An Integrative Model for Environmental Health Research

Environmental health research must achieve an integration of understanding, reaching from physiological research on health effects of toxic agents to actions that people may take, individually and collaboratively, to reduce their risks. This article proposes an integrative model of environmental health, encompassing four broad domains and their interrelationships: physiological, vulnerability, epistemological, and health protection. If we wish to empower communities to make the tough decisions necessary to truly protect the well-being of their most vulnerable members, each domain must be attended to, and links between scientific knowledge and social processes must be understood. Key words: *environmental health, exposure, health promotion, model, risk, toxins*

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FACTORS in the environment are major determinants of health for individuals and populations. Environmental health hazards such as lead exposure, poor air quality, pesticide exposure, contaminated water, and toxic sites are causes of premature mortality, morbidity, functional limitations, and symptom experience, affecting quantity and quality of life.[1] Potential outcomes include cancer, neurotoxic effects, developmental and reproductive impacts, and exacerbation of cardiovascular and respiratory disease. Butterfield[2] suggests the metaphor of "thinking upstream" to characterize efforts to proactively identify and eliminate precursors of illness, such as exposures to environmental health hazards. Changes in public policies, as well as changes in individual behaviors, are needed to achieve reduction of environmental health hazards. A major policy study on environmental health and

The authors express appreciation to Patricia Butterfield, PhD, RN, Professor at Montana State University College of Nursing, for her critique and personal communication regarding this article.

Adv Nurs Sci 2002;24(3):43–57

nursing has called for interdisciplinary research to enhance the knowledge base for "understanding [of] the complex relationship between human behavior and the physical and biological environmental hazards with the aim of helping to bring about requisite changes in societal action and human behavior."[3(p104)] This suggests a need for approaches in which knowledge about biological dynamics are integrated with knowledge about behavioral dynamics in order to work toward the goal of a health-promoting environment.

This article presents an integrative model of environmental health research. The proposed model is intended to provide a framework to support upstream thinking, and associated research, concerning the environment and health. The model brings together four broad domains of knowledge and describes their interrelationships. The *physiological domain* concerns chemical and physiological processes through which agents in the environment have effects on the health of persons exposed. The *vulnerability domain* concerns the broad array of individual and community characteristics that may alter pathways of the physiological domain, leading to variation between persons in environmental health risks experienced and, consequently, to health disparities. The *epistemological domain* concerns processes of personal thought and social knowledge by which people come to their understanding of the effects of the environment on health, thus providing a basis for actions. The *health protection domain* concerns engagement in environmental health, especially actions that people may take to reduce environmental health risks for self or those under one's care, or for the larger community in which one participates.

Each domain reflects an interdisciplinary area of knowledge. The domains also overlap, with each emphasizing a different lens by which a complex, multifaceted problem may be examined. Most important, the domains are closely interrelated, such that changes in any one domain lead to changes in other domains through both direct and indirect paths. Thus, it is necessary that the domains be considered in an integrated way. Knowledge of the physiological domain is not, by itself, sufficient to provide a basis for needed improvements in environmental health. In contrast, for developing an agenda for responding to environmental health challenges, it is essential that each domain be fully addressed. To be effective, we must become better versed in how the domains interrelate in their potential for leading to solutions to the problems we face.

The authors of this article have often attended academic seminars and lectures on environmental health problems, which frequently conclude with an expression of frustration by environmental scientists. Although there is substantial knowledge about the specific environmental health problem, this knowledge does not seem to be effective in reducing the magnitude of the problem in the lives of people. It seems that the source of this frustration is the almost exclusive focus in these seminars on research from the physiological domain, with little systematic focus on the other domains that could potentially shed additional light on approaches for environmental health promotion.

The proposed model derives from several years of participation in both academic and activist communities relative to environmental health, as well as review of the research literature as reflected here. The model is intended as a working hypothesis that may be useful in guiding investigations or suggesting needed policies. The authors are currently utilizing the model in research on engagement in environmental health issues at individual and community levels; the developing model also guided a recent review[4] of air pollution and children's health.

Fig 1 depicts the proposed integrated model. (Directionality indicated by arrows should be interpreted as meaning that one leads to the other, or forms a basis that makes the other possible, but not as implying causality.) The physiological domain may be considered the starting point, reflecting core physical dynamics of environmental health. This is the basis that allows elements of the vulnerability domain to have effects. Likewise, both of these domains form the basis for the development of knowledge, as this is represented in the epistemological domain. This knowledge forms the basis for elements of the health protection domain, including action, which, in turn, impacts on the physiological domain.

