Risk Evaluations Differ Depending upon Agency Performing Them: Implications for D.O.E – 14139

Joanna Burger*,Michael Gochfeld**,Charles Powers***,David Kosson****

* Rutgers University, Division of Life Sciences, Rutgers University, 604 Allison Road, Piscataway, New Jersey 08854-8082
** Robert Wood Johnson Medical School, Environmental and Occupational Health Sciences Institute, Rutgers University, Piscataway, New Jersey 08854
*** CRESP - Vanderbilt University, Consortium for Risk Evaluation with Stakeholder Participation (CRESP), Rutgers University, Piscataway, New Jersey, 08854 and Vanderbilt University, Nashville, Tennessee.
**** Vanderbilt University, Environmental and Community Medicine, Rutgers-Robert Wood Johnson Medical School, Piscataway, New Jersey, 08854

ABSTRACT

Different agencies perform risk assessment for contaminants affecting human and ecological health using varying assumptions and methods. We examine case studies of risk from mercury at the U.S..Department of Energy's (D.O.E) Oak Ridge Reservation and Brookhaven National Laboratory in which different agencies, using the same data, arrived at different conclusions. At Oak Ridge, risk evaluations by a federal agency (ATSDR) examined past and current risk from mercury to humans, D.O.E considered the potential risk to off-site receptors (human and ecological), and CRESP (Consortium for Risk Evaluation with Stakeholder Participation) evaluated current and future risk to human and ecological receptors in relation to mercury interdiction projects. At Brookhaven, EPA and State regulatory agencies concluded there was no risk from eating fish, while D.O.E concluded that people who frequently ate fish from the Peconic River would consume excessive mercury, given their other sources of exposure. At Oak Ridge, ATSDR examined all pathways for past and current human exposure. At Brookhaven 1) EPA and the state agencies dealt only with human risk from consuming fish from local waters, 2) federal and state agencies assumed "average" consumption levels, and 3) D.O.E examined mercury risk from all pathways to both ecological receptors and humans over 70-year lifetime. CRESP evaluated both human and ecological risk currently and in the future, for the food chain and from consumption. Both evaluations acknowledged that there was a completed pathway through fish consumption to humans, but the objectives and methodologies were different. We conclude that multiple risk evaluations are informative when goals, objectives, assumptions, methods, receptor types, time period, and exposure methods are clearly defined and distinguishing features amongst multiple studies are clearly communicated. These evaluations have relevance for D.O.E and other agencies involved in risk assessment and communication that influence individual and societal decisions about remediation and environmental management.

INTRODUCTION

The inclusion of Native American governments, resource agencies, health professionals, natural and social scientists, and other stakeholders in decisions involving environmental remediation is becoming more important as the United States examines future energy alternatives, including increased use of nuclear energy [1]. There are many levels of stakeholder involvement [2-4], and the outcomes of such involvement in nuclear energy policy and remediation decisions may vary. Public participation usually improves environmental decision-making, whatever the level of involvement [5]. The D.O.E has present or former sites in 34 states. Some of the sites cover hundreds of square miles [6-8], and many of the sites include valuable and rare natural resources [9-15], including consumptive resources (e.g. fish). Increasingly, stakeholders want to participate in decision-making regarding both clean-up and protection of human health and the environment. Part of public participation understands the different methods of determining risk with respect to human and ecological health, and being able to evaluate differences between methods.

In their everyday lives, people face hazards, make decisions about risks they face, and decide how to act concerning these hazards and risks. They cannot make decisions, however, without knowing what hazards they or their children face. The formal process of risk assessment, codified by the National Research Council publications [16,17], provides a uniform method for governmental agencies to evaluate risks to humans from toxic chemicals and other stressors. The paradigm has four components: hazard identification, dose-response, exposure assessment, and risk characterization. This basic methodology was modified to include eco-receptors and ecosystems, and to fit the needs of different agencies [17-21]. Different methodologies, however, can lead to different conclusions, forcing the public to evaluate competing risk evaluations.

In this paper, we use two case studies from the Department of Energy (D.O.E) complex (Oak Ridge Reservation, Brookhaven National Laboratory) to illustrate how risk evaluations can differ in objectives, scope, methods, assumptions, audience, and conclusions. Both deal with the risks from mercury. Risk evaluations play an important role in environmental management, remediation, and restoration. Yet when different agencies and groups evaluate risk, the objectives and methods may differ, leading to different conclusions, which can confuse managers, policy-makers, and the public. Implications for the D.O.E include a need to be clear about all risk evaluations and risk assessments, delineating the objectives, data used, methods, assumptions, and conclusions. This task is particularly important so the public distinguishes the risks from environmental management of D.O.E. legacy wastes from current or future risks from the nuclear power industry [22,25].

Environmental management of the risks from legacy management and nuclear power facilities must occur within a framework of protection of human health and the environment, and when it is cost-effective [26-28]. The public, scientists, governmental agencies, managers, and public policy makers recognize the importance of protecting human health and the environment around nuclear facilities within a framework of transparency, particularly in light of the recent events in the nuclear power plant in Fukushima, Japan [29-30]. Further, the risks from

contamination around nuclear power plants are not limited to past nuclear production and research, but to current exposures and remediation on site to remove legacy wastes, including mercury, chromium and other chemicals.

