

Perspectives

Chemical and Radiation Environmental Risk Management: Differences, Commonalities, and Challenges

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Driven by differing statutory mandates and programmatic separation of regulatory responsibilities between federal, state, and tribal agencies, distinct chemical and radiation risk management strategies have evolved. In the field this separation poses real challenges since many of the major environmental risk management decisions we face today require the evaluation of both types of risks. Over the last decade, federal, state, and tribal agencies have continued to discuss their different approaches and explore areas where their activities could be harmonized. The current framework for managing public exposures to chemical carcinogens has been referred to as a "bottom up approach." Risk between 10^{-4} and 10^{-6} is established as an upper bound goal. In contrast, a "top down" approach that sets an upper bound dose limit and couples with site specific As Low As Reasonably Achievable Principle (ALARA), is in place to manage individual exposure to radiation. While radiation risk are typically managed on a cumulative basis, exposure to chemicals is generally managed on a chemical-by-chemical, medium-by-medium basis. There are also differences in the nature and size of sites where chemical and radiation contamination is found. Such differences result in divergent management concerns. In spite of these differences, there are several common and practical concerns among radiation and chemical risk managers. They include 1) the issue of cost for site redevelopment and long-term stewardship, 2) public acceptance and involvement, and 3) the need for flexible risk management framework to address the first two issues. This article attempts to synthesize key differences, opportunities for harmonization, and challenges ahead.

KEY WORDS: Risk harmonization; risk management; ALARA; performance based risk standards; institutional controls; stakeholder involvement

BACKGROUND

The cold war and its nuclear legacy have had a profound impact on the management of radiation risks. Heightened concerns about radioactive fallout and public perception of the dangers of radiation have shaped the development of the radiation protection system since the 1950s. Establishing radiation

limits to the public are the shared responsibility of the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the Environmental Protection Agency (EPA). Their approaches have been guided by federal laws such as the Atomic Energy Act (AEA),^(1,2) evaluation of epidemiologic evidence about human health effects by the National Academy of Sciences Committees on Biological Effects of Ionizing Radiation (BEIR Reports),⁽³⁻⁵⁾ and consensus guidelines of national and international standard setting bodies (e.g., International Commission on Radiological Protection [ICRP] and National Council on Radiation Protection and Measurements [NCRP]).

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In contrast, chemical risk management is the responsibility of a broad range of federal, state, and local agencies. At the federal level, the EPA has assumed a leadership role in shaping risk management approaches that have arisen from environmental statutes first enacted in the 1970s and early 1980s and their amendments. These statutory approaches have been largely media-specific, with the exception of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)⁽⁶⁾ and, more recently, the Food Quality Protection Act (FQPA).⁽⁷⁾ Furthermore, chemical risk managers are typically guided by risk assessment information that is based on animal evidence, as outlined in the EPA's proposed Cancer Risk Guidelines.⁽⁸⁾ Despite the broad mandates for chemical risk management, there have been few occasions where human evidence is available (e.g., asbestos, benzene) to guide risk management decisions.

Driven by differing statutory mandates and programmatic separation of regulatory responsibilities between federal, state, and tribal agencies, distinct chemical and radiation risk management strategies have evolved. The separate treatment of the two fields by the scientific and professional communities has led to the evolution of two distinct "cultures." While the separation of radiation and chemical risk management persists—at legal, regulatory, programmatic, training, and professional practice levels—many of the major environmental risk management decisions we face today require the simultaneous evaluation and control of both radiological and chemical risks. This environmental reality requires interaction between the two cultures which often results in disagreements. The more than decade old wrangling between the EPA, NRC, and DOE on the issues of cleanup standards for contaminated waste sites is an example of this clash of cultures. Recognizing their differences, EPA, NRC, DOE, and other federal agencies have established interagency coordinating bodies such as the Interagency Steering Committee on Radiation Standards (ISCORS).

