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Comment: Toward a Coordinated System for the Surveillance of Environmental Health Hazards

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ABSTRACT

The rapid increases in the numbers and quantities of chemicals released into the environment have been accompanied by a lack of adequate prerelease testing for adverse health outcomes. Environmental health surveillance is used both to track changes in exposures that are known to have adverse health effects and to identify previously unrecognized hazards. Surveillance data can directly aid in the design of interventions to reduce the level of hazardous agents in the environment or the opportunities for human contact with them. Components of an ideal environmental health surveillance system are discussed. For well-recognized hazards, databases related to exposure alone are adequate. However, for uncovering previously unrecognized associations, linkage between exposure and outcome databases that are collected or aggregated at the same geographic scale and for regions of relatively homogeneous exposures are needed. (*Am J Public Health.* 1996; 86:638–641)

Introduction

The enormous number and variety of chemicals that have been introduced into the environment in the last few decades have caused considerable concern among the populations of both developed and developing countries. Annual releases of toxic pollutants into the air amount to over 2 billion pounds, with a similar amount released into surface water, land or underground.[1] In 1988, 22 air pollutants exceeded the health reference level (a level considered "safe" by the US Environmental Protection Agency [EPA]) at more than 25% of sites studied.[2] Agents of concern are found not only in industrial emissions and pesticides applied in agriculture, to buildings, and on roadsides, but also in food additives and constituents of commercial products such as carpets, furniture, household cleaning agents, art supplies, toys, and cosmetics. For most chemicals other than drugs and food additives, testing for long-term or chronic health effects is not required in the United States and is rarely done. A program of testing for carcinogens has produced an important database covering hundreds of chemicals,[3] but this number is a minute fraction of agents released into the environment. Even so, this number is far higher than the number of chemicals that have been tested for reproductive toxicity, neurologic effects, cardiovascular impact, etc. In the absence of adequate prerelease testing, systematic monitoring for adverse health effects would seem rational and appropriate.

Surveillance in environmental health is a strategy for identification of hazards in the environment that cause substantial death, disease, or disability, in order to facilitate the goal of prompt removal or reduction of exposures to the offending agents. Kline et al.[4] suggest a distinction between surveillance and monitoring: surveillance is the ongoing collection of data of all kinds on exposures or outcomes through time, while monitoring denotes the scrutiny of surveillance or other data for signals of excessive exposure or health effects that serve as indicators of effect, in

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order to initiate action. Surveillance is not a prerequisite for monitoring, inasmuch as observant clinicians often are the first to detect epidemics of diseases. However, when surveillance systems are in place, they provide systematic data for monitoring and therefore the potential for earlier warnings of an unusual incidence of disease, particularly if the disease is rare, if the increase occurs gradually, or if the affected population is spread over a wide geographic area.

Upon identification of an unusually or unacceptably high exposure level, or a hitherto unrecognized association between an agent and an adverse health outcome, surveillance data can aid in the design and implementation of an intervention strategy. These strategies can focus on removing or reducing the level of the exposure in the environment, or they can focus on limiting contact between the population and the agent, through education, legal restrictions, etc.

In this Public Health Policy Forum, Thacker et al.[5] distinguish three types of environmental health surveillance databases: hazard (providing documentation of substances in the environment); exposure (enabling determination of the extent of human contact with such hazards); and health outcome. Outcome surveillance is, of course, not unique to environmental health, but when linked to exposure data it can play this role.

Components of a Coordinated Surveillance System for Environmental Hazards to Health

When the health risks for a chemical or physical agent are already well-known, exposure surveillance, and in some cases, even hazard surveillance, may be sufficient. For instance, childhood lead screening programs provide data on exposure, not on health outcomes, but an abundant epidemiologic literature has established the detrimental effects of lead on childhood neurodevelopment. Monitoring for areas of high lead exposure therefore can be useful not only for identifying individuals at high risk who need information on how to lower their exposures, but also for tracking trends and targeting clean up and educational programs. Childhood lead screening is similar to surveillance in occupational settings, which is also used both to identify individuals at high risk and to assess trends and target interventions.[6]

