



Cumulative Risk Webinar Series

WHAT WE LEARNED





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by

Devon C. Payne-Sturges and Lawrence Martin



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List of Acronyms

ADHD	attention deficit hyperactivity disorder	NATA	National Air Toxics Assessment
ALT	alanine aminotransferase	NCA	Neighborhood Council of Advisors
AOP	adverse outcome pathway	NCEA	National Center for Environmental Assessment
BenMAP	Environmental Benefits Mapping and Analysis Program	NCER	National Center for Environmental Research
CAA	Clean Air Act	NCP	National Contingency Plan
CADDIS	Causal Analysis/Diagnosis Decision Information System	NDEA	N-Nitroso-N-Diethylamine
CalEPA	California Environmental Protection Agency	NDMA	N-Nitrosodimethylamine
CCL	Contaminant Candidate List	NESHAP	National Emissions Standards for Hazardous Air Pollutants
CEHI	Cumulative Environmental Hazards Index	NHANES	National Health and Nutrition Examination Survey
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act	NO ₂	nitrogen dioxide
CEVA	Cumulative Environmental Vulnerability Analysis	NPDWR	National Primary Drinking Water Regulations
CR	concentration response	NSPS	New Source Performance Standards
CRA	cumulative risk assessment	OAR	Office of Air and Radiation
CSAPR	Cross-State Air Pollution Rule	OEHHA	Office of Environmental Health Hazard Assessment
CWA	Clean Water Act	ORD	Office of Research and Development
DALY	disability adjusted life year	OW	Office of Water
DBP	disinfection byproduct	PCB	polychlorinated biphenyl
EJ	environmental justice	PM _{2.5}	fine particulate matter
EPA	Environmental Protection Agency	QALY	quality adjusted life year
EU	European Union	RAF	Risk Assessment Forum
FDCA	Federal Food, Drug, and Cosmetic Act	REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act	RfD	reference dose
FQPA	Food Quality Protection Act	SDWA	Safe Drinking Water Act
GIS	geographic information system	SES	socioeconomic status
HAP	hazardous air pollutant	STAR	Science To Achieve Results
HOME	Home Observation for Measurement of the Environment	SVI	Social Vulnerability Index
IRIS	Integrated Risk Information System	TMDL	total maximum daily loads
IVAN	Imperial Visions Action Network	UIC	underground injection control
MCL	maximum contaminant level	USDHHS	U.S. Department of Health and Human Services
MCLG	maximum contaminant level goals	USEPA	U.S. Environmental Protection Agency
MPCA	Minnesota Pollution Control Agency	VOC	volatile organic compound
NAAQS	National Ambient Air Quality Standards	WQS	Water Quality Standards
NAFLD	nonalcoholic fatty liver disease		
NAS	National Academy of Sciences		

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Disclaimer

The research described in this document was presented as part of the U.S. Environmental Protection Agency's (EPA) 2013 Cumulative Risk Assessment Webinar Series. The information provided does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. The report is intended to provide the reader with insights into the science and policy aspects of cumulative risk assessments.



CUMULATIVE RISK WEBINAR SERIES

WHAT WE LEARNED

by

Devon C. Payne-Sturges¹ and Lawrence Martin²

The Cumulative Risk Webinar Series was presented to examine and stimulate discussion of topical issues important to advancing cumulative risk assessment (CRA). The U.S. Environmental Agency's (EPA) National Center for Environmental Research (NCER) is funding extramural research to develop methods and strategies for assessing the combined effects of chemical, physical, biological and social stressors while factoring in population vulnerabilities (see <http://www.epa.gov/ncer/cra/>). EPA's Risk Assessment Forum (RAF) is developing Agency guidelines for CRA, building upon the existing methods for chemical mixtures risk assessment routinely employed by EPA programs and regions. Because of our common interest in advancing the science on cumulative risk, NCER and the RAF Cumulative Risk Assessment Technical Panel collaborated to host the webinar series, which ran from August 2012 through December 2013. Presentations were chosen for their innovative research on cumulative risk, particularly quantitative and qualitative methods and analytical strategies for examining combinations of multiple chemical, physical and biological stressors, as well as how to factor in population vulnerabilities, including socioeconomic stressors.

The webinar series presented 15 public webinars between August 2012 and December 2013. The series featured scientists from both inside and outside EPA, including Science to Achieve Results (STAR) grantees funded by EPA, who discussed the development of cumulative risk analysis methods, including methods for incorporating "nonchemical stressors." The CRA Webinar Series was open to the public to stimulate wide discourse on cumulative risk themes. The audience was broad and included representatives from academia, industry, state and local environmental and public health agencies, nonprofits, consulting firms, community-based organizations and environmental justice (EJ) organizations. Each webinar had between 100 and 250 participants. Archived recordings of each webinar can

be found on NCER's website. (See [Webinar Dates and Recordings](#), below, for a directory of webinar titles and links.)

Addressing multiple exposures to chemical and nonchemical stressors and cumulative risks and impacts in environmental decisions has long been a challenge for risk assessment and has concerned communities and EJ organizations. The webinar series identified a number of key science and science-policy issues for advancing the practice and utility of CRA, which are summarized below.

Complexity of the Concepts and Definitions for Vulnerability and Nonchemical Stressors

Stressful social environments may make a population that is already subject to chemical stressors even more sensitive to unhealthy environment exposures. Extensive studies show associations between disadvantaged communities and suboptimal health. Because of the push for CRA to include *social stressors* (also commonly referred to as "nonchemical stressors"), epidemiological studies are becoming very important and receiving greater emphasis in CRA as an approach to assessing the relative contribution of different stressors, and potential interactions between chemical and social stressors. The August 2012 webinar speaker, **Ari Lewis**, provided excellent definitions and conceptual frameworks for vulnerability. She also provided examples of how, within each of the four traditional risk assessment steps, CRA could move beyond screening assessments and include vulnerability and social stressors.

Epidemiological Methods, Effect Modifiers, Dose-Response Curves

More evidence is emerging that social conditions may amplify the effect of environmental agents on health and can contribute to health disparities. These social conditions may be quantitatively incorporated in

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cumulative risk assessment as effect modifiers in the dose-response assessment if data exist to support this relationship. The September 2012 webinar speaker, **Neal Fann**, presented an approach that showed that educational attainment, a marker of socioeconomic status (SES), modified the relationship between fine particulate matter (PM_{2.5}) and mortality: Lower educational attainment is associated with higher PM_{2.5} mortality risk. The January 2013 speaker, **Dr. Ramya Chari**, presented results of her research in which she replicated the risk assessment approach used by EPA in 2008 to revise the National Ambient Air Quality Standards (NAAQS) for lead, except Dr. Chari incorporated information from published studies that indicated lead health effects vary across socioeconomic position. Her results were startling: Children from low SES families are impacted more in terms of estimated IQ loss than are children from higher SES families who receive the same level of air lead exposure.

Statistical Models (Biomonitoring, Microdata, Logistic Regression)

Statistical models may be applied in a variety of ways to evaluate cumulative exposures and risks. The November 2012 speaker, **Dr. Krista Christensen**, demonstrated a regression model based on National Health and Nutrition Examination Survey (NHANES) biomonitoring data that could predict the effects on common health endpoints. She felt the best use of this statistical approach (logistic) would be for dose-response assessment for multiple stressors. CRA at community levels is challenged by the availability of relevant exposure and health data at the appropriate geographic scale. The April 2013 webinar STAR grantee, **Dr. Jonathan Levy** explained his use of regression models to generate a data set based on samples from a subset of individuals in the community—simulated annealing. He validated his model against state-level survey data. A statistical approach being developed seeks to overcome the limitations of traditional effect modification or interaction terms in regression equations and models. During the June 2013 webinar, **Dr. Wenyaw Chan**, also a STAR researcher, provided an overview of a new logistics regression framework to assess the combined effects of environmental and psychosocial stressors on hypertension. The psychosocial stressors that will be included in the model are identified through the community-based participatory research component of the project led by Dr. Chan's colleague, **Ms. Maria Jimenez**.

Mapping and Screening for Cumulative Burden (Indices)

We learned about the utility of several mapping and screening tools for cumulative community impacts/burden: Cumulative Environmental Vulnerability Analysis (CEVA) methodology (October 2012,

Dr. Jonathan London); an EJ mapping tool developed for metropolitan Atlanta (February 2013, **David Deganian** and **Nick DiLuzio**); and the California Environmental Protection Agency's (CalEPA) CalEnviroScreen (July 2013, **Dr. George Alexeeff**). These speakers demonstrated how geographic information system mapping of multiple pollution sources (all based on publically available data sets) overlaid with demographics information can help to identify locations with high environmental hazard burdens. The CalEnviroScreen and CEVA tools go further by incorporating indicators of population vulnerability and nonchemical stressors. Each speaker also championed the importance of community involvement and engagement in the development of these mapping tools and in the translation of the results. Dr. Alexeeff stated that extensive community engagement was conducted to identify key pollution sources or concerns, as well as which health and social indicators to include in CalEnviroScreen. Mr. Deganian and Mr. DiLuzio noted that their EJ mapping tool for Atlanta served as a public engagement vehicle, helping to educate residents about their neighborhoods. Although these mapping approaches for cumulative burden can be quite sophisticated, they are suitable for screening geographic locations for cumulative impacts and identifying overburdened populations or communities. These approaches can help regulatory and public health agencies better describe communities (conditions and vulnerabilities) that are potentially affected by pollution and help prioritize where regulatory action might be needed, versus using the screening tool to set standards or show causation of health effects.

Legal/Decision Frameworks

Webinar participants frequently asked (in the post-webinar evaluations) for information on decision frameworks for CRA. Risk assessors are concerned that CRA requires considering every possible stressor in the assessment, which seems daunting. Others are concerned about statutory authority for using CRA in decision making. Other complicated scenarios for applying CRA include cases where the objective is to apportion responsibility among parties (polluters) for an existing pollution problem, such as a hazardous waste site. Four webinar speakers addressed the use of CRA in decision making. The most concrete example of using cumulative analysis in a regulatory decision making context was Minnesota's new air permitting statute, *Minn. Stat. § 116.07, subd. 4a*, which applies only to the South Minneapolis area. As the December 2012 speaker, **Dr. Kristie Ellickson**, described, under this law, the Minnesota Pollution Control Agency first must "analyze and consider cumulative levels and effects" before it issues permits in the affected area. The law does not use the terms "cumulative impacts" or "cumulative risks," but it does include all pollutants, environmental

media, sources, and time periods and receptors. A federal statutory perspective on using CRA in decision making was presented in the September 2013 webinar by **Sarah Alves** and **Joan Tilghman**. We learned that Congress has intentionally addressed environmental pollutants/problems on a piecemeal basis (pollutant-by-pollutant). Congress also deliberately writes statutes broadly so that EPA can implement them more effectively over time. Furthermore, the statutes do impose a general provision on the Agency to “protect public health,” which could open a window to apply cumulative risk in a decision. Even if a court finds that an environmental statute with a broad mandate to protect public health gives EPA discretion to consider CRA, the Agency must be able to demonstrate that (1) its CRA methodology and its use of the results are scientifically reasonable (i.e., appropriate use of data and assumptions) and (2) that it considered all factors required by the statute.

EPA often supports or justifies its decision making by estimating the risks associated with various pollutants or stressors, although not every statute specifies using risk assessment (see [Appendix](#)). Although the value and relevance of risk assessments have been questioned, the National Research Council asserts in its report *Science and Decisions: Advancing Risk Assessment* that risk assessment remains an appropriate method for measuring the relative benefits of the many possible interventions available to improve human health. Our January 2013 webinar speaker, **Dr. Tom Burke**, who was one of the authors of *Science and Decisions*, spoke to the future direction of risk assessment, including the need to harmonize cancer and noncancer approaches (that is, move away from reference doses) and to make the CRA process more scenario-based and iterative, so that decisions about which stressors to include in a CRA target those stressors for which closer analysis might benefit risk-management decisions most clearly. Dr. Burke stated, “To orient the [CRA] around risk management options is the approach that we recommended so that we focus on the stressors under consideration.” This dove-tailed with the European Union view presented by **Dr. Peter Calow**, our December 2013 webinar speaker, who noted that one of the major challenges is to make risk assessment more relevant for risk management—that is, “more value-relevant” or relevant to public preferences. This must be done in a way that is transparent and avoids political interference with the science.

Differing Meanings of CRA/Use of Terms (Impacts, Risks, Levels, Effects)

For each of our webinars, we conducted a participant survey. Respondents shared their definitions of cumulative risk and cumulative impacts. Not surprisingly the definitions varied, as shown in the following examples:

Cumulative means—

- *The risks to/effects on human health over time when exposed to multiple contaminants.*
- *It is a holistic understanding of health risk, including environmental agents (chemical, biological, radiation) as well as socioeconomic factors.*
- *It means pushing the envelope on risk assessment beyond the “chemical-by-chemical” concentration measures to instead measure effects/endpoints/adverse outcomes.*
- *The combination and effects of multiple contaminants from multiple sources through multiple exposure pathways.*
- *The combined effects of multiple chemicals from multiple exposure pathways should be taken very seriously by the regulators.*
- *“Cumulative risk” involves the summation of exposure hazards for human or ecological populations to multiple environmental stressors.*
- *The risks that individuals and communities face as a result of all of the different risk factors they may have (social, economic, occupational, genetic, ...).*
- *The aggregate risk to either humans or the environment, taking into account multiple endpoints, as well as multiple contributing risk factors or contaminants.*
- *Understanding multiple stressors in a community context.*
- *As an environmental epidemiologist...everything.*

Some people think that there should be one definition for “cumulative,” while others can accept a broad definition or multiple definitions that can be implemented in varying ways to fit the particular situation. The important message is that perhaps the assessment or evaluation of cumulative does not necessarily mean we must arrive at one number. “Cumulative” can be described in multiple ways—as impacts, levels, risks and effects, both quantitatively and qualitatively—and still inform a decision.

It is our hope, through presenting this summary of the CRA Webinar Series, that EPA and its stakeholders will be inspired to continue the effort to move away from an approach that assesses the impact of one source, one agent on the average person toward the use of environmental and environmental health assessments and evaluations that better reflect reality, especially when setting policy and making regulatory decisions. It is possible, and our speakers presented on a number of tools and approaches to make CRA possible.

In the following Sections you will find [summaries of each CRA webinar](#), [links to archived recordings](#) of each webinar by date and links to [supplemental materials and background papers](#) provided by each of our webinar speakers.

Webinar 1

August 29, 2012

Nonchemical Stressors and Cumulative Risk Assessment—An Overview of Current Issues and Initiatives

Ari S. Lewis, M.S., Environmental Health Principal Scientist and Toxicology Team Manager at Gradient/Environmental Consulting

The speaker, a toxicology and risk assessment expert with particular expertise in toxic metals, described the current state of cumulative risk assessment (CRA) science. Her talk focused on three learning points, described below.

1. Potential vulnerabilities in populations and their consideration in cumulative health risk assessment

CRA's inclusion of social stressors—defined as “acute or chronic events of psychological or social origin that challenge the homeostatic state of biological systems”—clearly has linked CRA and environmental justice (EJ). Both share the overall goal of identifying health disparities among vulnerable communities and identifying the chemical and nonchemical stressors to target for intervention. Stressful social environments may make populations that potentially already carry a disproportionate chemical exposure burden even more sensitive to chemical exposures. Extensive studies show associations between disadvantaged communities and suboptimal health.

Income insecurity, racism, family instability and a violent community or home are among the psychosocial-related stresses potentially interacting with innate biological characteristics and an increased chemical burden from old, substandard housing, poor ventilation, traffic density and other sources. It would be useful for EPA to comprehensively list such putative psychosocial vulnerabilities. Natural disasters, such as Hurricane Katrina, would be included on the list because the general principle is that stress affects how chemicals

interact with biological systems. That principle is supported by animal studies that provide information on potential interactions.

2. Key facets of chemical risk assessment and how those issues inform efforts to advance the field of CRA, including consideration of the most significant challenges involved with incorporating nonchemical stressors

CRA needs to understand and quantify the extent to which current risk assessment methods capture nonchemical stressors and account for vulnerabilities. Research is needed, for example, to understand what the intraspecies uncertainty factor does not capture. Underlying criteria need to be studied for vulnerable populations.

Considering chemical exposures and psychosocial vulnerabilities in a single metric is complex. It is extremely difficult to express a nonchemical “dose,” which involves different metrics. Initial steps have focused on screening tools to identify communities with the greatest vulnerabilities. Indicators include social demographics, pollution exposures and public health indices that are used to semi-quantitatively rank communities, with the goal of identifying at-risk communities to target for more refined analysis.

A critical question for CRA is how science can measure exposure to social stressors. Biomarkers can provide a way to measure “allostatic load,” a useful concept that refers to “the physical consequences of chronic exposure to fluctuating or heightened neural or neuroendocrine response that results from repeated or chronic stress.” Examples are measurements of cortisol and epinephrine as biomarkers of neuroendocrine effects and of blood pressure and heart rate as biomarkers of cardiovascular effects. The concept captures the complexity of psychosocial stressors and interactions between chemical and nonchemical stressors. Any valid biomarker would be beneficial.

3. An overview of the research and approaches currently being explored to characterize cumulative risks, including mechanistic research, epidemiological evaluations and risk-ranking tools

To move beyond screening assessments requires an understanding of the increasingly complex interactions between multiple chemical and nonchemical stressors. Understanding the relative contribution of nonchemical and chemical stressors using the full array of epidemiological, animal and *in vitro* studies will inform both types of risk assessments. Animal and mechanistic research is less relevant for nonchemical stressor research, but it can provide important mechanistic information on interactions, as with the case of rat studies indicating the joint effect of lead exposure and stress on health outcomes. Mechanistic research also can help identify relevant biomarkers.

Epidemiology is receiving greater emphasis in CRA as an approach to assess the relative contribution of different stressors and potential interactions between chemical and nonchemical stressors. There is great potential in mining existing data, even if the data are in unsuitable form. In many epidemiologic studies stress is considered a confounder. The question can be asked: How did correcting for a social indicator change the results? Such analysis is not straightforward, and the contribution of socioeconomic status differs by endpoint.