Discussion about harmonization has been continuing during the last decade. The need for harmonization was also clearly articulated in a 1992 report by EPA's Science Advisory Board—Radiation Advisory Board (SAB-RAB).⁽⁹⁾ According to this report, harmonization does not mean that all decisions involving chemical and radiological hazards require identical treatment. Instead, it refers to fitting risk management decisions into a common policy framework aimed at aggregate risk reduction and public health protection. Presently, several major develop-

ments in environmental policy are increasing the common ground between radiation and chemical risk management. The emergence of comparative risk methodologies, the growing emphasis on cumulative risk assessment and risk management, and the legislative push for regulatory reform and risk-based decision making provide challenges and opportunities to examine, improve, and harmonize risk management strategies.

In June 1998, a panel of 40 chemical and radiation risk experts and managers from governmental, academic, trade, and tribal organizations were brought together at an interactive workshop in Annapolis, Maryland to discuss several perspectives on harmonizing chemical and radiation risk management approaches.³ Participant names and their affiliation at the time of the meeting are listed in the Appendix. The meeting was facilitated by the Johns Hopkins University Risk Sciences and Public Policy Institute (JHU-RSPPI) and the Environmental Law Institute (ELI), and sponsored by the U.S. EPA Office of Radiation and Indoor Air (ORIA). The Annapolis workshop sought to continue the harmonization dialogue and clarify differences between chemical and radiation risk management practices so that they could be effectively addressed. This paper attempts to synthesize key differences, opportunities for harmonization, and challenges that were discussed by the workshop participants.

KEY DIFFERENCES—A CONTRAST OF CULTURES

Moving toward harmonization requires recognition and understanding of key differences in risk management approaches. Table I is a summary of background information that compared the public health aspects of radiation and chemical risk management. This table was provided to the workshop participants as a starting point for discussion. From the lively debates among the participants, key differences are synthesized below.

Differences in the Scientific Information Supporting Risk Management Decisions

The principles and procedures for assessing carcinogenic risks of chemicals and radioactive materials

³ While there are many aspects of chemical risk management oriented to controlling both cancer and noncancer risks, this discussion solely focuses on cancer risks.

Table I. Comparison of Public Health Aspects of Radiation and Chemical Risk Management

	Chemical	Radiological
Data sources	Animal bioassays (toxicology) Epidemiology (workers and public)—limited	Animal bioassays (toxicology) Epidemiology (public and workers)—highly exposed populations
Current lifetime “acceptable risk”	1×10^{-3} (workers) 1×10^{-6} (public) 1×10^{-4} to 1×10^{-6} (public; target range)	10^{-1} (workers; without ALARA) 10^{-3} (public; without ALARA]
Exposure scenarios considered	Single source, single substance, single pathway, single route Evolving multi-media, source, pathway and routes	Multi-media, source, pathway and routes
Risk management time frame	Varies by statute and program—approximately 30–70 years; flexible, up to infinity	Long-term risk management—hundreds to thousands of years
Scope of risk estimates	Worker, individual, and population risk estimates	Worker, individual, and population risk estimates
Effects of concern	Cancer effects dominate Evolving: other (noncancer) effects; ecological impacts	Cancer effects dominate Evolving: “total detriment” concept (i.e., cancer morbidity and mortality); risk estimates for heredity effects decreasing.
Approaches to achieving public health protection	Bottom-up: set goal at risk level of 1×10^{-6} Adjust using other factors such as cost and implementability to risk level of 1×10^{-4} (CERCLA) Use technology-forcing (maximally achievable, or best available technology) and adjust based on residual risk (CAA NESHAPs) Set health-protective level; adjust based on feasibility, cost and field experience (SDWA)	Top down: Set dose “ceiling” based on aggregate exposure; adjust downward using ALARA process
Sources of uncertainty	Animal data to human extrapolation Exposure measurement High to low dose extrapolation/interpolation Variability in human population (e.g., racial, age- and gender-related) Multiple exposure mixtures Confounding risk factors	High to low dose extrapolation/interpolation Exposure measurement Variability of human population Confounding risk factors Differences in biological effects (per unit dose) from internal vs. external sources Conversion from partial body exposure to “effective” (equivalent whole body) doses.
Institutional controls	Use physical and legal controls to assist in public health protection End-of-pipe controls Pollution prevention approach	Front-end engineering plus institutional controls (“defense in depth”) Life cycle-based prevention approach
Background risk	Limited consideration to date (i.e., naturally occurring metals)	Dose rates from natural background source (except radon) are generally considered acceptable
Collective impacts	Not always addressed	Considers collective and time-integrated collective impacts