Brief Description of Case Studies

Oak Ridge Reservation

The Y-12 complex was constructed in 1943 as part of the Manhattan Project to develop nuclear weapons. In the 1950s and 1960s mercury was used in an exchange process to enrich lithium-6, which was concentrated as an amalgam. In the mid-1980s Oak Ridge engaged in weapons dismantling, and storage and management of enriched uranium. The Y-12 buildings are at the headwaters of East Fork Poplar Creek (EFPC), and operations resulted in the "discharge of large volumes of untreated effluents to the stream and the release of chemicals from spills" [31], and mercury continues to enter the waters of EFPC from secondary sources. Monitoring continues to the present time [32,33]. The mercury issue is critical at Oak Ridge because of a completed pathway to off-site humans and eco-receptors, and an active source remains in contaminated buildings and soil beneath the Y-12 buildings [32-34]. Although there has been a substantial decrease in mercury inputs to East Fork Poplar Creek (EFPC) due to active remediation and interdiction [35], some fish still have levels above the EPA's freshwater criterion of 0.3 ppm in fish tissue. Despite warnings, people continue to eat fish from the local waters [36, 37]). Eating fish despite warnings and advisories is common, likely because many enjoy fishing as a pastime, fish look safe, and people have been fishing these waters and eating the fish for many years, creating a deamplification of risk [38].

Brookhaven National Laboratory (BNL)

Brookhaven (5,262 acres), 100 km east of New York City, is in Upton (Suffolk county) New York. BNL was established in 1947 to develop advanced technologies in support of the nuclear weapons mission of the Department of Energy, and now has programs in nuclear and high-energy physics, physics and chemistry of materials, environmental and energy research, neurosciences and medical imaging, and non-proliferation [39-41]. During remedial investigations, elevated levels of pesticides, organic chemicals (PCBs), heavy metals (mercury, copper, silver), and radionuclides were detected in the sediments of the Peconic River [42]. The Peconic River headwaters begin about 1.2 km upstream from BNL. The river (a stream only a few meters wide in some places) passes through the site, and flows through the town of Riverhead, where it enters Long Island Sound (Fig. 1). The river is subject to great seasonal variation in flow, parts of it drying up altogether in some years. Parts of the Peconic River are designated as a Wild, Scenic and Recreational River by the state of New York. The main contaminant of concern for the Peconic River is mercury, which came from the release of treated waste water, which in turn flowed into streams at the headwaters of the Peconic River. At issue was what remediation was appropriate for the Peconic River, given the levels of

contamination, the potential for future changes in land use, and the levels of risk that contaminants pose for humans and ecological receptors, particularly fish consumers [43].

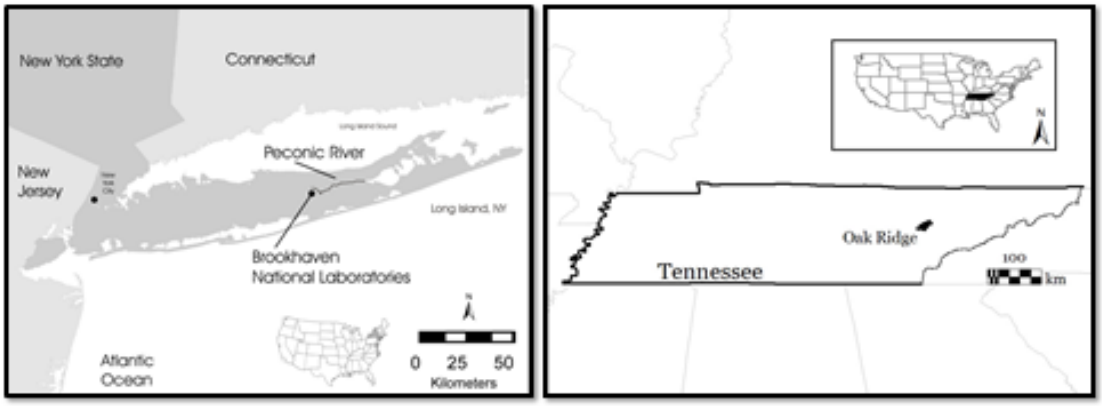

Fig 1. Map showing location of Brookhaven National Laboratory and Oak Ridge, Tennessee.

METHODS

Protocol

Our overall protocol was to examine the different risk evaluations at each site to determine whether there were significant differences in the methodology or conclusions, and to identify why any differences occurred. Each will be described separately, and in the discussion we examine implications for D.O.E. The Oak Ridge case compares an ATSDR [44] evaluation of the risk from mercury to humans, with a Consortium for Risk Evaluation with Stakeholder Participation (CRESP) evaluation of interdiction measures meant to reduce mercury exposure of off-site eco-receptors and humans. The Brookhaven case compares D.O.E's evaluation of the risk from mercury (and needed remediation) to the State of New York's evaluation and issuance of fish consumption advisories. For more detailed discussions of these two case studies, the reader is directed to Burger and Gochfeld [45] for Brookhaven, and Burger et al. [46] for Oak Ridge.

RESULTS

Human risk assessment usually involves designing scenarios that can include past, present and future activities and exposures (Fig. 2). Each of these (past, current, future) can in turn include a range of activities, as well as age groups (child, adult). Usually both cancer and non-cancer endpoints are considered, using established screening levels, hazard quotients and hazard

indices. The formal Environmental Protection Agency Procedures form the basis for most risk assessments, as they did in the cases discussed below.

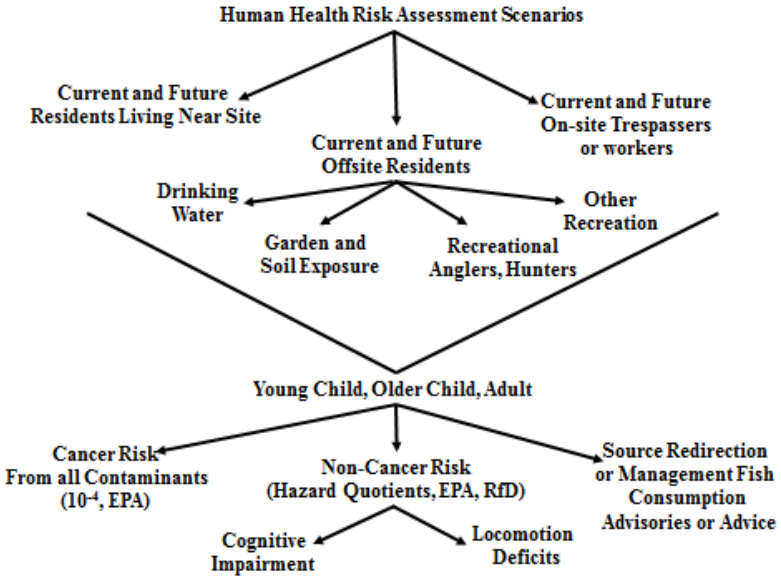

Fig 2. Model of risk assessment scenarios.

