional research.

Lee at al. (2008) demonstrated a plant agar test for homogeneous exposure of nanoparticles to plant species. The study demonstrated that the plant agar test was a good protocol for testing the phytotoxicity of nanoparticles, which are hardly water soluble.

Avoidance tests with earthworms (*Eisenia andrei*) and springtails (*Folsomia candida*) were performed by Natal-Da-Luz et al. (2008) to identify the influence of both organic matter content and texture on the avoidance response of representative soil organisms. They found that springtails were less sensitive to changes in these soil constituents compared with earthworms, indicating springtails can be used for site-specific assessments of contaminated soils with a wider range of respective soil properties.

The data presented from experiments with the deposit-feeding amphipod *Melita plumulosa* illustrated the use of new whole-sediment toxicity identification and evaluation (WS-TIE) methods that can be incorporated into existing procedures to demonstrate dietary toxicity in whole-sediment toxicity tests (Micevska and Simpson, 2008). The authors concluded that WS-TIE methods that

include a combination of manipulations that identify the contribution of toxicity causing contaminants occurring via both dissolved and dietary exposure pathways will be more successful in determining which of the chemical constituents are responsible for the observed toxicity.

Bhavsar et al. (2008) assessed the impacts of uncertainties in dioxin-like (dl) -PCB measurements and estimates, and mammalian toxic equivalency factors (TEFs) on toxic equivalent (TEQ)dl-PCB using the Monte Carlo technique. The authors indicated the analysis suggests that measurement errors for dl-PCBs translate into up to 1.3-fold uncertainty in TEQdl-PCB, while uncertainties in estimates of dl-PCBs generally produce up to a threefold uncertainty in TEQdl-PCB. In contrast, the uncertainty due to TEFs normally ranges 10- to 13-fold and spans over 30- to 40-fold under extreme cases.

Burkhard and Lukasewycz (2008) computed aquatic, avian, and mammalian species dioxin TEFs for Aroclor, Clophen, Kanechlor, Chlorofen, Sovol, Delor, Phenoclor, and Chinese PCB mixtures by using World Health Organization TEFs and compound-specific compositional data for PCBs, polychlorinated dibenzo-*p*dioxins (PCDDs), and (PCDFs) for the individual mixtures. The authors found that the resulting TEQs are similar for PCB mixtures of similar chlorine content, and depending on the mixture, the PCDD/F content of the PCB mixture can be responsible for 0 to 96% of the TEQ for the PCB mixture.

Hazard/risk assessment methods for complex environmental mixtures that involve a targeted, priority chemical approach based on the cumulative hazard/risk of known mixture components or analyses of sufficiently similar mixtures were evaluated by Lemieux et al. (2008). study. The results presented in the study confirmed other results which indicated that nonadditive interactions can influence the activation and overall mutagenic or carcinogenic activity of complex mixtures of polycyclic aromatic hydrocarbons (PAHs).

To provide data useful in assessing ecological risk for reptilian species, acute, subacute, and subchronic oral toxicity studies were conducted with the western fence lizard (*Sceloporus occidentalis*) using 2,4,6-trinitrotoluene (TNT) (McFarland et al. (2008). The data suggested a lowest-observed-adverse effect level of 25 mg/kg·d and a no-observed-adverse effect level of 15 mg/kg·d for TNT in *S. occidentalis*.

Western fence lizards, *S. occidentalis*, were used to develop a laboratory toxicity model for reptiles by using a hierarchical approach; acute to subchronic studies were conducted to provide toxicity data relevant to short- and longterm exposures for TNT (Suski et al., 2008). The study indicated that *S. occidentalis* is suitable for evaluating toxicity of compounds to reptilian species.

Verbruggen et al., (2008) describes a method for deriving ecotoxicological environmental risk limits (ERLs) for total petroleum hydrocarbons (TPH) by using toxicity data for two oil types (light and heavy) to benthic organisms and corresponding estimated internal lipid concentrations, calculated by equilibrium partitioning, as a measure of toxicity by narcosis. The distribution of estimated total internal concentrations for chronic endpoints was used as a basis for the ERLs and the

resulting ERLs for the mixture of TPH were comparable with ERLs for single compounds.

Beyer et al. (2008) related sediment ingestion rates of waterfowl to diet and to the sediments where waterfowl fed and found that waterfowl ingested the least sediment from hard-bottomed habitats with fast-moving water and ingested the most sediment from soft-bottomed areas with slow-moving water. The tundra swan (*Cygnus columbianus*), which ingests sediment at an estimated 8.4 percent of its diet, dry weight, was suggested as a potential generic model for use in environmental risk assessments designed to protect waterfowl.

The inhalation exposure pathway for burrowing animals was evaluated at the US Department of Energy's Hanford Site with the use of artificial burrows deployed at locations that had elevated levels of carbon tetrachloride in soil gas (Markwiese et al., 2008). The study showed that artificial burrows are an efficient method for obtaining relevant exposure data and illustrated the utility of directly measuring the medium for exposure under ecologically realistic conditions.

Strause et al. (2008) examined dietary exposures of great horned owls (*Bubo virginianus*) to PCBs in the terrestrial food web at the Kalamazoo River, Michigan, using a multiple-lines-of-evidence approach to evaluate the results of the predictive assessment approach with actual measurements of exposure (PCB concentrations in tissues, eggshell thickness) and population-level effects such as abundance or productivity at the same time at the same location. This evaluation indicated that a multiple-lines-of-evidence approach provided the best estimate of risk.

Ashauer and Brown (2008) examined existing toxicokinetic and toxicodynamic models and dynamic formulations of popular ecotoxicological concepts (e.g., the critical body residue concept) are examined. The underlying assumptions about speed of recovery and thresholds of the models were clarified, and a rigorous mathematical treatment showed that they can all be placed within a unifying framework.

Best et al., (2008) provided data to be used for predicting exposure-based effects of TNT aged in soil on endpoint organisms representing two trophic levels by conducting long-term exposure tests to evaluate sublethal toxicity and uptake of aged soil-based explosives. The mean bioconcentration factors, indicating the potential of a chemical to accumulate in an organism, were 0.9 for TNT metabolites, 71.8 for RDX, and 12.2 for HMX in *L. perenne* shoots; TNT, RDX, and HMX levels were below detection in earthworms.

The bioavailability of four sediment-spiked hydrophobic organic contaminants (HOCs; chrysene, benzo[*a*]pyrene, chlordane, and Aroclor 1254) was investigated by comparing bioaccumulation by the amphipod *Corophium colo* with uptake into a thin film of ethylene/vinyl acetate (EVA) copolymer (Golding ert al., 2008). The study indicated that all chemicals biomagnified over the duration of the exposure and demonstrating the potential for EVA thin-film extraction to assess trophic transfer of HOCs.

Sun et al. (2008) studied desorption of pyrene from three different soils using a semipermeable membrane device (SPMD)–assisted method to develop a new

approach to predict bioavailability of HOCs in soils. Good correlations were found between SPMD–assisted desorption and the biota–soil accumulation factor for both unaged and aged soils and the SPMD–assisted desorption was considered to be a reliable approach to predict the bioavailability of HOCs in soils.

Springer et al. (2008) we showed that reliable bioconcentration factor (BCF) estimates can be made using a study design that is based on standard regulatory guideline test procedures but that uses significantly fewer animals and resources, by taking tissue samples only twice during a 14-d depuration period.

Klock et al. (2008) developed quantitative structure–activity relationships (QSARs) for metal BCF and median acute lethal water concentrations (LC50) were developed for two species of mollusks, *Perna viridis* and *Mytilus edulis*. The endpoints were related to four metal ion characteristics, the covalent index, the softness index, the hydrolysis constant, and the ionic index.

Parkerton et al. (2008) provided guidance for evaluating key aspects of study design and conduct that must be considered when judging the reliability and adequacy of reported laboratory bioaccumulation data. Key criteria identified for judging study reliability include 1) clear specification of test substance and fish species investigated, 2) analysis of test substance in both fish tissue and exposure medium, 3) no significant adverse effects on exposed test fish, and 4) a reported test BCF that reflects steady-state conditions with unambiguous units.