Hypothetical examples illustrate how in each of the four traditional risk assessment steps CRA could move

beyond screening assessments. For hazard assessment, for example, a science-based list of stressors for each endpoint could be used to assess which community stressors contribute to particular health disparities. All the chemical, social, biological and physical stressors affecting a given endpoint, such as respiratory disease, would be listed. For exposure assessment, powerful geographic information system (GIS)-based databases can be used to predict community exposures; some indicators using this approach are less reliable for individual exposure assessments (e.g., the presence of brownfields, hazardous waste sites, etc.). These tools are powerful for organizing data and investigating associations, but they cannot be used to quantify risk absolutely, do not measure biological indicators and have other limitations. Validation is needed of the most useful indicators for approximating community and individual exposures and health. Science needs to determine how well traditional risk assessment reflects the spectrum of susceptibilities in a population, and—where required—more holistic approaches will have to be implemented.

Ms. Lewis was asked about epigenetic changes, or changes in gene expression, as a possible biomarker for stress. She replied that it is unclear if the concept is biologically sound; how one would measure epigenetic changes in people is a key question. If research supported using such a biomarker, however, that could be a powerful tool. A recent study suggests that neighborhoods have different, measurable epigenetic imprinting.

Webinar 2

September 26, 2012

Characterizing Cumulative Air Pollution Risks

Neal Fann, EPA, Office of Air and Radiation (OAR)

The speaker, a policy analyst with expertise in estimating the economic and health benefits of air pollution management options, described how OAR is moving incrementally toward adopting cumulative risk approaches in place of its traditional pollutant-by-pollutant risk reviews. His talk focused on three learning points, as follow.

1. How EPA estimates the human health impacts of air quality changes

OAR is concerned with reducing a variety of health impacts from air pollutants, including premature death and asthma attacks. To that end, EPA must be able to monetize the health impacts from air pollutants using the best available studies in the scientific literature. BenMAP (Environmental Benefits Mapping and Analysis Program) is EPA's principal tool for monetizing the benefits of air quality improvements by estimating the incidence and economic value of adverse health outcomes using population and air quality data. Full multi-pollutant BenMAP software is available at the EPA website: <http://www.epa.gov/airquality/benmap/index.html>. Establishing

a baseline risk is key because all of the other risk estimates are relative to that benchmark.

One example of how OAR monetized health impacts and benefits is the regulatory impact analysis of the Agency's 2014 Cross-State Air Pollution Rule (CSAPR) addressing fine particulate matter (PM_{2.5}) and ozone pollution. The analysis is not truly multi-pollutant; rather it uses studies that control for other pollutants as potential confounders.

2. The extent to which EPA can estimate the cumulative human health risks of air pollution with current methods and data

The health impact assessment for the CSAPR accounts partially for cumulative exposure, differential susceptibility and other factors critical to CRA, and it represents OAR's best effort to account for multiple pollutants to date. As a step toward performing a full-scale CRA, after first estimating the avoided deaths and illnesses expected to result from implementing CSAPR, the analysis next characterized the distribution of these avoided deaths among population subgroups, including those most susceptible to air pollution effects. Using BenMAP, OAR characterized the percentage of all-cause deaths attributable to PM_{2.5} in 2005 in each county; this established a baseline distribution of risk, against which the authors compared the distribution of risk in 2014, when the rule was to be implemented. The analysis illustrated that the number of counties at or above the median 2005 risk level fell significantly by the 2014 baseline (i.e., before the CSAPR rule was implemented, but after air quality policies affecting other sectors reduced emissions): from 1,505 in 2005 to 958 in 2014. After CSAPR was implemented, the number fell further to 180. Although focused on PM_{2.5}, the analysis could easily be applied to ozone. EPA is transitioning from characterizing only the overall health impacts a rule avoids to assessing the overall impacts from PM_{2.5} and ozone reductions, how the impacts are distributed over space, and how different populations (such as children and adults) are affected, thereby incrementally moving toward CRA.

3. Promising new approaches for characterizing the cumulative impacts of multiple pollutants and stressors

Mr. Fann presented graphs assessing education-modified PM_{2.5} mortality risk in the 2014 CSAPR. Two long-term epidemiological studies found that education status modifies PM_{2.5} exposure and risk. The reasons for the effect are unclear. An analysis showed that in 2005, populations without a 12th-grade education faced greater vulnerability to air pollution than other populations. This was demonstrated by a different dose-response curve for low educational attainment. Among the high-risk populations in the CSAPR analysis, the risk

falls precipitously; among the lower risk populations, the studies still show a benefit from the CSAPR, but not as large. By the time the 2014 rule is in place, the risks begin to equalize. This is an incremental step toward CRA because it is focused on more vulnerable populations.

The speaker described a Detroit project that explored a multi-pollutant risk reduction approach based on air quality management for the city, focusing on vulnerable and susceptible populations. The project characterized population susceptibility using both mortality rates and rates of hospital admissions for asthma. It demonstrated that to achieve maximum air quality benefits, a multi-pollutant approach delivers the most gains, no matter how "vulnerable and susceptible populations" are defined. EPA also has been asking how it can better express the joint, combined risk from conventional air pollution and air toxics, given that the differences in how those risks are estimated make them challenging to combine. As a draft proof of concept, OAR plotted the distribution of PM_{2.5} mortality risk across the United States from directly emitted PM_{2.5} and the cancer risks from metal air toxics. After plotting the risks, OAR identified the upper 80th percentile for both distributions, a first step for characterizing joint, cumulative risk across both pollutants and one that represents a potentially more comprehensive approach for the future.

Lastly, the speaker described an OAR attempt to estimate temperature-modified ozone mortality. EPA has not traditionally considered how temperature can modify health effects, and the science is still developing, so there is no definitive information.

During the question-and-answer session, Mr. Fann was asked: "In your 'cumulative risk' analysis, you seem to still be doing every pollutant individually and then adding risks or looking at percentiles. What seems missing here is an analysis of the joint effect of being exposed to both. What does it mean to be exposed to both metals and PM, for example?" He responded that EPA is making the best use it can of the epidemiological literature that is applicable for air pollution risk assessments. A developing body of research is looking at joint impacts of multiple pollutants, but it is very challenging. When EPA created the maps expressing the overlap between the risks from conventional pollutants and air toxics, the approach did not provide a total point estimate of risk and is therefore unsatisfying. If the prior belief is that being exposed to PM_{2.5} and metal air toxics is undesirable due to a potential for synergism, an air quality manager would want to know that. "What elements in air pollution contribute to diabetes?"

Populations with pre-existing chronic conditions, including diabetes, may be more susceptible to air pollution-related impacts than the general population.

Webinar 3

October 17, 2012

Cumulative Environmental Vulnerability Analysis—Opportunities for Innovation

Dr. Jonathan London, University of California, Davis, and Center for Regional Change (CRC)

The speaker, an Assistant Professor in the Department of Human Ecology and Director of the CRC, has an interest in conflict and collaboration in natural resource and environmental issues, with an EJ focus. He introduced a hazard and vulnerability screening method, including the social and institutional context through which the tool was developed. His talk focused on three learning points, described below.

1. An introduction to the science behind the Cumulative Environmental Vulnerability Analysis (CEVA) methodology

CEVA is a screening tool to help better target funding, monitoring, permitting and enforcement in the most vulnerable EJ communities. The methodology, which is a work in progress, was developed in an “engaged setting” working with communities. It helps to identify communities that have a relatively higher ranking using the combination of two key indices: the Cumulative Environmental Hazards Index (CEHI) and the Social Vulnerability Index (SVI), with health and other criteria layered into the resulting maps. CEHI indicators include such measures as pesticide applications, cancer risks from inhaled toxics and water quality assessments; SVI measures include the sensitivity of receptors (for individuals younger than age 5 or older than age 65) and the availability of social and economic resources to take action in the face of environmental concerns, such as the percentage of a community’s population older than age 25 without a high school diploma or who do not speak English very well. Health status is a separate indicator, but it might be merged into the SVI. Land use, transit and other factors are not in the indices, but they are considered as additional screening issues.

Important distinctions exist between the terms “risks,” “impacts” and “vulnerability,” although they are related concepts. Risks refer to the magnitude and likelihood of impacts, which are a measure of effect; vulnerability refers to the relative sensitivity of certain populations and individuals to the risks that might cause more of an impact or a greater likelihood of an impact.

The CEVA index is created by combining all of the indicators into a single multi-indicator CEHI/SVI index. A census tract’s CEHI/SVI indicators are classified by relative severity using the highest 20 percent of values in the High (H) category, middle 60 percent of values in the Medium (M) category, and lowest 20 percent in the Low (L) category. On a color-coded, numbered nine-cell grid, results are categorized, starting with the first cell for low-vulnerability tracts that have L/CEHI; L/SVI, moving up to the ninth cell for high-vulnerability tracts having H/CEHI; H/SVI, with all combinations in between. The highest three cells are selected as “CEVA Action Zones.” The results are mapped by census tract to show “red” for action zones and other colors for less vulnerable tracts. Tribal lands and other factors are layered onto maps to create a visual display of neighborhood differences in cumulative environmental vulnerability.

2. Enhanced understanding of the collaborative processes that supported the development of the CEVA

CEVA employed “community mapping” to inform and empower local residents’ advocacy for improving their vulnerable communities. In workshops, communities and CEVA partners marked up large-scale aerial maps to identify “hidden hazards,” potentially harmful sites not accounted for in government databases for various reasons. CEVA digitized the maps and layered community-identified sites over some of the base maps. In addition, the Imperial Visions Action Network (IVAN) interactive website was used for “crowdsourcing,” allowing residents to call or type in reports of hazardous waste or other environmental problems.

3. Innovative ideas for applying CEVA and other cumulative impact methods to inform and improve public policy

Several CRA-related initiatives in California over the past 5 years have employed CEVA-like innovations that could be explored for possible integration. The California Environmental Protection Agency (CalEPA) Environmental Justice Screening Method, for example, uses “land use polygons” to hone in on populated areas with hazardous and toxic sites and has been used for such policy initiatives as “Green Zones” and “Solar for All.” CalEnviroScreen, now under development by CalEPA, employs wide data sets for statewide coverage. EPA Region 9 (serving the Pacific Southwest) and the California Governor’s Office of Planning and Research

are comparing these and other methods to address concerns about duplicative efforts.

The speaker described several concerns that have been raised about CRA and related assessment tools, including CEVA, and outlined recommendations for how to avoid them. For example, one concern is the potential for government agencies to undergo paralysis by “infinite analysis.” This can be addressed if screening tool developers provide explicit descriptions of what job the tool is designed to do and set thresholds for when analysis should end and action begin.

A participant commented that CEVA does not appear to rank the significance of stressors or social vulnerability. Dr. London responded that for pesticides and point-source emissions sites, a ranking of sorts was conducted. For example, the pesticides included in the screening tool are the most toxic and those with the greatest likelihood of having fate and transport data to help define exposure potential. For water quality, the six chemicals of greatest concern were selected, but CEVA did not, for example, rank arsenic as more important than chromium VI. The fact of inclusion of the chemicals was an implicit ranking of importance. Waste sites were scored based on various criteria, such as whether the site was open or closed and the types of wastes processed.

Another questioner noted that with CEVA a lot of different information gets the same rank, and trying to combine more than two criteria is risky. The speaker

responded that there is a trade-off when developing multi-indicator matrices. As an analogy, a driver having to track 50 dashboard indicator dials would either crash or ignore them. CEVA combines data to focus on the two indicators of environmental hazard and social vulnerability and must recognize the trade-offs and make the limitations clear. CEVA communicates to stakeholders that the tool is for screening, not for risk assessment, and is finding better ways to develop an understanding of the implications of that distinction.

Noting that CEVA adds many different hazards together that do not all translate equally to risk and then categorizes indicators by L/M/H, a questioner asked: “Have you done any weighting?” Also, “Does this correlate with vulnerability or risk in real life, or is it just an indexing exercise you think might be related to vulnerability or risk?” Dr. London responded that weighting can be arbitrary; it is place-based, and deciding what is most important to a place is a value judgment. In addition, it is a much more complex process to analyze the toxicological and epidemiological data source by source; CEVA is a screening assessment. It is called “risk,” but it is not risk in the regulatory sense, in which a risk estimate is produced; it only identifies places with a relatively higher profile of risk phenomenon. CEVA is a way of adopting the precautionary principle and understanding the possibilities of risk and the potential magnitude of those harmful events and conditions.

Webinar 4

November 28, 2012

Assessing the Health Impact of Multiple Environmental Chemicals

Dr. Krista Christensen, National Center for Environmental Assessment (NCEA)

The speaker, an epidemiologist in NCEA’s Quantitative Risk Methods Group, has conducted research on environmental chemical exposures and impacts on children’s health and pubertal development; she also has worked on Integrated Risk Information System (IRIS) chemical assessments for asbestos, phthalates, polychlorinated biphenyls (PCBs) and beryllium. Her talk focused on three learning points, as follow.

1. What is CRA, and what are some methodological challenges when attempting to examine the effect of many environmental chemicals in relation to a health outcome?

Noting that CRA is a burgeoning area of research and interest that seeks to include all significant risk factors in an analysis, the speaker described key methodological challenges that a cumulative risk assessor might encounter. The first is “dimensionality,” which refers to the possibility that the many risk predictors encompassed by a CRA might far outweigh the data available on them, limiting the assessment’s statistical power. The second is the “multiple testing” issue, which refers to the increased

likelihood of false positives when many statistical tests are performed for a multifaceted CRA. Using exposure as a specific example, the speaker stated that exposures are likely to have very different ranges and metrics, making it difficult to gauge the relative contribution of the different exposures (e.g., chemicals in air and water, biomonitoring data and such factors as household income). Lastly, the most commonly cited CRA challenge is how to handle and evaluate the relationships among risk predictors. Relationships can include biologically and statistically formed relationships, such as collinearity, correlation and confounding. Given the challenges, traditional statistical methods may be inadequate for CRA. The speaker reviewed four specific statistical methods proposed for CRA and their limitations: regression models, discriminate analysis, cluster analysis, and principle component analysis.

2. Overview of a new statistical approach to examine the effect of many environmental chemicals in relation to a health outcome

Responding to the limitations of the four statistical approaches for simultaneously assessing many risk predictors, Dr. Christensen worked on refining a method for assessing multiple classes of chemical exposures using NHANES data for the major public health problem of nonalcoholic fatty liver disease (NAFLD). She used elevated levels of the liver enzyme alanine aminotransferase (ALT) as an effect metric.

3. Example of implementing this new approach using publicly available data

Employing standard epidemiologic models and NHANES data, she first generated 37 different models, each with demographic covariates and one chemical, which were later reduced to six models, one for each chemical class. Because of limitations with the initial modeling, the speaker focused on the new proposed approach, called “comprehensive analysis.” The approach assigned weights to the 37 chemicals, constrained the weights to add up to 1 and used nonlinear programming to generate a table that ranked each chemical analyte according to its relative “importance” in explaining an association with the risk of elevated ALT/NAFLD. Metals and phenols were significantly associated with elevated ALT risks, but it remains unclear which chemicals within the class are driving the association.

Dr. Christensen reviewed the results of the comprehensive analysis and discussed how it addresses the methodological challenges she had discussed earlier. To address dimensionality, a single variable is created—the “weighted sum”—representing the multiple risk predictors (i.e., 37 chemicals). To address

multiple testing, the speaker used only one model that simultaneously estimated both the weights themselves and the other model parameters; to address different exposures and metrics, the method used quartile indicators (e.g., low, medium, higher, highest exposure), not direct concentration. This makes relative contribution easier to discern.

Asked how the comprehensive analysis might fit into EPA’s efforts to develop CRA guidelines, the speaker said that the method would be useful as a screening approach for the hazard identification and dose-response steps; risk characterization will require further development. A questioner asked, “*What is the justification for using addition if the parameters have different metrics as you kind of alluded to?*” Dr. Christensen replied that using quartile indicators seems a “*decent way to look at the contribution of each chemical without having to necessarily go into all the details,*” such as one chemical being measured in nanograms per gram lipid and another in terms of creatinine.

One participant commented, “*Particularly when dealing with liver disease, without knowing anything about timing of exposures, these associations could simply represent changes in metabolic capacity and not necessarily causal association.*” Dr. Christensen responded that the issue is a big consideration for any study that uses NHANES or other cross-sectional data. When choosing chemicals for the analysis, compounds were selected by considering whether animal or human studies indicated associations between the broad chemical class and liver function. A broad range of exposures was considered. In addition, some compounds, such as PCBs and dioxins, are persistent; body burden at a given time is indicative of a person’s exposure history for years or decades. Biomonitoring urine concentrations often represent short-term past exposures. All such factors are a consideration when inferring associations, especially when inferring causality. Another questioner asked, “*Do you have any genetic data to include in your modeling?*” The speaker responded that the NHANES data include some measurements for single nucleotide polymorphisms, but it is “*restricted-use data,*” and with limited time and resources, the data could not be accessed for her analysis. She added that it “*would be another thing to consider.*”

A questioner asked, “*How can this be used to connect with the health effects of the chemicals?*” The speaker responded that if the analysis can be considered in a screening or hypothesis-generation context, a key CRA step is problem formulation, planning and scoping. When selecting health outcomes of concern based on exposure scenarios of interest, the results of the comprehensive analysis would be something to consider carefully, using evidence from toxicology, epidemiology, medical literature and other available evidence streams. A related

question was asked: “Is there a way this method or approach could be used for hypothesis generation, or is it strictly applicable when you have data supporting a relationship already, both in endpoint and chemical?”

Dr. Christensen replied that the method can be used not only for screening and hypothesis generation but also for examining the chemical weights and figuring out the relative ranking of the hazard associations.

Another participant asked, “How can you assume or be sure that the top quartile of some chemicals have

the same top quartile effects as the other chemicals?”

Dr. Christensen responded that an analysis will need to consider the potency of different exposures. For example, an extremely low-potency exposure can be in the top quartile of exposure for a particular compound with little effect on the outcome; conversely, a very potent chemical in the second quartile might have a large effect. She stated that she was uncertain if her analytical approach addresses the question well and she will think about it.

Webinar 5

December 19, 2012

Cumulative Levels and Effects—
Implementing a Unique Environmental
Justice Statute in Air Permitting in
Minnesota

*Dr. Kristie Ellickson, Minnesota Pollution
Control Agency (MPCA)*

The speaker, an MPCA risk assessor, incorporates CRA in her work and is the lead on an EPA community-scale air toxics grant targeting passive and active air sampling for polycyclic aromatic hydrocarbons in an urban environment. Her talk focused on three learning points, described below.