Both of the cases discussed below examine the risks from mercury, and in both, fish consumption plays prominently as a route of exposure. The agencies performing the risk assessments include the Department of Energy (D.O.E**),** the Agency for Toxic Substances and Drug Registry (ATSDR), and state agencies. Each has a different mandate, and thus uses risk assessment differently (Fig. 3). In this section we present a summary of the different risk evaluations at Oak Ridge and Brookhaven. While several pages could be written on both, our purpose is to provide a summary so that the differences can be highlighted, illustrating the importance of clarity in every aspect of risk assessments. Table 1 highlights the differences and similarities in the sites and evaluations.

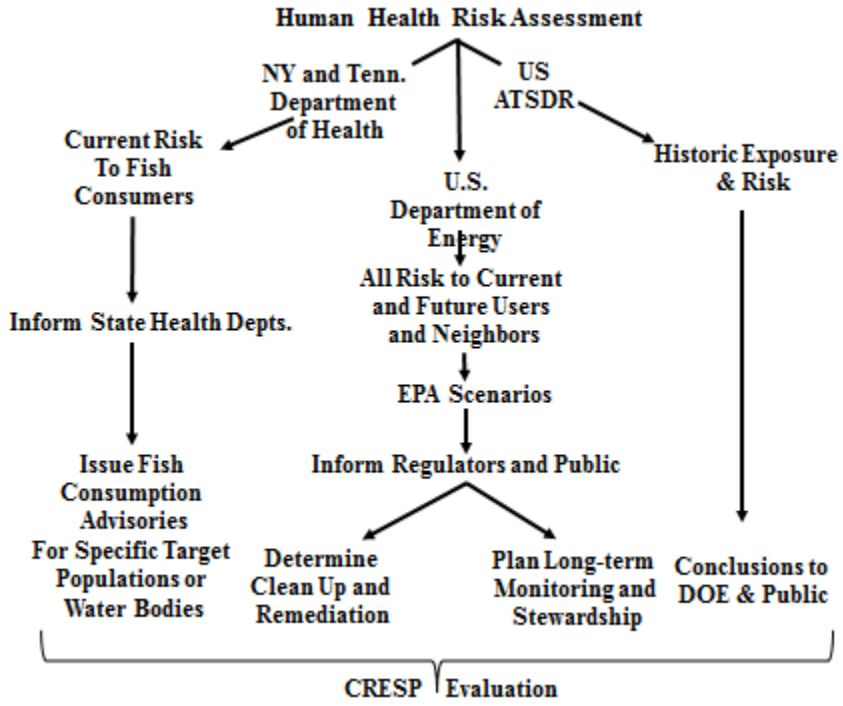

Fig 3. Overview of health risk assessments by state of New York, D.O.E, and USATR

TABLE 1. Comparison of Risk Evaluations of Mercury at Brookhaven NL and Oak Ridge Reservation.

CHARACTERISTIC	BROOKHAVEN NL	OAK RIDGE RESERVATION
Location	Ridge, New York	Oak Ridge, Tennessee
Size	8.2 mi^2 = 21.2 km^2	58 mi^2 (150 km^2)
Main Mission	Research	Research
Risk Evaluations D.O.E (Environmental Management) State	 Determine clean-up levels and remediation. Oversee clean-up Conduct Public Health Assessments of NPL sites when requested	 Determine clean-up levels and remediation. Oversee clean-up Conduct evaluations when requested

CHARACTERISTIC	BROOKHAVEN NL	OAK RIDGE RESERVATION
ATSDR CRESP	Provide advice/research with stakeholder participation	Provide advice/research with stakeholder participation
Risk Objectives D.O.E	Determine options for risk and remediation options: mercury.	Determine options for risk and remediation options: mercury.
State	Oversee D.O.E and determine consumption advisories	Oversee D.O.E and determine consumption advisories
ATSDR	None at Brookhaven	Conduct human health risk assessment, past and present.
CRESP	Examine mercury risks at Brookhaven	Develop risk-informed prioritization model for remediation projects
CRESP Comparative Evaluation Task	Determine why NY state felt no need for further fish consumption advisories near BNL, while BNL had clean-up goals based on mercury.	Determine why ATSDR study said there were no risks from mercury for the public to worry about, while interdiction projects had high priority
Endpoints D.O.E	Remediation to protect Human and ecological health	Remediation to protect Human and ecological health
State	Fish consumption in humans	NA
ATSDR	NA	Risk to humans
CRESP	Protect Human health	Protect human and ecological health
Time period D.O.E	Current and future	Current and future
State	Current conditions in adjacent water bodies	NA
ATSDR	NA	Past and future risks
CRESP	Current and future risks	Current risks in light of remediation interdiction options
Tools D.O.E	EPA reference dose, EPA freshwater	EPA reference dose, EPA

CHARACTERISTIC	BROOKHAVEN NL	OAK RIDGE RESERVATION
	criteria (0.3 ppm in fish), Meet MDLs, Meet CERCLA and RIFS drivers.	freshwater criteria (0.3 ppm in fish), Meet MDLs, Meet CERCLA and RIFS drivers.
State	EPA reference dose for mercury (0.0003mg/kg/day for organic mecury).	NA
ATSDR	NA	EPA reference dose for mercury (0.0003mg/kg/day for organic mercury), along with exposure scenarios for humans All applications and tools for comparisons of interdiction measures
CRESP	All applications and tools for comparison of risks from mercury	
Conclusions		
D.O.E	Clean-up of mercury necessary	Conduct interdiction projects to reduce mercury to meet requirements, until source reduction can be accomplished.
State	No new fish consumption advisories are necessary because of mercury.	NA
ATSDR	NA	No risk, but acknowledged completed pathways in past and present.
CRESP	State and D.O.E differ because objectives, time period, and assumptions differed	Currently a completed pathway from ORR to fish consumers and eco-receptors; interdiction measures necessary