Earthworms (*Eudrillus eugineae*) used in vermicomposting of municipal solid waste were studied by Kumar et al. (2008) to identify the effects of heavy metals (copper, cadmium, chromium, lead, and zinc). The results revealed that copper and cadmium at 1.5 and 0.1 g/Kg of waste were toxic, and as a free cadmium as a free form metal is the most toxic indicating that metals do accumulate in the earthworms.

The insect *Chaoborus* was evaluated by Hare et al. (2008) as a biomonitor for exposure to cadmium, copper, and zinc from lakewater. It was found that fluxuations exist in different areas at different times for larval cadmium concentrations, making it a useful building block for ecological risk assessments.

Pyle and Wood (2008) compared the uptake of copper through the gills of yellow perch and rainbow trout. New biotic ligand model parameters need to be developed based on particular species because the study found the rainbow trout able to take up more copper than the yellow perch when placed in equal exposure concentrations.

The concentration of metals (copper, nickel, and cadmium) in yellow perch were studied around Sudbury, Ontario by Rasmussen et al. (2008) to identify direct and indirect effects. Direct effects were visible in the growth and population of the yellow perch, and the indirect, foodweb mediated effects of elimination of large benthic invertebrates suggest an importance to ecological risk assessments since there is potential for trophic levels to be altered.

Studying fine root decomposition of copper, nickel, lead, and zinc in soil at forested sites near smelters and background sites in Canada, Johnson and Hale (2008) compared the depth gradients. The results show that

decomposition for roots and leaf litter do not need to be separated, and that soil layers should be considered when predicting exposure to metals in risk assessments.

Courchesne et al. (2008) researched the relevance of the rhizosphere to determine the importance it has as a component in assessing ecological risks in regards to trace metals in soils. The rhizosphere stands out from other soil layers because of its role in elemental uptake by plants and transfer of trace metals along the food chain.

Studying the dataset of regional and seasonal variation of metal accumulation, growth, condition, and physiology in wild yellow perch, Couture and Pyle (2008) were able to propose threshold tissue metal concentrations, identify factors influencing metal accumulation, and create an experimental approach for measuring effects. Even though yellow perch are highly suitable for studying metal effects in wild fish, fish size, season, and region accompanied by several reference sites must be included in the sampling design to produce relevant results.

Couture et al. (2008) studied metal (cadmium, copper, nickel, selenium, and zinc) concentrations in yellow perch in two regions in Canada during two seasons in order compare gut content, metal accumulation in the liver and kidney, and to investigate tissue accumulation during life-long chronic exposure. The results illustrated that there is a greater influence through metals in the water compared to the diet of the fish (cadmium was opposite), acclimation or selection for metal tolerance was evident when comparing the two sites, and that differences existed between seasons; however, repeat sampling would be needed for a proper assessment.

Schleier et al. (2008) performed an equine risk assessment looking at three pyrethroid insecticides, pyrethrins, two organophosphate insecticides, and piperonyl butoxide used to control mosquitos. Because of the conservative exposure assumptions the risks to horses were shown to be minimal and unlikely to exceed any regulatory levels of concern.

Trace metals in marine dietary supplements of algae, coral, krill, and shark cartilage were studied by Leblond et al. (2008). Algae was found to have the highest concentrations of lead, chromium, nickel; krill had the highest concentrations of cadmium, copper, and zinc; shark cartilage had the highest mercury and cobalt; however, no samples exceeded any provisional tolerable daily intakes.

Four species sensitivity distribution methods (Netherlands National Institute, U.S. Environmental Protection Agency, SigmaPlot, Environment Canada) were studied by Staples et al. (2008) to calculate predicted no effect concentrations (PNEC) for Bisphenol A. The study found that PNEC values ranged from 11 to 71 μg/L and that no adverse risks exist to aquatic organisms based on Bisphenol A concentrations.

An equation developed from the European Medicine Agency for an environmental risk assessment of human pharmaceuticals was used by Besse et al. (2008) to calculate Predicted Environmental Concentrations (PECs) for 112 parent molecules and metabolites using 2004 French drug consumption data. Calculating risk quotient ratios and PECs together proved to be a valuable estimation of exposure; however, pharmacological and

exotoxicological data from the literature should supplement any estimations.

Risk Characterization, Uncertainty, and Management. The sources of uncertainty in human health and ecological risk assessments conducted for several US Army sites were identified, categorized, and scored to identify better analytical practices and opportunities for targeted research to improve risk estimates (Stackelberg et al., 2008). They found that most of the risk assessments incorporated only qualitative uncertainty analysis to demonstrate the conservatism of selected data and predictive models and that food chain transfer dominated quantifiable sources of uncertainty across the risk assessments evaluated. Also, factors related to dermal exposures ranked high for human health, and effects assessment for ecological endpoints.

Whiteside et al. (2008) presented a new risk-based approach developed by Environment Canada for ranking pesticides and their potential risk to aquatic life and compared the rankings to those generated using a more traditional score-based approach. They concluded that a risk-based approach that considers a broad representation of species toxicity data and estimates of runoff and drift concentration in receiving aquatic systems (even from generic application scenarios) was a more realistic representation of potential toxicological effects and a superior method of ranking products for the risk they pose to the aquatic environment.

Singass et al. (2003) summarizes the Environmental Risk Management System (ERMS) project and presents a developed model by showing results from environmental fates and risk calculations of a discharge from offshore drilling operations. The developed model calculates environmental risks for the water column and sediments resulting from exposure to toxic stressors (e.g., chemicals) and nontoxic stressors (e.g., suspended particles, sediment burial) and characterizes the overall potential impact on the marine environment in terms of potentially impacted water volume and sediment area.

Sartjes and Tromp (2008) developed a tiered approach to assess the human health risks of asbestos from soil exposure. An Intervention Value of 100 $mg/kg_{soil,dw}$ was used in Tier 0 as a generic soil quality standard, and then Tier 1 through 3 are site specific in identifying probability for emission, potential for exposure, and measured indoor air values.

Researching data on lead pollution in soil and health effects in children in less developed nations, McBride (2008) was able to develop several ideas when comparing the data. Less developed nations have been studying lead levels in highway and farmlands because of traffic and leaded gasoline, and then the data has been used to explain the unhealthy blood lead levels of nearby populations.

Twining et al. (2008) conducted a probabilistic risk assessment looking at cadmium, copper, and zinc from Sydney Harbour sediments to produce contaminant probability density distributions using AQUARISK. This assessment generated risk maps of species impact for each metal separately as well as for the metals combined proportionally.

Organohalogen compounds measured in eggs of two Ardeid species from port cities along the South China coast were greatest from eggs collected from Hong Kong with the exception of DDTs (Lam et al., 2008). Predicted concentrations of the compounds were expected to affect some proportion of the Ardeid populations based on a risk assessment using published, consensus toxicity reference values.

The perception of ecological risk associated with the mountain pine beetle (MPB) in Canadian national parks, factors affecting perceptions of risk, and the influence of risk judgments on support for controlling MPB outbreaks were evaluated by McFarlane and Witson (2008) by collecting data through a mail survey in 2003 and an on-site survey in 2005. Knowledge of the MPB outbreaks and residency were found to be the best predictors of risk judgment and, of the variables involved evaluated in the study, only sex and risk to ecosystem domains influenced support for controlling the MPB in national parks.

Regulatory Agency Guidance and Standards. Becker and Ginn (2008) presented the results of a critical evaluation of the sediment effect concentrations (SECs) for PCBs and showed that the SECs represent questionable consensus values, are limited by the same biased databases as most other sediment quality guidelines (SQGs), are strictly correlative in nature (rather than causative), and can provide highly erroneous predictions when applied to site-specific conditions. Therefore, they concluded that the SECs for PCBs should be used only in the screening-level evaluations that typically precede more direct assessments of sediment toxicity at individual study sites, and should not be used to predict the presence of sediment toxicity.