The next sections of this article provide detailed descriptions of each domain. They are followed by a description of the interrelationships between the domains of the integrated model and a discussion of uses of the model.

PHYSIOLOGICAL DOMAIN

The *physiological domain* focuses on the question, "What is the problem?" It concerns chemical and physiological processes through which substances in the environment have effects on the health of persons exposed. Of the four domains, this domain has been most heavily emphasized in environmental health research. It includes four elements: *agents, exposure, incorporation,* and *health effects.*

An *agent* is a potential cause of disease. Agents include infectious microbes, such as high levels of coliform bacteria in a water supply. In addition, agents may be chemical (eg, lead) or physical (eg, ionizing radiation). Accumulation of an agent in the environment creates an environmental health hazard. Chemical agents that may be hazardous can be identified through chemical microanalysis of the component parts of a

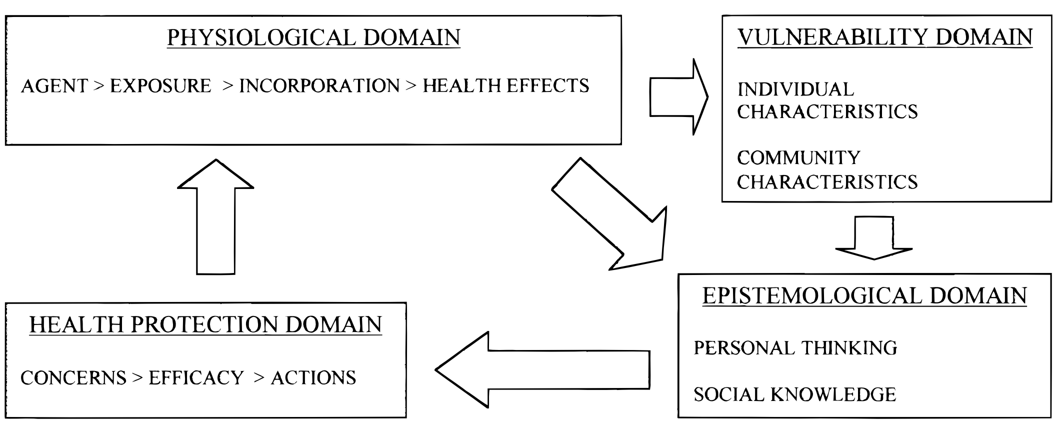

Fig 1. Graphic depiction of integrative model for environmental health.

substance, as when the contaminants present in a particular water source are identified. On a macro scale this can be accomplished through projects such as those currently being carried out in the United States and Britain, by their respective national geological services, to create maps indicating levels of chemicals in the environment and, in the United States, by the Toxic Release Inventory through which emission of toxins by industries is made publicly available. There is current awareness of potential for deliberate release of agents in terrorist acts.

Exposure refers to the "intensity and duration of contact with a substance or physical agent."[5(p5)] Exposure generally occurs through dermal contact or absorption, ingestion, or inhalation. An agent presents a risk to the health of a person only if there is a potential route through which exposure of the person to the agent may occur. For example, some environmental chemicals identified in geological surveys may be inert or inaccessible, such as lead embedded in rock. These would not be considered to present a health risk. In contrast, exposure of a child to lead may occur through flaking lead-based paint in one's home, from indoor and outdoor dust and soil contaminated with lead, and from lead particles in the air.[6] In a study of 274 children attending public lead screening clinics, Porter and Severtson[7] found that parents of 247 children (90.2%) reported exposure of the child to at least one source of lead. Similarly, Wargo[8] concluded that small children may receive excessive exposure to pesticide residue in their diets as a consequence of eating habits in which they may eat large amounts of a small number of foods, such as apples, a fruit typically grown with substantial use of pesticide. In a review of methods issues in exposure assessment in studies of cancer and herbicides, Blair and Zahm[9] point out that getting an accurate exposure history can be a particularly thorny methods problem, and that any inaccuracies in such assessment would lead to a bias toward false-negative results. Understanding the health effects of any specific exposure also is complicated by the reality that all human beings experience multiple exposures throughout life. Yet most research uses a single type of exposure (such as to lead or asbestos) as the independent variable under investigation in any specific study.

