A Multidisciplinary Paradigm and Approach to Protecting Human Health and the Environment, Society, and Stakeholders at Nuclear Facilities-12244

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ABSTRACT

As the Department of Energy (DOE) continues to remediate its lands, and to consider moving toward long-term stewardship and the development of energy parks on its industrial, remediated land, it is essential to adequately characterize the environment around such facilities to protect society, human health, and the environment. While DOE sites re considering several different land-use scenarios, all of them require adequate protection of the environment. Even if DOE lands are developed for energy parks that are mainly for industrializes sections of DOE lands that will not be remediated to residential standards, there is still the need to consider the protection of human health and the environment. We present an approach to characterization and establishment of teams that will gather the information, and integrate that information for a full range of stakeholders from technical personnel, to public policy makers, and that public. Such information is needed to establish baselines, site new energy facilities in energy parks, protect existing nuclear facilities and nuclear wastes, improve the basis for emergency planning, devise suitable monitoring schemes to ensure continued protection, provide data to track local and regional response changes, and for mitigation, remediation and decommissioning planning. We suggest that there are five categories of information or data needs, including 1) geophysical, sources, fate and transport, 2) biological systems, 3) human health, 4) stakeholder and environmental justice, and 5) societal, economic, and political. These informational needs are more expansive than the traditional site characterization, but encompass a suite of physical, biological, and societal needs to protect all aspects of human health and the environment, not just physical health. We suggest a Site Committee be established that oversees technical teams for each of the major informational categories, with appropriate representation among teams and with a broad involvement of a range of governmental personnel, natural and social scientists, Native Americans, environmental justice communities, and other stakeholders. Such informational teams (and Oversight Committee) would report to a DOE-designated authority or Citizen's Advisory Board. Although designed for nuclear facilities and

energy parks on DOE lands, the templates and information teams can be adapted for other hazardous facilities, such as a mercury storage facility at Oak Ridge.

INTRODUCTION

As the DOE continues to remediate its lands, and to consider moving toward the possible development of energy parks on its industrial, remediated land, it is essential to adequately characterize the environment around such facilities to protect society, human health, and the environment. While energy parks are being considered mainly for the industrialized sections of Department of Energy (DOE) lands that will not be remediated to residential standards, there is still the need to consider the protection of human health and the environment. Protection of human health and the environment, however, is not just about protecting the health of specific humans and human populations, but protecting the social, cultural, political and economic environment of people and their communities. Similarly, protecting environmental health is not simply preventing death or disease, but of maintaining the sustainable protecting of ecosystems and their component parts. Thus, we are suggesting that the usual phrase, protecting human health and the environment, around DOE sites and other facilities should be broadened to include a wider concept of environmental protection and of human health protection. Both should include all those aspects required to sustain all aspects of individual, population, and community well-being.

The goal of sustainable human and societal health, and of ecosystem integrity, health and sustainability, requires that all members of society are engaged, involved and considered in making relevant decisions about remediation, environmental protection, and the protection of human health, well-being, and safety. The inclusion of governmental agencies (state, federal, local), regulators, Tribal governments, natural and social scientists, and other stakeholders in decisions involving nuclear facilities is becoming more important as the Nation examines increased use of nuclear energy [1]. Stakeholder involvement occurs at many levels [2-4], and the outcomes of such involvement in remediation and restoration, environmental protection, and nuclear energy policy vary. Stakeholder involvements in environmental decision-making leads to better environmental decision-making [5], as well as to decision-making that is more cost-effective and less time-consuming (see examples in [1]). In the past, a top-down approach to decision-making has led to laws and regulations aimed at human health and environmental protection, this approach may no longer work, and both the science and eventual solutions may require more broadly based characterizations of the contaminants, resources at risk, and more broadly based stakeholder.

