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Feature article

Rethinking human health impact assessment

A. Steinemann*

City Planning Program, Georgia Institute of Technology, Atlanta, GA, USA 30332-0155

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Abstract

Most EIA programs around the world require the consideration of human health impacts. Yet relatively few EIA documents adequately address those impacts. This article examines how, why, and to what extent health impacts are analyzed in environmental impact assessments in the U.S. An empirical study of 42 environmental impact statements found that more than half contained no mention of health impacts. In the others, health impacts were analyzed narrowly, if at all, using risk assessment to quantify the carcinogenic potential of a single substance over a single generation. This analytic focus overlooks other significant morbidity and mortality risks, cumulative and intergenerational effects, and broader determinants of health. This article investigates these problems and provides recommendations to improve human health impact assessment, using strategic environmental assessment, qualitative health data, health outcomes in addition to cancer, and a precautionary approach to risk.

Keywords: EIA; Human health risk assessment; Precautionary principle

1. Introduction

Humans affect the environment, and the environment affects humans. Recognizing this interconnection, the environmental impact assessment movement has sought to promote more environmentally sound and informed decisions for the sake of human welfare. Meanwhile, the public health movement has long considered the environment to be a primary determinant of human health. So it's not surprising that most EIA programs around the world encourage the consideration of human health impacts

* Tel. +1-404-894-6491; fax +1-404-894-1628.
E-mail address: anne.steinemann@arch.gatech.edu (A. Steinemann).

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(Sutcliffe 1995). What is surprising, however, is that EIA documents often omit health impacts.

Even though, historically, the environment and human health have been linked in concept, they have been paradoxically separated in EIA practice in the U.S. Instead of analyzing health impacts, EIAs often just refer to an environmental standard. If health impacts are analyzed, the focus is typically narrow: a single health outcome (cancer), due to exposure to a single toxin, over a single lifetime, represented by a single number, calculated by a quantitative risk assessment methodology (e.g., NRC 1983; EPA 1984). But this focus misses a range of other significant health concerns, such as endocrine disruption (Colborn et al. 1994), neurotoxicity (Silbergeld 1990), chemical sensitivity (Ashford and Miller 1998), non-toxicological social impacts (Burge and Vanclay 1995), intergenerational genetic damage (Fan et al. 1995) and exposures to *combinations* of chemical, biological, or physical agents—the types of exposures that humans face.

This article investigates the role of EIA for reuniting the environment and human health, for preventing and reducing significant health risks, and for improving human health impact assessment (HHIA). It begins with an overview of human health impact assessment within EIA. It follows with the research approach and results from analyses of 42 environmental impact statements from the U.S. Then, drawing upon the empirical results and interviews with environmental and public health professionals, the article analyzes why human health impacts are often neglected in EIAs. Finally, the article discusses problems with traditional methods of HHIA, and provides recommendations to improve both HHIAs and our understanding of connections between environmental systems and human health. This understanding has an added benefit: showing how changes in the environment affect human health can create support for efforts to protect and promote environmental quality.

2. Human health impacts and environmental impact assessment

2.1. Evolution of human health impact assessment within EIA

The legislative origins and implementation of EIA in the U.S. provide insights into the role of human health impact assessment. Environmental impact assessment is required in more than half the countries around the world (Canter 1996). The U.S. National Environmental Policy Act of 1969 (NEPA) provided one of the earliest sets of EIA requirements, and many countries modeled their requirements after NEPA. NEPA grew from public concern that federal projects were significantly harming the environment and human health. This concern is reflected in the statute. Substantively, NEPA encourages "productive and enjoyable harmony between man and his environment" and "efforts which will prevent or eliminate damage to

the environment and biosphere and stimulate the health and welfare of man."[1] Procedurally, NEPA requires a detailed report—an environmental impact statement (EIS)—for "major Federal actions significantly affecting the quality of the human environment."[2] Thus, NEPA calls for the assessment of human health impacts if they are significant and result from the impacts of a major federal action on the environment.[3]

The first decade of EIAs, the 1970s, focused on biophysical impacts, such as air, water and land impacts. Subsequent regulatory guidance (CEQ 1978) clarified and broadened the required scope of impacts to include, for example, cultural, social and health impacts. But the guidance still emphasized biophysical impacts, "focusing on the environment rather than people" (Mauss 1994), as did the resulting EISs. Notably, even if EIAs excluded health impacts, the EISs were, in general, legally acceptable.[4]

In the second decade, the 1980s, EIAs gradually started to address impacts other than strict biophysical impacts, in accordance with CEQ regulatory guidance. Within the normative EIA literature, the term "environment" grew to imply not just the biophysical environment, but also social, cultural, and human health considerations. Similarly, in the public health arena, the term "health" came to imply not just physical health, but a general state of societal well-being. However, health impact assessments were usually limited to quantitative risk assessments of the carcinogenic potential of single toxins. Meanwhile, a renewal in public health, coined the new public health, placed increased importance on the physical and social environment as major determinants of human health. Adding to the momentum, a World Health Organization (WHO) meeting in 1986 recommended that the health component of EIA include not only disease-related effects but also all impacts that might change the well-being of humans (WHO 1987). But this recommendation was not reflected in EIA practice in the United States, and health impacts continued to be slighted.