ALARA = As Low As Reasonably Achievable principle; CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; CAA NESHAPS = Clean Air Act National Emission Standards for Hazardous Air Pollutants; SDWA = Safe Drinking Water Act.

are similar.⁽¹⁰⁾ Nevertheless, there are some basic differences in the databases that radiation and chemical risk assessors use to estimate dose and risks. In general, chemical risk management decisions are based on risk assessments that are supported by animal bioas-

says (except in a few cases based on human occupational exposure data, e.g., benzene, asbestos). According to Graham, Paustenbach, and Butler,^(11:4) as of June 1994, only 11 of the 218 chemicals evaluated for cancer in the Integrated Risk Information System (IRIS) da-

tabase have numerical slope factors that are based entirely or partially on epidemiological data. In contrast, radiation risk assessments are based on human data from cohorts such as the Japanese atomic bomb survivors, uranium miners, medical patients exposed to “therapeutic” radiation, and radium dial painters.⁽¹²⁾ Estimates of cancer risk from radiation are usually “central” or “best” estimates based on epidemiological data extrapolated from high to much lower doses using mathematical models fit to the data. The cancer risks from chemical exposures are usually based on mathematical models that calculate the 95% upper confidence limit on cancer risk by extrapolating from high to much lower doses using animal data.^(10,13) Thus, it has been frequently argued that chemical risk assessments are more conservative.⁽¹⁴⁾

It should be noted, however, that despite the strong human data base, numerous knowledge gaps exist for both chemical and radiation risk estimation. Currently, common issues of further exploration include:⁽¹⁵⁾

- the true nature of the dose-response curve at low doses;
- the appropriateness of incorporating data regarding DNA repair mechanisms;
- the applicability, if any, of the theory of hormesis, or the beneficial effects of low-level exposure;
- treatment of sensitive subpopulations, such as the fetus, children, and individuals who may be hypersensitive or receive greater exposure;
- the appropriateness of incorporating information about synergistic or antagonistic effects of combined exposures; and
- uncertainty related to other noncancer health effects that remain unrecognized or underappreciated (e.g., damage to the immune system or endocrine disruptions).

Differences in Risk Management Approaches

Numerical Risk Targets versus As Low As Reasonably Achievable Principle

The current framework for managing exposures of the public to chemical carcinogens has been referred to as a “bottom up” approach.^(16,17) Risk is typically evaluated for each source and an acceptable risk range, usually between 10^{-4} to 10^{-6} , is established. The lower risk of this range is then established as an “upper bound” goal. Risk managers seek to achieve protection at the “upper bound” goal by lim-

iting exposure or removing the environmental contamination. If this goal is not achievable after the considerations of technical feasibility, cost, and other factors, the risk manager may decide to accept a “lower bound” goal within the risk range that could lead to a less stringent level of protection.⁽¹⁷⁾

In contrast, the dominant framework for managing individual radiation exposures has been described as a “top down” approach.⁽¹⁶⁾ The top-down strategy involves aggregating risks from all sources and setting an upper bound dose limit, then using the As Low As Reasonably Achievable (ALARA) principle to reduce the risk. ALARA is a flexible term that incorporates a broad array of management techniques, including formal cost-benefit analysis and good work practices. According to the NRC, ALARA is defined as “making every reasonable effort to maintain exposures to ionizing radiation as far below dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of the technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations and in relation to utilization of nuclear energy and licensed materials in the public interest.”⁽¹⁸⁾