1. Background on why the cumulative levels and effects statute was enacted and the specific statutory language requiring analysis and consideration of “cumulative levels and effects” as part of air permitting decisions

The Minnesota statute (*Minn. Stat. § 116.07, subd. 4a*) was passed in 2008 in response to local opposition to a biomass incinerator proposed for siting in an area surrounding the Phillips Communities in South Minneapolis, the only area to which the law applies. Under the law, before MPCA can issue permits in this area, it first must “analyze and consider cumulative levels and effects.” The law does not use the terms cumulative impacts or CRA. It includes all pollutants, environmental media, sources, time periods and receptors.

2. The methodology Minnesota developed to screen, scope and consider the available environmental health data and information for the cumulative levels and effects air permitting requirement

MPCA began its analysis by comparing air dispersion modeling results against screening levels. MPCA used federal and state standards or the National Ambient Air Quality Standards (NAAQS) “significant impact levels” for criteria pollutants. For air toxics, MPCA used 10 percent of facility risk guidelines. The facility’s study area was defined as the farthest point from a facility fence line at which the model showed a pollutant exceeded the screening level. Pollutants above screening levels also were used to determine which health endpoints warranted further study, drawing on EPA’s Integrative Science Assessments for the criteria pollutants and inhalation health benchmark technical documents for air toxics. Minnesota’s asthma, drinking water, blood lead, U.S. Census and other data were used. MPCA wrote a “how-to” process document for conducting the cumulative analysis and a reference document organized by “environmental health data and context” for use by facility proposers in developing their facility modeling, report and permit application.

MPCA received input into the proposed process first by holding small technical “check-in” meetings of two to five people, with results incorporated into the agency’s method. One of these meetings included neighborhood leaders. Next, MPCA held a large open public meeting that included a short presentation and an unexpectedly lengthy question-and-answer period whose “huge range

in scope” included questions about the ethics of staff working in the area and MPCA’s inclusion of synergistic reactions between pollutants.

3. The results of two case studies of cumulative levels and effects analyses that were conducted, including general background, communication and outreach strategies, the permit application processes and related decision making

For the first permit processed by MPCA—for a light-rail vehicles operation and maintenance facility—outreach meetings were held, as is required for each permit and each “cumulative levels and effects” analysis.

During the permit process, the applicant went through several modeling iterations, which greatly refined the facility’s paint choices. The permit prohibits heavy metals in paints, resulting in modeled cancer risks below screening levels. Paints with diisocyanate also were eliminated from the proposed list. With the eliminated pollutants, MPCA achieved some “reduction in impacts.” The facility proposer’s modeling, however, showed that two pollutants were above screening levels: short-term nitrogen dioxide (NO₂), with emissions mostly from space heaters, and 24-hour PM_{2.5}, with emissions from both space heaters and the paint booth. Environmental health data for the health endpoints associated with NO₂ (respiratory) and PM_{2.5} (cardiovascular) were pulled into the cumulative levels and effects analysis. As much as possible, the data were arranged and compared spatially. Included in these data were socioeconomic indicators, the National Air Toxics Assessment (NATA), MNRiskS modeled results (the state’s version of NATA), health data, air measurements and potential nearby sources of these or similar pollutants.

Overall, using MPCA’s process, the resulting permit limits were “significantly below what they would have been.” Developing trust was the most important risk-communication step learned from the first permit. For a second permit under way for a hospital’s boilers and emergency generators, the analysis led the proposer to eliminate peaking programs for the facility’s generators. The method’s biggest limitation is that, although a variety of chemical and nonchemical stressor information can be included, the final result does not represent a true “integrated characterization.” Furthermore, if such indices could be created, “we would have nothing to compare it to because we don’t have a cumulative health benchmark.” Noting that the statute “requires a much more comprehensive approach to environmental regulation,” Dr. Ellickson stated that “even though the method isn’t perfect, it’s a good thing

that we’re required to do that. We have done some learning.”

The speaker was asked, “*Did you make adjustments to those screening levels for this methodology, or were you just utilizing what you already had access to?*”

Dr. Ellickson responded that MPCA adjusted the way it calculates multi-pathway risks. Specifically, for ingestion-based risks, the agency eliminated some of the meat products people are assumed to eat and created an “urban gardener” who eats some homegrown produce and eggs produced in the backyard. Another questioner asked about the response when data identified for further analysis do not indicate health impacts. “*How do you overcome the trust issues for the community, which may see that the health impacts do exist and [the] government may be just not paying enough attention?*” The speaker answered that MPCA definitely has not overcome the issue, with the comment received twice at one meeting: “With you guys’ giving this permit and allowing an increase, you are negating our vulnerabilities.” MPCA strives to make clear that its analysis uses a fraction of the state’s facility risk guidelines, so the risks do not exceed either state or federal standards.

A questioner asked, “*Could you discuss what kind of screening levels were used for air toxics? Was it one-in-a-million cancer risk?*” Dr. Ellickson stated that for noncancer effects, MPCA sums all of the risks for a facility’s chemicals—both from ingestion and inhalation exposures—and uses the facility risk guideline of 1.0 for hazard indices. If a pollutant-specific result is above 0.1 (10% of the facility risk guideline), then further environmental health data related to the health effects of that pollutant are included in the cumulative levels and effects analysis. Similarly, for cancer, all of a facility’s chemicals are summed—also for both ingestion and inhalation—and MPCA uses a one-in-100,000 for the total facility risk guideline. However, if a pollutant-specific cancer risk is above one-in-a-million, then environmental health data related to the cancer health endpoint are required to be included in the cumulative levels and effects analysis. To repeat, the screening levels for air toxics are 10 percent of the total facility risk guidelines. Dr. Ellickson also was asked, “*If some community had existing health conditions of concern [e.g., “socioeconomic status health issues”], how are those factored into your permitting decisions?*” She replied that MPCA obtains all of the Health Department’s data: asthma outcomes, cardiovascular events, blood lead and the like. In Hennepin County, a survey was conducted asking, “What type of health insurance do you have?” “Is there a smoker in the house?” and similar questions. The information is presented to decision makers as part of the final decision-making process.

Webinar 6

January 30, 2013

Integrating Susceptibility Into Environmental Policy— Implications and Information Needs for Cumulative Risk Assessment

Dr. Ramya Chari, Associate Policy Researcher, RAND Corporation

Dr. Thomas Burke, Associate Dean for Public Health Practice and Training and Professor, The Johns Hopkins Bloomberg School of Public Health

Dr. Chari's expertise is in environmental health risk assessment, environmental epidemiology and the assessment of population exposure to environmental pollutants, and Dr. Burke is Chair of the National Academy of Sciences (NAS) Committee on Improving Risk Analysis. Their talks focused on three learning points, described below.

1. Strengths and limitations in the use of epidemiological data for environmental decision making in the context of cumulative risks

Dr. Chari described a case study using EPA's process for setting the 2008 NAAQS for lead. The study's goal was to understand how susceptibility considerations—defined as “characteristics of an individual or population that alter biological response to environmental insults”—may affect policy decisions. The study also aimed to determine how an explicit, quantitative consideration of susceptibility in policy development may change the characterization of risk. For the NAAQS, EPA used an “air-related IQ loss framework,” which was a marked difference from the original way the lead NAAQS was developed because it was an effects-based rather than an exposure-based approach. An equation multiplying EPA's potential NAAQS level times the “air-to-blood ratio” was used to arrive at an estimate of IQ loss known as a concentration response (CR) function. The air-to-blood ratio translates the allowable air concentrations of lead into blood lead concentrations as a basis for assessing IQ loss. Acceptable risk was defined as no more than a 2-point IQ loss in the population mean IQ for the subset of children exposed at the level of the air quality standard.

The case study focused on SES as the susceptibility factor of interest because SES is the most-studied

acquired (as opposed to intrinsic) factor, and the literature suggests that the effects of lead may vary across different SES levels. The researchers systematically reviewed the epidemiological literature to identify CR functions, focusing on 40 studies that examined SES as a modifier of lead effects across different SES groups. Only four of the 40 studies provided enough information to extract CR functions for low- and high-SES groups.

The speaker noted several caveats about the epidemiological literature, which provides only “suggestive evidence of an SES effect modifier of lead neurotoxicity.” There are “healthy debates” over the four studies used in her analysis. For example, an analysis of a Cincinnati, Ohio, cohort found significant interactions between SES and lead only in earlier years, indicating that differential effects may not persist or may be attenuated in later years for unknown reasons. Uncertainty in the analysis also was introduced by such issues as the comparability of the four studies' measures of exposure, outcome and SES status. Thus, the studies did not provide definitive evidence about the existence or magnitude of SES-lead interactions.

2. The importance of incorporating susceptibility into CRA and data needs

Dr. Chari compared the results of her study with EPA's results, using a figure based on the CR function equation in which the x -axis represented different air lead standards and the y -axis represented estimated IQ loss. The figure showed EPA's standard of no more than a 2-point IQ loss as a dotted line, and the Agency's calculation that an air standard of 0.15 micrograms per cubic meter (mg/m^3) fulfilled the decision criterion. Dr. Chari's study found, however, that under EPA's 0.15 mg/m^3 standard, IQ loss for low-SES groups exceeded the Agency's 2-point acceptable risk level. Based on SES subgroup-specific CR functions, the case study concluded that EPA must consider a stricter standard of 0.1 mg/m^3 to ensure that all SES groups meet the Agency's acceptable risk level. By using CR functions that do not account for the possibility of increased susceptibility, “EPA's IQ loss framework may not protect the target population to the desired extent.”

The speaker noted that her study demonstrated a great need for quantitative information on susceptibility for the factor to be realistically included in EPA's policy decision framework. Although there is not much debate

about whether certain population groups might be more susceptible, “the question in the debate really is over how much more susceptible these populations really are.” To craft policies that are protective of all populations, that information is necessary.

Dr. Chari added that the NAS committee chaired by Dr. Burke recommended that EPA adopt a unified cancer and noncancer dose-response approach in risk assessment, a move that may result in more noncarcinogens evaluated under a no-threshold model. As a result, in the future EPA may rely less on “bright lines” indicating safe exposure levels, with more deliberation over acceptable risks. That development will make it more important than ever to include susceptibility in policy decision making. Determining acceptable risk depends on value judgments and the population to which it is applied, and quantifying susceptibility will foster open and transparent decisions about acceptability.

3. A new framework for risk assessment and implications for cumulative risk

Dr. Burke presented the perspective on susceptibility and CRA of the NAS Committee on Improving Risk Analysis, which wrote the 2009 report *Science and Decisions: Advancing Risk Assessment*. The committee emphasized the importance of problem formulation in risk analysis to ensure that the right questions are asked at the start of an assessment. This is especially critical given the need to consider susceptibility and population variability. To achieve better environmental solutions, the committee recommended a new three-phase approach: (1) problem formulation and scoping; (2) planning and conduct of the risk assessment; and (3) risk management. The unified dose-response approach that Dr. Chari mentioned was one of the report’s most controversial recommendations. Some people understood the recommendations to mean that EPA would abandon reference doses and thresholds in assessments. The recommendation, however, was focused on the importance of understanding key aspects of CRA: background disease processes and exposures, possible vulnerable populations and modes of action that may affect a chemical’s dose-response in humans.

The speaker showed a chart that presented dose-response curves for a susceptible subgroup, an average population response and a non-susceptible (resistant) subgroup. The susceptible subgroup’s dose-response curve was depicted as comparatively much steeper. The dose-response relationship is dependent on environmental stressors, heterogeneity in background exposure (endogenous and xenobiotic) and biological susceptibility. A chart showing an individual dose-response curve depicted the large differences in the probability of adverse health outcomes when background exposure and susceptibility are included as factors. Dr. Burke then showed a framework that the committee produced for

considering CRA and the factors that impact a disease endpoint, such as “precursors for upstream indicators of toxicity,” modes of action and vulnerable populations. A “vulnerable population assessment” would include an understanding that low SES may increase vulnerability. Factors considered under the framework should shape how a conceptual model for dose-response selection is developed. Dr. Burke also presented a stepwise approach developed by Dr. Jonathan Levy. In step 1, a conceptual model is developed for the stressors of interest that risk management options may significantly influence. In step 2, epidemiologic and toxicity data are evaluated based on how the stressors can be incorporated into a CRA targeted at stressors where closer analysis might benefit risk management decisions most clearly. In step 3, the benefits of risk management options are evaluated, and in step 4 the analysis is refined if the third step does not have clear conclusions. Dr. Burke stated, “To orient the [CRA] around risk management options is the approach that we recommended so that we focus on the stressors under consideration.”

Dr. Chari was asked about the role of researchers, and epidemiology researchers in particular, in addressing the gap in susceptibility data. She responded that more and better studies are needed, but efforts can be made to organize, manage and report existing data “*that would be extremely helpful to getting policy makers access to the type of data that would be directly relevant to crafting programs and policies.*” Such efforts are crucial for CRA, which requires extensive information.

A questioner asked, “*How do you see advances in toxicology around epigenetics informing cumulative risk . . . such as understanding broader health endpoints or system effects as opposed to specific health outcomes?*” Dr. Burke responded that this is an exciting time for CRA because the current substance-by-substance approach “*is being changed to a health outcome, adverse impact, systems approach*” that will be greatly supported by high-throughput computational toxicology tests that will enhance the understanding of mixtures and upstream endpoints. New information about thresholds and potential cumulative impacts will be available. A range of data can inform CRA, “*from those very fundamental changes in indications of cellular and subcellular and genetic impacts all the way to the evolution of health impact assessment to better understand the community health impacts of our environmental decisions.*” It will have a huge impact on EPA’s ability to rank, order and make better decisions about the kinds of environmental impacts the Agency seeks to prevent. Dr. Chari added that as computational toxicology strengthens the ability to assess genetic or “intrinsic” susceptibility, it would be helpful for funding agencies to have a good model of their exact research questions and goals across the entire continuum of issues so that acquired susceptibility factors are not neglected.

Another questioner commented that *Science and Decisions* seems oriented to CRA that begins with identified stressors and asked, “*Can it be applied to [CRA] that is initiated by a real or perceived increase in a disease rate?*” Dr. Burke responded affirmatively. As society moves beyond the 1970s’ and early 1980s’ dominant concern with cancer prevention and takes on “really difficult evolving health issues”—from endocrine disruption through immunological impacts and neurodevelopment—population health can provide a starting point for the CRA conceptual framework. CRA has a critical role to play in understanding the factors contributing to baseline population risk. Dr. Burke also responded to the question, “*Are you recommending considering nonchemical factors at the dose-response assessments stage?*” He stated that the NAS was recommending that nonchemical factors that may change the dose-response curve be considered during development of a risk assessment’s modeling approach.

The speakers were asked, “*Even though we are now exploring susceptibility, how do we get around the sort of one-size-fits-all approach and account for differential locational characteristics of cumulative exposures?*”

Dr. Burke responded that the one-size-fits-all approach to lead, for example, has been helpful, but if risk

assessment is going to adapt to evolving science—whether at the molecular or population level—better risk characterization using SES and other information is needed. Dr. Chari added that CRA is related to “scenario-based planning” and its output could be “something like 15 or 20 different risk scenarios.” That flexible approach does not require selection of only one critical health endpoint, vulnerable population or exposure pathway. “*You can consider a range. You can rank scenarios. You can try and get at worst-case and reasonable-case scenarios in a way that’s transparent and reasonable.*”

Dr. Burke made a point about ecological risk assessment, noting that it is a problem-driven approach that “*really gets at the whole issue of what we are trying to do here.*” CRA has much to learn from the overall approach. Regarding any major data collection and computational priorities, Dr. Chari suggested that “*studies that are constructed specifically to try and get at issues of susceptibility*” should be conducted. Dr. Burke advocated for more exposure information and human studies to understand the actual population impact. He also suggested that better cumulative risk management will require a “radical” iterative process in which risk management decisions are evaluated later to determine if they worked.

Webinar 7

February 27, 2013

The Patterns of Pollution—Perspectives From an Environmental Attorney and a GIS Scientist on the Identification and Assessment of Environmental Justice Communities

David Deganian, Visiting Assistant Professor of Law, Barry University School of Law

Nick DiLuzio, Project Manager/GIS Analyst, NewFields

Mr. Deganian’s work partly focuses on developing laws to protect EJ communities, and Mr. DiLuzio is a GIS analyst and project manager at NewFields, an environmental and environmental sustainability consulting firm. Their talks focused on three learning points, as follow.

1. Methods for identifying and prioritizing EJ communities using publicly available data and GIS software

Mr. Deganian’s Metro Atlanta Environmental Project—a public interest project supported by a 2-year fellowship from the University of Georgia School of Law—required a methodology that would locate EJ communities and then determine how they differed from nearby communities, both in demographics and types of pollution. The technical goals were to develop an objective methodology for identifying and ranking EJ communities; to evaluate the correlation between community demographic characteristics (e.g., race, language and income) and proximity to pollution points; and to create a user-friendly EJ mapping system for residents.

Mr. DiLuzio presented the methodology. He began by defining the 14 counties that constitute metropolitan

Atlanta as the study area. He then collected two types of data: (1) eight publicly available pollution data sets, which included information on permit violations, Toxics Release Inventory reports, Superfund sites and facilities holding permits to emit air pollutants or discharge water pollutants, and (2) seven demographic data sets, such as Census data, the American Community Survey data set and data sets on mean housing value and median family income. The project developed a model that normalized these two collections of data sets based on data type and spatial scale to enable an exact definition of where the overlay exists between pollution sources and demographic data. To address spatial scale, the project created a grid in which every cell was 10 square kilometers, to which was joined the pollution and demographic data.

Mr. DiLuzio presented two maps that consolidated the pollution data. One showed black points representing air-emitting facilities; the study grid was overlaid on top of the map and GIS software was used to sum up the number of points within each 10 square kilometer cell. The map summing up the black points was color-coded using green and red to produce a second pollution map. Green areas had zero facilities and red had between 11 and 25 facilities. The process was repeated for all eight pollution data sets, producing eight color-coded areas that were summed to produce a total pollution score map with values ranging from 0 to 55.

