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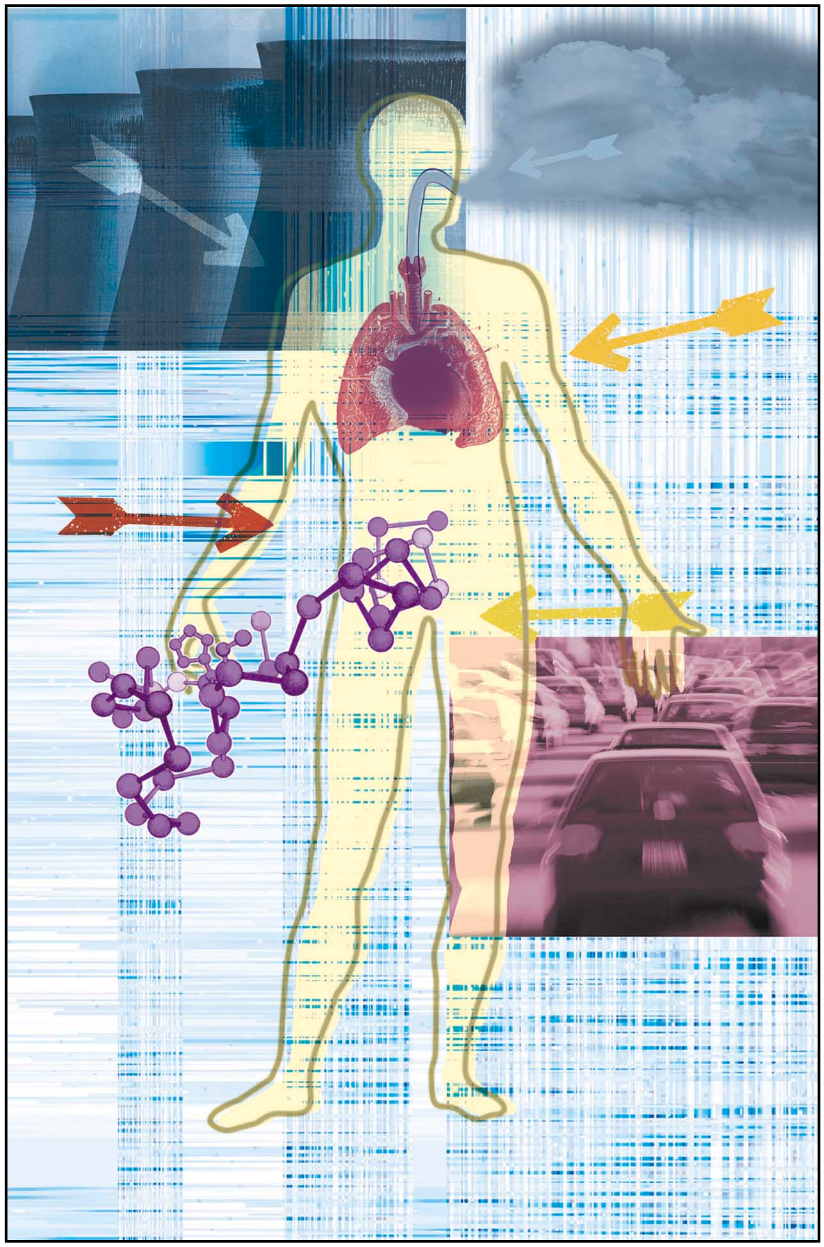

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Chris Furgal
Pierre Gosselin

International Joint Commission — Commission mixte internationale

Health Canada — Santé Canada

CANADIAN JOURNAL OF PUBLIC HEALTH

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Quebec City Consensus Conference on Environmental Health Indicators
October 2000

Guest Editors: Chris Furgal and Pierre Gosselin

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Karen Craven
400-1565 avenue Carling Avenue
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Telephone/Téléphone : 613-725-3769
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PREFACE

Environmental Public Health Surveillance for Healthy Environments

Surveillance and monitoring in the fields of environmental and public health are critical to both research and professional practice. The collection and monitoring of data related to the health status of populations and the factors influencing this status form the necessary baseline of information with which to establish diagnostic tools and to determine proper and effective intervention initiatives.

The importance of public and environmental health monitoring and surveillance has become recognized the world over, with essentially every country stating, in one form or another, the need for capacities in these areas. Also, countries have recognized their need to share information and to develop comparable data.

The explicit recognition of the serious state of many of the earth's environmental problems, and their significant influence on human health, was stated with consensus at the 1992 Rio Earth Summit. At this point in time, countries joined in recognizing that many of these situations (e.g., anthropogenic contaminants in the environment, human-induced climate change, etc.) were not improving, but were, in fact, getting worse and something had to be done to address these concerns. It was recognized that a better understanding, and analysis of these issues were required in order to begin to address them, and that this would neccessitate cooperative efforts as many of these issues were not specific to any one region or country, but were global in nature. Since then, several countries have undertaken large efforts to begin to implement monitoring and surveillance programs based on a variety of environmental and public health indicators. The 1998 World Health Organization European Charter, the 2002 statement from the Health and Environment Ministers of the Americas and the recent large (17.1 million dollar) initiative of the United States in this area are indicative of this commitment and the desire to advance capacities in these areas in order to protect and promote the health of all people.

In March 2002, the Health and Environment Ministers of the Americas met in Ottawa, Canada to discuss monitoring and surveillance issues for the first time in modern history. The results of this meeting led to their recent statement, highlighting the need for indicator development and implementation and capacity building for environmental and public health in the Americas. Further, they recognized the need to engage and involve civil society in these efforts towards action and intervention in the areas of human health and the environment. This could lead to hemispheric cooperation on a scale never before accomplished.

It is our opinion that the Quebec City Consensus Conference on Environmental Health Indicators, held in October 2000, and the papers contained in this supplement, are a great first step toward that goal. The International Joint Commission, Health Canada and our other partners were happy to support this initiative and will continue to promote the development of environmental and public health monitoring and surveillance. We feel that the knowledge generated through this and other exercises towards these ends, is critical in advancing our understanding, knowledge, and action on surveillance and monitoring and, in turn, in protecting and promoting a healthy environment to support public health throughout the world.

The Rt. Hon. Herb Gray, Chairman, Canadian section, IJC
Dennis Schornack, Chairman, US section, IJC

Challenges and Directions for Environmental Public Health Indicators and Surveillance

Chris Furgal, PhD[1]
Pierre Gosselin, MD MPH[1,2]

The official recognition of the state of many of the earth's modern environmental problems, and their influence on human health was first stated in unity by governments at the 1992 Rio Earth Summit. Issues such as anthropogenic contaminants in the environment, human-induced climate change, growing inequities between rich and poor, and the influence that these factors have on human health were identified and since then have been noted to be getting worse in many areas of the world. It was recognized that a better understanding and identification of these environmental health issues were required in order to begin to address them, and that this action would require collective efforts among communities and countries as many of these issues did not recognize political boundaries but were of a global nature. Here, we refer to "environmental health" in the following sense:

"Environmental health comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social and psychological factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially affect adversely the health of present and future generations."[1]

Some recent yet preliminary calculations of the burden of disease relating to these environmental and occupational determinants[2] estimate that these factors are related to approximately 11% of all diseases in Latin American countries. Other World Health Organization (WHO) studies show that the poor, and especially children and women, share a disproportionate burden of disease relating to environmental sources. The contribution of environmental factors to disease among the most vulnerable populations has been roughly estimated by WHO to be between 25% and 33% of the global burden of disease (many more studies are currently underway to further refine these figures).[3] This situation has generated a high level of activity towards the development of environmental public health indicators and surveillance systems, primarily in Europe[4] and the Americas.[5]

The Conference on Environmental Health Surveillance, Québec City, 2000

In October 2000, a group of researchers, practitioners and health professionals came together in Québec City to discuss the challenges facing environmental health monitoring and surveillance and to discuss the possibility of developing consensus on many of these issues (see List of Conference Attendees on page 71 of this Supplement). The conference was initiated and supported by the International Joint Commission (IJC), the Pan American Health Organization (PAHO), Health Canada, Environment Canada, and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR). To initiate discussions, a number of papers were commissioned, providing a review of the state of the knowledge in various pertinent areas and proposing a list of potential indicators to monitor the interactions between specific environments and human health. A number of common or cross-cutting themes emerged from the papers and conference discussions and are used in this supplement to propose an approach to developing a set(s) of common environmental health indicators to meet basic needs for environmental public health monitoring and surveillance.

Overview of the Conference

The concept of environmental health is multifaceted and complex in nature, consisting of both biotic and abiotic components of physical environments as well as aspects of social, economic and political processes which influence the health of ecosystems and in turn, the well-being of the world's populations. For example, the demographic changes that are taking place in coastal zones and the dependence of many groups on the sea (e.g., resources, travel, etc.) have associated health benefits and risks as discussed by Dewailly et al.[6] and are exemplified by such things as the rates of incidence and impacts of marine toxin poisonings. Similarly, Morris and Cole[7] describe some effects that industrial activities have had on freshwater systems (e.g., the Great Lakes) and the influence that the presence of these chemicals has on the health of populations living in these regions in North America. Similar extrapolations could be made to other large freshwater ecosystems in which intensive development and high population densities exist.

In discussing the relationships between human populations and the environment, Pong et al.[8] remind us of the importance of how populations are defined in relation to the information we collect to monitor their health status. Indicators for rural populations currently do not exist in Canada and in fact, there are few data of an environmental nature that describe them. Specific rural environmental health indicators would allow us to assess and improve the state of these environments and their impact on health in rural areas – this remains to be done. Hancock[9] describes the links between urban populations and the various aspects of these environments. He includes aspects of the built environment, as well as the bioregional and natural ecosystem on which urban settings depend. Also, he expands the view of "environment" to include components of the social, economic and political settings and processes that are part of everyday life and which affect human-environment relationships. The importance of the built environment is critical to consider when contemplating human-environment interactions as half of the world's population now lives in

1. CHUQ – Pavillon CHUL, Public Health Research Unit, Beauport, Québec
2. WHO / PAHO Collaborating Centre on Environmental and Occupational Health Impact Surveillance, CHUQ, Beauport, Québec
Correspondence: Chris Furgal, Public Health Research Unit, CHUQ - Pavillon CHUL, 2400 rue d'Estimauville, Beauport, QC G1E 7G9, Tel: 418-666-7000 ext. 555, Fax: 418-666-2776, E-mail: christopher.furgal@crchul.ulaval.ca

urban settlements, with Europe and North America being approximately 80% urbanized and with individuals spending as little as 5% of their time in what one might consider "natural" environments. These urban areas are reported to consume 75% of the world's resources and produce most of its waste.[10] Thus the "health" of these built environments is becoming increasingly important in assessing and monitoring the determinants of human health.

Monitoring, as described here, involves the collection and analysis of measurements aimed at identifying changes in the environment, the health of human populations, or both. Further, it can involve the assessment of actions taken to address issues related to these environment-human interactions. Surveillance has become a critical task in many governmental organizations responsible for ensuring the health and well-being of populations and/or the environment (see Eylenbosch and Noah[11]). As described in this supplement, the relationships between environments and human health are complex, and thus it is difficult to know what measurements are most appropriate to take when monitoring the status of environmental compartments, human health, or the relationship between them. To measure all factors in these relational chains would be too time- and resource-intensive and thus measurements that are indicative of the relationships and impacts we are concerned about, or interested in, are chosen as "indicators" to document and track. Briggs et al.[12] define an environmental health indicator as:

> *"an expression of the link between environment and health, targeted at an issue of specific policy or management concern and presented in a form which facilitates interpretation for effective decision making."*

Thus, the exercise would appear to be to simply identify a number of indicators that are representative of the relationships between human health and various aspects of different environments and to monitor their progress over time, adjusting private and public actions accordingly. However, this alone is a time- and resource-intensive task. In their paper on the identification of risks related to Great Lakes pollutants and human health, Hicks and De Rosa[13] emphasize the need to identify and monitor the health status of "at risk" populations, or sentinel situations. These geographic locations, populations, sub-populations, or individuals are defined as being the most susceptible to certain human-environment interactions, therefore more representative of the extent of the potential impacts on health and thus requiring more attention than the wider population. This choice of monitoring the 'most susceptible' becomes important when we consider the time and funds required to monitor all interactions for all environments and all populations.