Both the future of nuclear power, and the remediation and deposition of nuclear waste are related to public opinion about catastrophic accidents [6]. Three Mile Island (1979), Chernobyl (1986) and the recent even at the Fukushima plant in Japan (2011) all affect public opinion about the storage of nuclear wastes, the cleanup of nuclear wastes at DOE sites remaining from the Cold War, and the protection of human health and the environment [7]. Given that the full human and ecological health consequences of the Chernobyl accident will not be known for many decades [8-10], it is no wonder that the public (and here we all are public) is concerned about protecting society, human health, and ecological health. The recent even at Fukushima incident [11-12] has re-awakened considerable concern about nuclear facilities and nuclear energy, and about being prepared (or unprepared) for very low probability/high consequence events, such as the earthquake, tsunami [13], and loss of power at the Fukushima plant. It is a question of how confident society must be that such disasters won't happen again.

There are still over 500 Soviet-designed nuclear power reactors, and they have been described as "bombs temporarily generating electricity"[14]. The Department of Energy (DOE) faces the greatest cleanup mission in the Unites States, mainly from nuclear waste [15-17]. The DOE has present or former sites in 34 states; some of the sites cover hundreds of square miles [18-20] and many of the sites include valuable and rare natural resources [21-28]. For a full range of stakeholders, regulators, and governmental agencies (Federal and Native American) to be involved in decision-making with respect to cleanup of existing nuclear facilities, protection of all nuclear facilities (DOE and commercial nuclear power plants), and protecting human health and the environment around existing and new nuclear facilities, all concerned need to have the same technical information, speak the same language, and respect the divergent views and perspectives of all involved. More decision tools are essential for appropriate siting of new facilities, and for management of contaminated sites [29].

Building on our previous work [30-31] we develop templates of informational needs to protect human health and societies, and eco-receptors at DOE sites. The Nuclear Regulatory Commission has responsibility to conduct environmental assessments and licensing of commercial nuclear facilities, and they have developed impressive environmental assessment tools to do so [32-34]. However, we address DOE-specific issues and suggest an approach to address the informational needs to protect human health and the environmental in a broader context, in a manner that allows transparency for a broad range of stakeholders. That is, the resultant series of templates would allow stakeholders to assess relevant information easily.

METHODS

The development of overall approach, and these templates, emerged from our work at various DOE sites, and builds on previous work [30], taking into account the need for extensive stakeholder participation [1]. Together, the authors have worked some 15-20 years at various DOE sites, considering the factors that are important for protecting human health and the environment, which to the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) means the full inclusion of a range of stakeholders that includes the region and Nation, as well as site neighbors and interested and affected parties. To this end, we have designed a matrix of information needs that will ensure that human health and ecosystems are protected in both industrialized parts of the DOE complex, as well as any future land uses, such as energy parks.

We present an ecological, multidisciplinary approach to gathering the information needed to establish baselines, site new energy facilities in energy parks, protect existing nuclear facilities and nuclear wastes, improve the basis for emergency planning, devise suitable monitoring schemes to ensure continued protection, provide data to track local and regional response changes, and for mitigation, remediation and decommissioning planning. These informational needs are more expansive than the traditional site characterization, but encompass a suite of physical, biological, and societal needs to protect all aspects of human health and the environment, not just physical health. Although designed for remediation on nuclear facilities and for the siting of energy parks, the templates and information teams can be adapted for other hazardous operations, such as considerations of safety around a mercury facility planned for Oak Ridge.

Overall approach: Informational teams

The DOE has a number of advisory boards (e.g. Citizens Advisory Boards), technical teams (both external and internal), contractors, and DOE personnel that oversee various aspects of environmental protection. Such protection, however, often involves human safety analysis, performance measures, protection of human health and the environment, and sometimes specific environmental justice communities, such as Native Americans. However, there is not general overall protection of the full spectra of ecosystems and ecological health, and human health and well being, where the latter includes culture, societies, economic development, stakeholders, and environmental justice. Clearly all of these are important to DOE and its regulators, but informational needs for all aspects of the site are difficult for the public or public policy makers to find in one place.