During this past decade, several studies have evaluated NEPA, identified

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[1] Sec. 2 [42 USC § 4321].

[2] Sec. 102(C) [42 USC § 4332]. "Significance" is determined by both context and intensity, 40 C.F.R. §1508.27 (1978). "Human environment" is interpreted broadly to include the natural and physical environment and the relationship of people with that environment, 40 C.F.R. §1508.14 (1978).

[3] Court cases have characterized public health impacts as "significant" under NEPA. See *Audubon Society of Central Arkansas v. Dailey*, 977 F.2d 435 (8th Cir. 1992); *Public Service Co. of Colorado v. Andrus*, 825 Suppl. 1495 (D. Id. 1993). Earlier cases pronounced public health as part of the "human environment." See *Citizens Against Toxic Sprays v. Bergland*, 428 F. Supp. 908 (1977); *National Pork Producers Council v. Bergland*, 484 F. Suppl 540 (S.D. Iowa 1980); *Metropolitan Edison Co. v. People Against Nuclear Energy*, 460 U.S. 766 (1983).

[4] Agencies were, however, required to consider uncertain and incomplete information through "worst case analysis" 40 C.F.R. §1502.22 (1978). A 1986 amendment replaced "worst case analysis" with the need to assess incomplete or uncertain information only for "reasonably foreseeable significant adverse effects on the human environment" 40 C.F.R. §1502.22 (1986). See Harvey (1990) for a discussion of health risk assessment under the CEQ regulations.

trends and sought to improve its implementation (Clark and Canter 1997; CEQ 1997, 1995; Porter and Fittipaldi 1998; Welles 1997). One growing trend is the application of EIA to earlier and broader levels of decision making, namely Strategic Environmental Assessment (SEA).[5] SEA has been suggested as a framework for HHIA because of SEA's broader temporal and spatial scale, ability to consider cumulative impacts, early integration with agency planning and emphasis on concept and scope rather than data-intensive analyses (Therivel and Partidário 1996; BMA 1998). Yet, methods to integrate HHIA into SEA are still needed (Banken 1988).

2.2. Prior studies of HHIA in EIA

The research reported in this article builds upon previous studies that have also examined, and lamented, the gaps between environmental impact assessment and human health. Special issues of *Environmental Impact Assessment Review* [1990 10(40), and 1994 14(5/6)] provide a valuable collection of articles that address this concern. In these issues, environmental and public health professionals identify challenges in bridging their disciplines with policy, regulation and methodology. For HHIA methods, several sources provide guidance. A recent publication by the British Medical Association (1998) presents a detailed framework for conducting HHIA within EIA. An article by Martin (1986) compiles and discusses methods for health impact assessment. An early work by Lowrance (1975) outlines a rational decision-making process of HHIA, which resembles the risk management framework later published by the National Academy of Science (NRC 1983). And the field of risk assessment provides methods for human health impact assessment,[6] even though risk is also often neglected in EIAs (Ortolano and Shepherd 1995).

Only a few prior studies have empirically examined human health impact assessments in EIAs. Arquiaga et al. (1992) reviewed 39 EISs prepared in the U.S. for their assessment of health impacts. The study found that one-third assessed them using a risk assessment methodology, one-third assessed them in a cursory way and one-third did not assess them at all. Canter (1990), in a review of 11 EISs prepared in the U.S., found only four that addressed health impacts, even though all projects dealt with potentially significant health impacts. The British Medical Association (BMA 1998) reviewed 39 EISs, produced in the U.K. between 1988 and 1994, and found that 72% (28) of them did not discuss human health or health-related issues. Only one of those EISs made a direct reference to human health. Go (1987), in a study of 13 international EIAs dealing with carcinogenic risks, found only one EIA that contained a section on health impacts.

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[5] Strategic environmental assessment is EIA for strategic decisions: policies, plans, and programs (Therivel and Partidário, 1996).

[6] The literature on risk assessment is voluminous. Carpenter (1995) provides a valuable overview of risk assessment in EIA.