Further, as Innes[14] states "*more is required to inform policy than simply producing academically certified data and handing it to policy makers.*" This point is discussed in detail by Aron and Zimmerman[15] in their paper on the communication needs for translating indicator data into government action. They discuss the importance of being able to understand and enhance the processes of collecting, interpreting and drawing conclusions from indicators for effective use in decision-making processes. Information is needed to assess and monitor trends, identify and prioritize problems, develop and evaluate policies, guide research and development, set standards, monitor progress and inform the public. It is important that these data be conveyed in a comprehensible way, but with due regard to the complexities and uncertainties inherent in the data.

Chapter 40 of the global action plan on sustainable development, Agenda 21, dealing with information for decision-making states that, "*in sustainable development, everyone is a user and provider of information in the broad sense.*"[16] While health, environment and development problems differ in various parts of the world, as do priorities with regard to their management, there is a need in all situations for decision-makers and the public to have access to accurate information on health hazards associated with development and the environment. In a paper on indicators within the context of sustainable development, von Schirnding[17] provides an overview of specifically what type of information this includes and how best it is organized.

As discussed above, the activities of identifying and collecting these data consitute no small task. Additionally, the capacities to do so differ significantly among jurisdictions, countries and continents. How then is it possible to collect and organize information in a way that is valid, efficient and also meets the growing needs for comparable data across regions to address these environmental health issues that are bound by physical and chemical processes and not political boundaries? In their paper on information technologies and their application to environmental health monitoring and surveillance, Bédard and Henriques[18] describe some of the ways in which cost-effective and comparable data can be collected and analyzed. However, the reality of the situation is that the capacity to adopt and implement these technologies does not exist in all regions of the world. Cooperation, coordination, and commitment are required among governments and agencies to take advantage of the benefits these technologies offer in addressing data and information needs in environmental health practice. However, the Québec conference did show that common denominators link all of these levels of inquiry.

A common approach

Whether it is in relation to the need for basic information on human interactions with urban, rural, freshwater or marine ecosystems in the form of indicators, or the need for comparable, valid data for national and international level monitoring on water quality in Brazil, the papers presented at the conference stress the requirement for the identification and collection of valid, reliable and comprehensive data. The generation of and access to this information require significant commitment of resources, coordination of efforts and collaboration among agencies and organizations at various levels. Cost-effective and efficient technologies must be developed to support and enhance abilities to conduct this cooperative and transparent collection, organization, analysis and communication of information. Without the development of consensus on the required elements and concepts of such monitoring and surveillance efforts, we will continue to collect data that are only of immediate value at the local, regional or national levels for many issues that are global in nature and require higher levels of organization and analysis. Considering the disparate nature of many capacities and resources dedicated to these efforts, one might ask whether it is possible to develop such a collection, and if so "what to monitor". Many countries' and

TABLE I
Water-related Public Health Targets and Underlying Questions

Suggested Targets for 2015 (Source: WSSCC, 2001[11])	Examples of Underlying Questions
1. Universal public awareness of hygiene	Is the importance of personal hygiene well known?
2. Percentage of people who lack adequate sanitation decreased by 50%	What is the access to effective sanitation?
3. Percentage of people who lack safe water decreased by 50%	What is the access to sources of microbiologically and chemically safe water?
4. 80% of all primary school children educated about hygiene	Is the level of awareness and training in basic personal hygiene adequate?
5. All schools equipped with facilities for basic sanitation and hand washing	What is the access to facilities for basic hygiene in schools? other public buildings?
6. Diarrheal disease incidence reduced by 50%	What is the incidence of water-related diseases?

regions' environmental health problems are of a more "basic" nature than others, and many regions of the world do not have the resources, technologies or abilities to implement high technology surveillance programs to identify and address these issues.

Identifying a common set of indicators for global environmental health

In consideration of the articles in this supplement and the current dialogue relating to environmental health surveillance in various countries around the world, we argue that there is common ground among scales, jurisdictions, priorities, and abilities relating to environmental health surveillance and monitoring. Establishing a set of "basic environmental public health questions" founded in some basic needs may be one way through which to unify many resource and concept-related perspectives. These questions, or basic environmental health needs, remain the same on all scales. As stated in many papers in this supplement, indicators serve a purpose, which is usually presented in the form of a public health objective. For example, some United Nations agencies have recently suggested some basic water-related public health targets,[19] and in Table I we suggest some related environmental health questions we believe will remain the same across all geographic scales, levels of economic development and over time.

Similar objectives have been proposed by PAHO[20] for other sectors in the Americas such as indoor and outdoor air quality, toxic chemicals exposure management, climate change, technological and natural disasters, as well as for organizational needs in preparedness, surveillance, laboratory support, etc. Related questions could similarly be formatted for these objectives. In response to each of these questions regarding basic environmental health needs and objectives, there are a number of potential indicators or measurements that could be applied, many of which already exist but some (especially for interventions) for which new indicator development is required. In order to be comprehensive in the approach and allow indications of status from all regions, it is necessary to be flexible in the ways this information is collected.

Basic and reliable ways of gathering data

It is not always possible to have quantitative, organized and easily accessible data to answer these questions. Therefore, a flexible approach to "data collection" must be taken which includes the opportunity for traditional quantitative evaluations but also qualitative assessments comprised of such things as expert opinions, sentinel stories and questionnaires. These methods can still be applied at the smallest available scale in a valid and reliable manner (see Eyles and Furgal[21]) to allow for some form of rapid assessment. Of course, this is in lieu of an advanced monitoring and surveillance system. However, the identification and tracking of issues in whatever reliable and feasible manner, will support the establishment of priorities and implementation of programs to address these issues. Imperfect information collected under known constraints is much better than no information at all to support public health decision-making processes and represents a first and significant step towards a longer term commitment.

Selecting a core: Being flexible to regional needs and capacities

Evident in the papers presented in this supplement and the environmental health literature is the unique aspects of many environments, regions, and locales around the world. At the same time many basic environmental health issues are global and not only local in nature. It is for these reasons that a "core" set of indicators has been proposed and great effort has been put forth in utilizing these indicators by such organizations as the World Health and Pan American Health Organizations. Similarly, a set of basic or "core" questions could be proposed which are common to many or all regions and jurisdictions. Respecting the nature of global variability in environments and human-environment relationships (e.g., small island states vs large urban areas), "optional" questions could be developed in the same manner which involve many indicators and for which data could be collected in a variety of ways dependent upon resources and feasibilities in the respective locations. In order to move towards basic and standardized abilities to collect and access data though, these core questions must be comprehensive in their approach, including not only the basic needs, but access to basic services which support these needs, and the abilities to collect and organize these data. This will enable environmental health professionals and decision-makers to track not only the status of human-environment interactions, but also the inequities in access to services to meet these needs and the abilities to monitor such phenomena.

CONCLUSIONS

This paper argues that in consideration of the complex nature of human-environment interactions and our increasing understanding of their inextricably interwoven nature, it is critical to monitor the feedbacks and status of these relationships in the interests of human health. Further, as many anthropogenic-related environmental challenges, and the level of global industrialization and development increase, it is critical to keep a close eye on the impact we are having on the environment, and in turn, that environments are having on us. As many of the environmental influences on human health are global in nature and such problems as atmospher-

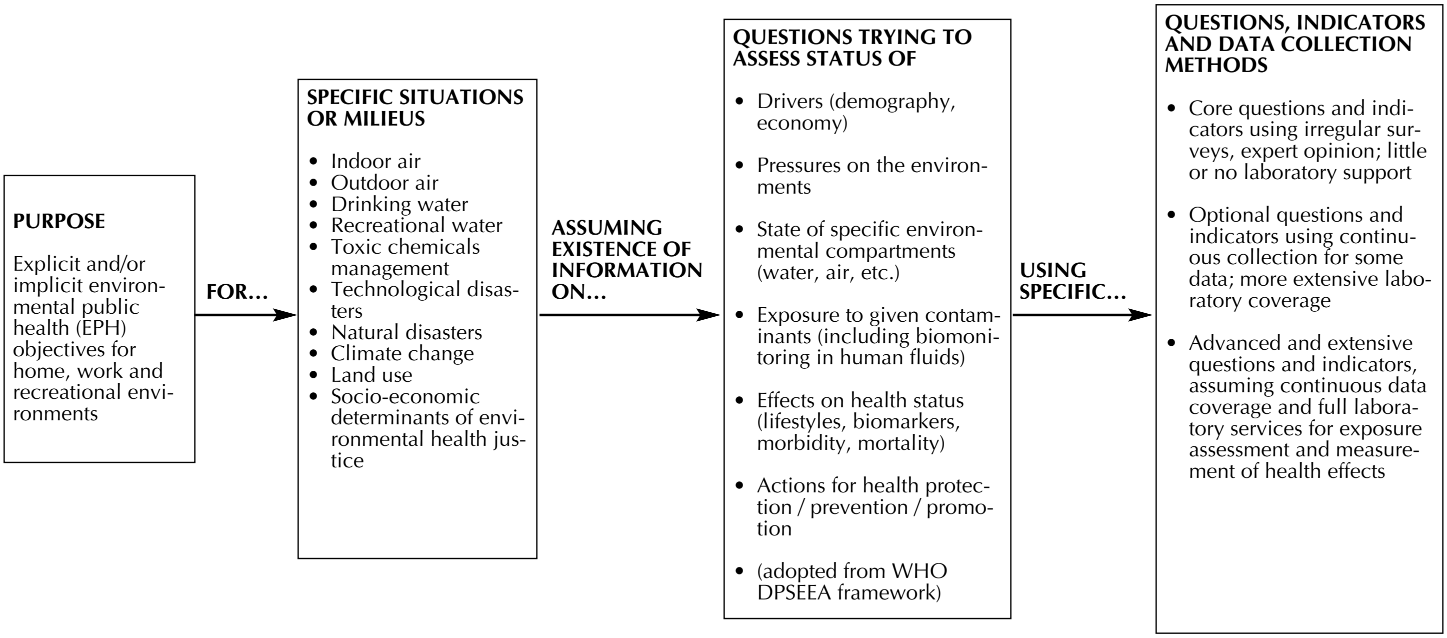

Figure 1. Process for development of a common approach in environmental health indicators and surveillance.

ic and ocean transport of environmental contaminants do not stop at political boundaries, collective efforts and actions are required (e.g., as recognized in the recently signed Stockholm Convention on Persistent Organic Pollutants). However, not all countries and regions have the same capacity to take part and act on these issues, thus some form of unifying or common approach must be proposed and pursued. This paper outlines the steps of an approach based on "basic questions" to develop indicators for environmental health considering the challenges of scale, capacity, data comparability and reliability. Such an approach would consist of the development of consensus around basic objectives (founded on basic environmental health needs), basic core and optional questions recognizing the unique nature of many environmental regions and geographic locations, and a 3-tiered approach to monitoring and surveillance for these questions reflecting the capacities present in various regions around the world to conduct such activities (Figure 1).