The basic paradigm we suggest includes five areas: 1) Geophysical, sources of contamination, fate and transport, and barriers, 2) Biological systems, including ecosystems and their component parts, 3) Human health and well-being, 4) Stakeholder and Environmental Justice communities and issues, and 5) Societal, cultural, economic, and political aspects and issues. Each of these teams would have a Chair, one or more scientists from DOE, DOE contractors, governments (state and federal), and universities (representing necessary disciplines), appropriate regulators, and relevant stakeholders. Teams should be dedicated to the particular topic, and not representative of the full spectrum of disciplines and ideas (Figure 1).

For example, the geophysical, sources, fate and transport team should have scientists that can address the relevant issues within these topics, as well as relevant regulators and stakeholders. The stakeholder and environmental justice group would contain relevant scientists, as well as appropriate social scientists, environmental justice groups (appropriate for the particular DOE site). For some DOE sites this would include Native Americans (e.g. Hanford, INL, Los Alamos), for others minorities it might include African Americans (e.g. SRS, Oak Ridge) or Hispanics (e.g. Los Alamos), for others it might be economically-challenged (perhaps all sites). For this team it is particularly critical to involve local communities in identifying particularly relevant stakeholder and environmental justice communities.

We also suggest that a Oversight Committee or Board should be established that reports to a suitable DOE entity or Citizen's Advisory Board that includes a wide range of stakeholders, as well as at least one technical person from each of the informational teams. It would be the responsibility of this group to eliminate undue overlap among the teams, identify data gaps that are not being filled by any other team, and ensure continued re-evaluation and continued iteration of informational needs and new data sources. While the information gathered by the different teams will overlap to some degree, the Oversight Committee will address the need for such overlap, and any conflicts between teams. The Oversight Board would make sure that the appropriate expertise is available for each team, and that they develop the templates appropriately (Figure 1).

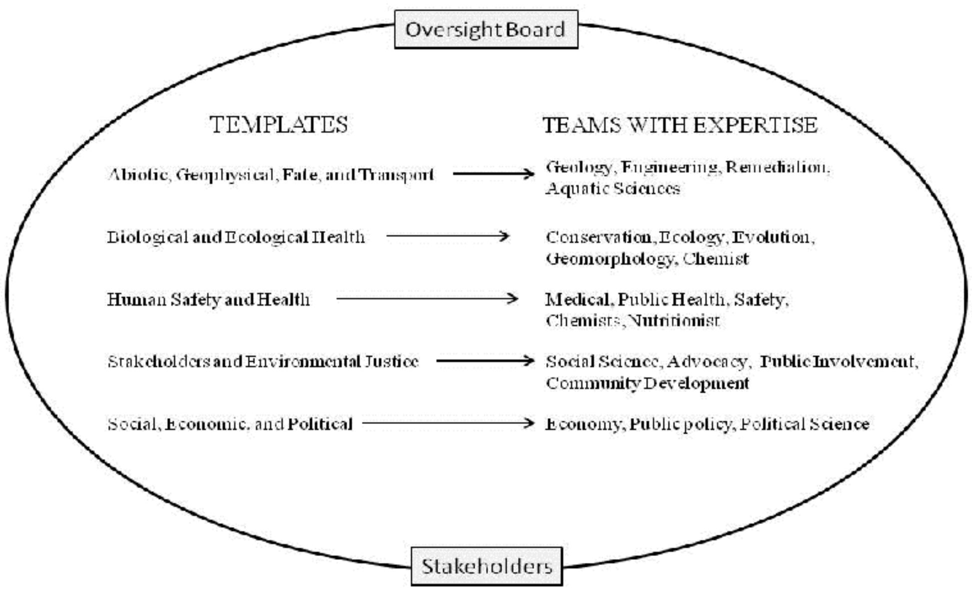

Fig. 1.Suggested paradigm of informational needs for all aspects of the DOE site.

Informational gathering by teams

The Informational Teams should include: 1) Geophysical, sources, fate and transport, 2) Biological systems, 3) Human health, 4) Stakeholder and Environmental Justice, and 5) Societal, Economic, and Political. The information to be derived by each team should include some broad categories of data (see below, [30-31]), but also site-specific information needs of interest to site neighbors, interested and affected communities, and the broader community.