To tackle demographic data, Mr. DiLuzio separated the data into five categories—quintiles, each representing 20 percent of the distribution for the demographic variable. He created a color-coded map showing on a census-tract level the percentage of nonwhite population for the study area; he created a second, similar map that rescaled and reclassified the data based on the quintiles. In the rescaled map, the number 1 represented communities that are predominantly white (shades of blue) and 5 represented communities that are predominantly nonwhite (shades of pink). As with the pollution data, he repeated the quintile exercise for all seven databases and summed them to produce a total demographic score—ranging from a minimum of 8 to a maximum of 35—that was presented in a color-coded map he displayed. Areas scoring 8 (light blue) were predominantly white, English-speaking, high income, with high levels of high school graduation rates and very low poverty; the top quintile areas (5), represented in pink, were primarily nonwhite and had low income and high poverty.

The two mapping results were used to identify the 10 square kilometer blocks that were in the top quintile for pollution (red) and for demographics (pink). These areas were called EJ hotspots. Fifty-two blocks were identified as hotspots, which then were ranked by their combined pollution and demographic scores from 1 to 52.

2. Results of an environmental justice assessment in the metropolitan Atlanta region

Mr. Deganian discussed the results generated by the methodology. The analysis showed that “there’s a direct relationship between the number of pollution points in a block and the percentage of the population in the block that’s nonwhite.” On average, blocks with less than 25 percent nonwhite populations had slightly fewer than two pollution points, and blocks with more than 50 percent nonwhite populations had slightly more than four pollution points. Pollution points are significantly higher in areas where a large number of residents are unable to speak fluent English; thus, EJ can be thought of in terms of linguistic isolation. The study showed a clear correlation between vacant housing rates and pollution points. Housing values, however, were not predictive of pollution points in the region; areas with the highest housing values on average have slightly more pollution points than where housing values are more than \$100,000 and almost three times more than where home values are below \$100,000. The speakers attributed this to the fact that the region’s population lives downtown and in central Atlanta where housing values are higher than in most areas of the region.

Besides identifying 52 EJ hotspots, the analysis identified what were called EJ “cold spots,” defined as blocks with relatively high pollution points but mostly white populations and positive economic characteristics, such as high housing values and income. Ten blocks were identified as EJ cold spots. According to Mr. Deganian, theoretically, “if all residents were impacted by pollution equally, hotspots and cold spots would exist in the same frequency,” but that did not occur in the study. He commented that the use of cold spots for comparison was a useful way for communicating the point about EJ.

Mr. Deganian described the three worst hotspots. The number-one EJ hotspot is located at the intersection of three counties and is one of the southeast region’s largest warehousing and transportation centers. The block’s population is 86 percent nonwhite, and roughly 80 percent of residents are African American; vacant housing rates are more than 20 percent. The second hotspot is in the region’s northeast, and the population is largely white, with a high school graduation rate below 65 percent. It has only one pollution point—the City of Canton’s water pollution control plant—but its 49 violations between 2008 and 2011 made the block a top EJ hotspot. The third hotspot, in the central part of the region, is called Buford Highway and is known as having a diverse ethnic population of Asian and Hispanic residents that is 45 percent linguistically isolated and has a high school graduation rate below 70 percent. Lastly,

Mr. Deganian noted that his project's EJ mapper allows anyone to type in an address in the region to receive a PDF report on the demographics and pollution in the area. Eleven months after its release, the mapper had 1,600 hits.

3. Practical uses of this data from an environmental attorney's perspective

A variety of uses have resulted from the analysis, including the establishment of regular meetings among EJ activists to identify and address a strategy for shared goals. It also served as a public engagement vehicle, giving Mr. Deganian a tool to make presentations to various citizen audiences typically uninterested in environmental issues. Fulton County, which has the most EJ hotspots, passed an EJ resolution several months after the project report was issued. The study also was a tool for engaging with decision makers.

A questioner asked, "*Shouldn't the pollution scores that you developed be weighted by the degree of potential hazard?*" Mr. Deganian responded that the project participants discussed that idea but could not figure out a way to provide weights that "*wouldn't be even more subjective than giving them all a value of one.*" For example, he said that he did not know how to give a risk assessment value to a Toxics Release Inventory release versus a Clean Water Act permit. Mr. DiLuzio added that they approached the analysis not so much from a risk perspective as from a "location perspective" to define hotspots that might warrant further investigation. Another questioner asked if the project had considered other spatial grids besides 10 square kilometers. Mr. DiLuzio stated that they had considered a 20-square-kilometer grid but decided it was too large. A smaller grid of 5 square kilometers could be used if the analysts wanted to focus on a single county or group of counties.

The speakers were asked if they had considered a metric tool for analyzing the data set, because the graphs show a trend but perhaps leave out a lot of high-impact qualitative results. "*Perhaps that spatial regression analysis also would have been appropriate.*" Mr. DiLuzio responded that such issues had been discussed but the analysis had been constrained by time and the project was only attempting a first-pass 40,000-foot view. A lot of GIS and other statistical analyses could be performed in the future. Mr. Deganian added that the project had considered adding cancer statistics and other elements, but that would have made it more difficult to achieve

the key goal of communicating to a variety of different audiences. He agreed, however, that more complex or thorough methods would be a useful addition to the analysis. They also were asked if it would make sense to specifically evaluate vulnerability when deciding which types of issues to include in the analysis. Mr. Deganian replied that it would be an interesting dimension to add to the analysis because it would play into identifying EJ hotspots, although his focus was on legal cases to advance policies. An objective way to evaluate vulnerability would have to be developed.

A questioner asked, "*How accurate are these existing data sources, particularly the location of pollution sites?*" Mr. Deganian responded that critics noted that some facilities counted in the study had been closed, but he added that the data were those provided by the federal and state government at the time of the study. Updating the data would be an important step if enough people were available to help. Another questioner commented, "*I would think that some of your variables would be correlated, such as percent nonwhite and linguistic isolation. If so, then counting each of these would be double counting this factor.*" Mr. DiLuzio responded that much of the demographic information was drawn from the variables used in similar previous studies. Mr. Deganian added that the demographic characteristics were tailored to the kinds of information of interest to the study sponsors, such as linguistic isolation. He agreed that some double counting likely did occur, but "*not as much as you would think in metro Atlanta,*" and not such that it skewed the results.

Another questioner asked, "*It is not apparent how you used the number of violations in your study. They did not affect your counts, correct?*" Mr. Deganian stated that they did affect the counts; each violation was included as a pollution point if it was not a technical violation. The study was more of a legal document than a risk document. For a related question, he explained that the violations data can generate other queries, such as, "*Are violations being enforced in higher income areas in a different way than in lower income areas?*" Mr. Deganian also was asked how the analysis would be applied to the location of a new permitted facility. He responded that when a new facility is proposed for an EJ hotspot, attorneys can use the data to request a deeper review prior to a new permit's receiving approval and to isolate areas whose permitting decisions they would want to focus on to ensure permitting is done properly.

Webinar 8

March 20, 2013

A Semi-Quantitative Framework for Cumulative Risk Assessment of Waterborne Contaminants

Dr. Douglas Crawford-Brown, Director of the Cambridge Centre for Climate Change Mitigation Research, University of Cambridge

The speaker has served on numerous committees and panels, including the U.S. National Drinking Water Advisory Committee, the U.S. Legislative Commission on Global Climate Change and the European Commission's Panel of Scientific Experts on Risk. His talk focused on three learning points, described below.

1. Understanding competing philosophical and policy foundations of cumulative risk

Dr. Crawford-Brown described two traditions of conducting risk analysis: the individual rights tradition in the United States and the cost-benefit analysis utilitarian approach employed in the European Union (EU). The goal in the United States is to achieve reasonable certainty, for example, that drinking water poses acceptable risk; it cannot be completely safe, but everybody has that right and EPA's job is to produce water that respects everybody's rights. The utilitarian goal is to produce the most cost-effective enhancements of overall welfare in a defined community.

2. Calculating cumulative risk based on disability adjusted life years

The speaker stated that he would be discussing a semi-quantitative framework—not a fully quantitative one—that incorporates certain kinds of judgments. His underlying message was that the EU's approach in the regulatory sphere and the United States' approach are slowly being harmonized, but a fundamental difference nevertheless exists between the two. In the United States, the regulatory framework centers on building in uncertainty factors and modifying factors based on points of departure. In the EU, the framework resorts to Disability Adjusted Life Years (DALYs) and Quality Adjusted Life Years (QALYs) and the like. In his view, it is impossible to conduct a CRA under EPA's traditional regulatory approach of using points of departure, developing Reference Doses (RfDs) for chemicals with

uncertainty factors and so forth. His semi-quantitative framework strips away the “policy apparatus” of uncertainty factors, which can be restored after a CRA is completed. To conduct a CRA, it is necessary to use the utilitarian cost-benefit framework employing such factors as DALYs and QALYs.

3. Using cumulative risk to identify strategies of risk reduction for water supplies

Dr. Crawford-Brown discussed his project using the concept of the “risk cup.” The semi-quantitative framework analyzes how to choose between water supplies of different purity by imagining glasses of water in the cup and calculating the total risk from that drinking water. Questions to pose are: Which glass meets individual rights on all compounds? Which produces the best overall welfare? Which does this at the lowest cost? Cost matters because if the price of water rises as a result of stricter standards and higher treatment costs, the poor could face difficult financial choices, such as postponing or neglecting health care visits or dropping access to drinking water. Trade-offs can result in reduced overall public welfare. Rates of asthma, high blood pressure and other diseases are affected by the lack of health insurance.

The speaker stated that the issue of cumulative risk is most important in terms of EJ problems. He noted that the risk management framework he was employing within his CRA analysis was a classical multi-criteria decision analysis methodology; the key to it is to define which health effects “you actually care about in the population” whose various risks are being assessed and managed.

Commensurability is a key challenge in CRA. “What are we going to do if we've got cancer that is being produced by our risk cup, and we've got respiratory diseases...reproductive diseases...liver damage and so forth?” One view is to regard these various health effects as incommensurable; the other is to reduce every health impact to a common metric, which for economists is the amount of dollars a person would be willing to pay to avoid a health effect. The speaker's framework for commensurability is DALYs, QALYs or any other social utility welfare function that can be compared when examining the implications of the various glasses of clean water in the risk cup.

The speaker discussed approaches for “weighting” effects, such as a 0-to-10 semi-quantitative score based on “care” (e.g., no discernible effect on quality of life, mild discomfort, hospitalization, etc.). The DALY calculation is semi-quantitative because weightings are partly subjective. He then presented the eight steps in his assessment framework, starting with the calculation of a time-weighted lifetime average concentration of each compound in water using monitoring data and ending with the multiplication of the “mean individual DALY” by the size of the exposed population to obtain a “population cumulative risk” that is equal to the “weighted total DALY value.” The speaker also presented slides showing the DALYs that were calculated for 51 compounds in drinking water. The results showed wide variations in the DALYs, and only about five compounds contributed most of the public health impact or DALYs, even though all of the compounds analyzed were assumed to be at their maximum allowable limit.

Dr. Crawford-Brown was asked how his work would apply to the enormous effort at EPA to define more appropriate assumptions about ingestion for children. He responded that at the heart of the work he and colleagues conducted was the need for a relatively simple way to measure toxicity when dealing with hundreds or thousands of compounds. They used EPA’s IRIS RfDs, but stripped out body weight assumptions and the like to obtain an exposure level based on milligrams per liter. If EPA is concerned about early life exposure, the Agency will have to force the IRIS RfDs to reflect that sensitive subpopulation.

Another questioner asked if the speaker had to deal with criticisms that QALYs and DALYs are too close to an economic valuation of life. Dr. Crawford-Brown responded that he shares “*legitimate concerns about whether one can put a value on life.*” He stressed, however, that QALYs and DALYs do not put an

economic value on life; they are a measure of how important a particular effect is relative to others for a person’s quality of life, and they represent the “*best of the worst options*” available. An alternative would be to avoid reducing effects to commensurable units and allow decision makers to use their discretion, although the result could produce an option that is not cost-effective, with potentially significant public health implications.

A questioner sought clarification of Dr. Crawford-Brown’s statement that there is no difference between cancer and noncancer risk. He responded that there is no biological reason why cancer cannot occur on a threshold model or noncancer effects must occur on a threshold dose-response curve, as is currently assumed. He added, “*But if you believe that cancer is a probabilistic event, and if you believe that noncancer effects are threshold effects, then our methodology is not for you.*” Another participant stated that EPA does not use the speaker’s interpretation of margin of safety. In reply, he stated that when he was on EPA’s Science Advisory Board, the panelists frequently argued with EPA because they did not agree with the Agency’s interpretation of margin of safety, which focuses on conversion and scaling issues for an equal toxic dose, as opposed to formulating it as “*a decision problem with probability density functions and so forth, with uncertainty and variability.*”

A final questioner stated that in economics “*the costs are not allocated across a population for environmental justice concerns.*” The questioner asked, “*Who bears the costs in such a situation and who gets the benefits?*” Dr. Crawford-Brown acknowledged that the question is philosophical, but he added that it is precisely at “*the heart of the kind of question EPA ought to be asking*” because cost-benefit analysis does not really ask those questions. Furthermore, none of his CRA analysis calculated economic impact. A DALY is not, he emphasized, an economic measure; it is a public health measure of impact.

Webinar 9

April 17, 2013

Simulating Population Characteristics and Exposures to Multiple Stressors for a Community-Based Cumulative Risk Assessment

Dr. Jonathan Levy, Professor and Associate Chair of the Department of Environmental Health, Boston University School of Public Health

The speaker, an EPA Science To Achieve Results (STAR) grantee, is interested in air pollution exposure assessment, health risk assessment with an emphasis on urban environments, multi-stressor exposure scenarios and issues of heterogeneity and equity. His talk focused on three learning points, described below.

1. The value of synthetic microdata for community-based CRAs

Dr. Levy described a STAR-funded effects-based CRA study focused on two health outcomes of interest: Attention Deficit Hyperactivity Disorder (ADHD)-like behavior and hypertension. The goal was to examine the cumulative impacts of chemical and nonchemical stressors on those two outcomes. His presentation focused on the project's exposure assessment, which involved constructing "synthetic microdata" and then developing exposure models linking to those data. The project used public microdata—individual records with extensive data, but coarse geographic resolution—to create models of simultaneous exposures to a large number of stressors that were highly specific to individuals in low-income New Bedford, Massachusetts. The research was able to employ a very large, robust data set from a cohort study that began in the early and mid-1990s and is continuing today. Between 1993 and 1998, newborns from New Bedford and surrounding communities were enrolled in the study, which examined ADHD-like behavior and collected a host of exposure data.

The speaker added that CRA exposure challenges have been underappreciated, such as the need to model a large number of stressors simultaneously. Because researchers are interested in vulnerable subpopulations that might be highly exposed to multiple contaminants, it is "important to figure out not just the broad distribution of these stressors but correlations among them, and individuals or subpopulations who might be highly exposed to two, three, four or five different stressors of interest."

To address the issue, exposure models must have high resolution across demographics and space. Dr. Levy noted that the project's fundamental premise was that "if you have measurements of exposure—biomarker measures or other measures on a subset of individuals in a community—you can build regression models to explain that variability and then apply those to the full population."

2. Statistical methods by which synthetic microdata can be generated and validated, relying solely on public databases

Analysts commonly collect a limited number of exposure measurements and find a way to explain variability, potentially allowing for extrapolation to other populations. The approach could be used for New Bedford if a lot of individual-level data were available that included where people live and their basic demographic attributes, but for privacy and other reasons such data do not exist. The microdata on individual attributes lack geographic resolution; Census data generally only provide one or two variables at a time, but never the full suite of cross-tabulated information. The researchers combined these data to create a "synthetic census" representing New Bedford's demographics and geography. This approach has been employed for decades by "micro-marketers" using geographic and demographic data to target the marketing of their products. It has not been used for health purposes, except in a few recent papers looking at smoking, and it has never been used for environmental health applications.

To construct "synthetic geographically resolved microdata" for New Bedford in a way that could inform the project's exposure models, Dr. Levy and his colleagues used microdata from the U.S. Census American Community Survey, which surveyed a random sub-sample of 5 percent of the population, or about 9,000 people in New Bedford and surrounding communities. A simulation approach (probabilistic reweighting using simulated annealing) was used to determine the census tracts where these individuals most likely lived, given 13 census tract-level constraints from the U.S. Census American Community Survey—8 individual (e.g., sex, age) and 5 household (e.g., household income, rent/own status). The procedure was validated, showing that the Census data and the constructed synthetic microdata were a good fit, both for the constraints and for other census fields.

3. Approaches for predicting exposures to key stressors as a function of synthetic microdata, with an example of applying this approach to cigarette smoking in a low-income urban community

The results of the synthetic microdata simulations were connected with an exposure model, and cigarette smoking was the first proof-of-concept test, using the Massachusetts Department of Public Health's 2006–2010 Behavioral Risk Factor Surveillance System data, part of a large survey by the Centers for Disease Control and Prevention. With more than 4,000 people identified as residing in New Bedford, the researchers built a model to predict the likelihood of smoking among the population as a function of the demographic variables available from the Census-based synthetic microdata. Although the resulting map could not be directly validated, it was possible to replicate the overall smoking rate in New Bedford and previously reported demographic patterns. By building a local model and linking it to the local synthetic microdata, the researchers were able to capture nuances of smoking in New Bedford that normally could not be captured.

The researchers next built models for other stressors related to ADHD-like behavior with the goal of being able to inform communities about measures that they could take to reduce their exposures. The researchers built a model with a multilevel structure that enabled them to leverage their microdata to define geographic and demographic patterns. The model was designed to determine some of the key behavioral predictors—such as fish consumption, breastfeeding and smoking—that contribute to PCB and other exposures of concern in New Bedford. A map was generated showing the modeled distribution of PCB exposures across Census tracts in New Bedford; Dr. Levy strongly cautioned, however, that the exposure model was not related to geography *per se* but to food consumption patterns, demographics and other such information. The researchers examined a nonchemical stressor indicative of psychosocial stress, data from the Home Observation for Measurement of the Environment (HOME), which provides a proxy for parental stress. The map based on HOME data was overlaid on other maps to

produce indications of communities—including subpopulations—that might be at elevated risk across multiple factors. Dr. Levy concluded that the model is “entirely generalizable to other settings” besides New Bedford as a framework for effects-based CRA modeling; the analytical structure identifies high-risk populations and focuses on risk-reduction strategies.