Suter and Cormier (2008) showed that the conventional framework for risk assessment may be easily modified to represent criterion development because the relationship between the process of criterion setting and risk assessment has not been clear. They noted that the critical step in criterion setting is the determination of an effect metric that can be modeled and that represents the environmental goal and that the same process applies to equivalent assessments, such as deriving screening benchmarks and remedial goals.

Specific metal compounds are important to take into consideration due to exposure, effects, and risks when developing ecological soil screening levels according to Menzie et al. (2008). Using the case of barium sulfate (barite), the value of considering specific metal compounds instead of elemental names is illustrated since barite is commonly found in soils where as soluble barium compounds could indicate a higher environmental risk.

The accuracy of SSDs generated from toxicity values derived from interspecies correlation estimation (ICE) models illustrated that fish predict fish better than invertebrates and *Daphnia magna* predicted invertebrates (Dyer et al., 2008). The application of ICE models is recommended for generating SSDs and hazard concentrations for chemicals with limited toxicity data.

Human Health

Methodology. Demonstrating that source-apportionment methods could be used to provide estimates

of acute health risk, Sarnat et al. (2008) evaluated the relationship between exposure to particulate matter (PM) and cardiovascular and respiratory disease in an epidemiologic study using a time series of PM measurements in Atlanta, Georgia. The study also looked at various source factors including mobile sources and biomass combustion, such as forest burning and residential wood burning, and the potential correlation with cardiovascular and respiratory-related emergency room visits using data collected between November 1998 and December 2002.

Eisenberg et al. (2008) developed a methodology to evaluate the potential human health risk associated with exposure to pathogens present in biosolids from wastewater treatment processes and subsequent biosolids disposal methods, including land application. Four models were developed that incorporated three exposure pathways and three sources of environmental data and it was demonstrated that a reasonable risk assessment methodology was available to evaluate potential risk in a manner similar to other water-related hazards.

Elliott and Savitz (2008) introduced a mini-monograph that explored spatial epidemiology and its use in the assessment of human health risk with a discussion of small-area studies that look at individual exposures based on geographic variables. Beale et al. (2008) explored issues of methodology and approach with respect to the underlying challenges of spatial epidemiology. Including the dimension of time with spatial models was studied by Abellan et al. (2008) in disease mapping. Ball et al. (2008) compared three methodologies for evaluating cancer incidence rates in residents living above a contaminated groundwater plume in Utah, including the standardized incidence ratio (SIR), SaTScan software, and the Rapid Inquiry Facility (RIF). A multi-level analysis incorporating both individual and community socioeconomic status into modeling of breast cancer risk was conducted by Webster et al. (2008) in Cape Cod, Massachusetts. In each of these studies, the researchers were using one or more aspects of spatial epidemiology to evaluate potential risk based on population and geographic variables.

Geographic information system-based models were used by Kim et al. (2008) to evaluate lead exposure in children that were based on different levels of geocoded data obtained from 18 counties in North Carolina and included information from blood lead surveillance, county tax assessors, and the 2000 U.S. Census. The models resulted in the identification of high-risk areas for lead exposure and the results supported the applicability of similar models to develop targeted intervention programs.

The measurement of drug residues in wastewater from major sewage treatment plants in Milan, Italy; Lugano, Switzerland; and London, United Kingdom, was used by Zuccato et al. (2008) to evaluate patterns of community drug abuse. The results demonstrated that the methodology was a useful tool that potentially could be used to evaluate other public health issues and provide real-time epidemiologic data.

The challenges in conducting a risk assessment of human environmental exposure to PCDDs and PCDFs was studied by Aylward et al. (2008) who identified and used a margin-of-exposure approach in a benchmark dose

framework using estimated population lipid-adjusted concentrations of PCDD/PCDFs from the 1970s and 2000s to estimate benchmark concentrations for three responses. The study showed a decrease in lipid concentrations in young adults between the 2000s and the 1970s; the margin-of-exposure assessment as it relates to benchmark dose framework was complicated by incomplete exposure characterization.

Human observational studies (HOS) and their suitability for use in quantitative risk assessment was evaluated by Vlaanderen et al. (2008), who proposed a three tier framework to evaluate suitability and then tested that framework using studies on the relationship between benzene exposure and the development of acute myeloid leukemia (AML); tier I of the framework addresses the quality of design, conduct, and reporting of the HOS; Tier II is used to categorize the HOS based on type of study design; and Tier III is used to determine the acceptability of the HOS based on design-specific criteria such as quality of exposure measurements, type of exposure metric, and specificity of the exposure indicator, among a number of other criteria. The framework was applied to seven HOS that evaluated benzene exposure and AML risk; only five studies were determined to be acceptable for quantitative risk assessment.

The connection between chemical exposures and early biological effects (identified as "upstream") and subsequent biological effects (identified as "downstream") was the subject of a workshop held in May 2007 in Berkley, California, where three case studies were evaluated including thyroid hormone disruption, antiandrogen-mediated male reproductive effects, and immunosuppression (Woodruff et al., 2008). It was determined that it was feasible to use upstream indicators of chemical exposure in risk assessment and risk-based decision making with consideration of other factors including biological background, chemical background, periods of susceptibility, and complex modes of action, among other factors.

Under the auspices of the National Academy of Sciences, the Committee on Improving Risk Analysis Approaches evaluated key elements of the risk assessment process, in particular the methodologies used by the US Environmental Protection Agency, focusing on improving the technical analysis that supports the risk assessment process and the utility of risk assessment (The National Academies Press, 2008). The Committee considered risk assessment design, uncertainty and variability, selection and use of defaults, dose-response assessment, cumulative risk assessment, applicability and utility of risk assessment, and various stakeholder issues, and proposed improvements to streamline the risk assessment process.

Toxicity. As an alternative to animal-based testing, Xia et al. (2008) used a quantitative high-throughput screening procedure in human and rodent cell types to profile 1 408 chemical compounds that had been previously tested using more traditional toxicological assays to evaluate cytotoxicity. The screening procedure generated high quality cytotoxicity data and the results support the potential use of the method to profile a wider group of compounds and to prioritize chemicals for further toxicological evaluation.

In a commentary discussing the limitations of the traditional 2-year bioassay for evaluating chemical carcinogens, Huff et al. (2008) propose extending the length of time a rodent bioassay is conducted by exposing the rodent *in utero*, versus after birth, and continuing the test for 30 months or until the natural death of the animal. The results of extended bioassays for aspartame, cadmium, and toluene were reviewed and it was concluded that researchers currently conducting 2-year bioassays should compare those results with the results of longer term studies to determine if better evidence of potential human carcinogenicity can be observed, and if so, regulatory agency guidance should be changed accordingly.

Slotkin et al. (2008) examined the potential neurotoxicity of perfluoroalkyl acids using an *in vitro* study of undifferentiated and differentiated PC12 cells and measured cell functions including DNA synthesis, decline in cell numbers and growth, oxidative stress, reduced viability, and shifts in differentiation toward or from dopamine or acetylcholine neurotransmitter phenotypes. Four compounds were studied, perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), perfluorooctane sulfonamide (PFOSA), and perfluorobutane sulfonate (PFBS), and it was determined that the compounds did have a direct adverse neurotoxic effect, but that each had a different mechanism and relative toxicity with the order of toxicity being PFOSA, then PFOS, then PFBS and PFOA being approximately equal.

Barregard et al. (2008) evaluated the renal effects attributed to the presence of mercury in dental amalgam used in children through the use of biomarkers and reported no significant effects of the mercury on the biomarkers, but reported a significant increase in the presence of microalbuminuria (MA) among the children in the amalgam study group. The MA was indicated to be a random finding, but the researchers concluded that the potential relationship should be studied further.

In an epidemiologic study using a cohort of women in a semi-rural area of Pakistan, Siddiqui et al. (2008) evaluated the relationship between exposure to wood fuel smoke and the risk of low birth weight and reduced mean birth weight using data for single live births between 2000-2002 and information on cooking habits, daytime habits, and type of fuel used during the pregnancies collected from a 2004-2005 survey. The study found evidence of low birth weight and marginally lower mean birth weight among wood fuel users versus those who used natural gas for fuel.