Incorporation refers to accumulation of an exogenous substance or its metabolites within body compartments, as well as any measurable biochemical or physiological changes that may be precursors to clinical manifestation of disease. These are sometimes classified as biomarkers of exposure and biomarkers of effect, although the distinction between these two categories can be unclear.[10] These terms may best be thought of as points on a continuum. Examples of indicators of incorporation may be seen in research and clinical practice with lead-poisoned children.[11] Body lead burden is often measured by blood lead level, which indicates amount of lead in circulating blood; however, lead moves about the body with only a small portion in the blood at any one time. A possibly superior approach to estimating body lead burden is through measurement of zinc protoporphyrin level, which indicates the magnitude of an enzyme that accumulates in the erythrocytes as lead absorption increases. The two measures are highly complementary; to classify the former as a biomarker of exposure and the latter as a biomarker of effect would not necessarily be useful. Another example of an indicator of incorporation is seen in tests for levels of dioxin in a current study[12] of the effects of exposure to Agent Orange among female nurses who served in the US military during the Vietnam War. Once again, the measure is an imperfect indicator, as dioxin levels measured currently may not accurately reflect either exposures, or the physiological processes set in motion by peak levels, as these occurred decades ago. Further, body burden of various chemicals exist in combination. In the first *National Report on Human Exposure to Environmental Chemicals,*[13] for 22 environmental chemicals (out of 27 chemicals measured) detectable levels were found in at least half of subjects providing blood and/or urine samples. Any individual person may have detectable levels of both lead and mercury, as well as various metabolites of organophosphate pesticides and phthalates (compounds commonly used in consumer products such as soap, nail polish, and some plastics). The number of chemicals to be measured will be increased to approximately 100 in future years. It will be important for researchers of the physiological domain to go beyond studies that assess the effects of just one chemical at a time in order to shed light on the effects of combinations of multiple chemicals, as these combinations are actually experienced by people.

A primary area of interest of environmental health researchers is in *health effects,* including mortality and morbidity indicators, such as disease diagnosis, hospitalization, functional limitations, and symptom experience. In Libby, Montana, the 20-year death rate from asbestosis (ie, lung disease related to exposure to asbestos) is 40 to 60 times what would be expected based on rates in reference populations.[14] In the case of lead poisoning high levels of toxicity may lead to encephalopathy or death, while low levels of toxicity result in neurotoxic symptoms or mildly impaired functioning as indicated, perhaps, by difficulties in school.[15] Various health effects also have been related to air pollution. Ambient (ie, outdoor) air pollution, especially particulate matter, is associated with excess mortality in metropolitan areas in the United States due to a variety of cardiovascular and respiratory causes.[16,17] In addition, elevated occurrence of lung cancer coincides with long-term, high air pollution exposure including ozone, sulfur dioxide, and particulates.[18] In the case of ozone exposure specifically, long-term residence in a county high on this pollutant also is related to respiratory symptoms and reduced lung function in healthy young adults.[19]

The physiological domain receives substantial research attention, as it should. Methods of inquiry include toxicology and epidemiology. However, this domain by itself gives an incomplete picture of how the environment relates to health status, and knowledge about this domain is not sufficient for effective problem solving about environmental health. One flaw is that it does not account for either individual variation or differences between groups. This is addressed in the vulnerability domain.

VULNERABILITY DOMAIN

The *vulnerability domain* focuses on the question, “Who is affected?” Risks to health due to environmental health hazards are not distributed equally among the population. Rather, some people experience a greater share of this burden than do others, reflecting either greater exposure or greater susceptibility to exposure. The vulnerability domain concerns the broad array of *individual* and *community characteristics* that may alter pathways of the physiological domain, leading to variation between persons in environmental health risks experienced.

Individual characteristics that may affect risk include developmental, health, nutritional, genetic, and gender-related characteristics. Developmental characteristics are of particular importance. Children are at high risk for exposure to toxins in the environment.[4,8] Because of their shorter stature, hand-to-mouth behavior, and patterns of play, children simply live closer to the ground where toxic agents such as lead may accumulate. Likewise, high ratio of skin surface area to body weight leads to increased risk of dermal absorption of some toxicants. Children may be particularly susceptible to toxic exposures related to critical periods and periods of rapid growth, organ system maturation, higher metabolic rate affecting absorption into body tissue, and increased bioaccumulation and period of storage simply due to future lifespan.[20]

