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Collaborative Research Priorities

Human health depends on both intrinsic characteristics and external biotic or abiotic environmental exposures that may occur via the pathways of air, water, food, or contact. Although many adverse exposures stem from anthropogenic disturbances of the natural environment, others come directly from natural sources near or at the earth's surface. Earth sciences—including geology, geophysics, geochemistry, geomorphology, soil science, mineralogy, hydrology, mapping, remote sensing, and other subdisciplines—are concerned with natural earth materials and processes, and knowledge of these materials and processes is an essential component for understanding such adverse exposures.

In the public health paradigm, early disease prevention, rather than control and treatment, affords good health to the greatest number of individuals. With increased emphasis on prevention, understanding disease-causing environmental exposures is essential for cost-effective improvements to human health—the recognition and resultant avoidance of bioassimilated earth materials potentially injurious to human health is likely to save considerably more money than would be required to treat the adverse public health effects caused by the ingestion, respiration, and/or absorption of such materials (e.g., savings in health and mortality costs as a consequence of improved air quality resulting from implementation of the Clean Air Act; EPA, 1997, 1999; NRC, 2002b). Despite such obvious and important links between the fields of earth science and public health, public health activities and research have paid relatively little attention to natural earth materials and processes. Improved integration of these disciplinary fields and communities offers significant potential for an imsearch Priorities

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proved understanding of exposure mechanisms and health risks, particularly in an era of extensive utilization of the earth's natural resources.

This report highlights examples of successful research collaboration and emphasizes the limited number of interagency initiatives at the interface of these disciplines. For the most part, government agencies have failed to adequately promote the necessary integration of the earth and health sciences. **The committee is convinced that substantial improvements in public health can be achieved as a result of increased collaboration between the earth science and public health communities.**

RESEARCH THEMES AND PRIORITIES

The research priorities presented here cut across the human exposure pathways described in Chapters 3 through 7 and are illustrated by the particular priority research activities proposed in those chapters. In compiling these recommendations, the committee required that the research proposed must involve collaboration between researchers from both the earth science and public health communities and did not consider the abundant examples of valuable research that could be undertaken primarily within one or other of the disciplines. These recommendations are not listed in any rank order. It is important to note that the multidisciplinary research teams needed to effectively address these priorities will in many cases require the involvement of other specialist disciplines beyond the narrowly defined earth science and public health areas (e.g., atmospheric scientists, environmental engineers).

Earth Material Exposure Assessments: Understanding Fate and Transport

Assessment of human exposure to hazards in the environment is often the weakest link in most human health risk assessments. The physical, chemical, and biological processes that create, modify, or alter the transport and bioavailability of natural or anthropogenically generated hazardous earth materials remain difficult to quantify. A vastly improved understanding of the spatial and geochemical attributes of potentially deleterious earth materials is a critical requirement for effective and efficient mitigation of the risk posed by such materials. **An improved understanding of the source, fate, transport, and bioavailability of potentially hazardous earth materials is a critically important research priority.** Collaborative research should include:

- Addressing the range of issues associated with airborne *mixtures* of pathogens and chemical irritants. The adverse effects arising from the inhalation of complex mixtures of pathogens and chemical and biochemical species in airborne pollution require detailed geological investigations of earth sources and the identification of atmospheric pathways to sites of bioaccessibility and potential ingestion by humans. The anticipation and prevention of health effects caused by earth-sourced air pollution prior to the onset of illness require quantitative knowledge of the geospatial context of earth materials and related disease vectors.

- Determining the influence of biogeochemical cycling of trace elements in water and soils as it relates to low-dose chronic exposure via toxic elements in foods and ultimately its influence on human health. In general, little is known of the elemental interactions and the influence of mixtures of elements on bioavailability in soils; in residential, industrial, and irrigated water supplies; and within the human body.