A participant asked Dr. Levy how the community partners (who are required as part of a STAR grant) reacted to the modeling approach for describing their communities. He responded that the partners were “intrigued” by the approach and pressed the researchers to stay focused on building models that were relevant to people’s everyday lives and to risk reductions that they could potentially implement. The partners advocated for a community survey that was undertaken to obtain current information. Another participant noted that the four maps Dr. Levy presented in his slides showed very different affected areas and asked if he is working on developing joint stressor models. The speaker responded that such models are the goal of the structural equation modeling that he and his collaborators are working on. Eventually, Dr. Levy envisions a single map or table that “*cuts across all stressors and gives a sense of the highest risk subpopulation.*”

A participant asked, “*How much is your model extendable to other cities?*” Dr. Levy responded that he would be cautious in extending the model itself to other cities because there are “*a lot of local population nuances that could mean certain behaviors, or certain demographic variables, seem indicative of exposures, and it just wouldn't represent elsewhere.*” Nevertheless, “*the approach is extendable to other cities,*” and if more exposure pathway variables were available “*that would enhance the generalizability.*” Another participant asked what degree of certainty Dr. Levy’s methodology would bring if an analyst were looking for cause and effect across multiple stressors. The speaker responded that there are appreciable uncertainties and unexplained variability in the modeling. He would provide a “*fair amount of caution before using it in something that was approaching an epidemiologic investigation.*”

Webinar 10

May 22, 2013

Why and How to Integrate Your Assessment

Dr. Glenn Suter, Science Advisor, EPA National Center for Environmental Assessment, and Chair, Risk Assessment Forum Oversight Committee

The speaker—who has a Ph.D. in Ecology and is the principal author of three texts in the ecological risk assessment field—has conducted research in the development and application of methods for ecological epidemiology and risk assessment. His talk focused on three learning points, described below.

1. Why health and environmental assessments need to be more integrated

Dr. Suter noted that “we all, human and nonhuman alike,” are exposed to the same environment and same pollutants. Permitting, remedial and policy decisions must “meet the needs of and protect humans, nonhuman organisms, ecosystem processes and even economic and political entities.” Integration thus leads into the domain of sustainability. Scientists must present a coherent, consistent risk assessment across such issues as multiple stressful agents or pollutants, multiple endpoints, different levels of ecosystem organization that affect organisms, populations, communities, ecosystems and even global levels. Human, nonhuman and socioeconomic systems face risks, and therefore “integration is imperative” because without it risk estimates will be incomplete, poor decisions will be made and stakeholders will be confused by disjointed assessments.

2. Ways in which assessments may be integrated

The speaker described various ways that ecological risk assessors deal with multiple agents and stressors—not just toxic chemicals, but also temperature, suspended sediment, physical habitat structure, nutrients, dissolved oxygen and other aspects of the environment, which also affect humans, although in different ways. As with human health risk assessment, ecological risk assessors begin by examining data on individual chemicals and other stressors. They use exposure and effects additivity models, and sometimes combined exposure and effects additivity for heterogeneous mixtures of agents. To get

beyond the limitations of single-chemical testing and modeling, however, ecological risk assessors developed chemical mixtures toxicity testing. Test organisms—most often fathead minnow and *Ceriodaphnia dubia* (a species of water flea)—are exposed to a mixture of chemicals that they experience in the environment as a result of pollutants in effluent discharges. If the tests show toxicity, assessors use toxicity identification evaluation techniques to test and retest fractions of the chemical mixtures to determine what is causing the toxicity. Toxicity profiling is a new technique being developed mainly in Europe for using tests to determine causes of toxicity in mixtures.

Although mixtures toxicity testing is better than single-chemical testing, the approach is limited by the relatively small number of species tested, which may not include sensitive species. The necessary life stages, such as spawning adult fish, may not be included, and the duration of exposure needed for chemicals that bioaccumulate may be missing. To address those limitations, biological surveys of animals or plants can be conducted. For example, electrofishing involves stunning the fish in a stream, weighing and measuring them and examining them for gross pathology. It has the advantage of including all species and life stages in a real-world setting. The disadvantage is that it assesses population- and community-level effects, which may be less sensitive than organism-level effects seen in a laboratory. Causation of field survey results can be obscure, so EPA developed a stressor identification method that is based on human health epidemiology for determining causation in ecological systems. The method was expanded into an expert system called CADDIS, the Causal Analysis/Diagnosis Decision Information System.

Dr. Suter described three case studies involving integrated assessments. In an assessment of the Poplar Creek Embayment on Watts Bar Reservoir in Tennessee, an ecological risk assessment based on conventional toxicity tests, mixture toxicity tests and biological surveys was conducted, along with a standard human health risk assessment. Although the ecological tests raised concerns about possible reproductive risks to humans based on those found in mink, the human health risk assessors rejected the data, causing public concern. In the assessment of a mining waste site in the Coeur d’Alene River Basin in Idaho, the National Research Council criticized EPA for failing to do a good job of integrating human health and ecological concerns to protect all receptors from mining contamination. In the

assessment for the proposed Pebble Mine in the Bristol Bay watershed in Alaska, the Yupik villages asked EPA to provide protection against the threats to salmon fisheries, which are the main source of their food and commercial livelihood, as well as a central part of their spiritual culture.

3. How to decide on the type of integration

Dr. Suter described integrated human health and ecological risk assessment frameworks. In 1998, for example, the World Health Organization, the Organization for Economic Cooperation and Development, the European Union and the United States developed an integrated human health and ecological risk framework. EPA's Risk Assessment Forum is completing a draft "Human Health Risk Assessment Framework" that will create a better basis for collaboration between human and ecological risk assessors. Dr. Suter emphasized that integration does not mean diverting ecologists to work on human health. He concluded by stating that "risk assessment is in everything" and various kinds of studies are necessary. Environmental epidemiology is needed to determine problematic conditions and their causes. Predictive assessments other than risk assessments, such as cost-benefit analyses, are needed. Outcome assessments are required to determine whether decisions provide the anticipated benefits. Integration should be conducted in a way that better informs decisions and provides a coherent understanding of the consequences of alternative actions.

A participant asked Dr. Suter if any attempts have been made to devise a common human health and ecological risk metric. He responded that it has not been done and would be a bad idea; important information is lost with multi-metric indices. It is preferable to have multiple

endpoints that are presented in a coherent, integrated manner. Another participant stated that because human beings are assumed to be the most sensitive species, the argument is made that human health risk assessments would be protective of ecological receptors and no ecological risk assessment is needed. Dr. Suter dismissed the conclusion, saying that a fish put in tap water would quickly die. He noted that "*nonhuman organisms have modes of exposure that cause them to be more exposed than humans, like respiring water. They are more intimately integrated into the environment than humans are and some are inherently more sensitive.*"

Asked about top research needs to advance integrated assessments, Dr. Suter responded that from the traditional toxicological standpoint, the ability is needed to examine toxic effects in a common mechanistic framework, such as adverse outcome pathways. Such research would be helpful to both human health and ecological risk assessors in developing models that produce outputs "*that are relevant to both those who drink water and those who respire water.*" Another need is for a better understanding of how humans interact with the environment and benefit from having a high-quality environment available to them. Studies show that "*people who have visual access to a park recover from surgery faster than those who are looking out their window at a wall.*"

Dr. Suter responded positively to a question about EPA assessors receiving more training in an integrated perspective. EPA, however, lacks guidance or training materials and faces inertia because many people are invested in proceeding as they have always done. They worry that if EPA adopted an integrated approach, the Agency could be challenged for departing from practices already approved by precedents. "*There is inherent institutional conservatism that we have to work against.*"

Webinar 11

June 26, 2013

A Novel Approach for Testing Interaction Effects of Environmental and Psychosocial Stressors on Disease Risk in a Logistic Regression Model

Dr. Wenyaw Chan, Professor of Biostatistics at the School of Public Health, University of Texas, Health Science Center at Houston

Ms. Maria Jimenez, Research Coordinator in the Division of Epidemiology, Human Genetics and Environmental Sciences at the University of Texas School of Public Health

Dr. Chan and Ms. Jimenez are involved in the STAR program. Dr. Chan has more than 20 years working in public health, and Ms. Jimenez has been a strong advocate working on social justice issues for the past 47 years. Their talks focused on three learning points, described below.

1. To describe the specific aims of the project entitled “Hypertension in Mexican-Americans: Assessing Disparities in Air Pollutant Risks”

Dr. Chan described a 4-year project led by Dr. Elaine Symanski with three collaborating institutions, including community partners, which seeks to understand the associations between air pollution and hypertension, and psychosocial stress and hypertension. The project is developing a new statistical method that will be applied to evaluate the combined effects of environmental and psychosocial stressors on hypertension. It builds on the “Mano a Mano Study” of more than 22,000 participants of Mexican origin in Harris County, Texas, which is under the direction of Dr. Sara Strom at the M.D. Anderson Cancer Center.

Ms. Jimenez explained the community-based participatory research component of the project, involving three groups that interact with researchers: (1) the existing Mano a Mano Community Advisory Board composed of agency heads, nonprofit executives and academicians who provide a broad view of Harris County-area problems; (2) a Neighborhood Council of Advisors (NCA) composed of 16 local residents with

an understanding of their residential areas convened by the project to provide input and feedback; and (3) 27 cohort participants who live and work in the “Mano a Mano corridor” neighborhoods and who participated in four focus groups. Focus groups were held to learn about important psychosocial stressors as well as behaviors and activities that influence exposure to air pollution.

Content analysis “domains” emerged from interchanges between researchers and community members.

Four domains were identified: (1) stress related to employment, economic, individual and family issues; (2) pollution-related stress; (3) discrimination-related stress; and (4) neighborhood-related stress. Using these domains and other sources, researchers developed a 36-question pilot survey employing a frequency scale with responses ranging from “not at all” to “most of the time” for specific questions. Seven one-on-one interviews have been completed, and 13 more are planned. The speakers described plans to administer a refined survey to more than 2,000 participants in the fall of 2013 and to evaluate the interacting effects of air pollution and stress on hypertension in the spring of 2014, using traditional and new methods. (*Note: Interviews began in February 2014, with almost 900 interviews completed as this goes to press in July 2014.*)

2. To explain the general, traditional approach of evaluating the statistical interaction of two factors on disease risk

Dr. Chan described the “interaction effect,” or an interdependent relationship between the effects of two or more factors, in this case, between air pollution and psychosocial stress. Traditional regression analysis usually uses the product of two variables called a “product term” as an interaction effect in a model; this approach is problematic as there are other effects not always represented in the form of the product term. Because the traditional linear regression model contains a high correlation between the product term and the main effect term, this might create a so-called “multicollinearity problem” in the regression.

In addition, the interaction of the coefficient of the interaction term is very difficult to interpret, “particularly when we are talking about the main effects of continuous variables.”

3. To discuss key elements of a new approach for testing interaction effects in a logistic regression framework and to compare this new approach with the traditional ones

As an alternative, the project researchers illustrated their approach with a table in which each cell represents different combinations of discretized factors X and Z, and they used either a Monte Carlo integration or a “bootstrapping analysis method” to calculate probabilities of a disease. The analysis identifies for which cells there is a high probability that interaction exists between factors X and Z (e.g., air pollution and psychosocial stress).

The advantages of the new method are that it can test for overall interaction, rather than just testing for a particular form of a product term. In addition, with the new method there is no difficulty in interpreting the interaction effect. Furthermore, with the product term used in traditional regression analysis, an assumption is made that interaction effects are constant across the values of factors X and Z. The new approach does not make that assumption because it focuses on the overall interaction effect. Disadvantages of the new approach, however, are that it is computationally very intensive—estimating probabilities for each cell on the table requires 14 hours of computer time—and it cannot estimate the magnitude of the interaction effect because the method assumes that the effect is not constant. (In the future, the magnitude of the interaction effect for each cell can be estimated using the proposed method).

Dr. Chan was asked if his methodology can discern whether an interaction is additive, antagonistic or synergistic. He responded that by rewriting the testing hypothesis, it would be possible to differentiate the three different scenarios. Another method that the project researchers developed focuses on those interactions and will be discussed in a forthcoming paper. Another participant commented that the lack of an estimate for the interaction effect magnitude is not an issue, but the “effect magnitude” must be evaluated to determine if the effect raises clinical public health concerns rather than simply achieving statistical significance. Dr. Chan

responded that focusing on a clinical concern might require more information to understand the interactions of clinical stressors.

A participant asked Dr. Chan how he distinguishes interactions that come from correlations among the exposures from those that are about factors influencing each other’s biological impact. He stated that because the project’s methodology is testing for overall interaction effect, we are not able to distinguish those differences. To identify different sources of interaction effect might require developing a new method, but meanwhile, identifying where interaction occurs and does not occur is useful. Responding to another question, Dr. Chan agreed that theoretically his approach can accommodate many different variables, but at a significant increase in computer time required. Regarding the question of how his methodology fits within EPA’s risk assessment paradigm, including cumulative risk, Dr. Chan responded that the information provided through the project’s epidemiologic study—concerning interaction effects between environmental and social stressors—could be used in risk assessment because the method allows researchers to identify subgroups for whom such interaction effects are present.

Regarding communication of the results, Ms. Jimenez noted that the NCA members recognize that they have a responsibility to explain the project results to neighborhood residents, which they will do at several meetings after the results are made available. Furthermore, several Houston-based experts in educational methodologies are available for consultation for communicating the results to the NCA who, in turn, will communicate what they understand to other neighborhood residents. A participant asked whether the questionnaire items will collect information on an individual’s educational level and annual income, and whether researchers will assess these factors that might be associated with the level of air pollution, which is typically higher in less desirable real estate locations, and psychosocial stressors. She responded that she believes some of that information is available and Dr. Symanski confirms that data on educational level are available but data on income are not.

Webinar 12

July 24, 2013

CalEnviroScreen 1.0—A New Tool for Evaluating California Communities

Dr. George Alexeeff, Director of the California Environmental Protection Agency (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA)

Mr. Walker Wieland, Environmental Scientist, OEHHA, Sacramento

Dr. Alexeeff has served on three NAS panels and serves on EPA Science Advisory Board committees; Mr. Wieland's expertise includes geographic information systems and watershed sciences. Their talk focused on three learning points, described below.

1. Describe a science-based approach to identify highly burdened ("environmental justice") communities in California

CalEPA developed the CalEnviroScreen modeling tool to broadly capture the relative burdens that California communities face from environmental pollution, using 18 indicators of environmental and socioeconomic conditions. It is not a health risk assessment process. The tool is built around a definition whose key terms include exposures, public health, environmental facts, emissions and discharges, geographic area, pollution sources, sensitive populations and socioeconomic factors. CalEPA chose the geographic unit of ZIP codes because they are a familiar scale, are not too small or too large and allow a statewide comparison, among other reasons.

CalEnviroScreen's 18 indicators are divided into two broad groups: pollution burden and population characteristics. Within pollution burden, there are two categories: exposures and environmental effects. Under exposures, the model uses indicators of fine particulate matter (PM_{2.5}) concentrations, ozone concentrations, diesel PM emissions, pesticide use, toxic releases from facilities, and traffic density. Under environmental effects, the model includes cleanup sites, ground water threats (leaking underground tanks and cleanups), impaired water bodies, solid waste sites and facilities, and hazardous waste facilities and generators. Population characteristics encompass sensitive populations and socioeconomic factors. Sensitive populations include the prevalence of children and elderly, emergency department visit rates and low birthweight rates. Socioeconomic factors include educational attainment,

linguistic isolation, poverty—defined as the percent of residents with household income below two times the national poverty level—and race/ethnicity.

2. Describe how multiple stressors in a community can be integrated with vulnerability and exposure data

For each of the 18 indicators, the state's more than 1,700 ZIP codes are assigned a percentile value based on where they fall in the distribution. For example, CalEPA had a PM_{2.5} value for each ZIP code. Each ZIP code was ranked from the highest to the lowest level of PM_{2.5} and then the ZIP codes were divided up by percentiles from 0 to 100 percent. After scoring each of the codes, CalEPA combined the 18 indicators. ZIP codes ranking within the 90th to 100th percentile were given a score of 10, those from the 80th to 90th percentile given a score of 9, and so on down the line, with each ZIP code receiving a score from 1 to 10 for each indicator. For exposures and environmental effects, the maximum score was 10, and those two scores were added together as part of the methodology.

CalEPA also scaled population characteristics from 1 to 10. The distribution of poverty within the state, for example, was classified by ZIP code, and then placed within a distribution from the 90th to 100th percentile to generate the values from 1 to 10. CalEPA then multiplied the sum of the exposures and environmental effects times the sum of the sensitive populations/socioeconomic factors to produce a single score for the individual ZIP codes. Scores were used to create color-coded maps showing communities' relative cumulative impact burdens. Higher scores were darker; lower scores were lighter.

3. Understanding how to use the CalEnviroScreen 1.0 tool

CalEnviroScreen 1.0, which is housed on the OEHHA website, is available in English and Spanish and provides various types of data files, as well as two color-coded maps. One map shows only the highest scoring ZIP codes in California, coded in blue for the top 5 percent of ZIP codes, and in orange for the top 6–10 percent of ZIP codes. The other map shows CalEnviroScreen scores for all ZIP codes across the state color coded in shades of blue. A user interested in Los Angeles communities could zoom in on a particular ZIP code in that area. A pop-up box provides the detailed basis of the scoring behind that particular ZIP code, such as the ozone or

PM_{2.5} percentile. Clicking an indicator brings up a summary description of the data sources for the finding, along with links to key reference documents.

Dr. Alexeeff was asked about the applicability of the CalEnviroScreen tool in developing regulations or environmental quality standards. He responded that it is premature, except for providing more information about communities potentially affected by pollution or helping prioritize where regulatory action might be needed. For setting standards, better understanding of inter-individual variability is needed. Another participant asked if Dr. Alexeeff anticipated that CalEPA will integrate information about community vulnerability into any risk assessments that might be conducted under its existing programs. He replied that, although it is beyond current capabilities, CalEPA is headed in that direction. The situation is comparable to regulators' understanding about children's health 12–15 years ago. Back then, the information available was limited to the locations of schools or large day care facilities. Today, there is extensive knowledge about children's susceptibilities that may increase their response to toxicants and age-dependent sensitivity factors for carcinogenicity.