We envision the teams as having a specific task related to, for example, new siting of a nuclear facility, decommissioning or decontamination of specific buildings or facilities, establishment of baselines or monitoring schemes, or considerations of future land uses. However, the teams could be fluid in the sense that they address new challenges and site uses as they evolve at the site, or in response to DOE headquarters, Congress or public needs. For example, the recent Fukishima accident identified additional geophysical conditions that require addressing [12]. Further, team members may cycle on and off, depending upon disciplinary needs and site issues.

Team responsibilities would include: 1) problem-definition, 2) statement of specific objectives, 3) delineating the questions or topic of information needed, 4) defining the data needed, 5) refining the data needed for the templates described below, 6) adding additional data gaps, 7) describing how this information will be used, or why it is needed, 8) designating responsible parties for obtaining the information, and 9) assembling and analyzing the information (or designating others to do so). The latter responsibility may mean that each team has an appropriate statistician as part of the team or available.

Geophysical, sources, fate and transport

The basis of understanding potential hazards and associated risks at contaminated sites, including those of the DOE, is characterizing the geophysical environmental at the site, around the site, and in the region. While the geophysical environment provides the background for potential risk, the sources of radiological or chemical contamination (the hazard), in concert with fate and transport pathways leads to the risk of consequences for humans and ecosystems. Understanding the geophysical environment and the likelihood of a single or multiple geological events (earthquake, tsunami, earthquake + tsunami, earthquake + hurricane) is critical for setting safety standards around facilities. As Tilford [35] mentioned, the four main requisites for a nuclear facility are "water, water, water, water", which suggests that this aspect is one requiring extensive assessment and monitoring, both for chronic conditions as well as potential catastrophic events [14].

We suggest several main categories of information are required for understanding the geophysical, sources, and fate and transport (Table 1). Examples for each type of informational needs are also given. The specific features within each category vary, and depend upon site-specific conditions. Each of these categories can be expanded, depending upon the local environment.

Table I. Geophysical, sources, and fate and transport information necessary to protection human systems and ecological systems at DOE sites [30-31].

TYPE	EXAMPLE
Abiotic features	Soil, bedrock Water pathways (streams, rivers) Weather (wind, rainfall, temperatures) Location relative to coasts
Contaminant sources	Types Amounts and locations Release sites
Transport Pathways	Rivers, streams Bedrock types Biotic transport (birds, mammals, etc)
Natural barriers	Bedrock types preventing movement Lack of rainfall Sediment, soil chemistry that affects transport
Engineered barriers	Containment types

	Covers or other protection
Institutional barriers	Fences to prevent access Consumption advisories
Time constraints	Movement times
Spatial constraints	Space between source and receptors
Conceptual models	For examining sources, transport and receptors

Biological systems

The biological system includes the living components of the system, and includes all microbes, invertebrates, and vertebrates, including people. However, as is traditional, a separate section on human health and well-being follows. The main categories for examining ecosystems and their component parts are shown in Table 2. As with geophysical systems, the actual features in each one may vary, and are site-specific. DOE sites often have valuable and unique ecological species and communities [22-25, 28], and they provide the goods and services that humans rely upon [36-37].

The important point to remember is that biological systems can be divided into different levels of consideration, including individuals, species, populations, communities, ecosystems, and landscapes (Table 2). Each level has features that are important to assess when examining the possible effects of contamination (given here as examples), and usually at least one or two indicators are selected for environmental assessment and long-term monitoring.