Finally, in order to better understand the impacts of human activities on the environment, and conversely, to protect and promote the health of both humans and the ecosystems upon which we rely, a common commitment and effort to cooperate on initiatives must be adopted. This commitment must include the enhancement of capacities in regions of the world where such capacities to monitor and act on these issues are challenged, in order to ensure a common minimal standard of global environmental health.

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Health-and-Environment Indicators in the Context of Sustainable Development

Yasmin E. von Schirnding, PhD

"Indicators are a way of seeing the big picture by looking at a small piece of it."
Jackson Community Council, quoted in Plan Canada 1999[1]

ABSTRACT

This paper gives a broad overview of issues relevant to the development and use of health-and-environment indicators in the broader context of sustainable development. Criteria for the construction of indicators are given, and their key characteristics are highlighted. Selected international indicator initiatives are discussed, as well as the concept and use of core indicators in policy and planning. Finally, an organizational framework for the consideration of health-environment-development linkages is presented, which can be used in the development of health-and-environment indicators in various contexts. This framework is the Driving forces-Pressures-State-Exposures-Health Effects-Actions framework (DPSEEA) of the World Health Organization (WHO). It is a descriptive representation of the way in which various driving forces generate pressures which affect the state of the environment, and ultimately human health through the various exposure pathways by which people come into contact with the environment. Throughout the paper, emphasis is placed on work done within the UN system, in particular that of the WHO, and examples of suites of indicators developed and in use are provided.

RÉSUMÉ

L'article offre une vue d'ensemble des enjeux relatifs à l'élaboration et l'utilisation d'indicateurs de santé et d'environnement dans le contexte plus large du développement durable. L'auteur propose des critères pour la construction d'indicateurs et en souligne les principales caractéristiques. Il traite de certains projets d'indicateurs à l'échelle planétaire ainsi que de la conception et de l'utilisation d'indicateurs de base pour l'élaboration de politiques et la planification. De plus, il présente un cadre organisationnel qui tient compte des liens entre la santé, l'environnement et le développement et qui peut servir à la mise au point d'indicateurs de santé et d'environnement dans divers contextes. Ce cadre de l'Organisation mondiale de la Santé (OMS) s'intitule Forces motrices-Pressions-État-Exposition-Effets sur la santé-Actions (DPSEEA en anglais). Il constitue une représentation descriptive de la manière dont les diverses forces motrices exercent des pressions qui touchent l'état de l'environnement puis la santé humaine, vu les diverses voies d'exposition par lesquelles les personnes entrent en contact avec l'environnement. L'auteur insiste sur le travail effectué dans le réseau de l'ONU, notamment dans celui de l'OMS, et fournit des exemples de groupes d'indicateurs mis au point et utilisés.

World Health Organization
Correspondence: World Health Organization, 20 Avenue Appia, Geneva 27, Switzerland 1211, Tel: 41 22 791 3533, Fax: 41 22 791 4153, E-mail: vonschirndingy@who.int

Information for decision-making

Chapter 40 of the global action plan on sustainable development, Agenda 21, dealing with information for decision-making, states that "in sustainable development, everyone is a user and provider of information in the broad sense."[2] While health, environment and development problems differ in various parts of the world, as do priorities with respect to their management, there is a need in all situations for decision-makers and the public to have ready access to accurate information on health hazards associated with the linkages between development and the environment.

Information is needed to monitor and assess trends, identify and prioritize problems, develop and evaluate policies and plans, guide research and development, set standards and guidelines, monitor progress and inform the public. It is important that these data be conveyed in a readily comprehensible way, but with due regard to the complexities and uncertainties inherent in the data.

Role of indicators

Indicators can play an important role in turning data into relevant information for decision-makers and the public. They can help to simplify a complex array of information with respect to the health-environment-development nexus and in this way provide a "synthesis" view of existing conditions and trends. They have become well established and widely used in many different fields and can be used at the global, regional, national, local or neighbourhood level, as well as at the sectoral level.[3] (see Figure 1)

Briggs et al.[4] have defined an environmental health indicator as: "An expression of the link between environment and health, targeted at an issue of specific policy or management concern and presented in a form which facilitates interpretation for effective decision-making." Embodied in this definition is the concept of a linkage between a factor in the environment and a health outcome.

Examples of indicators are numerous and include such measurements as GDP (Gross Domestic Product) as a way of assessing aspects of economic development in a country, the infant mortality rate (IMR) as an indicator of the health status of a community, or the rise in ambient temperatures, worldwide, as an indicator of climate change.

Criteria for indicators

To be useful, indicators should be user-driven, and not just technically relevant or relevant to the providers of data. The actual choice of indicators depends on factors such as the purpose for which they are to be used, and the target audience. Many organizations have attempted to define criteria for the construction and selection of indicators and have included various factors such as transparency, scientific validity, robustness, sensitivity and the extent to which they are linkable.[5] Further, they could be assessed according to whether they are relevant to the issue they are intended to describe, whether they relate to changes in policy and practice, or whether or not they are resonant with their intended audience.[5]

Criteria which could be used in the development of indicators are given in Figure 2. The applicability of the criteria will depend on the indicator in question, and the purpose of the indicator to be used. However, no single set of criteria will be applicable to all indicators as each situation will have its own priorities for data collection and analysis.

NATURE AND CHARACTERISTICS OF INDICATORS

Indicators may be specific, or may be composites which condense a wide range of information on different (but related) phenomena into a single measure or index. The construction of composite indicators is challenging, and demands high levels of statistical and measurement competence in weighting and combining various variables. Composite indicators may be difficult to test or verify as they may not relate to specific, measurable conditions. Composite indices can nevertheless be useful in summarizing data and information for decision-makers. For instance, in the field of health, the "DALY" is an example of a composite measure of the burden of disease based on the concept of disability-adjusted life years, which combines the years of healthy life lost due to premature death, disability or disease.[6]

At all levels (global, regional, local), indicators that describe the overall state (quality) of the environment, and that highlight factors influencing environmental quality, as well as potential impacts on human health, can be useful. They can provide an overview, or snapshot of a situation, or a profile of environment-and-health conditions, thereby identifying trends. In this regard, the indicator framework described in the last section of this article has application.

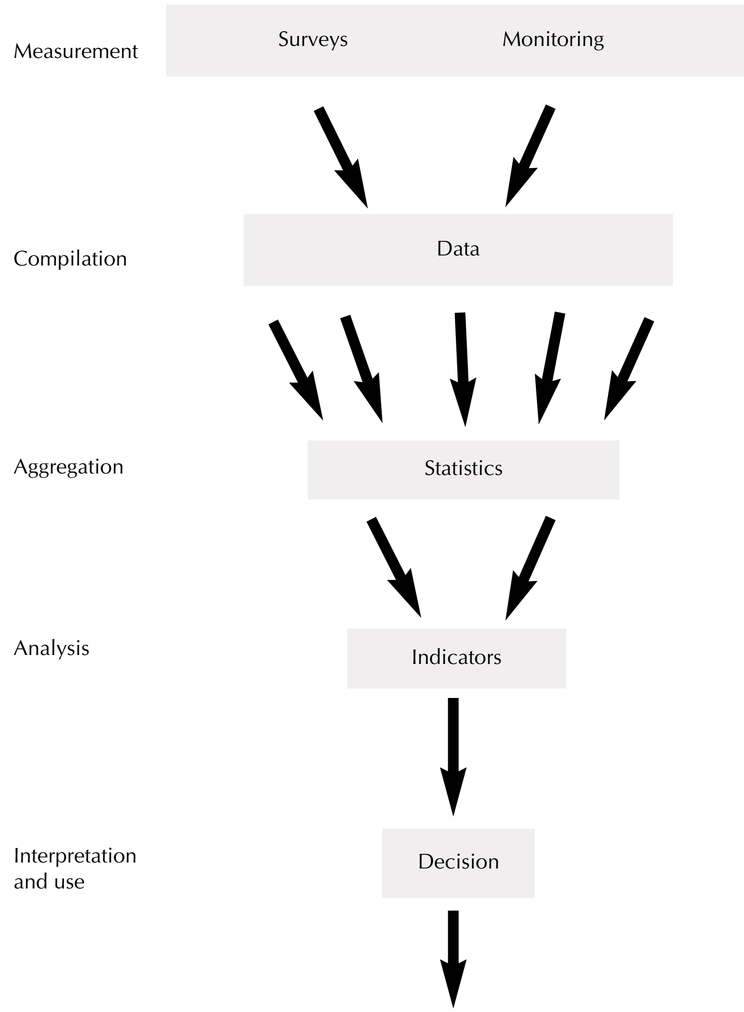

Figure 1. Hierarchy of information to indicators and their use in decision-making.

Of general relevance
- related to a specific question or issue of concern
- health-related and linked to environment/development factors
- sensitive to changes in the conditions of interest
- provide early warning of pending changes.

Scientifically sound
- unbiased and representative of the conditions of concern
- scientifically credible, reliable and valid
- based on best available data of acceptable quality
- robust and unaffected by minor changes in methodology/scale used for their construction
- consistent and comparable over time and space.

Applicable to users
- have relevance to policy and management needs
- based on data which are available or can be collected/monitored with a reasonable financial/time resource input
- easily understood and usable by potential users
- acceptable to stakeholders.

Source : Modified and adapted from Briggs et al.[4]

Figure 2. Criteria for indicators

Indicators that describe the various policy responses taken to address problems can be of value. In developing countries in particular, where the data base necessary to construct indicators may be limited, but the problems (and solutions) are well known, it may be more appropriate to focus on the development of response, or action indicators, than on indicators relying on data from extensive monitoring programs.[5] Performance indicators, which measure whether agreed targets and goals have been met, may be very useful in these cases.

INTERNATIONAL INDICATOR INITIATIVES

Sustainable development indicators

Many intergovernmental and nongovernmental organizations and countries have developed indicators of sustainable development, supported by the United Nations. In the early-to-mid 1990s, organizations such as the OECD,[7] UNEP/RIVM,[8] the World Resources Institute (WRI),[9] the World Bank,[10] SCOPE[11] and others became centrally involved in the development of indicators to monitor environmental trends.[3]

To date, around 130 indicators of sustainable development have been compiled by the Commission on Sustainable Development.[12] These indicators are currently being tested at the national level by countries throughout the world and, based on analysis of the test results and review of developments in other international indicator sets, a core set of indicators for sustainable development (and related methodologies) will be developed as a tool to support national-level decision-making in the future. The core set is based on the policy priorities of Agenda 21 and was presented for endorsement to the Commission on Sustainable Development in August-September 2002.

Housing and urban indicators

Indicators indirectly of relevance to health also include those developed by the UNCHS on housing and urban areas,[13] which constitute a monitoring package for cities and the shelter sector. Key indicators for this work were endorsed by the Commission on Human Settlements in May 1995, and constituted a set of indicators collected by countries as part of their preparation for HABITAT II.[13] The indicators cover the areas of socioeconomic development, infrastructure, transport, environmental management, local government, housing affordability, availability and provision, as well as some general related background topics.[13]

Social indicators of development

Social indicators of development have been compiled by the World Bank[14] to assess reductions in poverty. They include indicators of priorities, supplementary indicators of access to basic services and social safety nets, and indicators of human resources, natural resources, socioeconomic expenditure and investment in human capital.

Health indicators

WHO headquarters and regional offices have developed indicators (and targets) to assess its "Health-for-All" (HFA) policy. The purpose of the HFA indicators has been to guide member states in the evaluation of their national strategies for HFA, and to follow up on the implementation of the Global Strategy. HFA indicators previously developed dealt with trends in policy and socioeconomic development, health and the environment, health resources, health systems, health services and health status.[15] Further, global indicators are used for reporting purposes in the World Health Report of WHO and are used extensively in various regions of the WHO.