A participant asked Dr. Alexeeff how CalEnviroScreen's drinking water quality indicator is addressing people who obtain their drinking water from private wells. He responded that CalEPA has yet to figure out that issue and it is a major question for the agency. The approximately 10,000 drinking water providers listed by the California Water Resources Control Board must serve at least 25 individuals to be listed in the database, which provides some information about water quality.

It is unclear how that information will be incorporated. For private wells, CalEPA lacks information about water quality in the wells and ultimately might have to simply indicate well locations. Asked how CalEPA quantifies measures that are not risk-based, Dr. Alexeeff responded that proximity to facilities or cleanup sites is a factor that influences communities. In addition, sites were characterized in terms of whether they were closed, illegal, abandoned and on other factors used for scoring the potential impact of the sites.

Another participant asked how pollution reduction will affect linguistic isolation or how linguistic isolation changes the potential effects of pollution. Dr. Alexeeff noted that in early versions of CalEnviroScreen, linguistic isolation was not included. A Bay Area refinery, however, had a pollution release and the system for telephoning residents to tell them to shelter-in-place did not work for the segment of the Asian community who did not speak English. Therefore, they did not receive calls and were unaware of the refinery release. That incident convinced CalEPA that the Asian community was more vulnerable because they have less information to protect themselves.

Dr. Alexeeff was asked how the tool's 18 indicators relate to causes and effects, or "*dials that managers can control to reduce impacts in these various identified communities.*" He explained that the tool does not address causes and effects. Instead, some indicators are considered indicators of population susceptibility. Asthma incidence rates, for example, were used as an indicator that individuals who have visited emergency rooms for asthma are susceptible.

Webinar 13

September 25, 2013

Legal Authority for EPA to Use Cumulative Risk Assessments in Environmental Decision Making

Sarah Alves, ICF International

Ms. Alves, a manager at ICF International, has more than 5 years of experience in the areas of regulatory law, administrative process and public policy. She based her talk on a paper entitled "U.S. EPA Authority to Use Cumulative Risk Assessment in Environmental Decision Making," which she co-wrote with Ms. Joan Tilghman, a

Senior Technical Specialist at ICF International. Her talk focused on three learning points, described below.

1. Surviving a legal challenge to EPA decision making based on a CRA

Surviving a legal challenge to EPA decision making based on a CRA rests on (1) whether the Agency has statutory authority to use this methodology; and (2) whether the CRA methodology, analytical results and Agency use of those results are "reasonable." Ms. Alves described how a court would review a challenge to an EPA CRA using a two-step process defined by the U.S.

Supreme Court in a 1984 decision, *Chevron vs. Natural Resources Defense Council*. First, using Chevron Step 1, a court will independently review the relevant statute to decide if Congress has directly spoken to the precise issue in question. Next, in Chevron Step 2, if the statutory language does not unambiguously resolve the issue examined in Step 1, a court must defer to EPA's interpretation of a statute that the Agency implements provided that the interpretation is reasonable. In some cases involving vague statutory language, Ms. Alves said, "a court's analysis of reasonableness can involve complex inquiries into the specific factual circumstances of the decision, the placement of language in the relevant statute and the legislative intent of Congress." Even if a statute is ambiguous and a court finds that EPA's interpretation of the law was reasonable, EPA must demonstrate that its use of CRA in its decision-making process was "rational and not arbitrary and capricious."

The speaker summarized her analysis by stating that the legal viability of EPA's use of CRA to project risks from cumulative effects will depend on the specific statutory authority under which the Agency is acting and the soundness of the analysis it then yields. Courts can invalidate EPA decisions based on "bad science." Ms. Alves noted that EPA's statutory authorities generally focus on risks from single pollutants in a single exposure medium, even if in reality exposures are to multiple chemical and nonchemical stressors and despite the fact that EPA has made Environmental Justice a priority. Two laws explicitly specify how EPA must consider cumulative effects, but most impose more general provisions on the Agency "to protect public health" and address greater than *de minimis* risks. Overall, courts have accepted EPA's use of risk assessment under different statutes as an analytical tool in decision making.

2. Setting a formula for a legally sufficient CRA-based decision-making process is problematic

Setting a formula for a legally sufficient CRA-based decision-making process is problematic because CRA analysis necessarily involves uncertainty, and the sufficiency of evidence of risks will differ depending on the factual circumstances. Ms. Alves stated that a stakeholder challenging an EPA decision can assert that even if the Agency has the authority to use a CRA methodology, there were flaws in the conduct of the analysis itself or in the use of the results. The Supreme Court has defined several reasons that a court must vacate a federal agency's action, including (1) if the agency has relied on factors that Congress had not intended it to consider; (2) if the agency entirely failed to consider an important aspect of the problem; (3) if the agency offered an explanation for its decision that runs counter to the evidence before it; or (4) if the decision is so implausible that it cannot be ascribed to a difference

in view about the data or the product of agency expertise. EPA risk assessments rely on a series of assumptions that EPA believes reflect a reasonable understanding of potential real-world conditions but which inherently contain varying degrees of uncertainty. A court's analysis of this kind of issue is often undertaken in Chevron Step 2, when a court may tie a review of arbitrary and capricious issues regarding EPA's factual decision record to an inquiry into whether the Agency's interpretation of its ambiguous statutory directive was reasonable.

In their article, Ms. Alves and Ms. Tilghman reviewed a number of court cases and concluded that courts will apply basic rules when evaluating whether EPA has been arbitrary and capricious. "A court will find an agency to be arbitrary and capricious if EPA fails to show a rational relationship between its conclusions and the evidence before it." Courts are likely to defer to EPA's expertise and uphold the Agency's decision when a stakeholder challenges the quality of the data or technical process relied on by EPA or suggests that other data are more persuasive. However, when the record under review shows data gaps or missing steps in EPA's logic that preclude a meaningful review by courts and other interested stakeholders in the decision-making process, challenges tend to succeed. When reviewing a challenge to a risk assessment, courts attempt to ensure that EPA performs the most rigorous analysis possible given the available data and the inherent scientific judgment in the selection of data and assumptions at various steps of an assessment. If EPA fails to explain how its reliance on the results of a CRA relates to its statutory directive or how its decision is supported by the results, a court would likely overturn that decision.

3. Case law suggests reasons a court would uphold EPA discretion to use CRA-based decision making

Case law suggests a court would uphold EPA discretion to use CRA-based decision making if the court finds from the record that (1) statutory authority contains a broad, public health mandate; (2) data and assumptions are rational, based on available information; and (3) EPA's conclusions drawn from the CRA are reasonable. Ms. Alves presented a table listing factors that a court might consider when determining whether EPA has authority to change its interpretation of a statute that it implements. A court would approve of EPA's reinterpretation (1) if the Agency provides a rationale for the change; (2) if new evidence supports a different interpretation to satisfy the statutory mandate; and (3) if the Agency provides adequate notice and opportunity for public comment on the methodological changes. She noted that it is problematic to make a broad statement regarding how to construct a CRA analysis that would be upheld in a court of law because a court's decision about the sufficiency of the evidence

regarding risk will likely differ, depending on the data available and the actual circumstances for any risk analysis. A CRA can vary from a narrow consideration of cumulative risks, such as assessing the combined impacts of multiple contaminants to humans at a Superfund site, to a broad CRA that includes nonchemical stressors.

Asked if a court could find that a qualitative CRA is reasonable, but the quantitative method is unreasonable or insufficiently accurate, the speaker responded that if EPA's statutory mandate was vague or broad and the Agency had some real evidence of cumulative effects but simply could not quantify the effects perfectly, a court would find that conclusion reasonable. Another questioner asked if the burden is on EPA to show that CRA would be allowable under a statute or if the Agency would be shown deference. The speaker responded that EPA has the burden of explaining why a statute

would allow use of a CRA and why it is reasonable to do so, and it needs to explain that conclusion during the decision-making process, not after the fact. To a question about the legal foundation and arguments for using CRA depending entirely on the strength of the evidence, Ms. Alves said that EPA should not spend a lot of resources on a CRA whose results the Agency knows are going to be highly uncertain. A participant asked if nonchemical factors affecting the potency of chemicals of concern could be considered in a Superfund CRA. The speaker responded that they could be considered, but if the Superfund program wants to advance its CRA methodology, it would have to change its internal guidance and explain why it was doing so. Regarding states and CRA, Ms. Alves said that they need clear EPA guidance on its use; otherwise, they might be reluctant to adopt a CRA approach in their decisions.

Webinar 14

November 20, 2013

Implementation of Cumulative and Mixtures Risk Assessment in the Office of Water—Past and Future

Dr. Elizabeth Doyle, Senior Scientist, Office of Water (OW)

Dr. Doyle, a risk assessor with 28 years of experience at EPA, including 14 years as a toxicologist and exposure assessor in EPA's Office of Pesticide Programs, addressed three learning points, described below.

1. An understanding of the current status of mixtures in OW regulations

Dr. Doyle began by discussing the limited application of mixtures assessment within OW under the Safe Drinking Water Act (SDWA) and the Clean Water Act (CWA), which require the use of cost-benefit analysis. Under the SDWA, OW addresses two existing mixture groups. The first group, radionuclides, includes two groups: gross alpha emitters, and beta particle and photon emitters. OW regulates both groups for a single health effect—carcinogenicity—using one measurement technique, an approach that Dr. Doyle explained was simple but has been useful for the program since the mid-1970s. For beta emitters, for example, an aggregate “maximum contaminant level” (MCL) measure of 4 millirems

represents an aggregate measure of approximately 170 contaminants based on a “sum of fractions method.” The second group, disinfection byproducts (DBPs), contains hundreds of chemicals that are regulated; haloacetic acids and trihalomethanes are used as indicators that an acceptable level of DBPs has not been exceeded.

2. The impact of statutory and regulatory drivers in formulating new assessments under the SDWA and CWA

At the behest of the National Research Council, former EPA Administrator Lisa Jackson requested that OW conduct more multichemical assessments as a means of becoming more efficient and effective in how the office regulated chemicals. In 2010, OW began working on an implementable method of grouping chemicals and concluded that such a method would require that chemicals be linked by a common health effect as a basis for grouping. In addition, OW concluded that the grouped chemicals would have to be controllable using a common process or treatment technique because it would be too costly to deal with a random chemical mixture that would require treatments to be changed multiple times.

After evaluating several possible groups, starting with 45 carcinogenic volatile organic compounds (VOCs), OW selected the sample group of nitroso

compounds to address first. These are DBPs all of which are liver carcinogens that occur in response to chloramination, a modification of the disinfection process. Based on EPA's *Guidelines for the Health Risk Assessment of Chemical Mixtures*, OW decided the nitroso compounds would lend themselves to the "relative potency factor approach," which requires the identification of a common mode of action followed by a calculation to express the toxicity of each compound in the group as a proportion of the index chemical N-Nitrosodimethylamine (NDMA). For example, a chemical in the group, N-Nitroso-N-Diethylamine (NDEA), might be calculated to be 1.2 times as potent as NDMA, and the other chemicals in the group would be calculated in a similar manner. OW has developed the documentation for treating nitroso mixtures as a group using the relative potency factor approach and will issue that documentation in an upcoming regulatory notification.

Returning to the VOCs, OW adopted a "response addition approach" in which the carcinogenic risk of individual compounds at a specific concentration measured in drinking water is calculated and summed to estimate the total VOC cancer risk for a water sample. The approaches that OW used for nitroso compounds and VOCs both require calculating a measured risk value, rather than producing an MCL. OW refined its VOC assessment by also examining dermal and inhalation routes, going beyond the traditional focus on oral exposure. In a number of cases, inhalation was the most significant exposure route.

3. New ideas for future monitoring strategies to improve the focus on adverse outcomes

Looking to the future, Dr. Doyle stated that OW is trying to further improve its effectiveness and efficiency in implementing the SDWA and CWA. As the office moves forward with CRAs, it has found that this process is limited by the number of chemicals for which OW has developed MCLs. For drinking water, OW has 73 chemicals with MCLs, implying zero risk for the other chemicals for which there is no MCL. In addition, OW cannot incorporate interactions among chemicals in its assessments and faces uncertainties in its chemical-specific calculations that propagate throughout the assessments. To address these issues, OW has begun examining "bioactivity measures" using the high- and medium-throughput assays developed by the Office of Research and Development (ORD), which will enable the office to understand and remediate toxicity in both drinking and surface water systems more directly.

OW sees a window of opportunity as states pursue pilot projects on water reuse. California, for example, is conducting a pilot project examining the potential for

using estrogenic activity related to endocrine disruptor compounds as a first look at using bioactivity measures to directly estimate a risk from chemicals in the water. Although the approach is many years away from being used, it holds the promise of being able to "measure toxicity with a device." Bioassays also will be able to estimate or measure interactions of contaminants. Such bioassays have been used by OW in total maximum daily load and concentrated animal feeding operation work. Initially, bioactivity measures probably should be used together with traditional MCLs. A fundamental need is to understand what would constitute a "threshold," such as a threshold for estrogenicity. Identifying which adverse outcome pathways (AOPs) are the most important will be key. A challenge will be to demonstrate the relationship between AOPs and apical endpoints well enough that the regulated community will accept the association. Also, the tools will have to be usable by treatment plants' trained operators in a cost-effective, reproducible manner. Lastly, Dr. Doyle emphasized that it will be critical to define remediation approaches when concentrations of mixtures exceed acceptable levels.

The speaker was asked about OW's approach to VOC cancer risks. She responded that the office is conducting "total cancer summation" from the chemicals measured in water, not summing MCLs. Regarding how the new approach has affected the program's regulatory approaches, Dr. Doyle responded that OW must work within a cost-benefit framework to justify whether the occurrence of VOCs is sufficient to justify the cost of remediation. That is a significant limiting factor that requires consideration. Another participant asked whether too much uncertainty would hamper OW in even attempting to address complex mixtures. She stated that limiting its focus to the Contaminant Candidate List and regulated chemicals caused problems because OW was working with only a few hundred chemicals. Requiring a grouping theme, such as a health effect, as well as a treatment and a measurement approach for mixtures, were limiting factors.

Responding to a question, Dr. Doyle stated that some endpoints and methods—such as a zebra fish bioassay—have been considered for monitoring the mixtures process in the future, but at present, none have been adopted. OW is in the early stages of an exploratory effort. Asked about the application of epidemiological studies to OW's work, she stated that the office could draw on fairly large cross-sectional studies to identify issues within populations, but Dr. Doyle was uncertain if such studies would be applicable for cause-and-effect assessments. On the process for public communications about the effort, Dr. Doyle said that ORD's research plan includes studies on applying bioactivity and bioassays to municipal effluent, but no other activities are planned because OW is not using AOPs in regulations.

Webinar 15

December 11, 2013

Challenges in Making Risk Assessment More Relevant for Risk Management—A View From the European Union

*Dr. Peter Calow, Research Professor,
University of Nebraska-Lincoln*

*Lawrence Martin, Science Coordinator,
EPA Risk Assessment Forum (RAF)*

Dr. Calow's professional focus is on environmental risk assessment, about which he has written more than 300 articles and 20 books; Mr. Martin is a biologist who works in the Office of the Science Advisor where his principal responsibilities center on managing the RAF's CRA Technical Panel. Their talk focused on three learning points, described below.

1. Relevance of environmental risk assessments for risk management and environmental policy

Dr. Calow underscored his view that the deployment of risk assessment in risk management is "somewhat disappointing" and that, consequently, one of the major challenges is to make risk assessment more relevant for risk management—that is, "more value-relevant" or relevant to public preferences. This must be done in a way that is transparent and avoids political interference with the science. In his view, in Europe, and perhaps in the United States, risk assessment faces two major difficulties. First, the endpoints used often are far removed from public preferences, measuring molecular or cellular responses rather than lives, lifespan, quality of life, human health or ecosystem services. Second, risk characterizations often are expressed as thresholds—hazard or risk quotients, margins of safety—that make it impossible to "calibrate marginal changes in exposure with marginal changes in effect" to produce optimum management solutions, which require good dose-response analyses.

2. Making risk assessments more management relevant without introducing bias

To compare different values—what the speaker described as "chalk and cheese"—public preferences must be used for weighting choices. For example, mercury risks from energy-saving light bulbs involve trade-offs among

issues: human exposure from accidental breakage, environmental risks from disposal, reduced emissions from energy savings and climate impacts. The inclusion of public preferences requires more dialogue between risk assessors and risk managers. Ultimately, cost-benefit analysis is needed to properly compare very different preferences. The speaker advocated that all of the EU's advisory committees should include both natural and social scientists to facilitate the development of better value-relevant risk assessments that also can be better communicated to the outside world. Currently, neither the EU nor the United States has the right kinds of institutional arrangements to underpin the necessary dialogue among risk assessors and other stakeholders.

3. Moving toward more value relevance can facilitate CRAs

In his overview of progress being made in EPA's CRA Guidelines, Mr. Martin noted that CRA can potentially suffer a "kitchen sink crisis," in which the assessment becomes too large, cumbersome and expensive. To address that concern, from the outset a CRA requires a clear statement from the risk manager regarding the exact information needed to inform a specific decision, as required for the first step in planning and scoping a CRA. The 1996 National Research Council report *Understanding Risk* describes the process as "a mutual and recursive relationship between analysis and deliberation" to avoid managers' improperly imposing a preconceived analysis to reflect their policy preferences, as occurred with "mad cow" disease in the 1990s. The analysis and deliberation process does not involve efforts by risk managers to shape the outcome of risk assessments to match their policy preferences but instead seeks to ensure that, whatever their outcome, assessments will adequately serve decision making.

Closely adhering to key concepts in EPA's Framework for CRA, the evolving guidelines include a strong emphasis on stakeholder involvement in population-based assessments. The integration of nonchemical stressors—including biological agents, physical stressors and psychosocial stressors—in the CRA Guidelines goes beyond the earlier understanding of such assessments. The issues of how to address nonchemical stressors that EPA has no authority to regulate and how to evaluate vulnerability factors not specifically required under statute are among the more difficult challenges the Agency is working to resolve. Mr. Martin noted that

CRA raises the complexity of effective communication by an order of magnitude, including communication at the very beginning, as well as at the end of the assessment.