Oak Ridge Reservation

The two evaluations we compare for Oak Ridge are the ATSDR [44] human health risk assessment for mercury, and the CRESP risk ratings for interdiction projects aimed at reducing off-site mercury exposure [46,47]. The ATSDR [44] study examined only human health, and did not consider eco-receptors or ecosystem health, and it relied on data provided in government reports and the literature. Historic mercury exposure was obtained from the Oak Ridge Dose Reconstruction Report [48] which assessed exposure for a variety of scenarios and compared them to the EPA reference dose (approximately 0.0001 mg/kg-day). The reconstruction report and other sources were used to evaluate the historic and current environmental exposure to address the question: did people have, or could they currently come into contact with mercury that posed a risk, by any route. ATSDR evaluated children and adults separately, compared

estimated exposure to the ATSDR standards, and evaluated whether or not these contacts could result in harmful effects. The ATSDR [44, p. 4], report on mercury at Oak Ridge concluded that most past and current exposure pathways are not a public health hazard, but it identified a few pathways of potential concern:

1) Inhalation of elemental mercury by children of Y-12 workers (take-home exposure).

2) Exposure of children playing in Poplar Creek from 1956-1958.

3) Children who accidentally swallowed soil while playing in the EFPC floodplain during removal of mercury-contaminated soil.

4) Children born or nursing from mothers who ate fish from waterways near Oak Ridge Reservation have a small increased risk of developing subtle neurodevelopmental health effects from exposure to organic mercury" ATSDR [44, p. 4]. Children who ate fish may have a small increased risk.

ATSDR concluded that there was some probability of children having "subtle neurodevelopmental health effects from exposure to organic mercury" [44]. Their conclusions acknowledged that there was, and is, a complete pathway and potential health effects (which was the CRESP criterion for a "High" risk evaluation, as discussed below).

In contrast to the objectives and the methodology used by ATSDR, the prioritization model developed by CRESP was intended as a method to prioritize remediation and associated projects at Department of Energy sites, particularly at Oak Ridge [46,47]. These interdictions projects are considered essential by D.O.E because of their recognition that mercury from the Y-12 plant poses an off-site risk to humans and ecological receptors (which appears to conflict with the ATSDR evaluation). The CRESP prioritization model includes two important components: 1) a hazard evaluation and, 2) a management evaluation. The evaluation includes hazards (relative severity, magnitude, and facility configuration), pathways (routes of exposure, barriers, accident scenarios, episodic events) and consequences (effects and their importance to humans and ecological receptors). The management evaluation includes project elements, such as cost, urgency, time for completion, and project sequencing. The project elements integrate management considerations of accomplishing the interdiction or remediation, given the hazard level. This compilation of information and data allows for a risk rating and a risk management rating, which are intended to be used by D.O.E and its regulators to communicate with their constituencies and stakeholders, and to establish remediation priorities.

CRESP evaluated five Oak Ridge interdiction projects the aims of which were to further reduce mercury flux into Upper East Fork of Poplar Creek (UEFPC), with the ultimate objective of bringing water quality into compliance with the Clean Water Act at the point where the creek exits Oak Ridge and the Y-12 facility, and thus decreasing mercury in fish downstream. The CRESP risk rating evaluation for mercury interdiction was "High" based on a "Very High" rating for hazards and pathways, and a "High" rating for consequences. These ratings were based on mercury as a potential cause of harm, and on the complete pathway to off-site eco-receptors

through high levels of mercury in Poplar Creek (food chain effects), and to humans through consumption of contaminated fish [32,33,42]. ,49,50].

The exposure pathway is one of the most important aspects of all these valuations: ATSDR [44], D.O.E's interdiction projects, and CRESPs Risk-informed Prioritization [46,47]. Fish from EFPC, and other waterways, accumulate methylmercury to elevated levels, and fishing families are exposed. Both evaluations acknowledged that there is a completed pathway, and that harm could result, although the interpretation of the level of potential harm differed. The CRESP [46] risk rating evaluation of "High" was based on a known complete pathway to receptors (humans and eco-receptors) and a hazard quotient exceeding 1 [46]. ATSDR [44] acknowledged that children born to mothers who ate fish from waterways "may have a small increased risk of developing subtle neurobehavioral health effects from exposure to organic mercury".

Brookhaven National Laboratory

The two evaluations CRESP compared are the baseline risk assessment by D.O.E [42,43], and the State of New York's assessment of the potential need for additional fish consumption advisories for the Peconic River. The regulatory and public controversy surrounding fish developed because, using the same data on contaminants in fish, the State of New York stated that no additional fish advisories were necessary, while the risk assessments conducted by D.O.E concluded that cleanup to protect fish consumers (among other receptors) was necessary. D.O.E conducted baseline risk assessments for the Peconic River using standard exposure scenarios [42,43], which included cancer and non-cancer risks. The non-cancer risks mainly related to fish consumption and mercury, while cancer risks were examined for groundwater, soil, fish, surface water, and sediments, for the maximally-exposed individual [43]. Their cumulative cancer risks to off-site residents, resident angler/hunters, non-resident angler/hunters, and trespassers on site were all within the EPA target range of 1×10^{-4} to 1×10^{-6} [43]. D.O.E assumed that BNL would be in D.O.E ownership for the next 50 years. The D.O.E risk assessments indicated that non-cancer health hazard quotients exceeded 1.0 for recreational angler adults and children based on assumed reasonable maximum exposure factors due to mercury in edible fish tissue and for younger children due to PCBs [43].