The NRC and DOE have consistently favored the top-down, or ALARA, approach in their standard setting and risk management practices.⁽¹⁷⁾ The EPA uses a bottom up approach—consistent with its chemical risk management philosophy, EPA usually applies a 10^{-4} to 10^{-6} incremental lifetime target risk range in managing radiation risks. Participants at the Annapolis workshop described the rigid application of these two distinct risk management approaches as one of the major impediments to harmonization. A simple illustration can demonstrate this difference. Currently, 100 millirems per year (1 mSv/yr)⁴ is the dose rate limit recommended to protect the public against adverse effects from all sources of ionizing radiation.^(15,19) If one were to apply the chemical risk management “bottom up” philosophy, it would be assumed that a population is exposed at this limit over a lifetime. Using the EPA’s radiation cancer risk coefficient, this assumption would result in a lifetime risk of about 3 in 1,000.^(14,20,21) Within the chemical risk management framework such a risk would be consid-

⁴ICRP and NCRP recommended 1 mSv as the “long-term” annual dose limit from all sources (excluding natural background and doses received from medicine and dentistry) and 5 mSv as a “short-term” annual limit.^(15,19)

ered unacceptable, for it exceeds the acceptable 10^{-4} to 10^{-6} risk range. However, radiation risk managers would argue that this conclusion is incorrect because it does not take into account the reduction in risk gained by applying the ALARA principle. With ALARA in place, the actual exposure and risks are typically well below the predicted risks based on the 100 mrem (1 mSv) per year standard.

Natural Background Risks

Natural background radiation exposure ranges from 70 to 250 mrem (0.7 to 2.5 mSv) per year (excluding exposure to indoor radon).^(12,22) To some radiation risk managers, reducing total excess exposures from all sources much below 100 mrem/year (1 mSv/year) is deemed unnecessary and exceedingly difficult to monitor because it is within the natural variability of background.⁽⁹⁾ The incremental or excess risk associated with man-made radiation sources is evaluated in the context of total exposure.⁽²²⁾

In contrast, background levels of synthetic chemicals are typically considered to be de minimis.⁽⁹⁾ EPA generally concentrates on the incremental risk associated with exposure to nonbackground sources. In circumstances where background levels are not de minimis, background levels may be considered depending on the EPA's program office. For example, under Superfund, EPA distinguishes natural background levels from man-made contamination, and only lists sites with man-made contamination on the National Priorities List.^(23,24) However, background levels may be considered for the purposes of setting cleanup levels at Superfund or RCRA sites. For example, naturally occurring levels of metals such as lead and chromium are considered in cleanup goals.^(25,26)

Under the Safe Drinking Water Act (SDWA), EPA sets Maximum Contaminant Levels (MCLs) based on public health protection goals, taking into account a host of other factors such as feasibility of treatment and measurement. In fact, MCLs for some naturally occurring inorganic substances are sometimes set below natural background levels.⁽²³⁾ EPA does not permit water treatment facilities to consider the removal of radioactive materials from groundwater by water treatment and/or purification factors.

Cumulative Risks

EPA has defined "cumulative" risk broadly as "the consideration of aggregate ecologic or human health risk to the target entity caused by the accumu-

lation of risk from multiple stressors, i.e., multiple sources and pathways."⁽²⁷⁾ In radiation protection, the term "cumulative" implies "committed dose," which is a measure of the ultimate 50 or 70 year dose that a person will receive due to the deposition of a radiation within his/her body. When the dose from all sources to a given human receptor is estimated, the term "composite" dose is used by radiation risk managers. Differences in terminology such as this may also be obstacles to the harmonization discussion. For the purpose of this article, the term "cumulative risk" as defined by EPA will be used.