Dr. Calow was asked about the implementation of recommendations made by an EU working group on risk assessment and management. He responded that implantation is still in its early stages, but he noted that under the EU Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) legislation, two committees were established: one on risk assessment and the other on socioeconomic analysis. Both committees are formally involved in decisions about chemicals. Before the working group's recommendation on making risk assessment more relevant to risk management was issued, the two committees rarely exchanged notes. Now they are beginning to do so, and the risk assessment committee can take more account of what the socioeconomic analysis committee really needs to perform its tasks. He added that the exchange of information is an encouraging sign of progress toward overcoming the EU's reluctance to lower barriers between risk assessment and management.

The speakers were asked about whether CRAs will be used for health impact assessment and environmental impact assessment. Mr. Martin responded that a CRA is intended to inform a risk management decision; a health impact assessment informs any number of related decisions associated to whether to build a freeway, site a building or plant many or no trees, which is not necessarily a risk management decision. The two are easily confused, but distinctions between them should be made. With respect to the environment, EPA is striving

to incorporate the idea of human health and ecologically integrated risk assessments.

Dr. Calow added that in his presentation, he discussed integrated risk assessment, which differs slightly from CRAs that focus on the impact of multiple stressors on one target; integrated risk assessments focus on the effects of one or multiple stressors on a number of targets, some of which could be human health and some of which could be environmental. In that situation where analysts are trying to compare and weigh very different things (chalk and cheese), public preferences are best for weighing the different things. He stated that ecosystem services, which Mr. Martin mentioned, are part and parcel of the move toward value relevance because they connect ecological change with the value-relevant issue of how human health—lives, life spans and so forth—are affected. He said: *“You get them all down to common units, and that seems to me to be the way to go if you are dealing with complex cumulative and integrative risk assessment situations.”*

Asked to elaborate on the idea of “common units,” Dr. Calow commented that they are about quantifying public preferences, which in turn boils down to quantification in terms of monetary values. He stated that monetary values are a *“quantitative expression of public preferences”* on such matters as Quality Adjusted Life Years and other such measures. He noted, however, that most people are very suspicious of monetization because they do not really understand its basis, which is *“all about quantifying in a transparent way public preferences and getting them into the common units so we can do these complicated risk assessments and the complicated risk management that goes with it.”*

Webinar Dates and Recordings

August 29, 2012. Ari S. Lewis. “Nonchemical Stressors and Cumulative Risk Assessment: An Overview of Current Issues and Initiatives.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/aug2912-lewis.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/aug2912-questions.html>

September 26, 2012. Neal Fann. “Characterizing Cumulative Air Pollution Risks.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/sept2612-fann.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/sept2612-questions.html>

October 17, 2012. Dr. Jonathan London. “Cumulative Environmental Vulnerability Analysis: Opportunities for Innovation.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/oct1712-london.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/oct1712-questions.html>

November 28, 2012. Dr. Krista Christensen. “Assessing the Health Impact of Multiple Environmental Chemicals.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/nov2812-christensen.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/nov2812-questions.html>

December 19, 2012. Dr. Kristie Ellickson. “Cumulative Levels and Effects: Implementing a Unique Environmental Justice Statue in Air Permitting in Minnesota.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/dec1912-ellickson.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2012/dec1912-questions.html>

January 30, 2013. Dr. Ramya Chari and Dr. Thomas A. Burke. “Integrating Susceptibility Into Environmental Policy: Implications and Information Needs for Cumulative Risk Assessment.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/jan3013-chari.html>

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/jan3013-burke.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/jan3013-questions.html>

February 27, 2013. David Deganian and Nick DiLuzio. “The Patterns of Pollution: Perspectives From an Environmental Attorney and a GIS Scientist on the Identification and Assessment of Environmental Justice Communities.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/feb2713-speakers.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/feb2713-questions.html>

March 20, 2013. Dr. Douglas Crawford-Brown. “A Semi-Quantitative Framework for Cumulative Risk Assessment of Waterborne Contaminants.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/mar2013-crawford-brown.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/mar2013-questions.html>

April 17, 2013. Dr. Jonathan Levy. “Simulating Population Characteristics and Exposures to Multiple Stressors for a Community-Based Cumulative Risk Assessment.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/apr1713-levy.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/apr1713-questions.html>

May 22, 2013. **Dr. Glenn Suter.** “Why and How to Integrate Your Assessment.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/may2213-suter.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/may2213-questions.html>

June 26, 2013. **Dr. Wenyaw Chan and Maria Jimenez.** “A Novel Approach for Testing Interaction Effects of Environmental and Psychosocial Stressors on Disease Risk in a Logistic Regression Model.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/june2613-speakers.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/june2613-questions.html>

July 24, 2013. **Dr. George Alexeeff.** “CalEnviroScreen 1.0: A New Tool for Evaluating California Communities.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/july2413-alexeeff.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/july2413-questions.html>

September 25, 2013. **Sarah Alves and Joan Tilghman.** “Legal Authority for EPA to Use Cumulative Risk Assessments in Environmental Decision-Making.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/sept2513-speakers.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/sept2513-questions.html>

November 20, 2013. **Dr. Elizabeth Doyle.** “Implementation of Cumulative and Mixtures Risk Assessment in the Office of Water—Past and Future.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/nov2013-doyle.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/nov2013-questions.html>

December 11, 2013. **Lawrence Martin and Dr. Peter Calow.** “Challenges in Making Risk Assessment More Relevant for Risk Management; A View From the European Union.”

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/dec1113-martin.html>

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/dec1113-calow.html>

Question-and-Answer portion:

<http://www.epa.gov/ncer/cra/multimedia/webinars/2013/dec1113-questions.html>

Supplemental Materials

August 29, 2012. Ari S. Lewis. “Nonchemical Stressors and Cumulative Risk Assessment: An Overview of Current Issues and Initiatives.”

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Appendix

Select Statutory Provisions Regarding EPA Authority to Consider Risk

Statutory Action	Consideration of Human Health and Environmental Effects	Other Statutory Considerations	On Risk Assessment
Clean Air Act (CAA)			
Set National Ambient Air Quality Standards (NAAQS)	Must establish primary NAAQS “requisite to protect the public health” while “allowing an adequate margin of safety.” ¹ 42 U.S.C. § 7409(b)(1).	EPA may not consider implementation costs. ²	Statute does not mention risk.
Set New Source Performance Standards (NSPS)	Must establish NSPS for a category of stationary source when EPA determines that category “causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare.” 42 U.S.C. § 7411(b)(1)(A).	Must consider cost, and any non-air quality health and environmental impact and energy requirements. 42 U.S.C. § 7411(a)(1). ³	Statute does not mention risk.
List Source Categories of Hazardous Air Pollutants (HAPs)	The CAA requires EPA to list categories of sources of certain HAPs; these categories are further divided into major sources and area sources. Major sources are those sources that emit, or have the potential to emit, any single HAP at a rate of 10 tons per year or more, or 25 tons per year of any combination of HAPs. 42 U.S.C. § 7412(a)(1). For a “major source,” EPA may establish a cutoff emissions quantity of less than 10 or 25 tons per year “on the basis of the potency of the air pollutant, persistence, [or] potential for bioaccumulation...” 42 U.S.C. § 7412(a)(1). EPA must list any category of area source (i.e., a HAP source that is not a major source) “which the Administrator finds presents a threat of adverse effects to human health or the environment (by such sources individually or in the aggregate) ...” 42 U.S.C. §§ 7412(a)(2), 7412(c)(3).	For a “major source,” EPA may establish a cutoff emissions quantity of less than 10 or 25 tons per year “on the basis of ... characteristics of the air pollutant, or other relevant factors.” 42 U.S.C. § 7412(a)(1).	Statute does not mention risk.
Set Initial National Emissions Standards for HAPs (NESHAPs) (aka Maximum Achievable Control Technology Standards)	After listing the HAPs source categories, EPA must establish NESHAPs for each category. 42 U.S.C. § 7412(c)(2). “With respect to pollutants for which a health threshold has been established, the Administrator may consider such threshold level, with an ample margin of safety, when establishing [NESHAPs].” 42 U.S.C. § 7412(d)(4).	Must consider cost, and any non-air quality health and environmental impact and energy requirements. 42 U.S.C. § 7412(d)(2).	Statute does not mention risk.
Set Residual Risk NESHAPs ⁴	Must promulgate residual risk NESHAPs “if promulgation of such standards is required in order to provide an ample margin of safety to protect public health ... or to prevent, taking into consideration costs, energy, safety, and other relevant factors, an adverse environmental effect.” 42 U.S.C. § 7412(f)(2)(A). For HAPs that are known, probable, or possible human carcinogens, if the existing NESHAP standard does not “reduce lifetime excess cancer risks to the individual most exposed to emissions from a source in the category or subcategory to less than 1-in-1 million,” EPA must promulgate residual risk standards for the source category as necessary “to provide an ample margin of safety to protect the public health.” ⁵ 42 U.S.C. § 7412(f)(2)(A).	Must consider costs, energy, safety, and other relevant factors. 42 U.S.C. § 7412(f)(2)(A).	Mentions risk. ⁶

Statutory Action	Consideration of Human Health and Environmental Effects	Other Statutory Considerations	On Risk Assessment
Set Emission Standards for Mobile Sources	<p>Prescribe and revise motor vehicle emissions standards for any class or classes of new motor vehicles for any air pollutants that “cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.” 42 U.S.C. § 7521(a)(1).</p> <p>For heavy-duty trucks, the CAA states that based on available information “concerning the effects of air pollutants emitted from heavy-duty vehicles or engines and from other mobile source related pollutants on the public health and welfare,” EPA “may promulgate regulations ... applicable to classes or categories of heavy-duty vehicles or engines.” 42 U.S.C. § 7521(a)(3)(B)(i).</p>	<p>“Any [mobile source emission standard] shall take effect after such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period.” 42 U.S.C. § 7521(a)(2).</p> <p>For heavy-duty vehicle and engine standards, EPA must consider cost, energy, and safety factors. 42 U.S.C. § 7521(a)(3)(A)(i).</p> <p>“[N]o emission control device, system, or element of design shall be used in a new motor vehicle or new motor vehicle engine for purposes of complying with requirements prescribed under this subchapter if such device, system, or element of design will cause or contribute to an unreasonable risk to public health, welfare, or safety in its operation or function.”⁷ 42 U.S.C. § 7521(a)(4)(A).</p>	Mentions risk (see column 2). 42 U.S.C. § 7521(a)(4).
Set Mobile Source-Related Air Toxics Standards ⁸	Must prescribe and revise motor vehicle air toxics emissions standards for air toxics that “cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.” ⁹ 42 U.S.C. § 7521(a)(1).	Must consider availability and costs of the technology; noise, energy, and safety factors; and lead time.” 42 U.S.C. § 7521(l)(2).	Mentions risk. ¹⁰
Regulation of Fuels	The CAA authorizes EPA to “control or prohibit the manufacture, introduction into commerce, offering for sale, or sale” of a fuel or fuel additive if any emission product of such fuel or fuel additive “causes, or contributes, to air pollution or water pollution (including any degradation in the quality of groundwater) that may reasonably be anticipated to endanger public health or welfare.” ¹¹ 42 U.S.C. § 7545(c)(1).	<p>Must consider other technologically or economically feasible means of achieving emissions standards under the CAA provisions governing emissions controls on motor vehicles. 42 U.S.C. § 7545(c)(2)(A).</p> <p>EPA must consider a cost-benefit comparison of emission control devices that require the proposed control or prohibition with emission control devices that do not require the proposed control or prohibition. 42 U.S.C. § 7545(c)(2)(B).</p>	Mentions risk. ¹²
Safe Drinking Water Act (SDWA)			
Evaluate Contaminant Candidate List ¹³	Must regulate contaminants that “may have an adverse effect on the health of persons,” may occur in public water systems at a frequency and level of public health concern, and where, “in the sole judgment of the Administrator, regulation of the contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems.” ¹⁴ 42 U.S.C. § 300g-1(b)(1)(A).	Regulation of the contaminant must present a meaningful opportunity for health risk reduction. 42 U.S.C. § 300g-1(b)(1)(A).	Mentions risk (see columns 2 and 3).
Set Maximum Contaminant Level Goals (MCLGs)	Must set MCLGs at a level where, in the Administrator’s judgment, “no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety.” 42 U.S.C. § 300g-1(b)(4).	None.	Risk assessment required. See 42 U.S.C. § 300g-1(b)(3).

Statutory Action	Consideration of Human Health and Environmental Effects	Other Statutory Considerations	On Risk Assessment
Set National Primary Drinking Water Regulations ¹⁵ (NPDWRs)	<p>Must set the MCL for a contaminant as close to the MCLG as is “feasible.”¹⁶</p> <p>Must perform risk assessments to establish NPDWRs for contaminants,¹⁷ as well as analyze likely health risk reduction benefits.¹⁸</p>	<p>Must consider technological feasibility, cost. 42 U.S.C. § 300g-1(b)(4); 42 U.S.C. §§ 300g-1(b)(3)(C)(i) (III)–(IV); 42 U.S.C. § 300g-1(b)(6)(A).</p>	<p>Risk assessment required. See 42 U.S.C. § 300g-1(b)(3).</p>
Establish Underground Injection Control (UIC) Program Requirements	<p>Must set minimum requirements for state programs to “prevent underground injection which endangers drinking water sources.”¹⁹ 42 U.S.C. § 300h(b)(1).</p>	<p>Congress did not address how EPA should balance risks when evaluating endangerment of drinking water sources, and instead gave EPA discretion to give meaning to the endangerment criteria.²⁰</p>	<p>Statute does not mention risk.</p>
Clean Water Act (CWA)			
Set Technology-Based Standards ²¹	<p>No requirement to look at health or environmental effects.</p>	<p>Must consider cost, technological feasibility.²²</p>	<p>Statute does not mention risk.</p>
Set Water Quality Standards ²³ (WQS)	<p>Must set WQS to “protect the public health or welfare ... taking into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural industrial, and other purposes, and also taking into consideration their use and value for navigation.”²⁴ 33 U.S.C. § 1313(c)(2)(A).</p>	<p>None.</p>	<p>Statute does not mention risk.</p>
Set Total Maximum Daily Loads ²⁵ (TMDLs)	<p>Must set TMDLs “at a level necessary to implement the applicable [WQS] with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.” 33 U.S.C. § 1313(d)(1)(C).</p>	<p>None.</p>	<p>Statute does not mention risk.</p>
Set Toxic Effluent Standards	<p>Any toxic effluent standard must “be at the level which the Administrator determines provides and ample margin of safety.”²⁶ 33 U.S.C. § 1317(a)(4).</p>	<p>The CWA requires each listed toxic pollutant to be at least “subject to effluent limitations resulting from the application of the [best available technology] economically achievable for the applicable category or class of point sources...” 33 U.S.C. § 1317(a)(2).</p>	<p>Statute does not mention risk.</p>
Establish Management Practices and Numerical Limits for Disposal of Sewage Sludge ²⁷	<p>Must set management practices and numerical limits for sewage sludge containing toxic pollutants that are “adequate to protect public health and the environment from any reasonably anticipated adverse effects of each pollutant.” 33 U.S.C. § 1345(d)(2)(D).</p> <p>Must “identify those toxic pollutants which, on the basis of available information on their toxicity, persistence, concentration, mobility, or potential for exposure, may be present in sewage sludge in concentrations which may adversely affect public health or the environment, and propose regulations specifying acceptable management practices for sewage sludge containing each such toxic pollutant and establishing numerical limitations for each such pollutant for each use identified.” 33 U.S.C. § 1345(d)(2)(A)(i).</p>	<p>Must promulgate regulations that “specify factors to be taken into account in determining the measures and practices applicable to each ... use or disposal [of sewage sludge] (including publication of information on costs).” 33 U.S.C. § 1345(d)(1)(B).</p>	<p>Statute does not mention risk.²⁸</p>

Statutory Action	Consideration of Human Health and Environmental Effects	Other Statutory Considerations	On Risk Assessment
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and Federal Food, Drug, and Cosmetic Act (FDCA), as Amended by the Food Quality Protection Act (FQPA)			
Pesticide Registration ²⁹ Amend an Existing Registration ³⁰ Registration Review ³¹	Must register a pesticide if the Agency determines, among several criteria, that the pesticide “will perform its intended function without unreasonable adverse effects on the environment,” and if the pesticide, “when generally used in accordance with widespread and commonly recognized practice,” will “not generally cause unreasonable adverse effects on the environment.” 7 U.S.C. §§ 136a(c)(5)(C)–(D).	FIFRA defines the term “unreasonable adverse effects on the environment” to mean: “(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide, or (2) a human dietary risk from residues that result from a use of a pesticide in or on any food inconsistent with the [safety] standard under [the FDCA].” 7 U.S.C. § 136(bb). If additional time is needed to generate the required data for an unconditional decision on a new active ingredient, EPA may grant conditional registration. In such cases, EPA must determine that use of the pesticide is in the public interest. 7 U.S.C. § 136a(c)(7)(C); 40 CFR 152.114.	Mentions risk (see column 3). 7 U.S.C. § 136 (bb).
Set Pesticide Tolerances ³²	Must make a finding that the tolerance is “safe,” meaning EPA has determined that there is a “reasonable certainty that no harm will result from aggregate exposure to the pesticide residue, including all anticipated dietary exposures and all other exposures for which there is reliable information.” ³³ 21 U.S.C. §§ 346a(b)(2)(A)(i)–(ii). In establishing, modifying, maintaining, or revoking a pesticide tolerance or exemption, EPA must assess the risk of the pesticide chemical residue based on available information concerning the likely exposure and susceptibility of infants and children to the pesticide chemical residue and must “ensure that there is a reasonable certainty that no harm will result to infants and children from the aggregate exposure to the pesticide...” ³⁴ 21 U.S.C. § 346a(b)(2)(C).	Even if EPA cannot determine that a pesticide tolerance is “safe,” the Agency still may establish a tolerance if at least one of the following conditions exists: (1) “Use of the pesticide chemical that produces the residue protects consumers from adverse effects on health that would pose a greater risk than the dietary risk from the residue.” (2) “Use of the pesticide chemical that produces the residue is necessary to avoid a significant disruption in domestic production of an adequate, wholesome, and economical food supply.” AND if both of the following conditions are met: (1) “The yearly risk associated with the nonthreshold effect from aggregate exposure to the residue does not exceed 10 times the yearly risk that would be allowed” for the yearly risk to be considered “safe.” (2) “The tolerance is limited so as to ensure that the risk over a lifetime associated with the nonthreshold effect from aggregate exposure to the residue is not greater than twice the lifetime risk that would be allowed” for the lifetime risk to be considered “safe.” 21 U.S.C. §§ 346a(b)(2)(B)(i)–(iv).	Requires risk assessment (see columns 2 and 3). ³⁵ 21 U.S.C. §§ 346a(b)(2)(C)–(D).