The New York State Departments of Health (DOH) and Environmental Conservation (DEC) have responsibility to issue fish consumption advisories, a method of informing the public about a potential risk in the hopes of preventing high exposures. The DEC analyses fish tissue, and the DOH interprets these levels and issues consumption advisories. These departments found that all fish collected from the Peconic River in 2001 had levels below the FDA Action Level (1 ppm for methylmercury). The State Department of Health, Bureau of Toxic Substances Assessment concluded that no additional advisories were necessary at that time (E. G Horn, pers. comm. letter of 30 April 2002); there was a general fish consumption advisory for all New York State waters of "do not eat more than one fish meal/week (0.5 lb = 226 g)" [51]. This led to the perception that New York State did not believe there was a risk from consumption of fish from the Peconic River.

The CRESP evaluation of BNL's human health risk assessment indicated that they followed EPA guidelines, and that their choice of neighbor scenarios was reasonable given the densely populated region and the importance of recreation to the local population [43,52]. However, the exposure assumptions used in the risk assessments may have driven the risk toward overestimates of exposure. D.O.E assumed that people could fish all year, that there were always fish of legal size available to catch, and that people ate mainly fish from the Peconic River. Conditions in the Peconic River make these assumptions likely incorrect. The Peconic River flowing through Brookhaven has low flow, long periods of dry conditions, small numbers and sizes of most fish, and low attraction as a fishing site [43]. More than 90 % of its flow is from groundwater, and less than 10 % from runoff [53], which implies that river flow will depend upon the water table elevations. A study of flow in the past 15 years showed that there was no flow in a large section of the river through BNL for 3 of the years, and no flow for 6 months for an additional 4 years. Thus, in half of the years examined, fishing would have been impossible for at least 6 months each year, and for most of 3 years. With little or no water in the river, fishing is impossible because there are no fish or fish cannot grow to very large sizes. There are relatively low fish populations, the effort to catch fish would be high, and fish populations would have to be supplemented to maintain high enough levels for anglers to reach the EPA default fish consumption rates. Thus, the usual assumptions for fish consumption derived from continuously flowing rivers are not reasonable for the Peconic River. D.O.E's evaluation, however, was based on total risk from all pathways and sources, currently and in the future, while New York State only dealt with the need, or lack thereof, for fish consumption advisories.

Brookhaven National Laboratory

The two evaluations CRESP compared are the baseline risk assessment by D.O.E [42,43], and the State of New York's assessment of the potential need for additional fish consumption advisories for the Peconic River. The regulatory and public controversy surrounding fish developed because, using the same data on contaminants in fish, the State of New York stated that no additional fish advisories were necessary, while the risk assessments conducted by D.O.E concluded that cleanup to protect fish consumers (among other receptors) was necessary. The public was confused because the state agencies said that no additional fish consumption advisories were required, suggesting no immediate risk, while the risk assessments conducted for D.O.E suggested that additional cleanup of sediment was required because of the risk to the public from mercury in fish, among others. D.O.E conducted baseline risk assessments for the Peconic River using standard exposure scenarios [42,43], which included cancer and non-cancer risks. The non-cancer risks mainly related to fish consumption and mercury, while cancer risks were examined for groundwater, soil, fish, surface water, and sediments, for the maximally-exposed individual [43]. Their cumulative cancer risks to off-site residents, resident angler/hunters, non-resident angler/hunters, and trespassers on site were all within the EPA target range of 1×10^{-4} to 1×10^{-6} [43]. Non-cancer exposure scenarios were developed for off-site recreational anglers, off-site residents, on-site trespassers, and future activities [43]. D.O.E assumed that BNL would be in D.O.E ownership for the next 50 years. The

D.O.E risk assessments indicated that non-cancer health hazard quotients exceeded 1.0 for recreational angler adults and children based on assumed reasonable maximum exposure factors due to mercury in edible fish tissue and for younger children due to PCBs [43].

The New York State Departments of Health (DOH) and Environmental Conservation (DEC) have responsibility to issue fish consumption advisories, a method of informing the public about a potential risk in the hopes of preventing high exposures. The DEC analyses fish tissue, and the DOH interprets these levels and issues consumption advisories. These departments found that all fish collected from the Peconic River in 2001 had levels below the FDA Action Level (1 ppm for methylmercury). The State Department of Health, Bureau of Toxic Substances Assessment concluded that no additional advisories were necessary at that time (E. G Horn, pers. comm. letter of 30 April 2002); there was a general fish consumption advisory for all New York State waters of "do not eat more than one fish meal/week (0.5 lb = 226 g)" [51]. This led to the perception that New York State did not believe there was a risk from consumption of fish from the Peconic River.

The CRESP evaluation of BNL's human health risk assessment indicated that they followed EPA guidelines, and that their choice of neighbor scenarios was reasonable given the densely populated region and the importance of recreation to the local population [43,52]. However, the exposure assumptions used in the risk assessments may have driven the risk toward overestimates of exposure. D.O.E assumed that people could fish all year, that there were always fish of legal size available to catch, and that people ate mainly fish from the Peconic River. Conditions in the Peconic River make these assumptions likely incorrect. The Peconic River flowing through Brookhaven has low flow, long periods of dry conditions, small numbers and sizes of most fish, and low attraction as a fishing site [43]. More than 90 % of its flow is from groundwater, and less than 10 % from runoff [53], which implies that river flow will depend upon the water table elevations. A study of flow in the past 15 years showed that there was no flow in a large section of the river through BNL for 3 of the years, and no flow for 6 months for an additional 4 years. Thus, in half of the years examined, fishing would have been impossible for at least 6 months each year, and for most of 3 years. With little or no water in the river, fishing is impossible because there are no fish or fish cannot grow to very large sizes. There are relatively low fish populations, the effort to catch fish would be high, and fish populations would have to be supplemented to maintain high enough levels for anglers to reach the EPA default fish consumption rates. Thus, the usual assumptions for fish consumption derived from continuously flowing rivers are not reasonable for the Peconic River. D.O.E's evaluation, however, was based on total risk from all pathways and sources, currently and in the future, while New York State only dealt with the need, or lack thereof, for fish consumption advisories.