Prenatal exposure to tetrachloroethene (PCE) in drinking water and the subsequent effect on birth weight and gestational age was examined by Aschengrau et al. (2008) in a retrospective cohort study of women in Massachusetts using EPANET modeling software to estimate PCE exposure. The results indicated that there was no statistically significant difference between the group exposed to PCE and the unexposed group suggesting no adverse effect related to PCE exposure.

A series of articles in the September 2008 volume of *Environmental Health Perspectives* examine the relationship between exposure to ambient air pollution and mortality in various areas of China and Thailand. Qian et al. (2008) evaluated the effect of high temperature on air

pollution-related mortality in Wuhan, China, using data from 2001 to 2004 and concluded that there was a synergistic effect between exposure to particulate matter less than or equal to 10 micrometers (PM_{10}). Vichit-Vadakan et al. (2008) investigated the mortality risk associated with exposure to high concentrations of PM_{10} in ambient air in Bangkok, Thailand, over a period of time from 1999 to 2003 with the results suggesting a strong association between PM_{10} exposure and various mortality outcomes. In Shanghai, China, Kan et al. (2008) identified factors that could modify health effects resulting from exposure to air pollutants through a time-series analysis that examined season, sex, age, and education. Wong, Ou, Chan et al. (2008) studied the potential modifying effect of poverty on air pollution-related mortality in socially deprived urban areas of Hong Kong, China, determining an increased risk of mortality associated with exposure to air pollution in socioeconomically deprived neighborhoods. In the final article in the series, Wong, Vichit-Vadakan, Kan et al. (2008) presented the results of a multicity study of the effects of exposure to air pollution on public health in Bangkok, Thailand and in Wuhan, Shanghai, and Hong Kong, China, in comparison to health effects reported for Western industrialized cities and generally demonstrated that the health effects resulting from air pollution exposure were equal to or greater in the Asian cities than for those in the Western nations and that Asians tend to have higher exposures due to spending more time outdoors.

The potential for secondary pollutants to affect ozone-induced mortality was the subject of study by Franklin and Schwartz (2008) who used data from 18 U.S. communities to evaluate the relationship between ozone alone and non-accidental mortality and with ozone and other pollutants. The study demonstrated that ozone-induced mortality was affected by secondary pollutants, in particular particle sulfate, which could at least in part be responsible for a portion of the observed effect of ozone on mortality.

The incidence of lung cancer in workers in the trucking industry as a result of exposure to vehicle exhaust was studied by Garshick et al. (2008) using a cohort of 31 135 male workers in the unionized trucking industry in 1985 and lung cancer mortality data through 2000 from the National Death Index. The results identified elevated lung cancer hazard ratios in workers with routine exposure to vehicle exhaust and an increased risk of mortality associated with longer years of employment.

Tang et al. (2008) evaluated the potential neurotxocity of cadmium selenium quantum dots by using a hippocampal culture model and measuring cytoplasmic calcium levels and voltage-gated sodium channel function following exposure. The researchers demonstrated dose-dependent neuron death, elevated cytoplasmic calcium levels, and effects on the voltage-gated sodium channel. Quantum dot toxicity was also researched by Geys et al. (2008) who conducted both *in vivo* testing in mice and *in vitro* plasma studies using quantum dots, with carboxyl or amine surface coatings to evaluate the effect of surface charge, and measuring inflammatory response, tissue distribution, and prothrombotic effects following intravenous injection. The results indicated marked vascular thrombosis related to quantum dot exposure at

high doses, particularly related to those with carboxyl coating, and the quantum dots accumulated in the lung, liver, and blood. Potential adverse effects associated with cellular exposure to single-wall carbon nanotubes (SWCNTs) was investigated by Pacurari et al. (2008) who exposed normal and malignant mesothelial cells and measured reactive oxygen species (ROS) generation, cell viability, DNA damage and other molecular level events selected to represent the development of mesothelioma following asbestos exposure. Dose-dependent results included induced ROS generation, increased cell death, enhanced DNA damage and other molecular effects demonstrating potentially adverse effects at the cellular level in response to SWCNT exposure.

A relationship between exposure to arsenic via drinking water and the development of pterygium, a disease of the eye, was demonstrated by Lin et al. (2008) who evaluated the incidence of pterygium in three arsenic-exposed villages in southwestern Taiwan in comparison to four non-exposed villages. The study demonstrated that the incidence of pterygium was elevated in the exposed villages across all age groups and sexes and that the prevalence of pterygium increased with cumulative arsenic exposure.

The effects of B vitamins and antioxidants (vitamins A, C, and E) on skin lesions resulting from arsenic exposure were studied by Zablotska et al. (2008) in Bangladesh where high levels of arsenic are naturally occurring in the drinking water. The results showed that vitamin intake, including riboflavin, pyridoxine, folic acid, A, C, and E at doses higher than the recommended dose, had a significantly reduced the risk of arsenic-induced skin lesions.

Sunyer et al. (2008) measured the excretion of urinary porphyrins in 4-year-old children exposed to hexachlorobenzene in Flix, Catalonia, Spain, using surrounding communities with no airborne pollution to provide a control group. The study showed that there was no increase in urinary porphyrin excretion, but that total porphyrins and coproporphyrins I and III increased with increasing exposure to hexachlorobenzenes, and the outcome was particularly important with respect to exposure to 1,1-dichloro-2,2-bis(4-chlorophenyl)ethylene.

Kodavanti et al. (2008) evaluated the relationship between exposure to zinc as a component of particulate matter (PM) and cardiac effects in a study where rats were treated intratracheally with saline (as a control), PM with no water soluble zinc, a PM suspension containing water soluble zinc at both a high and a low dose, the aqueous fraction of the PM-zinc suspension, or zinc sulfate. The results indicated that the exposure to the PM with or without zinc resulted in pulmonary inflammation and the rats exposed to zinc demonstrated small scale cardiac mitochondrial DNA damage, inhibition of cardiac aconitase activity, and changes in cardiac gene expression patterns suggesting that zinc may play a role in cardiac effects associated with exposure to PM.

Using information from 1999-2004 NHANES participants greater than or equal to 20 years old, Tellez-Plaza et al. (2008) measured concentrations of cadmium in blood and urine and blood pressure to study the potential link between low level, chronic exposure to cadmium and

hypertension. The study results indicated that cadmium in blood, but not in urine, was linked to a modest increase in blood pressure with the effect observed more strongly among participants that never smoked that in those that were former or current smokers.

Silver et al. (2008) conducted a study to examine the link between occupational exposure to polychlorinated biphenyls and the incidence of breast cancer in women using a cohort of 5 752 women employed for at least one year in one of three capacitor manufacturing facilities and correlating potential exposure with breast cancer cases identified through questionnaires, cancer registries, and death certificates through 1998. Overall, the study did not identify an increased risk in the incidence of breast cancer related to duration or cumulative occupational exposure across the entire study group, but did demonstrate a potential elevated exposure risk among non-white workers.

Dose Response. Jarup et al. (2008) evaluated the dose-response relationship between hypertension and exposure to airport or road traffic noise for a group of people who had lived near one of six major airports in Europe for at least five years. The study identified a significant relationship between exposure to night-time aircraft or average daily road traffic noise and the risk of hypertension.

A linear relationship between cumulative inhaled arsenic exposure, increasing arsenic concentration, and the risk of respiratory cancer was demonstrated by Lubin et al. (2008) through a study of copper smelter workers. The results indicated that inhalation exposure to inorganic arsenic exhibited a direct concentration effect with higher concentrations and shorter duration exposure resulting in a higher risk versus lower concentration and longer duration exposure.