These prior studies show a general lack of attention to human health impacts. They also revealed inconsistent and unclear definitions. At this point, definitions are provided to help clarify terms used throughout the rest of this paper.[7]

2.3. Definitions

Environmental impact assessment is a process: identifying, predicting, evaluating and, ideally, monitoring potential impacts on the environment. An EIA typically includes these types of impacts: air, water, land, noise, visual, ecological, biological, social, economic, transportation, environmental justice, aesthetic, cultural and human health. Of these, social impact assessments may come the closest to considering a broader range of potential health impacts (Gangon et al. 1993; Craig 1990). The EIA process in the U.S. results in a product: a preliminary analysis and report, an Environmental Assessment (EA), to determine whether the action will have potentially significant impacts on the quality of the human environment[8]— and, if the potential impacts are deemed significant, a more extensive analysis and report, an Environmental Impact Statement. Because EAs do not usually cover health impacts, the research reported in this article focuses on EISs.

Health, as defined by the World Health Organization (WHO 1948), is a "complete state of physical, mental and social well-being, and not merely the absence of disease." Public health has been defined as efforts to protect, promote and restore the people's health (Last 1988). The new public health movement, emerging from the 1980s, stresses the importance of health promotion, acting on the collective determinants of public health, such as physical and social environments. This conceptual shift supported the field of environmental health assessment, which considers aspects of human health, including quality of life, that are determined by physical, biological, chemical and social factors in the environment (UK 1996).

Human health impact assessment, also referred to as health impact assessment, is a process to identify, predict and evaluate the human health impacts of a proposed policy, plan, program or project. A purpose of health impact assessment is to alert decision-makers to possible health impacts that could be reduced (WHO 1995). Classifications of health impacts include

[7] Definitions vary among countries and among research disciplines. These definitions are to provide context for this paper's discussion, rather than to declare unanimously agreed-upon meanings.

[8] 40 C.F.R. §1508.9. If the action will not have potentially significant impacts, the agency issues a "Finding of No Significant Impact" as a result of the EA, and can proceed with the proposed action. Alternatively, if the action will have potentially significant impacts, and the agency can demonstrate ways to mitigate those impacts to a less-than-significant level, then the agency can issue a "Mitigated FONSI," avoid the full EIS, and proceed with the proposed action. Finally, if the action is a type that normally requires an EIS, the agency can bypass the EA and commence the EIS.

causes or effects or both (BMA 1998; Birley 1995; Arquiaga et al. 1992). In terms of causes, sources can be chemical (e.g., toxic emissions from a factory), biological (e.g., pathogens in wastewater) and physical (e.g., construction noise). In terms of effects, health impacts can include communicable diseases (e.g., bacterial infections), non-communicable diseases (e.g., asthma triggered by air pollution), illness from chemical exposures (e.g., pesticide poisoning), injury (e.g., traffic accident) and psychological effects (e.g., stress due to relocation).

3. Human health impacts in environmental impact statements: an empirical study

3.1. Research approach

A goal of this research was to investigate how, why, and to what extent EIA addressed human health impacts. To do that, a two-phase study was performed.[9] The first phase involved a content analysis of 42 environmental impact statements produced in the U.S. under NEPA.[10] The EISs were selected according to two main criteria: the proposed actions were likely to have significant health impacts; and the proposed actions covered a range of agencies, time periods (from 1979–1996), geographic locations and types of impacts. For each EIS, the entire document was reviewed for any mention of "health impact," "human health," or "public health." Then, the second phase involved a contextual analysis of the EISs, which included site visits and interviews with individuals involved in the EIA process.[11] This provided a richer understanding of the circumstances surrounding the EIA, especially the factors that influenced how and why health impact assessments were conducted.

3.2. Research results

The conclusions were striking, but not surprising. Health impacts were consistently overlooked or superficially addressed in the environmental impact statements. The research findings and implications for health impact assessment are discussed below.

3.2.1. Health impacts generally not mentioned, and analyses rarely provided

More than half (62%) of the EISs (26/42) contained no mention of a health impact. In the other EISs (38%, or 16/42), health impacts were

[9] The research was conducted over a period of 18 months, from January 1998 to June 1999.

[10] These EISs are provided in the list of references.