According to the ICRP, limitation of individual risk is such that the maximum risk to individuals resulting from the *combined exposure to all relevant practices* should be subjected to an upper limit.⁽¹⁹⁾ Thus, the 100 mrem (1 mSv) per year individual dose rate limit for the general population is based on cumulative exposure from all sources, pathways, and radioactive materials, except natural background radiation and any doses received through the application of radiation in medicine and dentistry.

With the key exceptions of CERCLA, Resource Conservation and Recovery Act (RCRA) corrective actions,⁵ and, more recently, FQPA, chemical risk managers consider the risk of exposure to one chemical and single pathway at a time, rather than the cumulative risks from exposure to all chemicals and all pathways.^(6,7,23,28) EPA's approach to managing radiation risks in the Safe Drinking Water Act (SDWA) program follows the single substance/single pathway chemical risk management strategy.⁽²⁹⁾ Under its primary drinking water standard for radioactive materials, the MCLs for Radium-226, Radium-228, gross alpha (excluding uranium and radon), and man-made radioactive materials that are beta and photon emitters are independently established.⁽³⁰⁾ Groundwater contamination is an area of controversy in Superfund and other site clean-ups. The application of media-specific standards to groundwater by EPA is seen by radiation risk managers as inconsistent with the cumulative approach to reducing risks.

Different Views on the Annual Dose Rate Limit

An important difference in risk management philosophy between the EPA and NRC concerns

⁵ Under CERCLA and RCRA corrective actions (except for naturally occurring radon), EPA has usually applied the 10^{-4} lifetime risk limit to all radioactive contaminants collectively (e.g., 3 to 15 mrem/yr or 30 to 150 μ Sv/yr).^(23,28)

their interpretation of the 100 mrem (1 mSv) per year dose rate limit applied to the general public. The ICRP recognizes an important distinction between limitation of the maximum exposure of an individual from all sources combined, and the control of each source of exposure. This distinction is made because an individual may be exposed to several sources, and it is not equitable for him/her to be exposed up to the limit from one source.^(14,19) In EPA's view, no single regulated entity should be allowed 100 mrem (1 mSv) per year. Numerical limits that are a fraction of 100 mrem/yr (1 mSv/yr) are therefore established for categories of sources by EPA.⁽³¹⁾ In contrast, while the NRC limits individual sources per licensee (facility) to a fraction of the 100 mrem/yr (1 mSv/yr), each licensee (facility) may contribute up to the 100 mrem/yr (1 mSv/yr).⁽³²⁾ To NRC, the combination of ALARA and other aspects of the NRC regulatory program usually achieve exposure of only a few mrem⁶ per year for most licensees.⁽³¹⁾ To date, this difference in interpretation between the two agencies remains unresolved.

Site Differences in the Case of Cleanups

Sites with chemical hazards tend to be smaller and more numerous than their radioactive counterparts. Such differences result in divergent management concerns. The challenge for chemical risk managers is to track and oversee a wide range of contaminants, sites, and scenarios. In contrast, there are fewer radiation-contaminated sites, although they tend to be much larger.

Site ownership plays an important role in many risk management decisions. Sites with chemical hazards are more likely to be owned by private parties; some of the most prominent radioactively contaminated sites are government-owned. Privately owned sites are transferred more often than those owned by the government. Site purchases and sales can often complicate long-term management. Remedial actions at chemical sites must ensure protectiveness even when a site is transferred or sold, and this has led to the preference for complete cleanup or delisting of chemically contaminated sites.

At radiation sites, management options are influenced by a commitment on the part of the government to long-term stewardship and responsibility for operation and maintenance. DOE risk managers believe that site management should differ based on

the longevity of ownership. They expect to have a long-term role in maintaining contaminated government lands, and make their risk management decisions accordingly. Under this approach, DOE-owned sites can more readily apply management strategies such as institutional controls, containment, monitoring, and maintenance. Potentially more costly "walk-away" remedies are thus less likely to be adopted.