The relationship between dioxin exposure and mortality due to cardiovascular disease was reviewed by Humblet et al. (2008) using 12 cohorts of exposed individuals, 10 of which were occupationally exposed. The researchers identified significant dose-related increases in the risk of mortality due to ischemic heart disease and a lesser relationship with all mortality due to cardiovascular disease, although the potential bias associated with other risk factors for cardiovascular disease was not evaluated.

Fiedler et al. (2008) examined the potential for a dose-related response to hydrogen sulfide exposure and resulting sensory and cognitive function symptoms in 74 adult men and women with a mean age of 24.7 years and a mean educational history of 16.5 years. Measurements were made for three exposure concentrations (0.05, 0.5, and 5 parts per million) of hydrogen sulfide both before and after exposure and the results showed a dose-response relationship for observations of odor intensity, irritation, and unpleasantness, although the total severity of the symptoms was not significantly elevated for any exposure group and no dose-response relationship was demonstrated for sensory or cognitive measurements.

Looking at data sets collected from two studies where guinea pigs were given subcutaneous and aerosol exposure to the Lassa virus, Tamrakar and Haas (2008) developed dose-response models. The Beta-Poisson was found to be the best fit model since it was derived using biological considerations; however, when considering

mortality as an endpoint the log-probit dose-response model proved better and an exponential dose-response model when considering morbidity data.

The quality-adjusted life year (QALY) method was used by Guevel et al. (2008) to evaluate the health risks and nutritional benefits related to fish consumption by comparing medium n-3 polyunsaturated fatty acids (n-3 PUFAs) intake to high intake with respect to the cardiovascular system and on fetal neuronal development. The study indicated that increasing fish consumption may have a beneficial impact on health; however, the negative lower bound of the study confidence interval indicates that there may be negative impacts as a result of methylmercury contamination.

Subchronic and chronic oral reference doses (RfDs) and inhalation reference concentrations (RfCs) for acrylonitrile were determined to be 0.5 and 0.05 mg/kg·day and 0.1 and 0.06 mg/m^3 by Kirman et al (2008). Benchmark dose (BMD) methods were used to derive the methods as PBPK models were able to provide oral RfDs but were not used for the inhalation RfC estimation; this resulted in a medium to high level of confidence in the development of the toxicity values.

North American and European consumers were found likely to experience long-term uptake doses of perfluorooctane sulfonate (PFOS) and perfluorooctane acid (PFOA) ranging from 3 to 220 ng per kg body weight per day (ng/kg$_{bw}$·day) and 1 to 130 ng/kg$_{bw}$·day; with the greatest portion of chronic exposure being a result of intake of contaminated food and drinking water, and a higher uptake dose identified in children based on higher relative food consumption and hand-to-mouth behavior (Trudel et al. 2008). Uptake estimates were derived from blood serum data and applied in a one-compartment pharmacokinetic model for use in the scenario-based approach.

Exposure Assessment. Concentrations of triclosan, a chemical with antimicrobial activity widely used in consumer products, were measured by Calafat et al. (2008a) in a representative sample of the general U.S. population using urine samples from the 2003-2004 National Health and Nutrition Examination Survey (NHANES). Triclosan was detected in approximately three quarters of the sample group with concentrations varying by age and socioeconomic group with highest concentrations in people in the higher income group and in people in their 30s.

Högberg et al. (2008) studied the use of phthalate diesters and related metabolites in human breast milk, blood or serum, and urine as biomarkers for assessment of perinatal exposure to phthalates and the resulting developmental effects. The results showed the concentrations of phthalate metabolites in urine to be a better indicator than those in breast milk or serum and found no correlation between the concentrations, and concluded that the urine could not be used as an indicator of infant exposure to phthalates through breast milk ingestion.

The temporal effect of benzene exposure and leukemia mortality was studied in a group of 1 845 hydrochloride workers to evaluate the relationship between age at exposure and time since exposure to mortality (Richardson, 2008). The study indicated that the

relationship between leukemia mortality and exposure to benzene was strongest in the 10 years immediately after exposure and for exposures that occurred in people at greater than or equal to 45 years of age suggesting that additional investigation of the susceptibility of older workers should be considered.

A community of high dietary PCB exposure from whale blubber was examined for two groups of children with increased body burdens from breast-feeding to determine elimination half-lives (Grandjean et al., 2008). The longest half-lives correspond to elimination of the parent PCB by daily fat excretion and shorter half-lives assume metabolic break-down.

The contribution of dietary intake of organophosphorus pesticides on the overall exposure of children was the subject of a one-year study conducted in Seattle, Washington, using 23 children ages 3 to 11, who were evaluated seasonally via measurement of urine concentrations of the metabolites of malathion, chlorpyrifos, and other similar pesticides (Lu et al., 2008). The study included two 5-day periods during which the children were switched to organic fruits and vegetables in the summer and fall and it was demonstrated that the median metabolite concentrations in urine were non-detect or near non-detect following the 5-day organic diet period suggesting that dietary intake was a major source of organophosphorus pesticide exposure. The merit of community intervention as a tool to reduce exposure to organophosphorus pesticide exposure in the children of farm workers was the subject of a four-year study conducted by Thompson et al. (2008). The researchers discovered that the concentrations of urinary pesticide metabolites was higher at the end of the 4 years than in year 1 of the study and that there was no significant difference in metabolite concentrations between communities subject to intervention programs and the control communities. Corozza, et al. (2008) conducted an epidemiological study of the incidence of childhood cancers as it relates to potential pesticide exposure of children living in agriculturally intense areas versus those living in areas with lower agricultural activity using data for U.S. children 0-14 years old that had been diagnosed with cancer between 1995 and 2001 correlated with agricultural census data that was used to determine agricultural intensity. A statistically significant increase in risk for several types of childhood cancers was demonstrated in areas of moderate to high levels of agricultural activity and cancer type varied by crop.

The exposure to polybrominated diphenyl ethers (PBDEs) in children in a developing country was evaluated through analysis of serum samples from children 11 to 15 years of age scavenging scrap from or living at a municipal waste disposal site in Managua, Nicaragua (Athanasiadou, et al., 2008). The group showed high levels of “medium” PBDEs and the hydroxylated PBDE metabolites were demonstrated to bioaccumulate in the human serum.

Measured concentrations of PBDEs in southern Mississippi catfish were used to determine background levels, daily intake, and risk associated with the consumption of these chemicals from a primary food source (Staskal et al., 2008). Evaluation of cancer risks and noncancer hazard indicated that health risks due to fish

consumption by adults are substantially lower than risk levels generally considered to be at the US Environmental Protection Agency minimum concern level.

Drinking water contaminated with perfluorinated compounds (PFC) was identified in Arnsberg, Germany, in May 2006, which was ultimately attributed to agricultural applications of soil conditioners that contained varying amounts and types of the compounds (Hölzer et al., 2008). A cross-sectional study to evaluate exposure in 170 children, 317 mothers, and 204 men determined that PFOA was the main PFC identified in the drinking water and that PFOA concentrations in blood plasma of Arnsberg residents were 4.5 to 8.3 times higher than in the control group and volume of tap water consumed in the home was a significant predictor of exposure.

Fängström et al. (2008) conducted a study of the concentrations of arsenic in breast milk of mothers in Bangladesh with high exposure to arsenic and the resulting concentrations in their infants as it relates to the percentage of nutrition that is provided via breast-feeding. The results indicated that the arsenic concentrations in breast milk were low regardless of the degree of maternal exposure to arsenic and that the urine concentrations in infants not exclusively breast fed were higher leading to the conclusion that exclusive breast feeding was protective against infant arsenic exposure.

A study of individual exposure to pPAHs in pregnant women in Krakow, Poland was conducted by Choi et al. (2008) to characterize indoor versus outdoor exposure and to identify behavioral and environmental effects on person exposure. The results demonstrated that the outdoor PAH concentrations had the greatest effect on personal exposure even when the individual was indoors and also that the mean personal exposure was dependent on season, living area, and exposure to environmental tobacco smoke.