Women may be more susceptible than men to some toxicants due to accumulation in adipose tissue, reproductive physiology, and maturational changes in body tissue that women experience through their life span.[21] Women's exposure also leads to greater risk of transgenerational transmission of health effects to children. Thus, for example, mercury exposure among women of child-bearing age is considered to be of particular significance because of the potential risk that a fetus may be exposed to that level of mercury.[13] Women who are pregnant, or planning to become pregnant, and small children may be defined as high-risk groups in fish consumption advisories related to mercury accumulation in fish. In contrast, there is some evidence that among persons living in an area with a high level of air pollution, males may be more affected.[18,19] This is attributed to a possible protective effect of estrogen in reducing oxidative damage and to patterns of greater outdoor exertion among males.

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Exposures may have the most damaging effects in persons who have preexisting impairments. For example, Korrick and associates[22] found that hikers with asthma showed greater changes (fourfold) in pulmonary function in response to high ozone compared with changes in pulmonary function experienced by other hikers. Likewise, mortality related to air pollution often results from exacerbation of existing disease, with highest risks among the older adults and those with chronic cardiopulmonary conditions.[16,17] Nutritional status may affect risk. For example, deficiency of calcium or iron may promote absorption of lead, when lead is present in the environment. Genetic characteristics also affect susceptibility to environmental exposures.[20] For example, variation between people in the paraoxonase gene affects metabolism of the active component of organophosphate pesticides, from its neurotoxic state to a less harmful state. Because of this genetic variation, some people may be more susceptible than others to harmful effects of this class of pesticide, which is commonly used in production of apples and other food crops.

Community characteristics that may affect risk include sociodemographic and cultural characteristics. They also are impacted by public policies that allow or promote differential levels of risk. Important variables to consider include race, ethnicity, socioeconomic status, location of residence, and occupation. The Institute of Medicine Committee on Environmental Justice notes that "there is evidence that minorities and lower-income groups face higher levels of exposure to the hazards and, therefore, potentially higher rates of adverse health outcomes."[10(p15)] For example, African Americans and Hispanics, compared with non-Hispanic whites, are more likely to live in areas in which levels of air pollutants such as ozone and particulates are high.[10] Graham and associates[23] showed that census tracts near some sources of hazardous air pollution (ie, coke production plants) have high proportion of poor people, and that this proportion increases over time, as high-income families use their resources to migrate away from sources of pollution. Porter and Severtson[7] found that children in families with low incomes were more likely to be in contact with adults with lead-related hobbies or jobs, and to live in older homes with peeling paint. Such disparities in exposure to environmental health hazards may be a contributing factor to health disparities.

Differences in risk experienced by different groups present important issues of environmental justice. Differential risk may be promoted by government policies. For example, the regulatory practice of pollution credit trading allows emission of a pollutant to remain high in a specific location, while being reduced in other locations, as a strategy for reducing overall emissions within a state or region. Communities with the least political or economic power may be most affected.

The vulnerability domain is receiving increasing attention. Epidemiology is a principal method of inquiry, especially as this is informed by sociological or legal analysis, and by clinical understandings for identifying individuals at risk. This domain leads directly to questions of how knowledge of special risk is experienced by persons affected. Persons who understand that they are at increased risk of environmental health exposures may take actions to reduce their exposures.

EPISTEMOLOGICAL DOMAIN

The *epistemological domain* focuses on the question, "How does everyone know about this?" This domain concerns elements of *personal thought* and *social knowledge* by which people come to their understanding of the effects of the environment on health, thus providing a basis for actions. Each of these elements indicates a set of processes. While personal thinking and social understandings are each achieved through a rather different set of processes, both of these sets of processes seem to focus on a common challenge. This is the need to transform problematic uncertainties in such a way that they lead to confident wisdom. This may be illustrated in the difference of experience between an expert and a resident of a community affected by a toxic site. Whereas the expert has a greater technical command of the situation, the resident may experience a depth of feeling that drives an intense seeking for a way to understand the meaning of the situation in order to respond competently. The terms *intuitive toxicology*,[24] *popular epidemiology*,[25] and *democratic science,*[26] among others, have been used to describe perspectives on this phenomenon. Writing in a prestigious medical journal, Safe used the more negative term *chemophobia* to refer to the "the unreasonable fear of chemicals . . . a common public reaction to scientific or media reports suggesting that exposure to various environmental contaminants may pose a threat to health."[27(p1303)] Yet the degree of fear that may be reasonable or unreasonable is often, itself, a matter of scientific uncertainty or public controversy. Commonly used ways of knowing, including tradition, authority, group loyalty, experience, and intuition, as well as science, play a role in these processes.