When risks are unknown, as is the case for the majority of environmental pollutants, the purpose of surveillance is to yield data that will be useful in the primary identification of health effects. Kline et al.[5] assert that the success of a surveillance/monitoring system can be measured in terms of the lag between appearance of a new environmental agent and the recognition of adverse effects associated with it: the shorter the lag, the more successful the system. An ideal surveillance system for environmental health hazards would have the following elements: (a) high-quality mortality and morbidity data with residence information; (b) updated population data for denominators to calculate rates with adjustment for migration between censuses; (c) a wide range of information on exposures, based on emissions data, dispersion modeling and/or measurements from monitoring of air, water, and other media such as soil and food, all based on temporally appropriate sampling schedules; (d) geographic linkage of these three types of data; and (e) fine enough resolution for each of (a), (b), and (c) to enable the evaluation of effects from localized exposures in small areas. The usefulness of the system largely would depend on the linkage between exposure data and health statistics. Of course, before one can link the two, both types of data need to be collected, and while the infrastructure for health statistics data at the national and state level is quite strong in the United States, exposure surveillance is more of a hit-and-miss operation. For instance, extensive monitoring is conducted for the "criteria pollutants" (such as sulphur dioxide, carbon monoxide, oxides of nitrogen, etc.) regulated under the Clean Air Act, but surveillance of other air pollutants is not systematic. Similarly, water quality monitoring is based on standard microbiological tests, but many chemicals, including carcinogens and reproductive toxins, are tested rarely if at all. Determination of priorities for such testing is needed, but priorities may need to be adjusted for local needs.

Nevertheless, collection of both exposure and outcome data is not in itself sufficient to construct an effective environmental surveillance system capable of identifying new health hazards. If health data correspond to different geographic units from those of the exposure data, linkage of the two could entail tremendous error. Moreover, even if both are available for the same geographic units, but these units encompass nonhomogeneous exposures, the ability to assess associations is hampered. Thus, the obstacles to useful linkages are (a) inappropriate scale of data and (b) lack of congruence of boundaries for exposure and outcome databases.

At heart, the issue is at least partially the utility of ecologic data, because collection of individual exposure data on large populations is rather unrealistic. The example of air pollution illustrates a situation in which exposures *do* tend to be fairly homogeneous within cities. Excesses in mortality and morbidity follow time trends for acutely high air pollutant levels, as in the London fog,[7,8] Meuse Valley, Belgium,[9] or Donora, Pa,[10] incidents. Even at much lower levels, all-cause mortality tracks the peaks in mean particulate levels within large cities.[11,12] Linkage of existing databases of citywide exposures with health outcome data enables epidemiologic studies of pollutants that vary more from day to day than they do from one part of the city to another.

What makes an exposure–outcome linkage useful for surveillance? The air pollution example underscores the importance of "scale." If data are collected at the level of a county, then to evaluate differences across counties, exposures would need to be relatively homogeneous within counties and heterogeneous between counties. Thus, the scale of data collection should correspond to units that are relatively homogeneous. Furthermore, the boundaries of the exposure database need to correspond to the boundaries of the health outcome database.

Examples

Although for large countries, development of unified surveillance systems with data collection in regions of congruent boundaries may be unrealistic in the near future, there are some elements of such a system even here in the United States. The strategy that the National Cancer Institute developed in the 1970s with their county-specific cancer maps is an interesting example. These maps[13,14] served as an impetus to studies that identified higher mortality rates of nasal cancer in areas with furniture manufacturing industries,[15] lung cancer in counties with petrochemical manufacturing,[16] bladder cancer where chemical industries were located,[17] and oral cancer in regions where snuff use was common.[18] The maps of disease patterns served as a surveillance tool and constituted the first descriptive step of a multistage investigation that proceeded as follows[16,17,19]: maps of disease patterns were linked with spatial information on the geographic distribution of major industries and area-specific counts of employees in these industries.[20] This first stage of analysis was frequently correlational/ecologic; county disease rates were regressed against extent of specific industries or lifestyle factors. These ecologic regressions models adjusted for county-level characteristics such as median income, median education, population density, and percent of the population living in urban areas. Geographic analyses by gender were particularly of interest: in the United States and some other countries, geographic patterns observed for men but not women are likely to be related to occupational exposures, whereas those seen for women are less likely to be. Hence, the high rates of oral cancer in the southeast of the United States among both sexes served as a clue that occupational factors probably were not involved, leading to the hypothesis that snuff use was a major risk factor. To test the hypotheses generated by geographic correlation studies, the National Cancer Institute strategy employed a second stage of study that consisted of death certificate reviews, and finally, a third, namely case–control studies involving interviews with study subjects or proxies.[16,19] In short, county-level data were available for mortality and for a range of socioeconomic and demographic factors, as well as for the presence of industries and the proportions of the population working in those industries (i.e., outcome, covariate, and exposure data were aggregated in the same units). Even though exposures may not have been homogeneous throughout the county, the between-county variability in the exposures of interest apparently was large enough, relative to the within-county variability, to enable effective analyses. (For an excellent discussion of this type of "ecologic" measurement error, see Brunekreef et al.[21])