In 1968 in Japan, exposure to rice oil contaminated with PCBs and dioxin-related compounds resulted in a disease known as Yusho oil disease. Tsukimori et al. (2008) studied the effect of that exposure on pregnancy outcomes in 214 Yusho women and determined that in the 10-year period immediately following the exposure, there was an increase in the incidence of spontaneous abortion, preterm delivery, pregnancy loss, and medically induced abortion over the 10-year period immediately preceding the exposure; the relationship between the exposure and the pregnancy outcomes was observed to decrease over time and the differences in incidence rates disappeared by 10 years following exposure. The relationship between prenatal exposure to PCBs and intelligence, evaluated through intelligence quotient (IQ) testing in a cohort of 9-year-old children, was assessed by Stewart et al. (2008) using children from Oswego, New York, who are participants with their mothers in an ongoing study on PCB exposure as it relates to cognitive development. Correlating concentrations of PCBs in placental tissue with IQ test results and controlling for a number of potential confounders, the researchers documented that prenatal exposure to PCBs was related to lower IQ test results demonstrating that for each 1 nanogram per gram increase

in PCBs in placental tissue there was a corresponding drop of 3 points for Full Scale IQ and 4 points for Verbal IQ.

Total concentrations of urinary bisphenol A (BPA) and 4-tertiary-octylphenol, chemicals used in the manufacture of polycarbonate plastics and epoxy resins, were measured by Calafat et al. (2008b) in 2,517 2003-2004 NHANES participants and it was determined that exposure to BPA in the general U.S. population was widespread. In addition, the results demonstrated that urinary concentrations of BPA were different based on race or ethnicity, age, sex, and household income with non-Hispanic blacks and whites having higher concentrations than Mexican Americans, females having higher concentrations than males, children having higher concentrations than adolescents, who had higher concentrations than adults, and the high household income group having the lowest concentrations.

Phthalate exposure in the U.S. resulting from ingestion of medications that contain phthalates as inactive ingredients was the subject of a study by Hernández-Diaz et al. (2008) using data from 1999-2004 NHANES participants; the researchers identified several oral medications potentially containing phthalates and correlated this information with urinary concentrations of phthalates. The results suggested there may be a link between ingestion of medications containing phthalates and elevated concentrations of phthalate compounds in urine, although several study limitations were noted including inexact measures of medication use resulting in likely misclassification of phthalate exposure and lack of information on brand names to confirm phthalate content of medications.

Love Canal was one of the earliest events in the U.S. where historical operation of a hazardous waste site was linked to direct chemical exposure of nearby residents; using information from a cohort of 6 181 former residents of Love Canal, Gensburg et al. (2008) evaluated mortality for the years 1979-1996 and compared the mortality rates to those of New York State and Niagara County. No increased all-cause mortality rate was demonstrated for Love Canal residents versus the state and county rates, but the standardized mortality ratio was observed to be elevated for death due to acute myocardial infarction as compared to the state, but not the county rates, and the ratio was also elevated for death due to external causes of injury (e.g., suicide or motor vehicle injury) as compared to both the state and county suggesting a potential relationship between residence at Love Canal and mortality, although a number of study limitations need to be addressed before any specific pattern of association can be drawn.

The U.S. Food and Drug Administration (2008) released the results of its human risk assessment of melamine and melamine analogues found in foods, including an update for the 2008 reported cases of melamine found to be present in infant formula and the potential for related illness.

Kahn and Stralka used the United States Department of Agriculture's (USDA) 1994-96 and 1998 Continuing Survey of Food Intake by Individuals (CSFII) to estimate daily average water intake for women of child bearing age who were pregnant, lactating, or non-

pregnant/non-lactating. The estimates were then compared with previous data collected in 1978 showing that the estimates from the new data are less than the estimates from the earlier study.

Water samples collected from private wells in Saudi Arabia were analyzed for heavy metals to conduct a non-carcinogenic risk assessment by Zabin et al. (2008). The results illustrate that manganese, chromium and zinc have HQ values less than one, iron and fluoride have HQ values greater than one, and there was a concern for chronic non-cancer adverse effects from some samples where the Hazard Index (HI) values were greater than one.

A review of literature studying the chemical substances in drinking water being carried by plastic pipes was used by Stern and Lagos (2008) to examine potential health hazards as well as uncertainties where more research is needed. The research identified numerous chemical leachates of concern with human health effects, and one of the big concerns still in question is how some of the leachates may have synergistic effects.

Siriwong et al. (2008) conducted a human health risk assessment of freshwater organism consumption with exposure to organochlorine pesticide residues (OCPRs) in a canal located in the Rangsit agricultural area of Thailand. Low concentrations of α-, β-HCH, heptachlor, heptachlor epoxide, aldrin, dieldrin, DDD, DDE, and DDT were detected in part per billion levels, and a worst case scenario suggests a risk of cancer to the local population.

Sheehan et al. (2008) reconstructed the historical exposure of a worker to benzene during elevator bearing cleaning using mineral spirit solvent. The dose was estimated to be 0.2 mg benzene, which is similar to the amount an individual living in urban area receives from non-occupational sources.

Tissue distribution of PBDEs using rat models was found in all tissues, with lower brominated congeners distributing equally in lipids, which implied both adipose tissue and plasma are suitable for biomonitoring (Huwe et al., 2008). The higher brominated congeners were detected optimally in plasma, although on a lipid-weight basis resulted in an overestimation of the total body burden.

A study was conducted by Shama and Peterson (2008a) to characterize human dietary exposure to three proteins (aprotinin, gastric lipase, and *Escherichia coli* heat-labile enterotoxin B subunit) using three different exposure scenarios. The risk assessment came to the conclusion that dietary risks depend on the specific protein, protein expression, exposure scenarios and vary from case-to-case.

Modeling and Probability Simulation. Using Monte Carlo simulation, probability density functions for 24 hour inhalation rates were updated by Allan et al. (2008) using time-activity and minute volume data to compare with the metabolic energy conversion and doubly labeled water approaches. This study produced higher inhalation rates for adults and seniors, lower for toddlers and teenagers, and similar for infants and children.

A case study was conducted using the Theory of Planned Behavior to determine if the adoption of probabilistic risk assessments (PRA) by end-users and decision makers is feasible. Frewer et al. (2008) determined that in order for PRA to be adopted, training

programs need to be developed for specific end-user sectors.

Shama and Peterson (2008b) took their study of assessing risks of plant-based pharmaceuticals farther by looking at non-target organism exposure to three proteins (aprotinin, gastric lipase, and *Escherichia coli* heat-labile enterotoxin B subunit) produced in field-grown maize for four receptor species. The probabilistic risk assessment determined that risks will vary between species and proteins, and that it is important to identify risk on a case by case basis.

Using a Bayesian approach, Monte Carlo sampling, and available health outcome data Devine and Qualters (2008) updated model based risk estimates. Health data (lung cancer mortality) from a population exposed to ionizing radiation from a uranium processing facility was used to demonstrate the outcome of combining information to create more accurate estimates.

The procedures outlined in the *Guide to the Expression of Uncertainty In Measurement* (GUM), which evaluates the uncertainty of health risk and contribution of the variables, were evaluated using multiple substances and exposure routes by Sassi and Ruggeri (2008). Following usual risk methodologies, the GUM procedure was determined to be straightforward and indicated the major contributor to risk of the three volatile organic compounds evaluated, and identified criterion for treatment to reduce risk.

Chatterjee et al. (2008) used a Bayesian latent-variable model approach to predict levels of pesticide (Iprodione) intake via food consumption based on daily food consumption data from the Netherlands National Food Consumption Survey and concentration data collected by the Netherlands Ministry of Agriculture. The latent-variable approach allowed for both skewness and a large number of zeros in the data set.

Probability distributions for uncertain cancer risks for inhalation of formaldehyde was predicted by Small (2008) by using a combination of bioassay study results, targeted experiments, and judgment regarding biological mechanisms. The approach of Bayesian belief networks and use of weight of evidence procedure provided a manner to synthesize multiple sources of information.