DISCUSSION

While the National Research Council (NRC) [16,17] and other agencies have made their risk evaluation and risk assessment paradigms clear, these methods have been modified to fit the

goals and objectives of different agencies. This means that an assessment commissioned by one agency may have a very different goal than one requested by another. Agencies may not be clear about their goals (and the associated assumptions, methods, and desired data). Since the conclusions reflect the goals, they may not be applicable to other situations. Further, the emphasis on stakeholder involvement has opened the process so that risk assessments are not just meant for managers, regulators, and health professionals, but for the general public as well.

At Oak Ridge, D.O.E had determined that the mercury source from the Y-12 plant posed a risk to off-site human and ecological receptors (requiring remediation or interdiction), and CRESP's evaluation of the D.O.E's interdiction actions to reduce mercury to off-site receptors included both human and ecological receptors, now and in the future. The ATSDR [44] human health risk assessment involved only humans, and examined past and current risks. Over the long term, the risks from mercury are clear as there is a completed pathway to off-site receptors and to humans, which both evaluations acknowledged. Thus, the data used were the same, it was only the objectives, methods, and assumptions that differed, leading to an apparent contradiction (Table 1).

Similarly, at Brookhaven, the state of New York issues fish consumption advisories based on mercury levels (and those of other contaminants) in fish from state waters. When New York re-evaluated potential risks from mercury in the Peconic River at Brookhaven, it saw no need to change the advisories (based on current risk). In contrast, D.O.E is charged with clean-up missions that protect human and ecological health, now and in the future, from all exposures (not just fish consumption). Thus, the public was understandably confused, but the confusion resulted from a failure to clearly delineate the problem, objectives, methodology, and assumptions, not in either the basic data that were used, or the risk assessment methodology (Table 1). The conclusions, although appearing contradictory initially, were not.

These differences are summarized in Table 1, indicating clear differences in objectives, assumptions, spatial scale, temporal dimensions, and receptors. These two case studies illustrate the importance of clearly defining all aspects of risk evaluations in a simple, straight-forward manner so that the public, as well as D.O.E, states, and other regulators, can understand and act on the evaluations. Partly clarity could be achieved by using a standard summary box at the beginning of risk documents that outlines the objectives, methods, temporal and spatial scales, receptors, and conclusions. This is a practical solution to the problem of differing risk evaluations.

Protection of human health and the environment requires many different kinds of risk evaluations, and they act in concert to provide managers with the information needed to move forward with remediation and protection. Our analysis has policy recommendations for how consumption advisories are handled by different agencies. It is not a regulatory failing to have several agencies assess and manage risk of different aspects of the same policy issue. Such an arrangement provides a more thorough coverage of the risks that need to be managed, protecting different interests, providing the differences are clarified. State agencies, and even federal agencies such as ATSDR, have responsibility for human health. D.O.E and federal regulators must consider long-term risk reduction to levels that will be safe for humans and

ecological receptors, given current and future land uses. Although there should be uniformity in risk evaluations for fish consumption, there cannot be uniformity in the risk evaluations overall because D.O.E must consider the risks from all contaminants on site, not just the mercury in the fish, and to all receptors, not just people. In this study, each agency was acting according to their own mandates, which resulted in confusion among different agencies, fishermen and the public about the discrepancies. This analysis indicated that the divergence in assessment was not a reflection of inherent uncertainty in the science of risk assessment, in the culture or training of the different risk assessors, or in the types of risk assessors involved, but rather in the scope of the risk assessments. The conflicts in risk evaluations were more apparent than real.

CONCLUSIONS

Risk was an important component of the evaluations of all agencies and CRESP, and all evaluations found that there was a completed pathway of mercury from the source on the D.O.E sites, to off-site human receptors. However, the evaluations differed in their final conclusions. At both sites, one of the major pathways to off-site human exposure was through fish consumption. However, the objectives, purpose, specific goals, target audience, receptors, assumptions, time frames, evaluation criteria, and conclusions differed among agencies and CRESP. When these aspects are considered, the risk evaluations are congruent, although the risk communication messages differ.

The ramifications for D.O.E are clear: any and all risk evaluations and risk assessments should clearly state up-front what the objectives are, why the assessment is being conducted, what the spatial and temporal scales are, how it is being conducted, and how the conclusions will be used. Risk assessments will differ when: 1) the time frame for assessment differs (current vs. current and future), 2) the receptors differ (human health vs. human and ecological health), 3) the endpoints differ (individual effects vs. population effects, 4) the tools differ (EPA criteria for consumption, or freshwater criteria vs. MDLs), 5) the spatial scales differ, and 6) when human health protection is the goal, vs. long-term remediation to protect human health and the environment. From a risk communication standpoint, more information is better than less with respect to objectives and goals, methods, and final conclusions.

The implications for policy are: 1) there is a need for broader inclusion of all agencies and all stakeholders (including the public and target populations) during all phases of risk evaluation, assessment, and management, 2) the objectives, assumptions and methodologies used in any policies or advisories concerning risk should be transparent throughout the process, 3) the uncertainties in risk evaluation should be made clear (i.e. are there enough fish in the river to fish all year? do people actually fish there?), as well as their implications for risk evaluations, 4) the temporal scales of the risk evaluations should be clarified, and 5) the receptors (i.e. humans, eco-receptors) need to be clearly identified. Some of the confusion about the relative risk from mercury in fish, and its effect on cleanup or interdiction measure, could have been avoided by addressing these issues.