WHO has also developed programme indicators to monitor the health of infants and young children, women and the health of the general population, and to assess the status of specific situations (e.g., vitamin A deficiencies).[16]

Much work has also been done on indicators for environmental health.[4,17] No uniform set of EHIs has been recommended by WHO, however suites of indicators which can be selected from for various purposes have been compiled,[18] and methodology sheets for construction of selected indicators have been updated. (See Table I: Environmental Health Indicators) (For a comprehensive listing of example indicator sets, see http://ottserver1.ottawa.ijc.org/hptf/).

Baseline indicators have been developed by the WHO European Healthy Cities project, covering health, demography, health services, the environment and socioeconomic status.[19] The indicators were formally adopted by participating cities in 1990, and information has been collected on the 53 agreed indicators from cities for the period 1992 to 1994. Further, WHO has published a set of guiding principles to evaluate food safety programmes as well.[20]

CORE INDICATORS

Despite the existing arguments against a set of "core" indicators that could be used on a global scale to examine overall trends in environment and health conditions, most countries face the reality of having to deal with certain problems that are of universal significance. These might include air quality, access to potable water and sanitation, food safety, waste disposal, or toxic substances for example. While the specific dimensions of these problems will differ within and between countries, sets of universally applicable indicators could be valuable in improving shared knowledge on these and other issues. Further, common sets of indicators enable aggregation at various levels – local, country, regional, and global; provide momentum to countries in achieving uniform and rigorous standards; and provide tracking tools to monitor the success of international treaties.

It is argued that establishing agreement on a common set of indicators will significantly lessen the data-reporting burden on countries. Where user needs are similar, indicators should be harmonized. Efforts should be coordinated between government departments, agencies, NGOs, civil society and the donor community and where possible, existing data should be drawn upon, paying due recognition to the limitations of the data.

The common country assessment (CCA) indicator framework, developed by the United Nations Development Group (UNDG) as an indicator framework is currently being used by UN funds and programmes in over 100 countries.

Both the UN Statistics Division and UNDG are working with a selected number of countries to assess a) to what extent the national statistics system is involved in the CCA indicator effort and what the impacts are of the CCA indicator requirements on the national statistics system; b) which indicators are being used; c) what the data gaps are; d) how the UN Development Assistance Framework (UNDAF)-CCA indicator process is related to other policy processes (for example, IMF/World Bank Poverty Reduction Strategies for countries qualifying for enhanced debt relief); and e) what targeted programmes are being proposed to address the lack of data or data quality.[21]

TABLE I
Summary List of Environmental Health Indicators

Issue	Theme/Topic	Indicator	Example Definition	DPSEEA
Socio-demographic context	Poverty	Poverty	Human poverty index (compound index)	Driving force
	Population density	Population density	Population density	Driving force
	Population growth	Rate of population growth	Annual net rate of population growth	Driving force
	Age structure	Dependent population	Percentage of people aged <16 years or ≥65 years	Driving force
	Urbanization	Rate of urbanization	Annual net rate of change in the proportion of people living in urban areas	Driving force
	Infant mortality	Infant mortality rate	Annual death rate of infants under one year of age	Effect
	Life expectancy	Life expectancy	Number of years a newborn baby is expected to live, given the prevailing mortality rate	Effect
Air pollution	Outdoor air pollution	Ambient concentrations of air pollutants in urban areas	Mean annual concentrations of ozone, CO particulates (PM_{10}, $PM_{2.5}$, SPM), SO_2, NO_2, O_3 and lead in the outdoor air in urban areas	State
	Indoor air pollution	Sources of indoor air pollution	Percentage of households using coal, wood or kerosene as the main source of heating and cooking fuel	Exposure
	Respiratory illness	Childhood morbidity due to acute respiratory illness	Annual mortality rate due to acute respiratory infections in children under five years of age	Effect
	Air quality management	Capability for air quality management	Capability to implement air quality management	Action
	Air quality management	Availability of lead-free gasoline	Consumption of lead-free gasoline as a percentage of total gasoline consumption	Action
Sanitation	Excreta disposal	Access to basic sanitation	Proportion of the population with access to adequate excreta disposal facilities	Exposure
	Diarrhoea	Diarrhoea morbidity in children	Incidence of diarrhoea morbidity in children under five years of age	Effect
Shelter	Informal settlements	Percentage of population living in informal settlements	Percentage of the population living in informal settlements	Exposure
	Unsafe housing	Percentage of population living in unsafe housing	Percentage of the population living in unsafe, unhealthy or hazardous housing	Effect
	Home accidents	Accidents in the home	Incidence of accidents in the home	Effect
	Urban planning	Urban planning and building regulations	Scope and extent of building and planning regulations for housing	Action
Access to safe drinking water	Water quality/supply	Access to safe and reliable supplies of drinking water	Percentage of the population with access to an adequate amount of safe drinking water in the dwelling or within a convenient distance from the dwelling	Exposure/ Action
	Water quality/supply	Connections to piped water supply	Percentage of households receiving piped water to the home	Exposure/ Action
	Diarrhoea	Diarrhoea morbidity in children	Incidence of diarrhoea morbidity in children under five years of age	Effect
	Diarrhoea	Diarrhoea mortality in children	Diarrhoea mortality rate in children under five years of age	Effect
	Water-borne diseases	Outbreaks of water-borne diseases	Incidence of outbreaks of water-borne diseases	Effect
	Water quality monitoring	Intensity of water quality monitoring	Density of water quality monitoring network	Action
Vector-borne disease	Population at risk	Population at risk from vector-borne diseases	Number of people living in areas infected by disease vectors	Exposure
	Vector-borne disease mortality	Mortality due to vector-borne diseases	Mortality rate due to vector-borne diseases	Action
	Vector control	Adequacy of vector control and management systems	Percentage of the at-risk population covered by effective vector control and management systems, by disease type	Action
Solid waste management	Waste collection	Municipal waste collection	Percentage of population served by regular waste collection services	Action
	Waste disposal	Municipal waste disposal	Mass of solid waste disposed of by municipal waste management services	Action
	Waste management	Hazardous waste policies	Effectiveness of hazardous waste policies and regulations	Action
Hazardous/Toxic substances	Blood lead	Blood-lead level in children	Percentage of children with blood lead levels >10 ug/dl	Exposure
	Chemical poisonings	Mortality due to poisoning	Mortality rate due to poisoning	Effect
	Contaminated land	Contaminated land management	Scope and rigour of contaminated land management	Action
Food safety	Food-borne diseases	Food-borne illness	Outbreak rate of food-borne illness	Effect
	Diarrhoea	Diarrhoea morbidity in children	Incidence of diarrhoea morbidity in children under five years of age	Effect
	Diarrhoea	Diarrhoea mortality in children	Diarrhoea mortality rate in children under five years of age	Effect
	Monitoring of food safety	Monitoring of chemical hazards in food	Proportion of potentially hazardous chemicals monitored in food	Action
Radiation	Radiation exposure	Cumulative radiation dose	Percentage of the population receiving an effective radiation dose in excess of 5 mS/yr	Exposure
	UV exposure	UV light index	UV light index	Exposure

TABLE I, continued
Summary List of Environmental Health Indicators

Issue	Theme/Topic	Indicator	Example Definition	DPSEEA
Non-occupational health risks	Motor vehicle accidents	Mortality from motor vehicle accidents	Death rate due to road accidents	Effect
	Non-occupational injury	Injuries to children	Incidence of physical injury to children less than 5 years of age	Effect
	Poisoning	Incidence of poisonings of young children	Number of reported poisonings per year in children under 5 years of age	Effect
Occupational health risks	Occupational hazards	Exposure to unsafe workplaces	Percentage of workers exposed to unsafe, unhealthy or hazardous working conditions	Exposure
	Occupational morbidity	Morbidity due to occupational health hazards	Incidence of occupational injury	Effect
	Occupational mortality	Mortality from occupational health hazards	Incidence of occupational mortality	Effect

Source: WHO 1999[25]

TABLE II
Health and Environment Issues of Significance at Local, National and Global Levels

Local	National	Global
Dust	Hazardous waste	Climate change
Noise	Toxic chemicals	Transboundary pollution
Solid waste	Food safety	Ozone depletion
Water and sanitation	Ambient air pollution	Acid deposition
Pests	(major industrial/mobile sources)	Marine pollution

TABLE III
Global Reports

Report Title	Organization
Global environment outlook	UNEP, Nairobi
Human development report	UNDP, New York
State of the world's children	UNICEF, New York
United Nations statistical yearbook	UN, New York
Vital signs	Worldwatch Institute Washington
State of the world	Worldwatch Institute Washington
State of world rural poverty	IFAD, Rome
World development report	World Bank, Washington
World health report	WHO, Geneva
World health statistics annual	WHO, Geneva
World resources report	World Resources Institute Washington

While standard, internationally agreed upon sets of indicators are valuable for various reasons, nations may require other specific indicators to enable them to develop and evaluate national policies and plans. Therefore, any core set of indicators will have to be augmented in view of the particular national, regional and local policy concerns.

The roles and responsibilities with respect to various environment and health management functions at different tiers of government, the degree of decentralization of powers and functions, and other factors such as data availability and quality, will influence the extent to which it makes sense to examine data at different levels for international comparison purposes. Regardless of at what level the data are aggregated and examined, however, most information will normally need to be collected in the first instance, at the lowest level of resolution as is practicable and feasible.

The issues in Table II could have particular relevance at the global, national and local levels respectively, although it should be recognized that there are no rigid boundaries and the situation will vary from setting to setting, depending on the sources and the factors influencing their control (for example, local issues impact on global issues, and vice versa). At the national level, the setting of policies and standards may be fundamental, while at the local level, service delivery and implementation of policies is normally of key importance. Many issues require management over different tiers of government.

Table III provides examples of regularly published global reports containing detailed health and/or environment information.

The quality and quantity of health information has been improving over the years, with advances in health information systems and in health reporting. There are several international information sources available on environmental health effects, such as the Environmental Health Criteria (WHO, UNEP and ILO), the International Register of Potentially Toxic Chemicals, monographs on carcinogenicity of chemical substances (International Agency for Research on Cancer - IARC), and various WHO guideline documents such as those on drinking water quality and air quality.

Obtaining relevant data at the country level remains a significant problem and more so in poorer countries. Nevertheless most countries have some sort of health information system and problems in data coverage and data quality occur in almost all countries, to a greater or lesser degree.

LINKAGES AND FRAMEWORKS

It is important for decision-makers not only to obtain better data on, but also to obtain an enhanced understanding of, the linkages among the factors in the environment-development processes affecting human health. Several indicator frameworks for presenting the various linkages among factors influencing health in the context of environment and development have been developed, which are all adaptations of the "Pressure-State-Response" (PSR) framework developed by OECD[7] (in turn based on earlier work done by the Canadian government) (See Figure 3).

The PSR framework for the environment has been criticized for being linear and uni-directional. One example proposed to address this linearity is a model developed by the Commonwealth of Australia, indicating the feedback loops in circular fashion.[22] (See Figure 4)

Other adaptations to the PSR framework have made provision for the broader driving forces and pressures on the environment, as well as for the resulting impacts. A framework referred to as the PSIR framework (Pressure-State-Impact-Response) has been developed which makes provision for impacts such as those on human health, ecosystems, or economic and social systems.[23] (See Figure 5)

Both the exposures and resulting human health effects have been taken into account in a further adaptation of the framework for health purposes, referred to as the "DPSEEA" framework, which represents Driving forces, Pressures, State, Exposures, Health effects, and Actions.[4,17,18] It is a descriptive representation of the way in which various driving forces generate pressures which affect the state of the environment, and, ultimately, human health, through the various exposure pathways by which people come into contact with the environment.