The element of *personal thought* reflects principles of cognitive psychology.[28] Consciousness is directed to problematic areas in order to manage life challenges and build capacity for effective response. This must begin with awareness of a potential challenge to be responded to. People are not always aware of the environmental health risks that they experience. Stieb and associates[29] found that recall of smog advisories was best predicted by geographic area, with highest recall among persons living in areas commonly recognized as having an air quality problem, as opposed to another area commonly misperceived as not having such a problem. Presence in the household of a person who has asthma, heart, or lung disease was another predictor of recall. Living in an area recognized as having a problem with air quality or living with a person who has particular susceptibility to air pollution may both serve as cues that stimulate awareness of smog as an issue on which to focus attention. Similarly, a mother told of her child's lead level may read a pamphlet about lead poisoning. Then, perhaps, she will search the Internet for more information, in order to try to get a sense of the implications for her child's health. Whatever the effort to increase expertise, however, there are sharp barriers, including a limited capacity to focus consciousness on one issue, in the context of all of the competing demands of life. People who are not experts cannot become experts easily or quickly.

The element of *social knowledge* reflects principles of sociology of knowledge.[30] People bond together in mutual dependency. This includes development of a shared sense of what is true, as well as an understanding of differential responsibilities, as reflected in an assumption that government and environmental experts will use specialized knowledge to keep the environment safe. When events bring such an assumption into question, people may then initiate alternative knowledge mechanisms. For example, residents of a community thought to have an environmental hazard affecting health may share information informally, undertake a health investigation, or develop a social movement for promoting a world view.[25,31] This may become contentious, especially in a context of scientific uncertainty, as is often the case with issues of environmental health. Economic interests also may contribute to an adversarial dynamic, pitting those who see themselves as being put at risk against those who bear financial liability or who may feel threats to their job security.[31]

Health professionals attempt to influence perceptions of risks through systematic risk communication. Experts can provide information on topics such as the background of a toxic site, results of tests of environmental contamination, research on health effects, and potential methods of remediation; they can sometimes offer statements of reassurance. However, statements of reassurance based on incomplete knowledge may impede the building of trust or even provoke hostility. Certainly, any communication should involve listening to community concerns, as well as providing information. In a democracy, residents in a community "need and want to be actively involved in identifying, characterizing, and solving problems that affect their lives."[32(p4)] Methods of community dialogue for "coming to judgment" as described by Yankelovich,[33] may be useful in overcoming divergent interests and developing a communal sense that the problem can be competently managed, so that a feeling of safety is restored. In situations where questions of trust and distrust develop between those differentially affected, public opinion can be volatile and subject to considerable doubt in relation to scientific knowledge. Nevertheless, the public perspective should be recognized as having its own legitimate validity, especially if driven by knowledge of special vulnerability. Yankelovich[33] suggests approaches for the challenge of moving public opinion, which is unstable and erratic, on to public judgment, which has developed a sensitivity to expert knowledge, while at the same time disciplining that knowledge in the light of legitimate public concerns. This process of moving from public opinion to public judgment has to have its own proper pace. Experts need to respect that this process of coming to public judgment transcends their own expert knowledge, because democratic communities must take responsibility for themselves even in the face of controversy and doubt. This responsibility cannot be delegated to experts or agency officials. The most needed experts are those who know how to play their proper role in the necessary public ferment of discovering what is right for the community.

Methods of inquiry for the epistemological domain include qualitative methods such as ethnography and quantitative methods such as survey. Risk communication and coming to public judgment also are rich areas for intervention or action research. Studies focused on this domain are often published in different journals than those that publish studies on the physiological domain, and they may be addressed to different audiences. This fragmentation of effort illustrates one reason why an integrated model is needed. Ideally, understandings that people develop should reflect scientific knowledge of the physiological and vulnerability domains, as well as their more personal experiences and intuitions. These understandings then provide a basis for the actions that people take to limit their exposures to environmental health hazards and protect their health.