The Conway-Maxwell Poisson (COM) distribution was determined to be useful in both underdispersed and overdispersed count data when applied to the assessment of electric power system reliability by Guikema and Goffelt (2008) as a new approach to generalized linear models (GLM). The evaluation indicated that the proposed COM GLM both outperforms existing models used for underdispersed data sets and performs comparably to models for overdispersed data sets.

Building on a previously developed GIS-Integrated Risk Index that assessed human health risks in areas with environmental pollutants by ranking contaminants based on persistence, bioaccumulation, and toxicity in a self-organizing map (SOM) to determine the Hazard Index (HI), Nadal et al. (2008a) developed a neuroprobabilistic HI by combining the SOM and Monte Carlo analysis. The applicability of the probabilistic model was checked using a case study of a chemical and petrochemical industrial area of Tarragona (Catalonia,

Spain); while current levels of pollution did not mean a relevant source of health risks, the neuroprobabilistic HI was deemed an adequate tool in risk assessment and followed a similar pattern to the deterministic HI approach.

The utility of a modeled air pollution (MAP) scale derived from a perceived air pollution (PAP) scale was evaluated by Lederman et al. (2008) by using the scale to predict previously observed birth outcomes of pregnant women after September 11, 2001 and their proximity to the World Trade Center (WTC) site. A high correlation between proximity to the WTC for both MAP and PAP scales was reported and birth outcome relationships of the MAP scale were similar to those previously observed for the PAP scale when MAP values were used to measure exposure instead of proximity; therefore, use of a MAP developed from a PAP scale might be useful in predicting health outcomes when multiple sources of pollution are present and distance from a source is difficult or impossible to determine.

Bioassay data, toxicokinetic data, and pharmacokinetic analyses were used by Bogen (2008) to indicate that naphthalene is a dual mode of action carcinogen, in an application of an adjustment-factor approach of nasal tumors in rats induced by chronic lifetime exposure to naphthalene. This adjustment-factor approach was used to demonstrate that when non-linear toxicokinetic models can not be fully validated, the effect of dual mode-of-action uncertainty can be addressed, thereby, providing a method to determine low-level risk extrapolation.

Evaluation of biological and statistical uncertainties issues were determined to be necessary by Subramaniam et al. (2008) if the CIIT model for estimating respiratory cancer risk due to inhaled formaldehyde is to be applied for two-stage clonal expansion models for extrapolation of risk from animal bioassays to human exposure, including the use and interpretation of experimental labeling index and tumor data, the evaluation of biological interpretation of estimated parameters, and uncertainties in model specification. The claim by the CIIT model authors that their estimates of human risk were conservative was determined premature based on this evaluation.

A Monte-Carlo type model was used by Gagnon et al. (2008) with objective residential radon exposure data, population mobility, and tobacco use in Quebec homes to evaluate the effectiveness of reducing lung cancer mortality by implementing radon screening programs. Approximately 10 % of deaths due to lung cancer were found attributable to residential radon exposure in Quebec; radon screening in public buildings presented the most promising screening policy for reducing radon-related lung cancer: a reduction of 16.4 percent.

Risk Characterization, Management, and Policy. The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) conducted a review of the issues involved in the investigation and remediation of tungsten including an evaluation of fate and transport in the environment, sampling and analysis, toxicity and health effects, and federal and state regulatory guidelines.

Research was done on laypeople's view of results from a risk assessment study of hazards involved from cell phones and base stations. Siegrist et al. (2008) showed how participants in the study were more confident with the outcome when the study indicated a risk and when their prior opinion was proved to be correct.

Using five risk assessments for neurobehavioral effects of manganese, Peters et al. (2008) studied how systematic reviews and meta-analysis methods can supplement the risk assessments. The study concluded that the methodological approach revealed a more transparent and systematic human health risk assessment.

A comparison of U.S. state fish consumption advisories available on the internet was conducted by Scherer et al. (2008) using the US Environmental Protection Agency's National List of Fish Advisories as a starting point and evaluating factors such as audience and advice (particularly messages directed at sensitive groups), risk and benefit messages, and general advisory characteristics. The findings indicated that 48 state advisories were available with 100 percent targeting children, 90 percent targeting pregnant women, and 58 percent targeting women of child-bearing age; the advisories were generally limited to a dozen or less contaminants; and there was little emphasis placed on the benefits of fish consumption; the researchers concluded that there was general lack of clarity and consistency in presenting the information particularly for sensitive groups.

The possibility for industrial restructuring to achieve a sustainable outcome in Shandong, China was studied by Yuan et al. (2008) using predicted values through the year 2020. By putting policies in place from the Organization for Economic Cooperation and Development (OECD) the energy consumption, SO_2 emissions, wastewater, and Chemical Oxygen Demand discharges will be reduced and only water demand will increase slightly.

The Ebro River in Catalonia, Spain was the location where Nadal et al. (2008b) studied the metal exposure risks posed to humans from consuming fish and seafood. Risk values for metals were found to be below the threshold levels except for the risk of arsenic which was slightly increased from estimations in recent literature.

Pesticide residues (pirimiphos-methyl, fenitrothion, lambda-cyhalothrin, chlorpyrifos, folpet, cypermethrin, and endosulfan) on tomatoes from Ghana were studied by Essumang et al. (2008) for a human health risk assessment. Cancer risks were evident from the presence of endosulfan and chlopyrifos, and the highest residue levels were found to be 10.76 mg/kg for chlorpyrifos (dursban 4E or terminus 480 EC).

A risk analysis was done by Froom et al. (2008) on Israeli Naval divers from pollutants in the Kishon River. The relative risk for the worst-case scenario and actual diving areas was 1.13 and 1.004 respectively, indicating that a risk of cancer can not be seen based on the conservative assumptions used.

Cadmium bioavailability in agricultural soils and crops was studied by Grant and Sheppard (2008) looking at the impact of fertilizers. Risk is apparent from cadmium in fertilization; however, a balance needs to exist to develop sustainable nutrient management in agriculture.

A telephone survey of Canadians about chemical, biological, radiological, nuclear, and explosive (CBRNE) terrorist events was analyzed by Etchegary et al. (2008) This study found that based on responses there is a need to educate the public with more information about forms of CBRNE and ways to increase their emergency preparedness.

Using a risk assessment of contaminated sediment from the New York/New Jersey harbor, Kiker et al. (2008) illustrated the use of multi-criteria decision analysis. Rankings were created to show different sediment management alternatives under different criteria and utility relationships.

Innovators of nanotechnology are examined to determine if risks and adverse effects are taken into consideration from previous technological developments. Kohler and Som (2008) suggest that innovators may not calculate the risks involved before moving forward with technology, and then developed approaches to consider the potential risks in a proactive manner.

White et al. (2008) estimated the increase in premature deaths of people living in the Kingdom of Saudi Arabia from the particulate matter in the air caused from the Gulf War of 1991 and 1992. The study estimated that approximately 1 080 to 1 370 Saudi citizens died in relation to the elevated particulate matter levels.

A "safe" population-level threshold concentration of zinc exposure was derived by Kamo and Naito (2008) using published toxicity results and the concept of species sensitivity distribution. The 95 percent protection level of zinc was calculated to be 107 μg/L, the 95 percent protection criterion was 14.6 μg/L, and the "safe" concentration for a population-level endpoint was found to be 7 times greater compared to an individual-level endpoint.

The infant mortality rate (IMR) in U.S. Mid Atlantic States and poor water quality of streams at a local scale were compared by Paul et al. (2008) to observe any relationships that may exist. Based on the data a hypothesis was developed indicating that stream degradation and increased IMR may be linked to socioeconomic conditions, land use, and human activities.

Severe accident risks were assessed in full energy chains using the Energy-related Severe Accident Databse (ENSAD) and the Probabilistic Safety Assessment (PSA) by Burgherr and Hirschberg (2008). Countries in the Organisation for Economic Co-operation and Development (OECD) were compared to non participating countries to show that non-OECD countries are more accident prone due to less safety regulations, and costs associated with these accidents are less than the cost associated with damages caused by air pollution.