People may become directly "exposed" to potential hazards in the environment when coming into direct contact with these media through for example breathing, drinking or eating. A variety of health effects may subsequently occur, ranging from minor, subclinical effects (i.e., effects that may not yet have manifested in overt symptoms) through to illness and sometimes death, depending on the intrinsic harmfulness of the pollutant, the severity and intensity of exposure and the susceptibility of the individual exposed (for example, the elderly, the young and the sick may often be more susceptible than others).

While the DPSEEA framework, like the original PSR framework, represents the various components in a linear fashion to more clearly articulate the connections among factors influencing health and the environment, in reality the situation is much more complex, with various interactions occurring at different levels among various components. The different components of the DPSEEA framework are shown in Figure 6. The framework can be applied to information gathering and indicator development at the national, sectoral, or indeed at the community or neighbourhood level.[24,25] (See Figure 6)

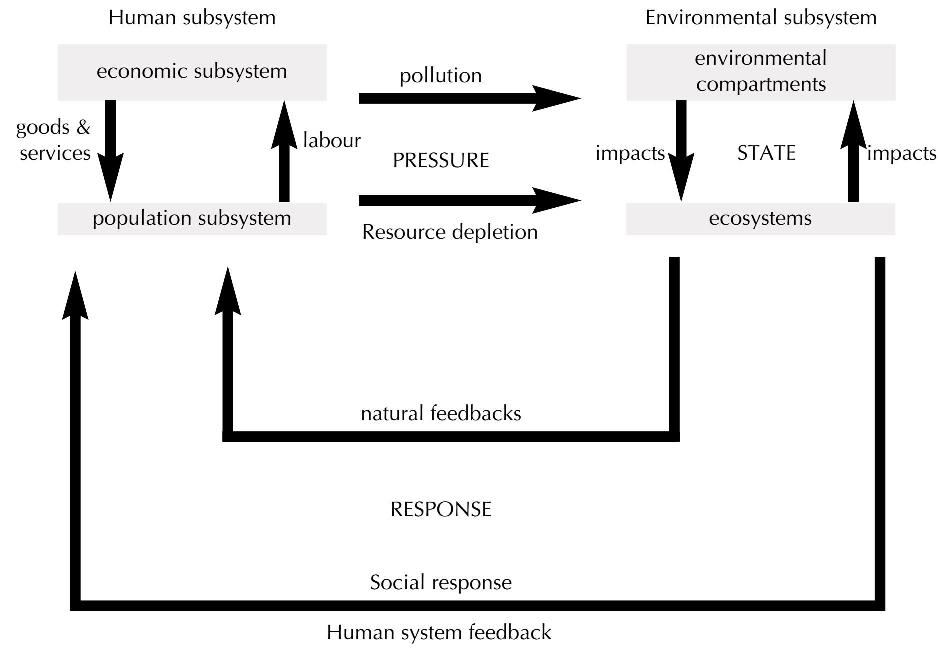

Figure 3. OECD Pressure-State-Response framework for indicators.

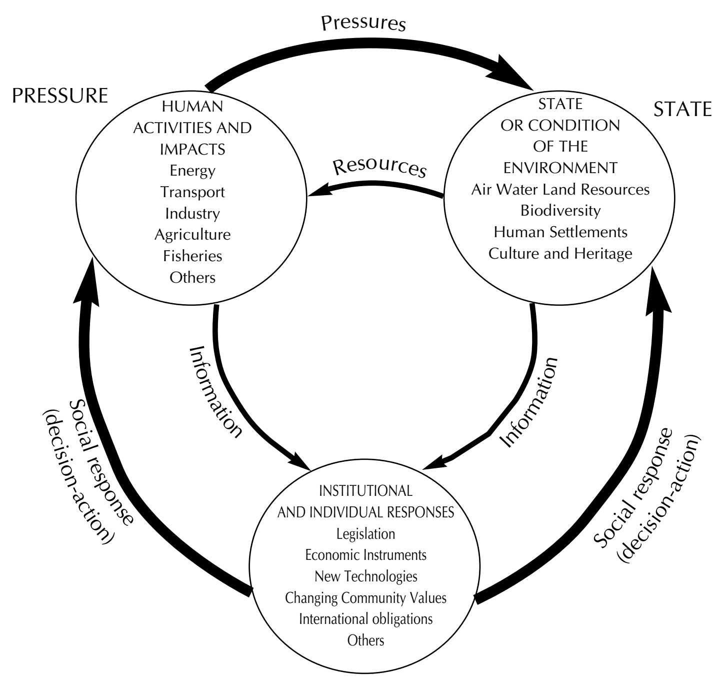

Figure 4. Commonwealth of Australia Pressure-State-Response framework for indicators.

SUMMARY

This paper has attempted to give a broad view of issues relevant to the development and use of health-and-environment indicators. Criteria for indicator development, national and international indicator initiatives, and the concept of core indicators have been presented and discussed. Finally, frameworks for the consideration of health-environment-development linkages have been presented, which may be useful for the development of health-and-environment indicators in various contexts throughout the world.

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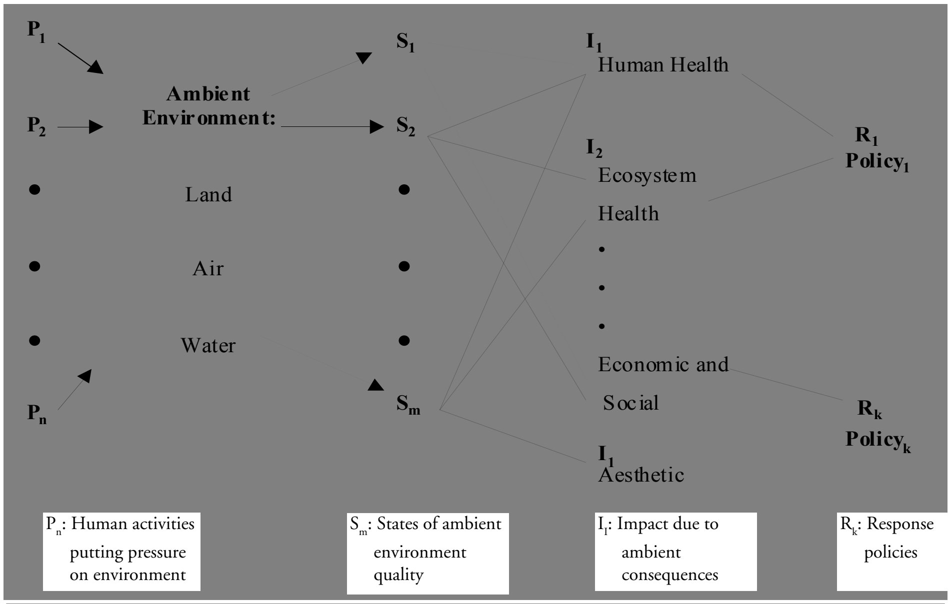

Figure 5. The Pressure-State-Impact-Response framework for indicators.

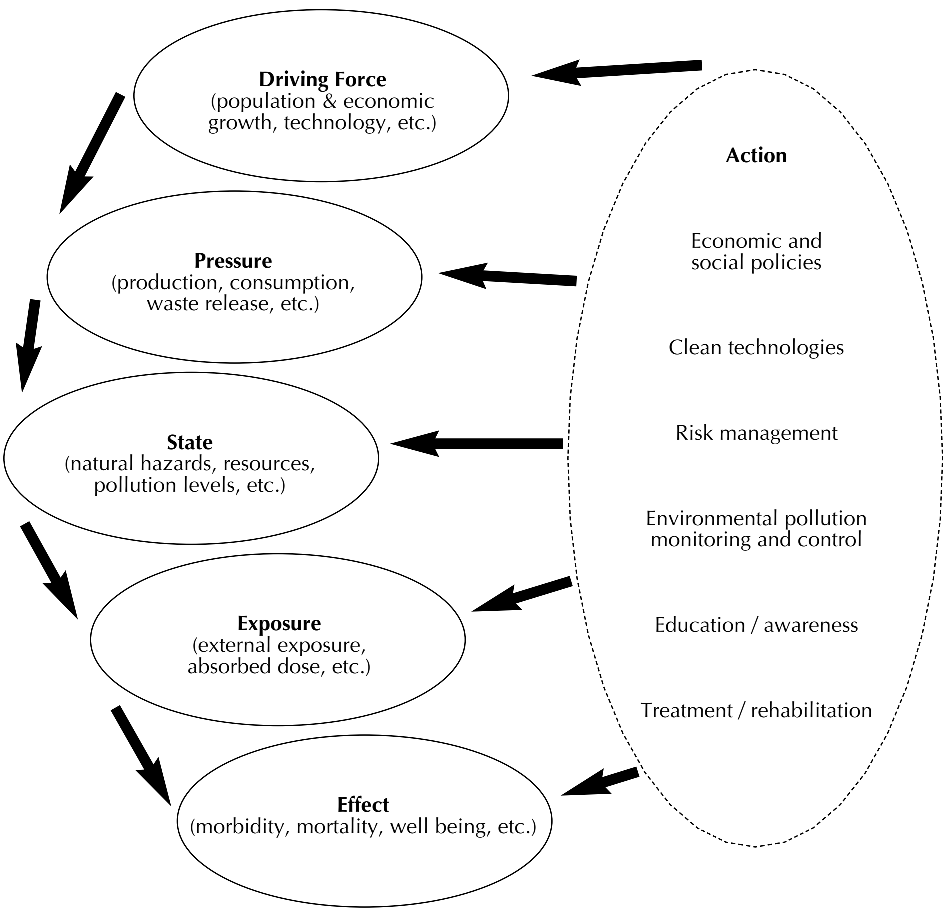

Figure 6. The Driving Forces, Pressure, State, Exposure, Effect, Action (DPSEEA) model of WHO[25]

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International Monitoring for Environmental Health Surveillance

R. Anthony Hodge, BASc, MASc, PhD
J.M. Justin Longo, BA, MPA, PhD (candidate)

ABSTRACT

This paper offers an overview of existing international monitoring systems with relevance for environmental health surveillance. Representative monitoring systems are described that: address areas of chronic and acute exposure, and diseases and behavioural effects resulting from human-environment interactions; have an ecosystem focus with perhaps a secondary motivation of ascertaining human health impacts that may result from ecosystem conditions; and that incorporate socio-demographic and economic data that may reflect population health determinants. General conclusions on the state of environmental surveillance systems and suites of indicators reviewed are provided in relation to their utility for the development of a generic environmental health surveillance system. This review indicates, among other things, that no obvious short list of core indicators exists which spans "environmental health" to provide a sufficient set applicable in a global context. Through a summary of challenges and limitations in existing systems and indicator sets, recommendations are provided for the discussion of indicator selection and organization, and of developing general and widely applicable environmental health monitoring and surveillance systems.

RÉSUMÉ

Dans cet article, les auteurs présentent un survol des réseaux de surveillance internationaux en matière d'hygiène de l'environnement. Ils décrivent des réseaux de surveillance typiques de secteurs d'exposition chronique et aiguë, de maladies et d'effets sur le comportement liés aux interactions entre les humains et l'environnement. De tels réseaux sont centrés sur les écosystèmes et ont peut-être comme intérêt secondaire l'évaluation des impacts des conditions de l'écosystème sur la santé humaine. Ils comprennent aussi des données sociodémographiques et économiques qui peuvent être à l'image des déterminants de la santé de la population. Les auteurs analysent l'état des réseaux de surveillance environnementale et étudient des groupes d'indicateurs en fonction de leur utilité pour la mise sur pied de réseaux de surveillance générale de l'hygiène de l'environnement, et tirent des conclusions générales à ce sujet. Ils soulignent notamment qu'il n'existe pas de présélection évidente d'indicateurs de base couvrant l'hygiène de l'environnement et applicables au contexte planétaire. À l'aide d'une synthèse des problèmes et des limites des réseaux et des groupes d'indicateurs actuels, les auteurs émettent des recommandations quant à l'analyse du choix et de l'organisation des indicateurs et quant à la construction de réseaux de surveillance de l'hygiène de l'environnement de portée générale et applicables à grande échelle.