HEALTH PROTECTION DOMAIN

The *health protection domain* focuses on the question, "What do people do about it?" It concerns environmental health engagement. Through engagement, people may reduce environmental health risks for self or those under one's care, or even for the larger community. This may be accomplished by avoiding exposure, as when a family moves from a building with peeling, lead-based paint, or by eliminating the hazards that make the exposures possible, as when the building is remediated so that the lead hazard is no longer present. The health protection domain includes three elements: *concerns* about environmental health, *sense of efficacy* about environmental health, and *actions* related to environmental health. These three elements are conceptualized as a process. In addition, many of the individual and community characteristics of the vulnerability domain also are relevant. For example, gender and place of residence may affect elements of this domain in important ways.[34]

Conceptualization of this domain is drawn loosely from the work of Lazarus and Folkman[35] on cognitive appraisal of stressful situations. The ability to appraise situations accurately is necessary to human survival. By appraising situations people distinguish those situations that threaten their well-being from those that are benign. These appraisals serve as the basis for responses. To overcome the focus on individual responses to immediately threatening situations, conceptualization of this domain also is specifically informed by the call for "thinking upstream" concerning environmental health.[2,36] The concept of thinking upstream (and more recently, "moving upstream") has been developed as an inspirational metaphor for nurses. It suggests an alternative to the metaphoric scenario in which health care providers are rescuing victims drowning in a swiftly flowing river (representative of illness), but they do not look upstream to see who is pushing their patients into the water. The thinking upstream metaphor supports a proactive stance of mutual empowerment for problem solving and action to reduce or eliminate exposures to environmental health hazards in order to prevent future health effects.

The element of *concerns* is an overlapping, short step from the epistemological domain discussed above. Based on what is believed to be true, the person feels a sense of threat. This involves a primary appraisal in which one sees personal implications for health, related to one's exposure to toxic agents or other environmental condition. Or, it may extend out from the person to family or community. In a study of persons living near a hazardous waste site in a Southern community, Carruth and colleagues[37] found that the residents attributed health problems to their exposures, especially among those living closest to the site. These problems included skin rashes, respiratory complaints, headache, reproductive system problems, and cancer, as well as cancer deaths of others within the community.

The element of *efficacy* refers to confidence in ability to carry out actions for the reduction of environmental health hazards. This is a secondary appraisal involving cognitive exploration of the possibilities for actions that may reduce the threat. One reason that environmental health hazards often seem so stressful is the feeling that there is nothing that we can do about them.[38] In a recent study on perceptions of health and environment, James and Eyles[39] found that although many individuals reported some perceived ability

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to influence their own health, this often did not extend to environmental influences on health. Instead, powerful others (frequently referred to as "they" by subjects) were seen as controlling the environment and its health influences. The sense that there is nothing to be done may be experienced as an uncomfortable incongruity or "health-environment tension." However, an alternative possibility of secondary appraisal is an optimistic belief that one can take effective actions. For example, one may believe that one can protect oneself by personally avoiding exposure to an environmental health hazard. This is reflected in Martinelli's[40] measure of environmental tobacco smoke avoidance efficacy, on which people are asked to rate their confidence in their ability to avoid environmental tobacco smoke. One also may believe that one can take actions to improve the wider environment. James and Eyles quote one subject as stating, "Everybody has some control over environmental influences in terms of how many chemicals they stick in their broom closet and how much they drive their cars instead of using the bus or walking."[39(p96)] Persons also may believe that they can act together with others to reduce environmental health hazards in their community; this belief may enable the formation of grassroots organizations by individuals with similar concerns. This has occurred in Woburn, Massachusetts, and Love Canal, New York, as well as in many other communities throughout the country.[25,41] Thus, the term *efficacy* is used broadly. Confidence in the conjoint ability of a group to organize and execute courses of action to achieve a desired goal has been termed *collective efficacy*.[42]

Appraisals of situations relative to environmental health are important because these appraisals lead us to doing what we do—the *actions* we take. Again, this may occur through strategy of personal avoidance, or by acting to change the environment. Another dynamic is whether the concerns-efficacy-action process is focused on the well-being of self and family members or whether it extends out to the wider world. Parallel to the distinction between types of efficacy, actions taken may focus on protecting self and family (eg, as by minimizing use of toxic chemicals in one's home) or protecting one's community (eg, as by minimizing use of toxic chemicals on one's lawn creating exposure for others). Actions may be taken individually or in collaboration with others (eg, as when a neighborhood association votes to ask all residents to minimize use of toxic lawn chemicals for the welfare of all). The latter also may take the form of an environmental justice protest, when a community movement develops to oppose a proposed business or industry that will involve hazardous emissions in an area that already has high levels of such emissions. Public participation in decisions relevant to environmental health is considered to be a key mechanism for correcting problems of environmental injustice.[10]