Also relating to the issue of ownership is the question of who pays for the cleanup. At many of the radiation cleanup sites, the cleanup activities are funded by the federal government, and provide for continued employment in the area. For local economic reasons, there is often little incentive to stop the flow of federal funds. The situation for most chemical sites is much more complex and varied from location to location. For example, there may be strong economic incentives for cleanup of chemically contaminated, commercially valuable lands. Separate approaches to chemical and radiation risk management might be justified because of these site differences.

It should be noted that this discussion on radiation cleanup focuses on sites operated by the federal government such as DOE. There is an increasing number of commercial nuclear power plants, formerly operated by licensees of the NRC and/or the Agreement States, that are being decommissioned and decontaminated. The majority of these sites are relatively small and cleanup is the primary responsibility of private owners. Consequently, there is perhaps greater incentive to bring the cleanup activities at these sites to completion as quickly as possible.

ON HARMONIZATION

The rapidly changing fields of risk science and technology will directly impact risk management. Chemical risk assessments are being expanded to examine cumulative impacts and better incorporate scientific uncertainty. In particular, the current statutory push under FQPA toward cumulative risks has prompted numerous research activities.⁽³³⁾ From the methodologic front, it would seem that over time, as more scientific information is obtained, uncertainties can be reduced and similarities in the way we assess chemical and radiation risks are likely to increase.

Regarding risk management, the Annapolis workshop participants endorsed the idea that some level of harmonizing is desirable and potentially achievable. Several suggestions are offered as potential bridging issues to begin the harmonization efforts.

⁶mrem = 10 μ Sv.

Flexible Risk Management Principles and Performance-based Risk Standards

Increased flexibility in the interpretation of regulatory mandates would greatly enhance efforts of harmonization. The existing network of legal mandates lends itself to at least two distinct management frameworks. Flexible management principles based on national criteria would enable risk managers to tailor solutions to specific problems, improving the likelihood that risk management decisions would be as protective as possible. Flexibility is also important when addressing socioeconomic and cultural factors. Different communities have distinct views and value systems that should be considered and incorporated into risk management decisions whenever possible. Harmonized risk management principles should enhance the ability of risk managers to craft solutions reflective of public values and concerns. For site cleanups, use of institutional controls and other creative risk management strategies could be part of a harmonized risk management model. With harmonized risk management principles, performance-based risk standards could be developed to supplement or replace current “bright line” approaches. This flexible, yet harmonized approach could be especially applicable in hazardous and radioactive waste cleanup situations.

Costs and Institutional Controls

A practical concern among both radiation and chemical risk managers is the issue of cost for site redevelopment and long-term stewardship. The high cost of “walk-away” cleanups has led risk managers to consider the benefits of alternative use scenarios (e.g., industrial or restricted use) and the use of institutional controls and other in-place management tools.

The use of institutional controls is increasing throughout the state and federal agencies. Under RCRA, EPA requires institutional controls when a Treatment, Storage, and Disposal (TSD) facility closes. These institutional controls include several requirements to assure that the physical barriers used to isolate residual hazardous wastes are not compromised and to warn potential buyers that the land is contaminated. EPA and state environmental agencies also are increasing their use of institutional controls in programs for cleaning up sites contaminated by hazardous chemical substances and radioactive materials. In this context, institutional controls can help prevent exposure (hence risk) in the absence of cost-effective technology that can lower contami-

nants to more protective levels. At nuclear power facilities, institutional controls are used, or contemplated, throughout the life cycle of the power plant. Because of the nature of the planning for nuclear power facilities, institutional controls are integrated at the beginning of the process. Institutional controls are also a key element in the rapidly expanding programs for cleaning up and redeveloping Brownfields.⁷ DOE is currently in the process of implementing institutional controls as an integral part of the cleanup of tailings left at former uranium mill sites.

A harmonized risk management framework that allows for cost consideration up-front would enable cost-effective risk management options to be fully utilized. Nevertheless, any kind of cost evaluation must be inclusive of public acceptability. For example, in the context of site cleanup, closure of businesses has widespread economic impacts, as does restricting access to a site for an extended period of time. These costs include the loss of potential land and site uses, the costs of maintaining institutional controls, if applicable, and the societal and cultural resource losses. In practice, all risk management practices pose some costs to the affected community, ranging from direct financial impact to lifestyle and cultural change. The early solicitation of public opinion on these matters will ensure more accurate estimate of the true cost of a remedy to the government and to the affected community.