Correspondence: Anthony Hodge, Anthony Hodge Consultants Inc., 767 Matheson Avenue, Victoria, BC V9A 6E4, E-mail: thodge@anthonyhodge.ca

This paper offers an overview of existing international monitoring systems with relevance for environmental health surveillance. The challenge of generating such an overview may be seen as either very simple or extremely complex. On the one hand, the international organizations that are maintaining primary global data sets are few in number: the World Health Organization, the World Bank and a number of key elements of the United Nations system. On the other hand, if "international" is taken to mean any grouping of more than a single nation, or the extra-territorial observations of a national agency, and if "environmental health" is taken to encompass the state and all of the factors influencing human and ecological well-being, the scale of the challenge explodes. The tact that is taken here lies somewhere between these extremes.

Representative monitoring systems are described that:

1) from a public health profession perspective address areas of chronic and acute exposure, and diseases and behavioural effects resulting from human-environment interactions;
2) have primarily an ecosystem focus with perhaps a secondary motivation of ascertaining human health impacts that may result from ecosystem conditions; and
3) incorporate socio-demographic and economic data that may reflect population health determinants.

The breadth and depth of "environmental health surveillance"

In much of the extensive environmental health literature, the word "environment" brings with it a connotation of *the suite of external factors that are important to human health*. Some of the direct effects of a degraded ecosystem on human health are well understood. These include the impacts of exposure to:

- toxic chemicals,[1,2]
- air pollution,[3,4]
- contaminated water, and
- UV radiation.[5,6]

Additionally, cumulative and synergistic effects of exposure to contaminants are resulting in the definition of new diseases, such as Multiple Chemical Sensitivity or MCS.[7]

Indirect impacts of environmental conditions on human health are becoming better understood and include such things as the effects of climate change resulting in the extension of the range of vector organisms leading to an increased transmission of infectious diseases (e.g., malaria, dengue, yellow fever), and an increase in severe weather events leading to increased mortality and illness among others.[6,8-11]

In recent years, the effects of human and animal health care systems on the ecosystem have been gaining a great deal of attention. Particularly relevant are the important negative feedback loops created by health care by-products which degrade ecosystems on which human health depends. Some impacts, such as the effects of overuse of antibiotics[12] and widespread endocrine-disrupting compounds such as birth control pills[1,2] on aquatic organisms, are emerging as major concerns. In this sense, "environment" relates to the enveloping natural world of which human society is an integral part and includes many (perhaps even a majority of) components that exist in their own right and may or may not directly interact with human society, let alone influence human health.

The human-ecosystem relationship is best seen as a two-way interaction of both stress and nourishment (physical, chemical, and biological). This requires the realization that by using the motivation of concern for human health as the driving force behind action to monitor, protect and remedy environmental conditions, the "environmental health" movement, in some respects, originates in efforts that might be labelled "agenda setting" or "issue framing". The "agenda" is considered to be the list of subjects or problems to which government officials, or those close to them, are paying some serious attention at any given time.[13] "Issue framing" is the set of processes by which certain features of a problem area are singled out for attention by particular actors or communities.[14]

There has been an evolution, most noticeable over the past 10 years, in the motivations underlying concern for the biosphere. Where once the issue of, for example, acid rain was framed as a concern for the health of forests and lakes, the dominant framing of environmental issues has moved to where the *prima facie* question is: "how does this condition impact human health?" The concluding observation on this point is that by focussing so much on the discernible human health impacts of environmental stresses, we risk missing more subtle ecosystem changes that could hide important long-term consequences for ourselves and the biosphere.

The matter has been made more complicated by the growing realization that the overall well-being/integrity/health of the ecosystem is a powerful determinant of human well-being and vice versa. In short, because of this interdependency if the ecosystem collapses, so too will the human species. To untangle this, help is sought through applying systems ideas.

Systems ideas have emerged over the past 75 years largely driven by a recognition of the importance of understanding the relationship between conditions of the "whole" to those of constituent parts. Such systems are characterized by: 1) emergent properties which are critical for understanding the whole but may have little or no meaning in terms of constituent parts; 2) a hierarchical structure in which systems are nested within other systems; and 3) processes of communication, feedback, and control that allow for adjustment and adaptation in the face of stress.[15-17]

Systems thinking involves the use of conceptual models to link components to the "whole" and the identification of controls and feedback loops. It is the need to assess the state or performance of the constituent parts, controls, feedback loops, and the whole system, that gives rise to indicators or performance measures. In the absence of such a framework (and related expression of values), the choice of indicators among the many that are possible, occurs in a vacuum[17,p.112] and the results are ad-hoc, reactive to current concerns, and potentially an impediment to anticipatory thinking.[18,p.11] Environmental health indicators can be thought of as a set of feedback signals that facilitate tracking of conditions within the system that includes people and the enveloping ecosystem.

A large number of models have been developed over the years that in some way address the human-ecosystem interface and are found in the literature of a variety of interests and disciplines including: economics, geography, ecology, health, planning (community, urban, regional, water resources, etc.), quality-of-life, resource management, state-of-environment and more recently, ecosystem health and the broad interest areas of sustainable development and sustainability. An interesting trend over the past 50 years is clearly discernible in this literature that offers insight into why it is important to include the classical health-oriented organizations and data sets, the focussed environment-oriented organizations and data sets, and others as well in this review.

As perspectives have broadened and more effort has been put into capturing a sense of the larger system, a number of these models have evolved and expanded to overlap and in some cases encompass the subject areas of others. Thus, templates used to guide state-of-environment assessments now have expanded to consider human health, and similarly, population health models now recognize conditions in the surrounding ecosystem as important human health determinants.

Two specific examples are: 1) Evans and Stoddart's determinants of health model developed through the Population Health Program of the Canadian Institute for Advanced Research;[19] and 2) the evolution of thinking related to the concept of sustainability that in early debate focussed on (mainly renewable) resource management and environment-economy linkages and latterly has swung into a much more holistic concern for ecosystem and human well-being together.

Evans and Stoddart's conceptual framework links an individual's well-being to: 1) their physical environment; 2) their level of prosperity (economic environment); 3) their social environment; and 4) a series of factors traditionally dealt with by medical sciences (genetic endowment, health care, disease, health and function, individual's particular response (behaviour and biology)). Their "social environment" is based on a concern for lifestyle impacts on health but goes farther, recognizing that:

Feelings of self-esteem and self-worth, or hierarchical position and control, or conversely powerlessness, similarly appear to have health implications quite independent of the conventional risk factors.[19,p.36]

They define "well-being" as "sense of life-satisfaction of the individual," arguing that this broad sense of well-being should become the objective of "not only health policy, but of all human activity."[19,p.40]

Meanwhile, at the core of the concept of sustainability is a value set best described as

TABLE I

Principal Activities Within "Monitoring"

1. **Collecting** quantitative and/or qualitative data and information at its source using a variety of survey instruments;
2. **Tracking** pressures and conditions either remotely or in situ using a variety of technologies;
3. **Organizing** a variety of disparate data into coordinated, centralized databases;
4. **Synthesizing** data collected using different methodologies into comparable formats;
5. **Assuring** quality and consistency in methodology across all data collection and recording points;
6. **Building** capacity in methodology and techniques across jurisdictions through the transfer of knowledge and resources;
7. **Interpreting** data in order to draw out key insights;
8. **Presenting** information using a variety of interface design strategies and technologies; and
9. **Communicating** to decision-makers the underlying message that may be masked by the volume of data.

TABLE II

Organizations that have Contributed to the Development of the UN's "Working List of Indicators of Sustainable Development"

1. United Nations Department for Economic and Social Information Policy and Analysis (DESIPA)
2. United Nations Department for Policy Coordination and Sustainable Development (SPCSD)
3. United Nations Department for Development Support and Management Services (DDSMS)
4. United Nations Department for Humanitarian Affairs (DHA)
5. Secretariat for the Framework Convention on Climate Change
6. United Nations Children's Fund (UNICEF)
7. United Nations Conference on Trade and Development (UNCTAD)
8. United Nations Development Programme (UNDP) and its office to Combat Desertification and Drought (UNSO)
9. United Nations Environment Programme (UNEP) and the Secretariat of the Basel Convention
10. United Nations University
11. the Regional Commissions of the United Nations
12. United Nations Centre for Human Settlements (Habitat)
13. the International Labour Organizations (ILO)
14. the Food and Agriculture Organization of the United Nations (FAO)
15. United Nations Educational, Scientific and Cultural Organization (UNESCO)
16. World Health Organization (WHO)
17. International Telecommunication Union (ITU)
18. World Meteorological Organization (WMO)
19. United Nations Industrial Development Organization (UNIDO)
20. the World Bank
21. the International Atomic Energy Agency (IAEA)
22. European Communities Statistical Office
23. the Organization for Economic Co-operation and Development
24. the International Centre for Tropical Agriculture (CIAT)
25. IUCN – the World Conservation Union
26. International Institute for Sustainable Development (IISD)
27. International Institute for Applied Systems Analysis
28. National Institute for Public Health and Environmental Protection of the Netherlands (RIVM)
29. New Economics Foundation
30. Scientific Committee on Problems of the Environment (SCOPE)
31. Worldwatch Institute
32. World Resources Institute (WRI)
33. World Wide Fund for Nature (WWF)
34. Wuppertal Institute

Source: United Nations, 1996[23]

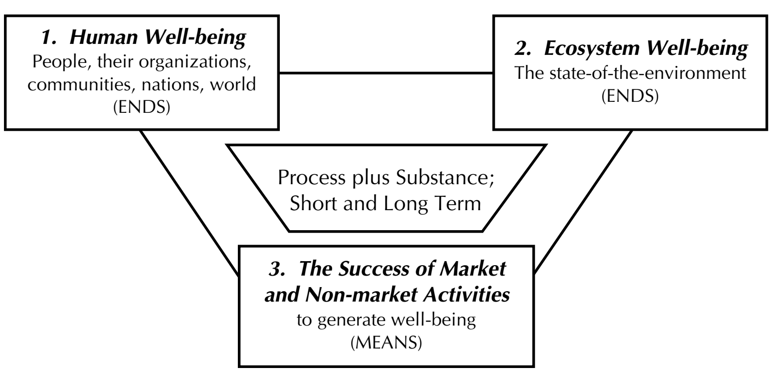

Figure 1. The results-based triangle of sustainability

a "parallel care and respect for the ecosystem and people within – not one or the other, not one more than the other but both together as one."[20,21:p.223] From this value set emerges an overall goal for achieving progress toward sustainability: "to maintain or improve human and ecosystem well-being." The convergence with Evans and Stoddart's thinking is striking, although the sustainability perspective reaches far beyond their anthropocentric focus. Thus, the treatment of environmental health indicators must eventually cover the range of data and information covered by the "results-based triangle of sustainability" shown in Figure 1. From a data/information systems perspective, each corner of Figure 1 can be expanded in a hierarchy of indicators (e.g., see Appendix 7).