Statutory Action	Consideration of Human Health and Environmental Effects	Other Statutory Considerations	On Risk Assessment
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), aka Superfund			
National Contingency Plan (NCP) ³⁶ : Assessment and Listing of Facilities	<p>Must establish “criteria for determining priorities among releases or threatened releases throughout the United States for the purpose of taking [response] action” (i.e., criteria for listing which facilities/locations with hazardous substance releases need to be cleaned up).</p> <p>Criteria and priorities must be based on “relative risk or danger to public health or welfare or the environment ... taking into account to the extent possible the population at risk , the hazard potential of the hazardous substances at such facilities, the potential for contamination of drinking water supplies, the potential for direct human contact, the potential for destruction of sensitive ecosystems, the damage to natural resources which may affect the human food chain and which is associated with any release or threatened release, the contamination or potential contamination of the ambient air which is associated with the release or threatened release...”³⁷ 42 U.S.C. § 9605(a)(8)(A).</p>	Criteria for listing facilities must also “[take] into account ... to the extent possible ... State preparedness to assume State costs and responsibilities, and other appropriate factors.” 42 U.S.C. § 9605(a)(8)(A).	Mentions risk (see column 2). 42 U.S.C. § 9605(a)(8)(A).
NCP: Remedy Selection	<p>Must “select a remedial action that is protective of human health and the environment ... and that utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.” 42 U.S.C. § 9621(b).</p> <p>EPA must “conduct an assessment of permanent solutions and alternative treatment technologies or resource recovery technologies that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant.”³⁸ In assessing alternative remedial actions, at a minimum, EPA must take into account: (1) the long-term uncertainties associated with land disposal; (2) the goals, objectives, and requirements of the Solid Waste Disposal Act; (3) the persistence, toxicity, mobility, and propensity to bioaccumulate of hazardous substances and their constituents; (4) short- and long-term potential for adverse health effects; and (5) the potential threat to human health and the environment associated with excavation, transportation, and redisposal or containment.</p>	Must consider costs. ³⁹	Mentions risk. ⁴⁰ EPA regulations require risk assessment. See 40 CFR 300.430(a)(2), 300.430(d)(1).

Endnotes

- 1 EPA must base NAAQS on relevant “air quality criteria.” 42 U.S.C. § 7409(b)(1). “Air quality criteria for an air pollutant shall accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutant in the ambient air, in varying quantities.” 42 U.S.C. § 7408(a)(2). Criteria for an air pollutant, “to the extent practicable, must include: (1) variable factors (including atmospheric conditions) which of themselves or in combination may alter a pollutant’s effects on public health and welfare; (2) the types of air pollutants which, when present in the atmosphere, may interact with such pollutants to produce an adverse effect on public health or welfare; and (3) any known or anticipated adverse effects on welfare.” 42 U.S.C. §§ 7408(a)(2)(A)–(C).
- 2 See *Whitman v. American Trucking Ass’n*, 531 U.S. 457, 464–71 (2001) (holding that 42 U.S.C. § 7409(b) “unambiguously bars cost considerations from the NAAQS-setting process”).
- 3 EPA has interpreted the provision requiring the consideration of non-air quality impacts to mean that the Agency must analyze the environmental and energy impact of proposed emission control requirements. However, a reasonable interpretation of this directive could be that EPA may consider whether a proposed regulation that decreases air pollutant emissions might also increase some other health or environmental risks (for example, create water pollution). See Cass R. Sunstein, “Cost-Benefit Default Principles,” 99 *Michigan Law Review* 1651, 1664–65 (2001).
- 4 To address residual risks, the CAA provides for a second regulatory phase of the HAPs program, which focuses on reducing any remaining (“residual”) risk to the public health remaining from sources regulated under the NESHAPs program.
- 5 Note that this statutory directive obligates EPA to promulgate standards that provide an adequate margin of safety, but does not require that EPA establish residual risk standards that reduce the risk to below 10⁻⁶. See *NRDC v. EPA*, 529 F.3d 1077, 1081–1083 (D.C. Cir. 2008).
- 6 42 U.S.C. §§ 7412(f)(1)–(2). Although the statute does not direct EPA to perform a risk assessment, a risk assessment is arguably necessary for carcinogenic HAPs for which the statute directs EPA to promulgate residual risks standards “to provide an ample margin of safety to protect the public health” if the existing NESHAP standard does not “reduce lifetime excess cancer risks to the individual most exposed to emissions from a source in the category or subcategory to less than 1-in-1 million.” 42 U.S.C. § 7412(f)(2)(A).
- 7 “In determining whether an unreasonable risk exists ... the Administrator shall consider, among other factors, (i) whether and to what extent the use of any device, system, or element of design causes, increases, reduces, or eliminates emissions of any unregulated pollutants; (ii) available methods for reducing or eliminating any risk to public health, welfare, or safety which may be associated with the use of such device, system, or element of design, and (iii) the availability of other devices, systems, or elements of design which may be used to conform to requirements prescribed under this subchapter without causing or contributing to such unreasonable risk.” 42 U.S.C. § 7521(a)(4)(B).
- 8 Mobile source air toxics are compounds emitted from highway vehicles and non-road equipment that are known or suspected to cause cancer or other serious health and environmental effects. The 1990 CAA Amendments require EPA to regulate air toxics from motor vehicles by promulgating standards for fuels, vehicles, or both. EPA’s Office of Transportation and Air Quality refers to these pollutants as “air toxics,” as opposed to HAPs. This table follows that convention, although many mobile source air toxics are also HAPs regulated under the NESHAP program for stationary sources.
- 9 Note that EPA must establish mobile source air toxics emission standards under the same criteria as regular mobile source emissions standards.
- 10 “Not later than 18 months after November 15, 1990, the Administrator shall complete a study of the need for, and feasibility of, controlling emissions of toxic air pollutants which are unregulated under this chapter and associated with motor vehicles and motor vehicle fuels, and the need for, and feasibility of, controlling such emissions and the means and measures for such controls. The study shall focus on those categories of emissions that pose the greatest risk to human health or about which significant uncertainties remain, including emissions of benzene, formaldehyde, and 1,3 butadiene.” 42 U.S.C. § 7521(l)(1).
- 11 EPA may regulate a fuel under the CAA only if the Administrator “finds, and publishes such finding, that in his judgment such prohibition will not cause the use

of any other fuel or fuel additive which will produce emissions which will endanger the public health or welfare to the same or greater degree than the use of the fuel or fuel additive proposed to be prohibited.” 42 U.S.C. § 7545(c)(2)(C).

¹² “The gasoline shall have no heavy metals, including lead or manganese. The Administrator may waive the prohibition contained in this subparagraph for a heavy metal (other than lead) if the Administrator determines that addition of the heavy metal to the gasoline will not increase, on an aggregate mass or cancer-risk basis, toxic air pollutant emissions from motor vehicles.” 42 U.S.C. § 7545(k)(2)(C).

¹³ The SDWA requires EPA to publish a list of currently unregulated contaminants that may pose risks for drinking water (referred to as the Contaminant Candidate List, or CCL) every 5 years and to make determinations on whether to regulate at least five contaminants from the CCL with a National Primary Drinking Water Regulation (NPDWR) every 5 years. See 42 U.S.C. § 300g-1(b)(1)(B).

¹⁴ “Such findings shall be based on the best available public health information...” 42 U.S.C. § 300g-1(b)(1)(B)(ii)(II).

¹⁵ NPDWRs must include either maximum contaminant levels (MCLs) or treatment technique requirements that reduce the level of the contaminant so that it satisfies the requirements of the SDWA. 42 U.S.C. § 300f(1)(C) (defining “primary drinking water regulation” to mean a regulation that specifies for each contaminant either an MCL or, if it is not economically or technologically feasible to ascertain the level of the contaminant, treatment techniques that lead to a reduction in the contaminant level sufficient to satisfy section 1412).

¹⁶ EPA may “establish a [MCL] for a contaminant at a level other than the feasible level, if the technology, treatment techniques, and other means used to determine the feasible level would result in an increase in the health risk from drinking water by (i) increasing the concentration of other contaminants in the drinking water, or (ii) interfering with the efficacy of drinking water treatment techniques ... that are used to comply with other [NPDWRs].” If using this authority, EPA must set the MCL or require alternative treatment techniques to “minimize the overall risk of adverse health effects by balancing the risk from the contaminant and the risk from other contaminants” that would be affected by the feasible level. 42 U.S.C. § 300g-1(b)(5).

¹⁷ In a provision titled “Risk assessment, management, and communication,” the SDWA directs EPA to use “the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices” when

setting standards under the SDWA. This section further directs EPA to produce a public health effects document in support of any NPDWR, specifying “each population addressed by any estimate of public health effects,” “the expected risk or central estimate of risk for the specific populations,” “each significant uncertainty identified in the process of public health effects and studies that would assist in resolving the uncertainty,” and peer-reviewed studies “that support, are directly relevant to, or fail to support any estimate of public health effects and the methodology used to reconcile inconsistencies in the scientific data.” 42 U.S.C. § 300g-1(b)(3)(A)(i)-(v).

¹⁸ In a provision entitled “Health risk reduction and cost analysis,” the SDWA requires EPA, when proposing a NPDWR that includes an MCL, to publish, seek comment on, and use an analysis of the quantifiable and non-quantifiable health risk reduction benefits that are likely to occur as the result of treatment to comply with each MCL being considered, as well as the risk reduction benefits “that are likely to occur from reductions in co-occurring contaminants that may be attributed solely to compliance with the [MCL], excluding benefits resulting from compliance with other proposed or promulgated regulations.” 42 U.S.C. §§ 300g-1(b)(3)(C)(i)(I)-(II).

¹⁹ Underground injection endangers drinking water if it “may result in the presence in underground water which supplies or can be reasonably be expected to supply any public water system of any contaminant, and if the presence of such contaminant may result in such system’s not complying with any [NPDWR] or may otherwise adversely affect the health of persons.” 42 U.S.C. § 300h(d)(2).

²⁰ See *Miami-Dade County v. EPA*, 529 F.3d 1049, 1063 (11th Cir. 2008) (“Through repeated reference to the possibility that [an underground drinking water source] could be endangered, Congress established no particular metric for evaluating endangerment. Instead, it explicitly left the EPA to give specific meaning to the endangerment standard.”).

²¹ EPA must establish effluent limitations guidelines and standards for different non-municipal (i.e., industrial) categories, which are developed based on the degree of pollutant reduction attainable by an industrial category through the application of pollutant control technologies. See <http://cfpub.epa.gov/npdes/techbasedpermitting/effguide.cfm> (last accessed Feb 13, 2012).

²² See 33 U.S.C. § 1314(b) (describing “best practicable control technology,” “best available technology,” and “best conventional pollutant control technology”); http://cfpub.epa.gov/npdes/glossary.cfm?program_id=0 (last accessed Feb. 13, 2012).

- ²³ The CWA directs states to adopt WQS for their navigable waters. 33 U.S.C. § 1313(c). Any new or revised WQS must be submitted to EPA for review and approval. 33 U.S.C. § 1313(c)(2)(A). If EPA determines that any revised or new state standard is not consistent with applicable CWA requirements, the Agency must inform the state and specify the changes to meet such requirements. 33 U.S.C. § 1313(c)(3). If the state does not adopt such changes within 90 days, EPA must promulgate the standards. 33 U.S.C. § 1313(c)(3)–(4).
- ²⁴ The CWA directs EPA to publish recommendations periodically for states to use in setting water quality criteria to protect recreational and aquatic life uses of waters. EPA’s water quality criteria must accurately reflect the latest scientific knowledge “on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water, including ground water.” 33 U.S.C. § 1314(a)(1)(A).
- ²⁵ For waters in which technology-based standards have proven insufficient to meet the WQS, states must establish a “total maximum daily load” (TMDL) for each regulated pollutant. Essentially, a TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet WQS. See <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/> (last accessed Feb. 13, 2012). States must submit TMDLs to EPA for approval, and if the Agency does not approve, EPA is authorized to promulgate TMDLs it considers necessary to meet the WQS. 33 U.S.C. § 1313(d)(2).
- ²⁶ A toxic effluent standard must “take into account the toxicity of the pollutant, its persistence, degradability, the usual or potential presence of the affected organisms in any waters, the importance of the affected organisms and the nature and extent of the effect of the toxic pollutant on such organisms, and the extent to which effective control is being or may be achieved under other regulatory authority.” 33 U.S.C. § 1317(a)(2).
- ²⁷ Where use or disposal of sewage sludge (biosolids) resulting from municipal waste treatment “would result in any pollutant from such sewage sludge entering the navigable waters,” such disposal is subject to the standards and permit requirements of the CWA. 33 U.S.C. § 1345(a)–(b).
- ²⁸ Although the statute does not use the word “risk,” a Federal appellate court has interpreted EPA’s sewage sludge statutory authority to set standards to protect “from any reasonably anticipated adverse effects” as mandating regulations that bear some relation to risk. See *Leather Industries of America, Inc. v. EPA*, 40 F.3d 392, 400 (D.C. Cir. 1994) (remanding sewage sludge effluent limitations to EPA because they were based on the 99th percentile concentrations in current sludge output, rather than based on risk).
- ²⁹ FDCA and FIFRA do not direct EPA to regulate pesticides using standards, but instead require EPA to evaluate pesticides and their tolerances case-by-case and periodically through the registration and registration review processes.
- ³⁰ If a registrant has a product previously registered with EPA and wishes to make a change to the registration (e.g., changing the product formulation or adding a new use), the registrant must file an application to amend its registered product, and EPA must approve the amendment under the FIFRA registration criteria before the registrant may legally distribute or sell the modified product. 40 CFR 152.44(a).
- ³¹ The FQPA requires that EPA review pesticide registrations at least once every 15 years. 7 U.S.C. § 136a(g)(1)(A). The statute states only that the “registrations of pesticides are to be periodically reviewed,” without specifying the criteria by which EPA is to review the registrations. EPA has interpreted its registration review authority as requiring the Agency to make “a determination that a pesticide continues to meet the standard[s] for registration in FIFRA,” i.e., that a pesticide will not pose an unreasonable risk to man or the environment. See *Final Rule, Pesticides, Procedural Regulations for Registration Review*, 71 FR 45720, 45725 (Aug. 9, 2006); 40 CFR 155.40(a)(1).
- ³² As amended by the FQPA, the FDCA authorizes EPA to set tolerances, or maximum residue limits, for pesticide residues on foods. 21 U.S.C. § 346a(b)(1) (authorizing EPA, either in response to a petition or on the Agency’s own initiative, to issue regulations “establishing, modifying, or revoking a tolerance for a pesticide chemical residue in or on a food”).
- ³³ The statute establishes nine specific factors “among other relevant factors” that EPA must consider in establishing, modifying, maintaining, or revoking a pesticide tolerance or exemption, including several factors relating to the health effects of the pesticides and the relation of those studies to human health risk. See 21 U.S.C. § 346a(b)(2)(D).
- ³⁴ EPA must use “an additional tenfold margin of safety ... to take into account potential pre- and post-natal toxicity and completeness of the data with respect to exposure and toxicity to infants and children.” 21 U.S.C. § 346a(b)(2)(C). EPA may “use a different margin of safety for the pesticide chemical residue only if, on the basis of reliable data, such margin will be safe for infants and children.”
- ³⁵ The legislative history of the FQPA, which established the “reasonable certainty of no harm” standard for tolerances, stated that EPA should implement this new

standard through the 1-in-1 million-lifetime risk test, which EPA had used prior to 1996. H.R. Rep. No. 104-669, pt. 2, at 41 (1996).

- ³⁶ CERCLA requires that EPA develop and regularly revise the NCP, which consists of regulations that provide the organizational structure and procedures for preparing for and responding to releases of hazardous substances, pollutants and contaminants. 42 U.S.C. § 9605(a); 40 CFR part 300.
- ³⁷ Through the Hazard Ranking System regulations, EPA has established the criteria for determining response priorities for releases or threatened releases. EPA uses the Hazard Ranking System to determine whether a site should be placed on the National Priority List (NPL), which is “the list, compiled by EPA ... of uncontrolled hazardous substance releases in the United States that are priorities for long-term remedial evaluation and response.” 42 U.S.C. § 9605(a)(8)(B); 40 CFR 300.5.
- ³⁸ 42 U.S.C. § 9621(b)(1). Note that EPA NCP regulations build on the statutory requirements regarding remedy selection. The EPA NCP regulations require a comprehensive risk assessment for a Superfund site as part of investigations that follow listing on the NPL of uncontrolled wastes sites as Superfund sites. 40 CFR 300.430(a)(2), 300.430(d)(1);

see U.S. EPA, Office of Solid Waste and Emergency Response, *Rules of Thumb for Superfund Remedy Selection*, EPA 540-R-97-013, at 2 (1997), available at <http://www.epa.gov/superfund/policy/remedy/rules/rulesthm.pdf> (last accessed Feb. 14, 2012).

- ³⁹ CERCLA requires the selection of remedies that provide “cost-effective response. In evaluating the cost effectiveness of proposed alternative remedial actions, the President shall take into account the total short- and long-term costs of such actions, including the costs of operation and maintenance for the entire period during which such activities will be required.” 42 U.S.C. § 9621(a). Further, in assessing alternative remedial actions, EPA must consider, at a minimum, long-term maintenance costs and the potential for future remedial action costs, if the alternative remedial action were to fail. 42 U.S.C. § 9621(b)(1).
- ⁴⁰ “The President may select a remedial action meeting the requirements of paragraph (1) that does not attain a level or standard of control at least equivalent to a legally applicable or relevant and appropriate standard, requirement, criteria, or limitation ... if the President finds that ... compliance with such requirement at that facility will result in greater risk to human health and the environment than alternative options.” 42 U.S.C. § 9621(d)(4)(B).

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