ACKNOWLEDGEMENTS
We thank the many people who have discussed these topics with us, or who have helped in the research, including K. Brown, J. Clarke, S. Golian, R. Schoeny, A. Stern, L. Bliss, C. Chess, M. Gilbertson, C. Jeitner, and T. Pittfield. This project was mainly funded by the Consortium for Risk Evaluation with Stakeholder Participation (Department of Energy, DE-FC01-86EW07053), with additional funding from NIEHS (P30ES005022) and Rutgers University. The views and opinions expressed in this paper are those of the authors, and do not represent the funding agencies.

REFERENCES

[1] J. BURGER, Ed., *Stakeholders and scientists: Achieving implementable solutions to energy and environmental issues,* Springer, New York, NY (2011).

[2] S. ARNSTEIN, "Eight rungs on the ladder of citizen participation," American *Institute of Planning Journ*al, **35**, 16-224 (1960).

[3] PRESIDENT'S COMMISSION (PCCRAM), "*Presidential/Congressional Commission on risk assessment and management*," U.S. Government Printing Office, Washington, D.C. (1997).

[4] J. BURGER, "Perceptions as indicators of potential risk from fish consumption and health of fish populations," *Environmental Bioindicators*, **3**, 90-105 (2008).

[5] NATIONAL RESEARCH COUNCIL (NRC), *Panel on public participation in environmental assessment and decision-making.* National Academy Press, Washington D.C., (2008).

[6] J.D. CROWLEY and J.F. AHEARNE, "Managing the environmental legacy of U.S. nuclear-weapons production," American *Scientist*, **90,** 514-523 (2002).

[7] J. BURGER, " Incorporating ecology and ecological risk into long-term stewardship on contaminated lands," *Remediation*,**18,** 107-120 (2002).

[8] J. BURGER, "Protective sustainability of ecosystems using Department of Energy buffer lands as a case study," *Journal of Toxicology and Environmental Health,* **70,** 1815-1823 (2007).

[9] DEPARTMENT OF ENERGY (D.O.E), *Stewards of national resources,* Department of Energy (D.O.E/FM-0002), Washington, D.C., (1994a).

[10] DEPARTMENT OF ENERGY (D.O.E), *National environmental research parks,* Department of Energy. Office of Energy Research, Washington, D.C., (1994b).

[11] V.H. DALE and P.D. PARR, "Preserving D.O.E's research parks," *Issues in Science and Technology*," **282**, 616-617 (1997).

[12] J. BURGER, M.A. CARLETTA, K. LOWRIE, K.T. MILLER, and M. GREENBERG, "Assessing ecological resources for remediation and future land uses on contaminated lands*," Environmental Management,* **34,** 1-10 (2004).

[13] J. BURGER, M. GOCHFELD, K. PLETNIKOFF, S. PLETNIKOFF , R. SNIGAROFF, D. SNIGAROFF, and T. STAMM, "Ecocultural attributes: evaluating ecological degradation: ecological goods and services vs. subsistence and tribal values," *Risk Analysis,* **28,**1261-1271 (2008a).

[14] J. BURGER, M. GOCHFELD, and, M. GREENBERG, "Natural resource protection of buffer lands: integrating resource evaluation and economics'" Environmental *Monitoring and Assessment,* **142,** 1-9 (2008b).

[15] F.W. WHICKER,T.G. HINTON, G. MACDONEL, J.E. PINDER III, and L.J. HABEGGER, "*Avoiding destructive remediation at D.O.E sites*," Science, **303**, 1615-1616 (2004).

[16] NATIONAL RESEARCH COUNCIL (NRC), *Risk Assessment in the Federal Government, Managing the Process,* National Academy Press, Washington D.C., (1983).

17] NATIONAL RESEARCH COUNCIL (NRC), *Issues in Risk Assessment,* National Academy Press, Washington D.C. (1993).

[18] NATIONAL RESEARCH COUNCIL (NRC), *Ecological knowledge and environmental problem-solving,* National Academy Press, Washington D.C., (1986).

[19] NATIONAL RESEARCH COUNCIL (NRC), *Understanding risk: informing decisions in a democratic society, National* Academy Press, Washington D.C. (1996).

[20] S.B. NORTON, D.R. RODIER J.H GENTILE, W. H. VAN DER SCHALIE W. P. WOOD, and M.W. SLIMAK, "A framework for ecological risk assessment at the EPA," Environmental *Toxicology and Chemistry*, **11,** 1663-72 (1992).

[21] M.A. KAMRIN, "Environmental risk harmonization: federal/state approaches to risk assessment and management," Regulatory *Toxicology and Pharmacology*, **25**, 158-65 (1997).

[22] R.E. HAGEN, "Prospects for nuclear energy in Canada, the USA, and Mexico," *International Journal of Global Energy Issues*, **30**, 324-341 (2008).

[23] A. MCDONALD, "Nuclear power global status," Vienna, Austria; International Atomic Energy Agency, (2009), Accessed 1 December 2010 http://www.iaea.org/Publications/Magazines/Bulletin/Bull492/49204734548 2009.

[24] B.D GOLDSTEIN, J. KRIESKY, and B. PAVLIAKOVA, "Missing from the table: Role of the environmental public health community in governmental advisory commissions related to Marcellus shale drilling," *Environmental Health Perspectives,* **120,** 483-486 (2012).

[25] R. MCDERMOTT-LEVY, N. KAKTINS, and B. SATTLER, "Fracking, the environment, and health," *Environments & Health,* **113,** 45-51 (2013).

[26] NUCLEAR REGULATORY COMMISSION (NRC), *Nuclear reactor risk: fact sheet,* Nuclear Regulatory Commission, Washington, D.C, (2003). Accessed 10 November 2010 http:// Opa.resource@nrc.gov
[27] NUCLEAR REGULATORY COMMISSION (NRC), *Nuclear power plant licensing process,* NUREG/BR-0298, Nuclear Regulatory Commission, Washington, D.C, (2004) Accessed 10 November 2010 http:// Opa.resource@nrc.gov

[28] CANADIAN NUCLEAR SAFETY COMMISSION (CNSC). *Licensing process for new nuclear power plants in Canada*. INFO-0756. Canadian Nuclear Safety Commission, Ottawa, Ontario, (2008).