- Determining the distribution, survival, and transfer of plant and human pathogens through soil with respect to the geological framework. Collaboration would involve earth scientists to characterize the biogeochemical habitat, such as the exchangeable cations, mobile metal species, and/or reactive geochemical surfaces, including sources of nutrients, or the presence of antagonistic and/or synergistic metal species. Microbiologists would characterize the microbial community that surrounds the pathogen and examine its viability in different biogeochemical habitats, and public health specialists would examine the incidence of human and plant disease from soil pathogens as a function of the biogeochemical framework and the role of soils in long-term survival of pathogens and as reservoirs of pathogens.

- Improving our understanding of the relationship between disease and both metal speciation and metal-metal interaction. In this research, earth scientists would characterize metal abundance and metal speciation in water and soils and the mobility and availability of these metals to the biosphere; microbiologists would characterize the microbial populations and mechanisms that are responsible for metal species transitions in water and soil environments; and public health specialists would use spatial information on the distribution of metal speciation to examine the incidence and transfer of specific disease.

- Identifying and quantifying the health risks posed by "emerging" contaminants, including newly discovered pathogens and pharmaceutical chemicals, which are transported by earth processes. The health effects of many naturally occurring substances at low concentrations and the health effects associated with interactions of multiple naturally occurring substances are poorly understood. A particular focus should be the "emerging" contaminants, such as hormones, pharmaceuticals, personal care products, and newly identified microbial pathogens, for which sources and transport processes are poorly understood. The synergistic and antagonistic interactions of contaminants with naturally occurring substances in water, and similar interactions among multiple naturally occurring substances or multiple contaminants, also pose priority research questions.

Improved Risk-Based Hazard Mitigation

Natural earth processes—including earthquakes, landslides, tsunamis, and volcanoes—continue to cause numerous deaths and immense suffering worldwide. As climates change, the nature and distribution of such natural disasters will undoubtedly also change. **Improved risk-based hazard mitigation, based on improved understanding of the public health effects of natural hazards under existing and future climatic regimes, is an important research priority.** Such collaborative research should include:

- Determining processes and techniques to integrate the wealth of information provided by the diverse earth science, engineering, emergency response, and public health disciplines so that more sophisticated scenarios can be developed to ultimately form the basis for improved natural hazard mitigation strategies. Any assessment of population vulnerability is dependent on the merging of earth science information describing the spatial distribution of hazards with public health information describing population characteristics and medical response capabilities. Effective scenarios to form the basis of improved response strategies must be scientifically valid and believable for broad acceptance by those charged with disaster response planning. The scientific validation will require collaborative involvement of a broad range of experts from the earth science, public health, emergency management, and engineering communities.

Assessment of Health Risks Resulting from Human Modification of Terrestrial Systems

Human disturbances of natural terrestrial systems—for example, by activities as diverse as underground resource extraction, waste disposal, or land cover and habitat change—are creating new types of health risks. **Research to understand and document the health risks arising from disturbance of terrestrial systems is key to alleviating existing health threats and preventing new exposures.** Such collaborative research should include:

- Analysis of the effect of geomorphic and hydrological land surface alteration on disease ecology, including emergence/resurgence and transmission of disease. The effects of land surface modifications on the bioaccessibility of the vectors responsible for disease outbreaks, deleterious chronic disease levels, and human senescence need to be measured individually and collectively in order to better safeguard public health. This will require a seamless integration of geological, hydrological, and epidemiological research efforts.

- Determining the health effects associated with water quality changes induced by novel technologies and other strategies currently being implemented, or planned, for extending groundwater and surface water supplies to meet increasing demands for water by a growing world population. Water stored in a brackish aquifer during aquifer storage and recovery will experience an increase in total dissolved solids due to mixing with ambient brackish water and dissolution of minerals from the aquifer matrix, and this may introduce contaminants such as microbial pathogens, organic contaminants such as pesticides or solvents, and inorganic contaminants such as nitrates or metals. Of particular interest with respect to surface water are changes in water quality induced by urban and agricultural runoff, discharge of waste effluents from municipal or industrial sources (including the extractive mineral and energy industries), construction and operation of dams and reservoirs, drainage of wetlands, and channel modifications for purposes of flood control, navigation, or environmental improvement.