[11] These individuals included EIS preparers, environmental scientists, public health professionals, agency officials, and stakeholders. Interviews were conducted both in person and over the telephone. In this article, "EIA analyst" will be used to refer to an individual involved in the EIA process. Interviews were conducted under conditions of confidentiality.

mentioned, but inadequately supported by analysis. For these other EISs (16/42) the assessments can be characterized as follows:

In 21% (9/42) of the EISs, the analysis of health impacts was only one sentence, such as, "The project is not expected to have adverse health impacts," "Health is a serious concern," and "The disruption of hazardous material sites during roadway construction can sometimes have a detrimental effect on surface waters, ground waters, soils, vegetation, wildlife and human health and welfare." Other one-sentence explanations cited statutes, for instance, "Neither federal nor state regulations will be exceeded," "The U.S. EPA has promulgated air quality standards," and "Air quality standards are designed to protect human health." One EIS did provide an additional explanation: "CO inhibits delivery of oxygen. Ozone is a tissue irritant and can damage agricultural crops. Due to these health risks, it is important to reduce vehicle emissions." None of these EISs provided supporting analyses, such as the increase in mortality and morbidity risks resulting from an increase in ozone concentrations.

In 17% (7/42) of EISs, health impacts were assessed in a section titled "Human Health." The length of these sections varied from one paragraph to several pages, but the scope of health impacts did not vary widely. All of these EISs focused on risks of cancer due to exposure to toxic and radioactive chemicals.

It should be noted that each of the 42 EISs, however, did address biophysical impacts, which have implications for human health, although only 16 of these EISs mentioned that health impacts could result from biophysical impacts.[12]

3.2.2. Focus on carcinogenic risks, rather than other mortality and morbidity risks

In the EISs that did address health impacts, the assessments focused on cancer risks of a single toxin. Quantitative risk assessment was used to estimate mortality risks from cancer, such as "The proposed project is not expected to have significant adverse effects on human health . . . since the total individual cancer risk is at the 1.8×10^6 level." Excluded from consideration were toxicological health effects other than cancer.

In addition, none of the 42 EISs addressed non-toxicological health

[12] Four EISs addressed health related to water quality (one sentence each) (J, U, O, JJ). One addressed a health problem due to mosquitoes and rodents (one sentence) (U). Two addressed impacts on social centers "receptors" and impact on the quality of life (one sentence each) (I, N). Three addressed impacts on health related to noise (one sentence) (I, J, M, Z). Three addressed health related to hazardous materials (one sentence) (I, J, W). One addressed relocation of peoples (one sentence) (M). Two linked pollution emissions to health (one sentence each) (J, N, QQ, YY). Two identified air quality standards (one paragraph for each EIS document) (N, W). One discussed effects of management activities on human health (FF). One EIS had five sections that addressed human health and risks to wildlife (LL). Six addressed cancer risks (Z, U, II, BB, LL, EE, JJ) in a section titled "Human Health."

impacts. The closest an EIS came to evaluating broader determinants of health was: "The quality of life . . . should not be dramatically impacted by the project." Notably, all of the transportation EISs contained a "safety" section. But, in general, the safety discussions did not relate back to human health. For instance, one EIS stated that a goal of the project was to "provide a safer, more efficient transportation system," and then referred to noise abatement standards rather than safety risks. Another EIS made the implicit assumption that the construction of additional roadway capacity would automatically increase safety.

3.2.3. Focus on a single cause, single effect and single generation, rather than cumulative impacts

None of the EISs attempted to analyze cumulative impacts. One EIS acknowledged that "the project would result in cumulative impacts" but provided no analysis. None of the EISs looked at intergenerational health risks.

3.3. Reasons for lack of attention to human health impacts

As these results suggest, human health impacts receive little if any attention in EISs. Using results from the second phase of the research, four main reasons emerged. The first concerns analytic complexity. Many factors complicate health impact assessment, such as multiple causes and multiple effects, lag times between causes and effects, uncertain mechanisms between causes and effects, indeterminate health outcomes and individual susceptibilities. Trying to analyze health impacts can be difficult and costly—an additional burden upon already complex analyses in EIA. Understandably, health impact assessments tend to focus on well-defined and perhaps more defensible analyses: lifetime population cancer risk of a single chemical, using risk assessment as a specific methodology for health. Trying to address other health impacts would be, as one EIA analyst said, "opening up a can of worms." As another EIA analyst put it, "Sure, my instincts tell me this [project] is going to have all sorts of health impacts. But how do I figure them out? If I can't measure them, I can't put them in the EIS."

The second, which is related to the first, concerns the lack of methods for human health impact assessment. Although risk assessment is widely applied, it can fail to capture significant human health impacts, both toxicological and non-toxicological. A more complete assessment of human health impacts would require a more complete understanding of causes and effects, possible health outcomes, associated risks and cumulative effects. But it may be nearly impossible to identify and predict the effects of an action on the health of current and future populations. And methods for quantifying health risks other than cancer, or even cancer risks of multiple toxins, are, as one EIA analyst said, "just not there yet." Cumulative effects characterize many health risks but, as another analyst said, "One could go on forever

trying to address cumulative impacts." Apparently, the lack of methods provides a rationale for the current state of human health impact assessment: Trying a new approach could subject an agency to greater costs, greater delays and greater uncertainty.