[29] J.P. CHRISTODOULEAS, R.D. FORREST, C.G. AINSLEY, Z. TOCHNER, S.M. HAHN, and E. GLATSTEIN, "Short-term and long-term health risks of nuclear power plant accidents," *New England Journal of Medicine,* **16,** 2334-2341 (2011).

[30] NUCLEAR POWER PLANT JOURNAL (NPJ), *Information on status of nuclear power plants in Fukushima.* Nuclear Plant J March 29, 2011. (E-news).

[31] J.M. LOAR, A.J. STEWART, and J. G. SMITH, "Twenty-five years of ecological recovery of East Fork Poplar Creek: review of environmental problems and remedial actions," *Environmental Management,* **47,** 1010-20 (2011).

[32] M.J. PETERSON, R.A. EFROYMSON, and S.M. SDAMS, " Long-term biological monitoring of an impaired stream: synthesis and environmental management implications," *Environmental Management,* **47**,1125-40 (2011A).

[33] M.B. PETERSON, G. LOONEY, C. SOUTHWORTH, D. EDDY-DILEK, D. WATSON, R. KETELLE, and M.A. BOGLE, "*Conceptual model of primary mercury sources, transport pathways, and flux at the Y-12 Complex and Upper East Fork Poplar Creek, Oak Ridge, TN,"* ORNL/TM-2011/75 (2011b).

[34] G.R. SOUTHWORTH, S. BROOKS, M. PETERSON, M.A. BOGLE, C. MILLER, M. ELLIOT, and L. LIANG, "*Controlling mercury release from source zones to surface water: initial results of pilot tests at the Y-12 National Security Complex*," ORNL/TM-2009/035, Oak Ridge National Laboratory, Tennessee (2009).

[35] G.R. SOUTHWORTH, M.J. PETERSON, W. KELLY ROY, and T.J. MATHEWS, "*Monitoring fish contaminant responses to abatement actions: factors that affects recovery,"* Environmental Management, **47**, 1064 -1076 (2011).

[37] J. BURGER and K.R. CAMPBELL, "Fishing and consumption patterns of anglers adjacent to the Oak Ridge Reservation, Tennessee: higher income families ate more fish and more at risk," *Journal of Risk Research*, 3-4, 335-350 (2008).

[38] J. BURGER, "Consumption advisories and compliance: the fishing public and the deamplification of risk," *Journal of Environmental Planning and Management*, **43,** 471-488 (2000).

[39] DEPARTMENT OF ENERGY (D.O.E), *Charting the Course: the Future Use Report,* (D.O.E/EM-0283), Washington, DC, Department of Energy, (1996).

[40] DEPARTMENT OF ENERGY (D.O.E), *From cleanup to stewardship,* (D.O.E/EM-0466), Washington, DC, Department of Energy, (1999).

[41] DEPARTMENT OF ENERGY (D.O.E), *About Brookhaven.* Department of Energy, (2003), Accessed 18 March 2004 http://www.bnl.gov/bnlweb/about-BNL.htm. (2003).

[42] DEPARTMENT OF ENERGY (D.O.E), *The operable unit V remedial investigation and feasibility study*, Upton, New York, Brookhaven National Laboratory, (2002a).

[43] DEPARTMENT OF ENERGY (D.O.E), *Baseline human health risk assessment (Operable Unit V. Peconic River),* Upton, New York, Brookhaven National Laboratory, (2002b).

[44] AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR), "Public Health Assessment for Evaluation of Y-12 Mercury Releases," Center for Disease Control, Atlanta, Georgia (2012).

[45] J. BURGER. and M. GOCHFELD, "The Peconic River: Concerns associated with different risk evaluations for fish consumption" *Journal of Environmental Planning and Management,* **48**, 78-808 (2005).

[46] J. BURGER, M. GOCHFELD, C.W. POWERS, D. KOSSON, J. CLARKE, and K. BROWN, "Mercury at Oak Ridge: outcomes from risk evaluations can differ depending upon objectives and methodologies" *Journal of Risk Research,* (in press).

[47] D. KOSSON, C.W. POWERS, J. BURGER, J. CLARKE, M. GOCHFELD, and K. BROWN, *Risk prioritization paradigm for remediation projects at Oak Ridge Reservation.* Consortium for Risk Evaluation with Stakeholder Participation (CRESP), Vanderbilt University, Nashville,

Tennessee, (2012).

[48] OAK RIDGE NATIONAL LABORATORY (ORNL), “Oak Ridge Reconstruction Project Summary Report, Vol. 7, March 2000” Tennessee Department of Health, (2000), Accessed 10 June 2005 http:// http://health.state.tn.us/ceds/oakridge/ProjSumm.pdf

[49] AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (ATSDR),”Toxicological profile for mercury,” (1999) Accessed 4 March 2013 http://www.ATSDR.CDC.gov/toxprofiles/tp46.pdf

[50] NATIONAL RESEARCH COUNCIL (NRC), *Toxicological effects of methylmercury,* National Academy Press, Washington D.C., (2000).

[51] NEW YORK STATE, *2002-1003 Health advisories: chemicals in sport fish and game - New York State Department of Health,* (2002), Accessed 17 November 2008 hhttp://www.health.state.ny.us/nysdoh/environ/fish.htm.

[52] J. BURGER, “Assessment methods for concerns about contaminated sites,’” Journal *of Toxicology and Environmental Health*, **67,** 31-42 (2004).

[53] M.P. SCORCA, W.R. DORSCH, and D.E. PAQUETTE, “Stratigraphy and hydrologic conditions at the Brookhaven National Laboratory and vicinity, Suffolk County, New York, 1994-1997,” USGE, Water resources investigation Report 99-4086, Long Island, New York (1999).