The Need for Public Involvement

Political decisions are frequently shaped by risk perception. The most effective and enforceable risk management alternatives are likely those that are acceptable to affected communities. In order to be acceptable, a proposed remedy—both its costs and benefits—must first be understood by the parties at risk. Effective risk management decisions must also incorporate the values and concerns of the public. Currently, neither chemical nor radiation risk management has accomplished this consistently.

Obviously, social acceptability of risk management decisions is a concern that is shared by both chemical and radiation risk managers. Additionally, radiation risk managers have to confront the fact that the public tends to view radiation risks as being more

⁷EPA defines “Brownfields” as abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.⁽³⁴⁾

dangerous than chemical risks, and should therefore be subject to stricter standards. This disparity in public risk perception should be considered in any attempts at harmonization. The Annapolis workshop participants generally agreed that improved public involvement and communication is an important component of a harmonized risk management framework. The right-to-know efforts associated with chemical risk management were recognized as potentially successful models.

CHALLENGES AND NEXT STEPS

Perhaps the greatest challenges in any attempt to harmonize the way we manage radiation and chemical risks are political and historical. Federal agencies such as the EPA, NRC, and DOE have used different approaches to implement different statutes, or different parts of the same statutes. Their approaches are of historical and philosophical importance to the original missions upon which they were created: environmental protection (EPA), regulation of privately-owned nuclear facilities (NRC), and noncivilian nuclear power and weapons production (DOE). Because of the different missions, these agencies must answer to different constituencies and different regulatory mandates. Therefore, they face distinct risk management challenges in responding to constituent concerns.

Continuing dialogue, improved interagency interaction, and mobilized coordination will be crucial to the harmonization effort. Nevertheless, fostering an environment of open communication in which all parties can discuss opportunities for collaboration freely will be a challenging process that will require strong leadership. Furthermore, most risk managers work within either the chemical or radiation approach, but not both. A combined knowledge base for education purposes does not exist. This lack of understanding of the counterpart's management process poses practical barriers.

A careful analysis of the application of both risk management approaches is essential so that harmonization can proceed. To increase the prospects for harmonization, it was unanimously agreed by the workshop participants that case studies of actual events—especially a study of clean-up sites at which radioactive materials and hazardous chemical risks were addressed—should be developed. Information from these case studies will help educate participants in the harmonization dialogue about their counterpart's issues. In addition, concrete information from case studies will help stimulate further discussion and

sharpen the issues identified at the workshop in a way that they can be resolved. With the continued support of the EPA Office of Radiation and Indoor Air, Johns Hopkins University's Risk Sciences and Public Policy Institute and the Environmental Law Institute in Washington, DC, are developing the case studies to explore the common goals of the two approaches, illustrate the real-world challenges confronted by risk managers, and highlight the opportunities for harmonization.

Over the past two decades, risk-based environmental decision making has become the dominant public policy tool for managing a wide range of risks. The interaction of changing societal needs, public values, resource limitations, and advances in science has provided the substrate for a complex web of legislative and regulatory risk management strategies. Progress in risk harmonization must address legitimate concerns of both chemical and radiation risk managers and stakeholders. Harmonization should not be interpreted as a "one size fits all" regulatory straightjacket, nor should it be perceived as an approach to deregulating or relaxing current environmental standards for chemical risks. The Annapolis conference brought together the two worlds of radiation and chemical risk managers and underscored their expanding common ground. With ever-increasing regulatory mandates, and advances in risk assessment, this common ground should continue to grow to inform discussions and enhance public health and welfare.

APPENDIX: ANNAPOLIS WORKSHOP PARTICIPANTS AND AFFILIATIONS

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