The third concerns legal requirements. Legislation (NEPA) does not clearly mandate human health impact assessment, and this contributes to the lack of incentives to conduct these analyses. Agencies' motivation to conduct EIA stems from "litigation, fear of litigation and fear of adverse publicity."[13] They are concerned with preparing a "legally bullet-proof document"—the EIS. Trying to address possible health impacts may only cast a wider liability net. As one EIA analyst said about HHIA, "The risk of doing them is greater than the risk of not doing them. If we do them, we open ourselves up and can get shot down. If we don't do them, it's a whole lot easier, and we probably won't get sued." Another EIA analyst indicated that public concern could prompt an agency to conduct a human health impact assessment, but that "if the public is not aware of a particular hazard, the lead agency probably won't address human health concerns."

The fourth is separation between the environment and human health, and the view that EIA applies to impacts on the environment, not on humans. As one EIA analyst said, "We'll spend all this time and money, figuring out the environmental impacts on a plant, but we won't bother to study the impacts on humans." As seen in this study, agencies tend to relegate human health to the purview of environmental regulations rather than integrate it with environmental planning. Consequently, when projects have human health concerns, EISs often provide a reference to relevant statutes, rather than provide analyses. This problem is compounded by the lack of communication between EIA analysts and public health professionals regarding potentially significant health impacts from environmental changes. One EIA analyst said, "We need a public health person on board to tell us what might be a red flag." Another analyst explained that EIAs tend to be one-directional—examining the impacts *of* humans *on* the environment, rather than impacts *on* humans *from* the environment—and that "we need to be looking at the interactions between the two."

4. Improving human health impact assessment

The results of this study suggest a need to take a harder look at human health impacts, and use EIA as an opportunity to prevent or reduce health risks. It's not enough to say, "Well, just do the analyses." The needs are more than analytic. And more analyses do not necessarily mean better

[13] Ray Clark, current Principal Deputy Asst. Secy. of the Army, former Associate Director CEQ, June 28, 2000, personal communication.

decisions. What is needed is a rethinking of human health impact assessments, and the ways they can improve environmental decision-making.

Recognizing significant health impacts—and sources of health impacts—is a first important step. Health impacts are more than just a single number representing a single cause and single effect over a single generation. Yet this is the current focus of health impact assessments. A second important step is to understand why health impact assessments are neither frequently conducted, nor easily improved. With this in mind, these conclusions will discuss not just what should be done, but what reasonably could be done to improve human health impact assessments in EIA.

4.1. Develop and screen alternatives based on potential health impacts

Because agencies lack methods and incentives to conduct HHIA, these analyses may never be conducted. So this places all the more importance on the alternatives, which are considered the "heart of the EIS" (CEQ 1987). The earlier that health considerations enter the decision-making process, the easier and more cost-effective it can be to prevent and mitigate future adverse impacts (Steinemann 2000). Thus, it may be more feasible for agencies to incorporate health concerns at the alternatives development[14] stage, rather than to rely on subsequent analyses and mitigations. Also, the choice of strategic-level alternatives (for policies, plans and programs) is critical because it establishes a decision pathway that determines future project-level alternatives.

4.2. Address sources of health impacts, rather than just the symptoms

That is a goal of EIA: to be a proactive planning tool, rather than a reactive remedial tool. Yet both the fields of health and the environment tend to focus on symptoms rather than sources. For instance, because health professionals often receive inadequate training in occupational and environmental health (Hu 1994), they may overlook possible environmental sources for patients' complaints. And this can lead to even greater health risks. For instance, an individual exposed to indoor air pollutants could experience symptoms similar to the flu. Misdiagnosed, and given decongestants and antibiotics, this individual would continue to expose themselves to the pollutants, and take the medication, which could contribute to larger public health problems such as antibiotic-resistant diseases, while the real source of illness remains undetected.

Similarly, EIAs often result in mitigation measures or minor project modifications, rather than substantive changes to the proposed action. And

[14] Alternatives development is the process of creating and selecting alternatives that will be considered for subsequent analyses.

this can lead to greater environmental problems. Failure to address policy-level sources of environmental problems trickles down to subsequent projects. For instance, by the time an EIS is conducted for portions of a major highway, it is usually too late to revise the strategic decision—such as a regional transportation plan—that predestined the construction of highways. And that strategic decision may not have been subject to NEPA.[15]

Strategic environmental assessment could provide a framework for dealing with the sources of significant environmental and human health impacts, rather than relying on mitigation. Because SEA occurs earlier in the planning process, an agency could consider more *alternative approaches* to an action rather than just *alternative designs*. For example, an alternative approach to using pesticides to control weeds would be integrated pest management; an alternative design would be a different type of pesticide. As another example, an alternative approach to building a highway would be expanding mass transit; an alternative design would be a different road alignment. Another advantage of SEA is that detailed analyses are not always necessary: SEA considers alternative concepts and scopes, which could alleviate the perceived data burden placed on human health impact assessment.