This domain is broad and relationships within it are complex. However, research has tended to indicate associations between perception of threat and actions taken in a variety of areas, including childhood lead exposure, pesticide exposure among immigrant farm workers, and homeowners' response to radon hazard.[43–45] Likewise, association between efficacy and actions has been reported regarding response to air pollution health advisories in Los Angeles and personal avoidance of environmental tobacco smoke.[40,46,47] Other variables, including sociodemographic, health, and psychosocial characteristics such as trust, also are relevant to these dynamics and should be considered in research on this domain.[29,34]

DOMAIN INTERRELATIONSHIPS AND INTEGRATIVE MODEL

The model proposes a circular pattern. Knowledge about health impacts of the physiological domain, and the associated vulnerability domain, may lead, in turn, to actions through which elements of the vulnerability domain and the physiological domain are altered, and thus health impacts are reduced. For example, this occurs when a community uses evidence of high asthma rates, and evidence of asthma exacerbations on high pollution days, to generate public pressure by which a power plant is required to reduce emission of air pollutants. If asthma exacerbations are then reduced, this illustrates the circular process by which knowledge of the physiological and vulnerability domains may lead to actions that alter elements of these domains.

USES OF THE MODEL

Butterfield[48] points out that nurses are well positioned to participate in and provide leadership for interdisciplinary efforts to improve environmental health. The model presented in this article is intended to be helpful in shaping research relative to such efforts. The model is offered merely as a starting point, and as a guide for factors to be considered, not as a firm framework into which every detail must fit. It is hoped that this integrated model may be useful to environmental health researchers and advocates in seeing their particular environmental health issue comprehensively. The model also is intended to help in building bridges between the various domains. This is a huge challenge for researchers. Persons involved in scientific investigation on environmental health most often have a particular specialty, based in just one of the domains. It is difficult to move outside of that particular area of comfort. Yet interdisciplinary research and communication across the domains are necessary for providing a comprehensive scientific basis for improvements in environmental health. The value of the model will be apparent in its patterns of use by researchers undertaking investigations of environmental health problems. If successful, the model will stimulate a broadening of the range of interventions attempted. Much further development of all domains will be needed. For example, more detailed specification of the vulnerability domain may be particularly important for appropriately identifying target populations for research in order to reduce health disparities.[49]

The article does not intend to suggest that researchers contemplating use of this integrative model should feel compelled to design studies reflecting all domains simultaneously. Such a study may seem more unwieldy than useful. Each domain, by itself, would be a large area to cover. Rather, it is intended that research would focus on one, or perhaps two, domains, but with full recognition that the domains of focus are but a piece of a larger puzzle. Thus, it is hoped that use of this model will facilitate an understanding of context into which each study fits. Ideally, use of this model also should lead to consideration of balance between the various domains. Too often, attention is focused on the physiological domain, with perhaps some moderate focus on the vulnerability domain question of who is most affected. Domains based firmly in the physical and biological areas of inquiry may seem most "objective," and most deserving of research funding. Meanwhile, there is less attention to the epistemological domain and the health protection domain, which are drawn from areas of inquiry that seem "softer." Thus, their potential to contribute to solutions to environmental health problems goes unfilled. For example, there is a great deal of knowledge about the chemical structure of lead and its biochemical and biological effects on neurological functioning and child development. However, latest figures indicate that some geographic areas in the United States continue to have high rates of lead-poisoned children—up to 27% in some counties measured.[50] Neither the epistemological nor the health protection domains have been fully developed in relation to the problem of lead poisoning. This leaves our children vulnerable to a health condition that could be prevented.[1]

Continued investigation based in the physiological domain is necessary, but not sufficient, for facilitating progress in environmental health. An expanded conceptual framework is needed. The integrated model presented here is one attempt to provide such a framework. If we wish to empower our communities to make the tough decisions necessary to truly protect the well-being of our most vulnerable members, each of the domains described in the model must be attended to in a balanced way, and links between scientific knowledge and social processes must be understood. Health researchers concerned with environmental health must conduct studies that expand our knowledge of approaches for helping people to understand, dialogue, and act on behalf of health. This research base will create conditions necessary for appropriate precautionary measures through which risks to health due to environmental health hazards may be reduced.

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