IMPLEMENTATION STRATEGIES

Understanding the importance of bridging the "interdisciplinary divide" will not, by itself, promote communication and collaboration. The following recommendations to facilitate research across the disciplinary boundaries are those the committee believes can realistically be implemented, particularly in the constrained fiscal environment that is likely to apply.

Interdisciplinary Spatial Analysis

Spatial attributes describe the distribution of natural earth materials and processes and the distribution of infectious and noninfectious diseases. The epidemiological analysis techniques commonly used by public health scientists, when linked with geospatial analysis techniques developed by earth scientists, provide a powerful tool for understanding the public health effects of earth science materials. The immense potential offered by modern spatial analysis tools provides a strong impetus to break down existing institutional barriers to making public health data ncluding emergence/resurgence and of land surface modifications on the nsible for disease outbreaks, deleteri- nan senescence need to be measured ler to better safeguard public health. ation of geological, hydrological, and

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Spatial Analysis

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with adequate geographic detail more widely available for research. **The application of modern complex spatial analytical techniques has the potential to provide a rigorous base for integrated earth science and public health research by facilitating the analysis of spatial relationships between public health effects and natural earth materials and processes.**

The committee, therefore, suggests pursuing research that (1) leads to spatially and temporally accurate models for predicting disease distribution based on integrated layers of geological, geographic, and socioeconomic data; (2) develops better technologies for high-resolution data generation and display; and (3) establishes user-friendly Geographic Information Systems (GISs) for the earth science and public health communities and includes GIS and spatial analysis in the training of public health professionals.

Before it will be possible to take advantage of the considerable power of modern spatial analysis techniques, a number of issues associated with data access will need to be addressed. Improved coordination between agencies that collect health data will be required, and health data from the different entities will need to be merged and made available in formats that are compatible with GIScience analysis. Existing restrictions on obtaining geographically specific health data, while important for maintaining privacy, severely inhibit effective predictive and causal analysis. To address this, it will be necessary for all data collected by federal, state, and county agencies to be geocoded and geographically referenced to the finest scale possible, and artificial barriers to spatial analysis resulting from privacy concerns need to be modified to ensure that the enormous power of modern spatial analysis techniques can be applied to public health issues without compromising privacy. The potential of the research community to perform sophisticated multilayered spatial analysis for both predictive and causal modeling requires that epidemiological data be presented in a useful (i.e., detailed geographic) format so that public health problems can be correlated with earth science parameters.

Interagency Support for Interdisciplinary Earth and Public Health Sciences Research

The value of interdisciplinary research has been convincingly and repeatedly described (e.g., NRC, 2004d). However, while important gains have been made *within* individual funding agencies toward interdisciplinary research, a dearth of collaboration and funding *between* agencies has restricted significant scientific discovery at the interface of public health and earth science. The importance of the links between these disciplines and the considerable potential for collaborative earth science and public health research to produce major societal benefits has led the committee to conclude that multiagency funding for collaborative research will achieve greater disease prevention than will traditional single-agency funding. The committee recommends that—in order to achieve the innovative research at the intersection of public health and earth science required for societal benefit and protection—the intellectual and fiscal resources presently existing within a number of agencies should be reallocated to a shared interagency pool to support an interdisciplinary public health and earth science initiative. The ultimate goal is to enhance interdisciplinary collaboration, both across federal agencies and across academic and other research institutions, so that society can benefit from the nation's considerable expertise in earth science and public health.

The interface between the earth sciences and public health is pervasive and enormously complex. Collaborative research at this interface is in its infancy, with great potential to ameliorate the adverse health effects and enhance the beneficial health effects from earth materials and earth processes. The earth science and public health research communities share a responsibility and an obligation to work together to realize the considerable potential for both short-term and long-term positive health impacts.