Following the Earth Summit in 1992, the UN Commission on Sustainable Development (UNCSD) set out to identify a core set of indicators of sustainability that could be used as a guideline for national reporting. A desire to achieve some degree of compatibility between data and information sets gathered by individual nations to make possible a meaningful global synthesis was the motivation (see Appendix 2 for UNCSD original draft indicators).

The above discussion serves to demonstrate that the range of data sets and related information systems that are implicated by the phrase "environmental health surveillance" is vast.

What is "monitoring" and who is active at the "international" level?

Where is the wisdom we have
lost in knowledge?
Where is the knowledge we have
lost in information?
T.S. Eliot, *Choruses from 'The Rock', I*

At the basis of any knowledge-building exercise lies an empirical record: data, methodically captured and recorded, so crucial to building a scientific argument. But as T.S. Eliot laments, data is neither information nor knowledge nor wisdom. So while the collecting of data at its source through a variety of instruments (a narrow definition of monitoring) is crucial for the building of knowledge, there is a range of activities that fall under a broader definition of monitoring; the principal activities in this range are listed in Table I.

Each of these, often building upon one another, "adding value" to the original data – working to make sense of the system to improve decision-making. It is the "value added" nature of these succeeding activities that places them within the category of "monitoring". Not all organizations participate in all of these activities.

The 34 organizations listed in Table II are the contributors to the UN-led work on developing a core set of indicators of sustainable development. The nature and breadth of the indicators' work illustrates the variation in function described above. This listing represents a small proportion of organizations active in environmental health-related indicators work at the international level. The list also reflects the fact that no single organization is mandated to assemble the breadth of information required to track and assess the state of the Earth's people and ecosystems. Those interested in doing so must draw together data and information from many sources.[22,p.233]

The scale issue

Whereas the dictionary definition of "international" might refer to issues relating to or involving two or more nations, there is – in the international arena, beyond national or state-specific programs – a spectrum of scales within which any given multi-party monitoring or surveillance-related activity might be categorized. Such a spectrum is set out in Table III.

Example data/information systems and indicator sets

This section presents a summary description of six "surveillance" systems from the vast potential number of organizations that are implicated through the discussion above. In all cases, a "filter" is used in the form of the principal periodic (usually annual) report that is issued to summarize and communicate the principal observations that are drawn from the underlying data and information. Table IV lists the organizations and report titles along with the Appendix numbers that contain the detailed indicator lists.

The following concluding observations arise from a review of the Appendices and the material from which they are drawn.

1. There is no obvious short list of core indicators that spans "environmental health" and provides a generic set that would apply everywhere.

TABLE III
Scales of Data and Monitoring Activities

1. **Global:** data collection on a world-wide scale with no *prima facie* reference to national boundaries, such as monitoring carried out through satellite imaging and remote sensing to measure atmospheric conditions, land use change and marine conditions. A prominent example of such a system is the IGOS (International Global Observing Strategy) Partnership which includes the: Global Terrestrial Observing System; Global Ocean Observing System; and Global Climate Observing System (see Appendix 8).
2. **International:** data collection on a world-wide scale organized on the basis of national monitoring and reporting. National data are forwarded to or collected by international bodies which organize them into international reporting systems. Examples include the United Nations System of National Accounts, reporting by the World Health Organization and various UN agencies.
3. **Multi-national:** data collection exercises organized among a number of countries, undertaken as a regionally coordinated effort or supported by an international agency usually designed to test specific hypotheses across a number of jurisdictions or to meet the objectives of a regional co-operation or governance agreement. Examples include wildlife and habitat monitoring programs co-ordinated by the North American Commission for Environmental Cooperation, pollution monitoring efforts by the Arctic Council, and a variety of programs carried out by the European Commission.
4. **Externally-supported National:** Where a developing country might not have the capacity to monitor important systemic conditions, an international body or the agency of another government may provide resources to build such capacity. Such initiatives have been undertaken, for example, by the Canadian International Development Agency and the United States Agency for International Development.
5. **National:** In order to ascertain how its own performance (measured in terms of locally determined values and preferences) compares to other jurisdictions, or for other domestic policy development purposes, a national (or sub-national) government may organize and interpret data from its own jurisdiction and compare it to data from a range of other jurisdictions. While the extra-territorial data may be acquired from an international body, this activity would constitute a distinct effort from those delineated above since organization, interpretation and presentation of data would add additional value to the existing data exercises. A prominent example of this type is the annual World Factbook compiled by the United States Central Intelligence Agency.
6. **Non-government Organizations (NGO) and Academic:** Again, while their activities may not represent data collection and monitoring efforts distinct from those listed, NGO and academic projects designed to organize, interpret and report on pressures and conditions from an international perspective represent an important contribution to our understanding of human-ecosystem interactions. Just three of the vast range of examples here are: 1) the annual *State of the World* report and *Vital Signs* published by the Worldwatch Institute; 2) work by a number of NGOs aimed at calculating alternative measures of "genuine progress" as a counterpoint to traditional national income measures (e.g., the Genuine Progress Index of the Genuine Progress Institute); 3) the *Penn World Tables* compiled by the Center for International Comparisons at the University of Pennsylvania.

TABLE IV
Example Surveillance Systems with Indicator Sets

Appendix 3.	International Global Observing Strategy (IGOS) Partnership;
Appendix 4.	World Health Organization (WHO) as reflected in their *World Health Report;*
Appendix 5.	United Nations Children's Fund (UNICEF) as reflected in the *State of the World's Children* report;
Appendix 6.	United Nations Environment Programme / World Health Organization *Global Environment Monitoring System – Freshwater Quality Programme* (GEMS – Water Programme)
Appendix 7.	World Resources Institute (WRI) with United Nations Environment Programme, United Nations Development Programme and The World Bank as reflected in their *World Resources* report;
Appendix 8.	a transboundary perspective as reflected in the work of the *State of the Lakes Ecosystem Conferences* (SOLEC);
Appendix 9.	a provincial perspective as reflected in the Reports of the Provincial Health Officer of British Columbia.

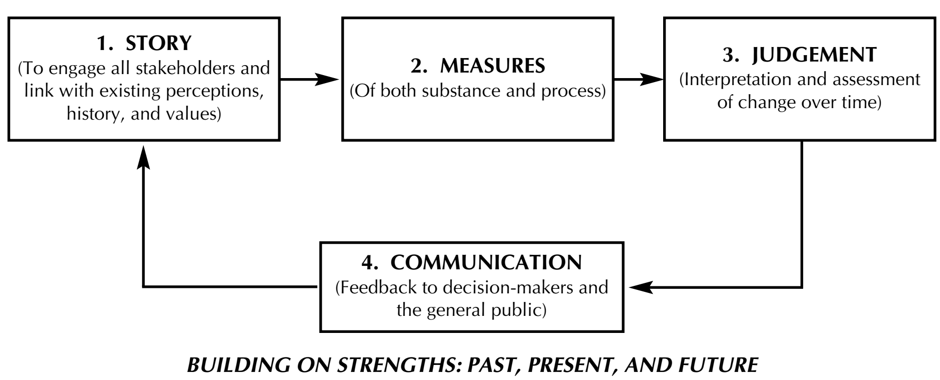

Figure 2. The Performance Measurement and Progress Assessment Cycle

Appendix 7*

The World Resources Institute (WRI), United Nations Environment Programme (UNEP), The United Nations Development Programme, and the World Bank as reflected in World Resources 1998-1999 (special focus on Environmental Change and Human Health)

1. Economic Indicators
- GNP (Atlas Method), total and per capita
- GDP total and per capita
  - ❑ Exchange rate based
  - ❑ Purchasing power parity (PPP) based
- GDP: average annual growth rate in %
- Distribution of GDP:
  - ❑ Agriculture
  - ❑ Industry
  - ❑ Services
- Average annual Official Development Assistance (ODA)
- ODA as a % of GDP
- ODA per capita
- Total external debt
- Total debt service costs
- Debt service as a % of total exports
- Direct foreign investment
- Central government expenditures
- Commodity indexes, various commodities
- Commodity prices, various commodities

2. Population and Human Development
- Population
- Average annual population change
- Average annual increment to population
- Average annual growth of the labour force
- Crude birth rate (births per 1000 population)
- Total fertility rate
- Percentage of population in specific age groups
- Income distribution: gini coefficient
- Percentage of income in each quintile of population (poorest to richest)
- Distribution of agriculture land ownership
  - ❑ Gini coefficient
  - ❑ % owning < 10 ha
- Population in poverty
  - ❑ International poverty line
  - ❑ National poverty line
- % of population with access to (urban, rural, total):
  - ❑ safe drinking water
  - ❑ adequate sanitation
  - ❑ health services
- Health expenditure as a percentage of GDP
- Public education expenditure as a % of :
  - ❑ GNP
  - ❑ Total government expenditures
- Number of public libraries

3. Health
- % of low birthweight infants
- % of children under 5 suffering from:
  - ❑ underweight
  - ❑ wasting
  - ❑ stunting
- Daily per capita calorie supply as % of total requirement
- % pregnant women aged 15-49 with anemia
- % children aged 6-11 with goitre
- % of households consuming iodized salt
- % of children under 5 with Vitamin A deficiency
- Crude death rates per 1000
- Infant mortality rate per 1,000 live births
- Under 5 mortality rate per 1,000 live births
- Average annual change in under 5 mortality rate
- Maternal mortality rate per 100,000 live births
- Cases per 100,000 population:
  - ❑ Tuberculosis
  - ❑ Measles
  - ❑ Malaria
  - ❑ Polio
  - ❑ Cholera
- % of births attended by trained personnel
- Percentage of 1-year-olds immunized against
  - ❑ TB
  - ❑ DPT
  - ❑ Polio
- Measles
- % of pregnant women immunized for tetanus
- ORT use
- Contraceptive prevalence (%) any method/modern method
- Population per doctor/nurse
- City air pollution:
  - ❑ City population
  - ❑ Mean annual TSP
  - ❑ Mean annual black smoke
  - ❑ Mean annual PM_{10}
  - ❑ Mean annual SO_2
  - ❑ Mean annual NO_2
- Lead in gasoline
  - ❑ Consumption of motor gasoline
  - ❑ Gasoline cost per litre
  - ❑ Market share of leaded gasoline
  - ❑ Maximum concentration of lead in gasoline
- Lead production
  - ❑ Concentrate produced in metric tons
  - ❑ Refined lead produced in metric tons (primary/secondary)
- % of households without (urban/rural):
  - ❑ Piped water
  - ❑ Own flush toilet
  - ❑ Finished floor
  - ❑ Refrigerator
  - ❑ Radio or television
- % of children under 5 with (urban/rural):
  - ❑ Diarrhea
  - ❑ A cough

4. Urban Indicators
- Urban population
  - ❑ Total
  - ❑ Percentage urban
- Population growth rate:
  - ❑ Urban
  - ❑ Rural
- Population in urban agglomerations > 750,000
- City level:
  - ❑ Population by largest city
  - ❑ Average annual growth rate by city
  - ❑ Urban residential density
  - ❑ Gross city product per capita
  - ❑ Socioeconomic indicators
    - ◆ Informal employment (%)
    - ◆ % poor households
    - ◆ % female-headed households
    - ◆ % female-headed households that are poor
- Crowding (floor area/person)
- % of urban households connected to:
  - ❑ Water
  - ❑ Sewerage
  - ❑ Electricity