4.3. Consider mortality and morbidity health impacts other than just cancer

This is not to suggest that we ignore cancer risks. Rather, it is to suggest the consideration of other types of health risks that are significant. EIAs tend to address the health impacts that can be measured, not necessarily the health impacts that are most significant. Human health impact assessment has focused on mortality effects of cancer, largely because cancer and mortality are easily recognized endpoints, and because the risk assessment paradigm for cancer is widely accepted. But as Colborn (1994) suggests, "By using cancer and mortality as the end points to determine the safety of chemicals in use every day, we have put biodiversity, actually even human survival, at risk. This is far more insidious than cancer or mortality; its measure is functionality or the ability to reproduce."

Also frequently overlooked and misattributed are the effects of environmental contaminants on morbidity—which, because of the number of people affected, can be among the most significant. Arguably, all humans are affected by environmental contaminants, albeit to varying degrees and with varying effects. For instance, exposure to an indoor air pollutant,

[15] In Atlanta Coalition v. Atlanta Regional Commission, 599 F.2d 1333 (5th Cir. 1979), the court held that an environmental impact statement was not required on a regional transportation plan: "Here, the availability of federal funds for the planning process is not in any way tied to any sort of substantive review of the plans produced by that process. Moreover, federal financial assistance to the planning process in no way implies a commitment by any federal agency to fund any transportation project or projects or to undertake, fund, or approve any action that directly affects the human environment."

formaldehyde, may cause severe headaches in one individual, and dizziness in another individual. But because we lack an objective quantitative measure for many morbidity effects, such as headaches and dizziness, they are rarely assessed, even though they drain human productivity and quality of life.

4.4. Incorporate qualitative information into health risk assessments

Qualitative forecasts are common in EISs; one study found that nearly three-fourths of all forecasts were qualitative (Culhane et al. 1987). Yet, human health impact assessment relies almost exclusively on quantitative risk assessments, which yield a summary number.

Risk assessment has quantitative appeal, but this strength may also be its shortcoming. Quantitative information may "drive out" other information, and, "the regulator become[s] vulnerable to 'number-hungry' analyses and critics" (Leape 1980). Numerical estimates of risk can lose crucial issues of context. Further, risk assessment is not well suited for analyzing health risks associated with non-threshold events.

The need to establish causality to determine health risks may have hindered HHIA. For chemical exposures, toxicology and epidemiology are useful for studying the relationship between a single substance and a single effect. But causes and effects may be impossible to determine in cases of exposures to multiple stressors and pollutants, over multiple time periods, which are precisely the types of exposures that confront humans. And some classes of illness defy traditional models of toxicology and epidemiology (Ashford and Miller 1998).

Individuals are a valuable source of expertise and experience, and human health impact assessment needs to capture that information. In many environmental exposures, patients' verbal reports of symptoms are the clearest and perhaps sole evidence of impacts (Ozonoff 1994). The unfortunate tendency to discredit patient-reported data may result in missed opportunities to better understand and prevent environmentally related health impacts. Also listen to human canaries. Sensitive individuals can help to identify and evaluate health risks, such as problematic chemicals and even mixtures of chemicals. They can also serve as harbingers of serious and pervasive environmental health problems. For instance, individuals with multiple chemical sensitivity (MCS) react earlier and more significantly to environmental contaminants, and at levels far lower than the general population. MCS is typically initiated through an acute exposure to a chemical (such as a pesticide or solvent) or repeated low-level exposures to chemicals (such as diesel exhaust, fragrances or indoor air pollutants) (Ashford and Miller 1998). Once sensitized, individuals with MCS suffer severe, even disabling, reactions when exposed to environmental toxins. Reducing exposures is important both for secondary prevention in individuals with MCS, and for primary prevention in the rest of the population.

4.5. Emphasize adaptive management and monitoring

Adaptive management is an approach that modifies actions in light of new information and changing environmental conditions. It recognizes that project implementation is a type of an experiment: Project outcomes are uncertain, and thus we should be prepared to gather information, learn from surprises, improve our understanding, and change actions. This is especially true with projects that create health impacts, which may be difficult to predict at the time of the EIA.