A second instructive surveillance model is provided by that of Great Britain. In response to media reports of excess childhood leukemia cases around the Sellafield nuclear reprocessing plant, the government of Great Britain set up an enquiry to investigate the situation.[22] The resulting report called for a centralized surveillance system to monitor risk in small areas around major installations that discharged potentially carcinogenic or mutagenic substances. In the mid 1980s, the Small Area Health Statistics Unit was established with ties to the Environmental Monitoring Project at the Office of Population Censuses and Surveys. Its missions were (a) to respond to reports of disease clusters, especially those around industrial sites; (b) to develop reliable information on background rates of disease in small areas; (c) to study the data for evidence of elevated rates of disease; and (d) to develop statistical methods for the study of small areas. This development of methods for small area analyses is a major need for environmental effects that occur in localized regions. The British Small Area Health Statistics Unit appears to have stimulated important contributions in the statistical and epidemiologic literature in the area of cluster analysis, both for clustering as a generalized phenomenon, and for measuring associations between a point exposure and the occurrence of disease in nearby communities.[23–25] Internally, what appears to be rather unique and particularly promising is the development of small units for simultaneous collection of a variety of types of data. In particular, many health events now are routinely assigned postcodes that correspond, on average, to 14 households apiece[22]; population data and corresponding socioeconomic variables are available at the level of an enumeration district, corresponding to about 170 households or 400 persons. The system is not perfect; for instance, postal codes can straddle enumeration districts. Nevertheless, it is clear that such a fine resolution of geographic units for health outcome data will improve the chances that environmental exposures are homogeneous within these units and will increase the sensitivity of findings generated by the surveillance data.

The Scandinavian countries have greater opportunities for linkage of databases because, within those countries, each individual is assigned a unique identifier that becomes part of all hospital records and workplace records. Finland, for example, has a large number of databases that contribute to surveillance of occupational safety and health, including registers of occupational disease cases, hospital discharges, congenital malformations, industrial hygiene measurements, employees exposed to carcinogens, occupational radiation levels, hazardous chemical products, and safety inspection databases.[26,27] There also are several linked databases including disability/occupation, cancer/occupation, and mortality/disability. The Finnish population register contains links to all residences, with dates of moving in and out, allowing phenomenal possibilities for environmental exposure studies. As an example, these data were exploited in a cohort study on the relation between cancer and residential proximity to high-power lines.[28]

Although the Finnish system, if proposed for the United States, would raise concerns about confidentiality, many of its elements might well be acceptable, for example, the register of persons exposed to carcinogens. The British system underscores the advantages of a coordinated unified approach across many government organizations.

There also is a role for one-time or periodic surveys, such as those administered by the US National Center for Health Statistics (National Health and Nutrition Examination Surveys [NHANES], National Health Interview Surveys, National Survey of Family Growth, National Mortality Followback Surveys, etc.), that are able to obtain much more detailed data on a subset of the population. Using scientific sampling, these surveys are extremely useful; but again, the concept of homogeneity of exposure is critical. For many environmental exposures, the areas of high concentrations may be quite small and could easily be missed by this approach. One of the better examples of the success of such surveys is the identification of leaded gasoline as a major source of human body burdens. This discovery occurred serendipitously: the phaseout of lead in gasoline began during the 4-year NHANES II, and the impact of the reduction was nearly immediate (lead has a half life of about 45 days in blood), such that those surveyed earlier in the study period had substantially higher blood lead concentrations than those surveyed later. The NHANES II analyses were critical in preventing reintroduction of lead into gasoline.

Comprehensive environmental surveillance, with all of the elements outlined above, certainly would be costly. However, the benefits would be numerous: as an early warning capability (i.e., the ability to detect any unusually high incidence of diseases covered by the system); in the avoidance of public anxiety and costly investigations of situations where no excess risk is ascertained; and in the potential for increased public confidence in the commitment of government officials and health scientists to protect the population's health. ☐

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