Table II. Biological information necessary to protection human systems and ecological systems at DOE sites [30-31, 38-40]

TYPE	EXAMPLE
Species, populations and communities	Threatened and endangered species Species diversity Population trends On-site and off-site differences
Habitats, biomes, and unique assemblages	Unique habitats (pine barrens) List of habitats and biomes Acreage of each type
Structure and function of ecosystem	Biochemical cycling Nutrient cycling Types of herbs, shrubs, trees Food chains and webs Invasive species

Landscape features	Patch size and shapes Corridors and pathways On-site and off-site habitats and species
Regional features	Build-out Ownership and protected habitats
Risk assessments	Available species and group assessments for different chemicals or combinations
Conceptual models	Models for particular species or assemblages

Human health and safety

While humans are only one receptor within ecological systems, they are the key species in terms of influencing the other components in ecosystems, and self-interest. Human health and safety are key components of the well-being of individuals, groups, communities and societies. While the different levels of ecological organization (individuals, populations, communities) are also important for examining human health, we are also far more interested in individual health and well being, and thus in levels below the individual, such as organ systems, cellular and molecular. Thus, for human health and well-being, many indicators are at the organ and cellular level. Similarly, we are much more interested in how radiation and other contaminants affect community dynamics, neighborhoods, and societies than merely whether population levels are increasing, decreasing or stable (often the key characteristic for eco-receptors). Environmental impact assessments often fail to mention human health [41], although the initial laws and regulations were aimed at protection human health.

Human health and safety can be divided into workers, site neighbors, and regional populations, each with its own hazards, exposure pathways, and risks [42]. Similarly, risks may be subdivided into more categories, such as a) radiation risk produced by radioactive materials; b) chemical risk produced by radioactive materials; c) plant conditions which affect the safety of radioactive materials and thus present an increased radiation risk to workers, and d) plant conditions which result in an occupational risk, but do not affect the safety of licensed radioactive materials [43]. The last category includes many of the same safety and exposure hazards that might occur in other industrial facilities, such as falls and other accidents.

As with ecological health, there are a number of categories (or types) that need to be considered, and depending upon the individual DOE site and its conditions, the parameters within each category might differ (Table 3).

Table III. Human health and safety information necessary to protection human systems and ecological systems at DOE sites [30-31, 38, 44].

TYPE	EXAMPLE
Population Characteristics	Density of industrial/recreational Demographics
Sensitive Populations	Percent of women in child-bearing age

	Percent of children Potential exposed groups
Sensitive Communities	Environmental justice communities Unequal distribution of people locally
Exposure Pathways	Water usages and sources Consumption of local herbs, plants, fish and game Presence of gardens
Public health characteristics	Response information Health facilities Evacuation routes
Risk assessments	Availability of risk assessments for different radionuclides or contaminants, for different target populations
Models	Models of exposure pathways and routes

Stakeholder and Environmental Justice

One aspect of environmental assessment usually not considered separately are stakeholders, and environmental justice communities. Yet, within the context of radiological and contaminant exposure, and the protection of human health, it is critical to do so. This topic will receive sufficient attention only if it is specifically examined, and has a team devoted to these issues, and trained to do so. While the team itself may be heavily weighted toward governmental or other organizations, the interests of a far wider group are required.

A critical phase of any environmental assessment is stakeholder identification, which involves making sure that all interested and affected parties and organizations are identified and involved. This often involves a pyramid scheme whereby each new addition might suggest others not previously involved. Further, identification of environmental justice communities within the overall region, especially for site neighbors, is a critical step in environmental assessment as this group often is exposed to the negative aspects of a site, without the benefits. Further, the inclusion of low income, minority, Native American and other environmental justice communities is mandated by Executive Order 12898, which established the necessity for federal agencies to identify and address disproportionately high adverse human health or environmental effects to minority and low-income populations.

Criteria for success of stakeholder and environmental justice community involvement include: 1) obtaining input early and often, 2) involving the public throughout the planning process, 3) having face-to-face discussions, 4) fostering equality among experts, administration officials, and other stakeholders, and 5) developing sufficient information tools that are help visualize impacts, uncertainties, and trade-offs, as well as including stakeholders in the research itself or information gathering phase [45]. While including stakeholders may be time-consuming and expensive, the majority of cases provide evidence that stakeholders improved environmental decisions [1,3,46-47].

As with the other informational templates, specific indicators should be site-specific and relate to the local conditions and communities. The types of information, with examples, are given below (Table 4). This template encompasses an area often not considered when conducting environmental assessments, and we expect that site-specific types will be developed.