A study conducted by Monheit et al. (2008) evaluated the health hazard for Native Americans ingesting tules in Clear Lake, California and being exposed to the herbicide fluridone. The results illustrate that the hazard quotients were 10^{-5} and 10^{-4} for subchronic and chronic exposures, respectively, which ultimately indicates that little to no hazard exists from the herbicide applications.

Margin of Exposure values were calculated for background arsenic exposures by Boyce et al. (2008) by comparing no-observable-adverse-effect-levels from the

literature with exposure estimates from a Monte Carlo simulation. This analysis shows there are no carcinogenicity risks from background inorganic arsenic exposure in U.S. populations.

The health risks from dioxins in fish and airborne fine particles were quantitatively analyzed and the changes in risk views of current and forthcoming European Union regulations on pollutants were studied by Leino et al. (2008) by performing a comparative risk assessment for both pollutants in the Helsinki metropolitan area and estimating the health effects with several scenarios. Substantial improvement to public health was found if emission standards were reduced indicating that the estimated fine particle risk outweighed the estimated dioxin risk and the benefits of increased omega-3 exposure through fish consumption were greater than the potential carcinogenic risk from dioxins.

Data on the occurrence of binary and ternary mixtures of arsenic, cadmium, and manganese were used by Ryker and Small (2008) to prioritize future toxicological studies based on the potential to reduce uncertainty in risk. National groundwater quality data were used to evaluate U.S. Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry models of noncancer mixture toxicity.

Kellstedt et al (2008) deduced that public informedness, public confidence in climate scientists, and the role of personal efficacy are related and exert significant influence on risk assessment of global warming and climate change from the review of results from a survey of Americans, which have substantial implications for the interaction between scientists and the public. Specifically, more informed respondents and respondents with high confidence in scientist feel less responsible for and show less concern for global warming and climate change.

Residents were found to be able to make the distinction between hazards from contamination and human health risks in a case study conducted by Vandermoere (2008) to examine hazard and risk perceptions in people exposed to soil pollution. Drawing on psychological and sociological perspectives on risk perception, including ecological variables, an ecological-symbolic approach was used in the study.

Based on a literature review, Trumbo et al (2008) concludes that risk perception is in the common psychological dimension within the context of cancer clusters and community-level measures have limited impact on individual factors. This study focused on psychometric model of risk perception, an adaptation of the heuristic-systematic information processing model, and cancer anxiety as well as five community-level variables: demographic, epidemiologic, sociologic, etiologic, and pathologic.

Johnson (2008) determined that, while a majority of residents were able to appreciate a drinking water standard, compare the contaminant level of the standard to a government standard, some residents were unable to tell whether the contaminant levels were better or worse than the standard and a large degree of skepticism about the degree of risk associated with various standards was observed. The population of New Jersey residents surveyed

by mail tended to apply higher levels of risk to those better known pollutants (e.g. mercury, lead, arsenic).

According to Nauta et al. (2008), risks associated with Campylobacter on broiler meat decreased when behavioral cues in addition to information intervention supported by the emotion "disgust" in a risk model in the Netherlands. Therefore a transdisciplinary approach between the social and natural sciences was deemed successful in reducing potential risks and provides a new tool for science-based risk management in food safety.

Risk ratings from Togolese villagers without access to media, African city-dwellers with access to media, and French participants were compared by Kpanake et al. (2008) to evaluate the impact of media on people's risk perceptions. An increase of 15 percent on risk perception was estimated to be the impact of media; which was found to be independent of education level.

Poortinga et al. (2008) surveyed 1 528 members of the public via a postal questionnaire (with a 28 percent response rate) to identify causes of the different perception of risks associated with radon and overhead powerlines. The evaluation indicated that either risk perception varied directly with proximity or that risk is more concerned people in exposed area; that, while people living in high radon areas are more concerned with risks associated with indoor radon gas, they have more trust in government authorities and the risks are more acceptable.

Regulatory Agency Guidance, Standard, and Policy. The US Environmental Protection Agency (2008a) published an update on state brownfields and voluntary response programs include an overview of the environmental, technical and financial programs. The update includes an overview of state program descriptions, financial elements, programs elements, cleanup activities, public participation requirements, statutory authorities, and contact information for each state program.

A database for the storage and analysis of data from vapor intrusion sites was developed and is being managed by the US Environmental Protection Agency (2008b). A description of the how the database was developed and how it can be used to derive attenuation factors and otherwise evaluate vapor intrusion data is available in the March 2008 draft US Environmental Protection Agency*'s Vapor Intrusion Database: Preliminary Evaluation of Attenuation Factors*.

Estimates of cancer incidence and mortality risk resulting from exposure to low dose ionizing radiation for the U.S. population is presented in the US Environmental Protection Agency's (2008c) draft *Radiogenic Cancer Risk Models and Projections for the U.S. Population* including a discussion of biological mechanisms, epidemiology, risk projections from low- and higher liner energy transfer, risks from prenatal exposure, and radionuclide risk coefficients.

The US Environmental Protection Agency's Office of Inspector General (2008d) conducted a review of the scientific literature as it relates to the health effects of perchlorate and other sodium/iodide symporter (NIS) stressors that have been associated with disruption of the uptake of iodide by the thyroid. The analysis concluded that evaluation of the risk from perchlorate is only one part of the larger public health issue and that perchlorate should be included in a cumulative risk assessment using the dose

addition method and incorporating other major NIS stressors that act on the thyroid including thiocyanate, nitrate, and lack of iodide.

The First External Review Draft of the *Integrated Science Assessment for Particulate Matter* was released by US Environmental Protection Agency (2008e) and presents the agency's evaluation of the relevant science for evaluating potential exposure, health effects, and protection of public health for particulate matter.

The US Environmental Protection Agency (2008f) released an external review draft of its exposure assessment for polybrominated diphenyl ethers for public comment. The document addresses exposure assessment needs identified by an interagency working group and provides an evaluation of U.S. exposure that includes production, use, and lifestyle; environmental fate; exposure concentrations, and human exposure routes and monitoring.

Factors used to evaluate risk in children aged 0 to less than 21 years of age were published by the US Environmental Protection Agency (2008g) in the Child-Specific Exposure Factors Handbook, which includes nonchemical-specific data for a number of areas including ingestion, inhalation, dermal exposure, body weight, dietary intake of specific food groups and total food intake, human milk intake, activity factors, and consumer products.

A final report on cumulative health risk assessment was issued by the US Environmental Protection Agency (2008h) that focused on initiating factors and technical approaches for assessing human health risk associated with potential exposure to multiple chemicals. The report addresses population characterization, data collection and organization; chemical grouping; evaluating exposure timing; internal dose measurements; mixture risks using the Relative Potency Factor; multiple effects modeling; hazard index considerations; and cumulative risk characterization, and includes a Risk Assessment Toolbox.

The US Environmental Protection Agency (2008i) released its final *Framework for Application of the Toxicity Equivalence Methodology for Polychlorinated Dioxins, Furans, and Biphenyls in Ecological Risk Assessment*, which is intended to be used in concert with the agency's published ecological risk assessment guidelines and is specific to the evaluation of ecological risk associated with dioxin and dioxin-like chemicals. Key elements of the guidance document include presentation of the toxicity equivalence methodology and its specific application to the ecological risk assessment process, including planning, problem formulation, analysis, and risk characterization.

A review of how industry approaches issues of nanomaterial risk and safety was conducted for 40 companies in Germany and Switzerland that had a diversity of properties (Helland et al., 2008). Over half of the companies (65 percent) did not perform risk assessments of their nanomaterials, indicating the necessity of developing risk and safety decision frameworks to ensure that the potential risks of engineered nanomaterials are taken into consideration.

Examples of exposure to radiation and an acute chemical were used by Cooke et al. (2008) in the classic newsboy problem to demonstrate that if scientists could quantify uncertainty in dose-response and if stakeholders

could quantify the loss rate ratios, the uncertainty of the dose-response relation can be determined. In doing this, regulators will have a tool for use in setting action levels or limits for health protection.

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