Monitoring provides a critical link in adaptive management and in EIA. Traditionally, agencies follow a linear, one-time process of impact assessment: identify, predict, and evaluate impacts before project implementation. Yet once the project is implemented, and EIA documents approved, impact assessment is largely forgotten. But that is when the impacts start to accrue.

Monitoring changes that: It transforms a one-time pre-project report into an ongoing assessment. Under NEPA, agencies are required to conduct monitoring for compliance: to determine whether mitigation measures were implemented.[16]

But monitoring has other benefits. It can improve forecasting methods by comparing the actual effects of a project to the predicted effects. It allows decision-makers to better manage impacts, adapt to surprises, and improve environmental outcomes. It can provide the data and analytic framework for assessing cumulative effects. Finally, monitoring can increase our understanding of the interconnections among actions, impacts, environmental systems and human health.

4.6. Apply a precautionary approach to health risks

Health impacts are complex and uncertain. Risk assessment deals with uncertainty by assessing the probability of the frequency of the impact, and the severity of the impact. This requires information on the frequency and severity of a health outcome, typically cancer. But with many types of environmental exposures and health impacts, true uncertainty arises. We lack information on the frequency and severity of certain health outcomes—even assuming we could identify all significant health outcomes.

Given these uncertainties that may never be removed, a new paradigm for health impact assessment can emerge, based on the Precautionary Principle: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (Wingspread 1998). In this way, the burden of proof changes from the public to the project proponents. And new standards of proof can also emerge to accommodate

[16] CEQ regulations require monitoring for compliance with an EIS: "A monitoring and enforcement program shall be adopted and summarized where applicable for any mitigation" 40 C.F.R. §1505.2c (1978).

uncertainty, using judicial concepts such as "preponderance of evidence" or "substantial cause or factor" (Walker 1996; Ashford 1999). Traditionally, decision-makers try to avoid Type I errors[17]: to avoid taking action unless conclusive evidence exists. The response to inaction is often, "We need more research." But the costs of a Type I error may be dwarfed by the cost of a Type II error[18]: Significant environmental and human health risks can occur from inaction. The precautionary approach recognizes that more and more research may never produce a definitive model of causality, or a quantitative measure of risk. Instead, we should act now, based on available information, in order to avoid more costly mitigations, substantial risks, or irreversible impacts in the future.

4.7. Promote collaboration between environmental and public health professionals

EIA was designed to be an interdisciplinary planning tool, and we need to join forces to improve understanding of the health effects of environmental conditions. EIA documents typically become a patchwork of isolated analyses, with little synthesis among the sections. Moving away from analyses of isolated risks and toward a broader understanding of environmental and public health will require a more holistic, integrated view of impact assessment. As Carpenter (1999) and others have argued, EIA should stay focused. True, EIAs were not intended to analyze all impacts. This article does not recommend producing more paperwork, but rather to better consider the types of significant health impacts that are commonly overlooked and that will prove significant in the future.

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Appendix A. Environmental impact statements

(A) Proposed Bobby Jones Expressway Extension, Richmond County, Georgia and Aiken County, South Carolina. Final EIS, US DOT et al., November 1988.

[17] A Type I error occurs when the null hypothesis is rejected when it is actually true; that is, incorrectly concluding an effect exists. An example would be to prevent an action that later is found to be not as harmful as expected.

[18] A Type II error occurs when the null hypothesis is accepted when it is actually false; that is, incorrectly concluding that no effect exists. An example would be to allow an action that is found to be much more harmful than expected.

(B) Eastern/Northern Urban Loop from I-85 East of Greensboro to Lawndale Drive North of Greensboro, approximately 13 miles in Guilford County, North Carolina, North Carolina Dept. of Transportation, Division of Highways, November 1992.

(C) Technical Memorandum on Natural Resources, Greensboro Eastern/Northern Urban Loop. A report to Kimley-Horn Asso., Inc., by CZR, Inc., Wilmington, NC, March 1991.

(D) US 421 Watauaga County, North Carolina, US DOT et al., July 1994.

(E) Proposed 840 North from Interstate 40 East to Interstate 65 North in Wilson, Sumner and Robertson Counties, Tennessee, volume 1, Draft EIS, Federal Highway Administration, US DOT.

(F) GA 400 Extension, Atlanta, GA, Draft EIS volumes 1 & 2(appendix), October 1986.

(G) State Road (SR) 312 Extension SR 207 to U.S. 1 North (SR5), St. Johns County, Fla., US DOT, et al., May 1993 and October 1995.

(H) Brunswick County Replacement of Bridge No. 198 on SR 1172 over the Intracoastal Waterway at Sunset Beach, North Carolina. Administrative Action DEIS and Draft Section 4(f) evaluation, US DOT et al., September 1995.