Table IV. Stakeholder involvement and environmental justice information necessary to protection human systems and ecological systems at DOE sites [30-31].

TYPE	EXAMPLE
Site-specific information	Derived from tables 1-3
Schedule of remediation or other activities	Time frames for actions, particularly those involving transport of hazardous material
Stakeholder involvement plans	Written plans from DOE and contractors Written plans from stakeholder groups or environmental justice communities List of key points of input to decisions
Information systems	Availability of types of information Availability to managers and technical support Methods of dialogue
Environmental Justice communities	Maps showing spatial distribution Maps and percent dual vulnerability (low income + minority, low income + pregnant, minority + high percentage of children). Differential access to information
Long-term monitoring	Monitoring plans for human health indicators Monitoring plans for eco-receptors of concern On-going information systems

Societal, economic, and political

Human health assessors with respect to radiological and chemical contamination are just beginning to include the full range of societal, economic and political considerations into their assessments. This is another critical aspect of assessment because it influences attitudes, perceptions, and well-being of people and their communities, which in turn directly affects human health defined more narrowly. It does, however, pose a more difficult task than the other categories because the direct links to human well-being may be less clear. This category is also more dependent upon site-specific information, and information on these aspects often have a great deal of influence on site selection, site development, and long-term stewardship on the site.

The “not in my back yard” (NIMBY) concept symbolizes public sensitivity and resistance to the siting of factories, chemical plants, major highways, low-income housing, and energy facilities near the public [48], especially for nuclear facilities or waste sites [7]. This led to “not in anyone’s backyard,” “not in my term of office,” and finally to “build absolutely nothing anywhere near anyone” [16-17]. It is thus extremely important to include this aspect in environmental assessment to protect human health and the environment right from the start of any project (whether it be site selection, remediation, or determinations of future land use).

Possible indicators (types) and aspects to examine are given in Table 5. While some examples of each type are given, these also will depend upon site-specific conditions.

Table V. Informational needs for societal, economic and political aspects of environmental assessment [7].

TYPE	EXAMPLE
Facility characteristics	From Tables 1-4
Vulnerabilities	Sensitive human populations Environmental justice communities Sensitive biotic communities or species Geophysical conditions Potential catastrophic events Local demographic vulnerabilities
Economic	Construction/operating costs On-site economies Effect on infrastructure
Regional Planning	Local and regional economic plans Local and regional spatial plans/zoning
Geo-political	Spatial aspects of demographics Build-out Legal conditions Changing political conditions

DISCUSSION

Above we have proposed a number of templates that would provide the public and others with the information needed to make sound decisions about environmental management at DOE sites, as well as at other contaminated sites. Although the templates are designed to protect human health and the environmental around sites, they are more broadly based to consider societal needs as well.

We emphasize particularly that both the overall categories within each template, as well as the examples are site-specific, which illustrates the importance of having teams that particularly address each template area. Each site will want to use these as a guideline to develop their own templates and indicators of health and well-being. Further, as the site changes, so will the indicators. Thus the teams that continue with the process may require new personnel from time to time to address new issues. For example, the recent event in Fukishima clearly demonstrates the importance of considering multiple geophysical stressors combined with infrastructure failure (loss of power). Further, it suggests that the location of sites be given more consideration (e.g. location near coasts with possibilities for severe storms, tsunamis, hurricanes). These are suggestions for an approach that should be broadened for each site, in the templates, indicators, and team members.

Finally, the approach we suggest has not been implemented at any site, although elements have been used at several sites, both as part of formal EIS procedures, and to satisfy Nuclear Regulatory Commission environmental reports. We suggest that the broader approach suggested in this paper will provide information to a broad range of stakeholders (including governmental, private and Tribal organizations). There are many different situations where having a list of indicators will be useful, including siting of new nuclear facilities, re-licensing of existing nuclear facilities, siting of any chemical facilities, developing monitoring plans for any existing or future facilities, considerations of remediation and restoration, and for development of long-term stewardship plans.

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