(I) Birmingham Northern Beltline from I-59/20 West of the city of Birmingham to I-59 Northeast of the City of Birmingham, Jefferson County, Alabama. US DOT et al. (Administrative Action and Technical Appendix), 1995

(J) SR 0322, Section B01, Mifflin County Pennsylvania, Draft EIS Section 404 Permit Application, US DOT et al., May 1994.

(K) Appalachian Corridor H. Elkins to Interstate 81, Alignment Selection SDEIS, Wyoming, West Virginia, DOT, Air, Noise & Energy Technical Report, October 1994.

(L) Appalachian Corridor H, Elkins to Interstate 81, Wyoming, West Virginia, Socioeconomic Technical Report, October 1994.

(M) Draft EIS, Section 4(f) evaluation, US Dept of Transportation, Federal Highway Administration and FL Dept of Transportation, Work program # 7140004, State project # 99007-1402, Federal Aid project #IR-9999(43), Willsborough County, FL, November 6, 1995.

(N) I-287/Cross Westchester Expressway: Design Report/Draft Environmental Impact Statement, New York, US DOT et al., May 1995.

(O) Blount County, Tennessee Wastewater Facilities, Draft EIS, Environmental Protection Agency, December 1982.

(P) Proposed Route 840 North from Interstate 65 to Interstate 40 West of Nashville in Robertson, Cheatham, Dickson and Montgomery Counties, Tennessee, volume 2, Draft EIS, US DOT.

(Q) US Courthouse Annex, Savannah, Georgia Draft EIS, Lead Agency: US General Services Adm. Region 4, Prepared in Conjunction with BAT Associates, Inc., Norcross, GA, February 1996.

(R) Interstate 81 interchange SR 8016 Franklin County, Pennsylvania, Draft Environmental Impact Statement, May 1994.

(S) Projects M-8508(1) and ST-697-7 Southern by-pass and Weatherley Road Extension Hobbs Island Road to I-565 City of Huntsville and Madison County, Alabama, volumes 1 & 2. US DOT et al., 1992.

(T) Kealakehe Parkway: Mamalahoa Highway to Queen Kaahumanu Highway North Kona, Hawaii, Draft EIS, US DOT et al., July 1994.

(U) US 70 Goldsboro Bypass from SR 1237 to SR 1731 Goldsboro, Wayne County, North Carolina. Administrative Action Draft, US Department of the Army, Corps of Engineers, August 1994.

(V) US Highway 71- Texarkana, Arkansas to the Louisiana State Line, Miller County, Arkansas, Draft EIS, Federal Highway Adm. et al., 1994.

(W) NC 16 Lucia to North of NC 150 Gaston, Lincoln and Catawba Counties, North Carolina. US DOT et al., September 1994.

(X) Draft Wild and Scenic Rivers Suitability Study and EIS for Six Rivers on the Daniel Boone National Forest, Kentucky, US Dept. of Agriculture, August 1994.

(Y) US Courthouse Annex, Savannah, Georgia Final EIS, U.S. General Services Adm. Region 4, Prepared in Conjunction with BAT Associates, Inc., Norcross, GA, April 1996.

(Z) Basic Transport Airport for South Broward County: Draft EIS, Florida, April 1992.

(AA) Carolina Bays Parkway Georgetown and Horry Counties South Carolina Draft EIS, submitted pursuant to 42 U.S.C. 4332(2)(c), US DOT et al., January 1996.

(BB) Cedar Bay Cogeneration Project, Jacksonville, Fla., Final EIS, US EPA, November 1993.

(CC) CF Mining Corporation Hardee Phosphate Complex II Hardee County, Florida, Primary Document Draft EIS, US EPA, March 1988.

(DD) Estech General Chemicals Corporation Duette Mine, Manattee County, Florida, Biology and Ecology, Draft EIS, US EPA, October 1979.

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(GG) Kanawha River Navigation Study, Marmet Lock Replacement Draft Feasibility Report, vol. 1 Main Report and EIS, West Virginia, US Army Corps of Engineers, August 1993.

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(LL) Tampa Electric Company-Polk Power Station Draft EIS, volumes 1 & 2, Florida US EPA, February 1994.

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(OO) Draft EIS and Wild and Scenic River Study on the Hiwassee and Tellico Rivers, Monroe and Polk Counties, Tennessee, Cherokee National Forest and Cherokee County, North Carolina, Nantalaha National Forest Draft, USDA Forest Service and TVA, September 1994.

(PP) Final Supplement to the Final EIS for Wilmington Harbor Channel Widening New Hanover and Brunswick Counties, North Carolina, US Army Corps of Engineers, June 1996.

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