5. Food and Agriculture
- Index of agriculture production (total, per capita)
- Index of food production (total, per capita)
- Average production of cereals (total, % change)
- Average production of roots and tubers (total, % change)
- Average production of pulses (total, % change)
- Cropland:
  - ❑ Total hectares
  - ❑ Hectares per capita
- Irrigated land as % of cropland
- Average fertilizer use (Kg per hectare of cropland)
- Tractors (average, % change)
- Harvestors (average, % change)
- Food security
  - ❑ Average annual net trade in cereals
  - ❑ Average annual donations or receipts of cereals
  - ❑ Grain consumption as a % of domestic production
  - ❑ Grain fed to livestock as a % of total grain consumption
  - ❑ Average daily per capita calorie supply
  - ❑ Average daily per capita protein supply
  - ❑ Average yield of cereals (kilograms per hectare, % change)
  - ❑ Average yield of roots and tubers (kilograms per hectare, % change)

Appendix 7 – Continued

The World Resources Institute (WRI), United Nations Environment Programme (UNEP), The United Nations Development Programme, and the World Bank as reflected in World Resources 1998-1999 (special focus on Environmental Change and Human Health)

- ➤ Per capita water use
- ➤ Waste water treated %
- ➤ Per-capita solid waste generated
- ➤ Households with garbage collection
- ➤ Transportation:
  - ❑ Cars per 1,000 population
  - ❑ Percentage of work trips by public transport
- ➤ Murders per 100,000 population

6. Forests and Land Cover

- ➤ Forest area
  - ❑ Extent by year, average annual % change
  - ❑ Natural forest (extent by year, average annual % change)
  - ❑ Plantations (extent by year, average annual % change)
- ➤ Forest industry structure: number of entreprises, number of employees
- ➤ Total land area by country
- ➤ Closed forests
  - ❑ Original forest as a % of land area
  - ❑ Forests as a % of original forests (current forests, frontier forests)
  - ❑ % frontier forests threatened
- ➤ Forest Ecosystems (area, percent protected)
  - ❑ Mangroves
  - ❑ Tropical forests
  - ❑ Nontropical forests
  - ❑ Sparse trees and parkland
- ➤ Average annual roundwood production (volume, % change)
  - ❑ Total
  - ❑ Fuel and charcoal
  - ❑ Industrial roundwood
- ➤ Average annual production (volume, % change)
  - ❑ Sawn wood
  - ❑ Paper
- ➤ Average annual net trade in roundwood
  - ❑ Volume, % change
  - ❑ Value, % change
- ➤ Land area and use
  - ❑ Total land area by nation
  - ❑ Population density
  - ❑ Domesticated land as a % of total
  - ❑ Land use (total, % change):
    - ◆ Permanent pasture
    - ◆ Forests and woodlands
    - ◆ Other land

7. Fresh Water Resources and Withdrawals

- ➤ Annual internal renewable water resources (total, per capita)
- ➤ Annual river flows (from/to other countries)
- ➤ Annual withdrawals (total volume, per capita, % of total)
- ➤ Sectoral withdrawals (domestic, industrial, agriculture)
- ➤ Average annual groundwater recharge (total, per capita)
- ➤ Annual groundwater withdrawals
  - ❑ Total
  - ❑ % of annual recharge
  - ❑ Per capita
  - ❑ Sectoral share (domestic, industry, agriculture)
- ➤ Desalination water production
- ➤ Water quality in European Lakes by lake
  - ❑ surface area
  - ❑ depth (maximum, mean)
  - ❑ catchment area
  - ❑ secchi depth
  - ❑ pH
  - ❑ concentrations of:
    - ◆ chlorophyll
    - ◆ phosphorous
    - ◆ nitrogen
    - ◆ chloride

8. Oceans and Fisheries

- ➤ Average annual marine catch (total, % change)
- ➤ Average annual freshwater catch (total, % change)
- ➤ Average annual aquaculture production
  - ❑ Marine fish
  - ❑ Diadromous fish
  - ❑ Freshwater fish
  - ❑ Molluscs and crustaceans
- ➤ Average annual balance of trade
  - ❑ Fish
  - ❑ Molluscs and crustaceans
  - ❑ Fish meal
- ➤ Per capita annual food supply from fish and seafood (total, % change)
- ➤ Marine fisheries, yield and state of exploitation, 1950s – 1990s
- ➤ Marine biological diversity of Regional Seas, 1990s (numbers of species, endemic/total)
  - ❑ Seagrasses
  - ❑ Corals
  - ❑ Molluscs
  - ❑ Shrimps and lobsters
  - ❑ Sharks
  - ❑ Seabirds
- ➤ Marine mammals (includes % of endemic threatened)

9. Biodiversity

- ➤ National protection systems
  - ❑ All protected areas (IUCN Categories I – V)
    - ◆ Number
    - ◆ Area
    - ◆ % of land area
  - ❑ Totally protected areas (IUCN Categories I – III)
    - ◆ Number
    - ◆ Area
  - ❑ Partially protected areas
    - ◆ Number
    - ◆ Area
  - ❑ % of protected areas (IUCN Categories I – V) at least
    - ◆ 100,000 ha
    - ◆ 1 million ha
- ➤ International Protection Systems
  - ❑ Biosphere reserves
    - ◆ Number
    - ◆ Area
  - ❑ World Heritage Sites
    - ◆ Number
    - ◆ Area
  - ❑ Wetlands of International Importance
    - ◆ Number
    - ◆ Area
- ➤ Globally threatened species
  - ❑ Mammals
    - ◆ Numbers: total, endemic, threatened
    - ◆ Number per 10,000 km^2
  - ❑ Birds
    - ◆ Numbers: breeding, endemic, threatened
    - ◆ Number per 10,000 km^2

Appendix 7 – Continued

The World Resources Institute (WRI), United Nations Environment Programme (UNEP), The United Nations Development Programme, and the World Bank as reflected in World Resources 1998-1999 (special focus on Environmental Change and Human Health)

- ❑ Higher plants
  - ◆ Numbers: all species, endemic, threatened
  - ◆ Number per 10,000 km^2
- ❑ Reptiles
  - ◆ Numbers: total, endemic, threatened
  - ◆ Number per 10,000 km^2
- ❑ Amphibians
  - ◆ Numbers: total, endemic, threatened
  - ◆ Number per 10,000 km^2
- ❑ Freshwater fish
  - ◆ Numbers: all, threatened

➤ Endangered species management programs

10. Energy and Materials

➤ Commercial Energy Production (total in petajoules, % change)
- ❑ Total
- ❑ Solid fuels
- ❑ Liquid fuels
- ❑ Gaseous fuels
- ❑ Primary electricity

➤ Total Energy Production (total in petajoules, % change)
- ❑ Commercial energy
- ❑ Traditional fuels

➤ Electricity Production (total in million Kwh, % change)
- ❑ Total
- ❑ Thermal
- ❑ Hydroelectric
- ❑ Geothermal
- ❑ Nuclear

➤ Trade (total in million Kwh, % change)
- ❑ Import
- ❑ Export

➤ % of total final consumption
- ❑ Industry sector
  - ◆ Total
  - ◆ Iron and steel
- ❑ Transportation sector
  - ◆ Total
  - ◆ Air
  - ◆ Road
- ❑ Agriculture
- ❑ Commercial and public sector
- ❑ Residential

➤ Production of selected minerals and materials
- ❑ Bauxite
- ❑ Iron ore
- ❑ Copper ore
- ❑ Silver ore
- ❑ Gold
- ❑ Sulfur
- ❑ Salt
- ❑ Nitrogen (ammonia)
- ❑ Phosphorus
- ❑ Potassium
- ❑ Sand and gravel

➤ Hydraulic cement

11. Atmosphere and Climate

➤ Emissions from fossil fuel burning and cement manufacturing
- ❑ CO_2 Emissions: total
  - ◆ Solid fuels
  - ◆ Liquid fuels
  - ◆ Gaseous fuels
  - ◆ Gas flaring
  - ◆ Cement manufacturing
  - ◆ Total
- ❑ Per capita CO_2
  - ◆ Emissions
  - ◆ Bunker fuels
- ❑ Inventories of National Greenhouse Gas Emissions
  - ◆ CO_2 (fossil fuels, land use change, industrial processes, net)
  - ◆ Methane (fossil fuel extraction, fuel combustion, agriculture (livestock, other) waste) total
  - ◆ Nitrous oxide, total
- ❑ World CO_2 Emissions from Fossil Fuel Consumption and Cement Manufacturing
- ❑ Atmospheric Concentrations of Greenhouse and Ozone-depleting Gases
  - ◆ Carbon dioxide (CO_2)
  - ◆ Carbon tetra chloride (CCl_4)
  - ◆ Methyl Chloroform ($CH3CCl_3$)
  - ◆ CFC – 11 (CCl_3F)
  - ◆ CFC – 12 (CCl_2F_2)
  - ◆ CFC – 113 (CCl_3F_3)
  - ◆ Total gaseous chlorine
  - ◆ Nitrous oxide (N_2O)
  - ◆ Methane (fossil fuel extraction, fuel combustion, agriculture (livestock, other) waste) total

* For appendices 1-6, 8 and 9, see http://ottserver1.ottawa.ijc.org/hptf/

2. Indicators are part of hierarchical systems that extend from the most general perspectives to specific measurable conditions reflected in the data points at source. Appendices 2 through 8 fit this format. Identification and selection of indicators should start at the general level, to be followed by a discussion of the more specific set of indicators that would support a general orientation. Starting instead at the bottom by identifying indicators will fail to point towards the desired generalized objectives.
3. As subtleties of systems come to be understood, indicator sets tend to expand. A good example is that if the issue of distribution (equity and disparity) within nations is added to the WHO indicator set listed in Appendix 3, a significant increase in complexity occurs.
4. Capturing ecosystem conditions, particularly in a range of different settings, is significantly more complex than describing the state of human society, a challenging task in itself.
5. Choosing an indicator set is an important task but only a small part of the larger task of identifying and tracking ongoing change, synthesizing meaning from often contradictory indicators, and communicating the results to key communities. In fact, attention must be paid to a “Performance Measurement and Progress Assessment Cycle” illustrated below in Figure 2.

Each of the elements of Figure 2 require a different set of skills and insights. For example, those who are comfortable with the science and technique of measurement are often not well schooled in nor comfortable with the qualitative insights that emerge from story and vice versa. Neither of these groups are necessarily skilled in either synthesis and judgement or communication.

6. The phenomena that require attention in assessing "environmental health" function on different time scales. These differences have significant implications for indicators work.

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Cross-disciplinary Communication Needed to Promote the Effective Use of Indicators in Making Decisions

Joan L. Aron, PhD
Robert H. Zimmerman, PhD

ABSTRACT

This paper examines problems of assessment and decision-making that result from poor or inadequate communication of indicators among the disciplines of public health, the physical sciences, and economics. The specific examples used are drawn from climate impacts in the Americas although the issues are more general to environmental health. In terms of physical processes, problems arise in confusion about indicators at different steps along the DPSEEA framework of environmental health indicators and general scientific uncertainty about the underlying physical processes. Communication between public health and economics is hindered by a lack of understanding of economic costs used in making decisions and the presence of implicit value judgments in economic analysis. Organizational structures may further inhibit the effective use of indicators. Finally, the paper discusses the Pan American Health Organization proposal to enhance the communication of indicators by using information technology networking to support communication among program managers and decision-makers at the national and local levels. The aim of this initiative is to establish a better environment for making decisions. The problem of cholera in Peru is shown as an example of the need for better communication.

RÉSUMÉ

L'article porte sur les difficultés de l'évaluation et de la prise de décisions liées à de mauvaises ou trop peu nombreuses communications au sujet des indicateurs entre les disciplines de la santé publique, des sciences physiques et des sciences économiques. Même si les enjeux sont d'ordre plus général sur le plan de l'hygiène de l'environnement, les exemples sont tirés des répercussions sur le climat des Amériques. Du point de vue des processus physiques sous-jacents, il y a confusion quant aux indicateurs de l'hygiène de l'environnement pour les diverses étapes du cadre DPSEEA, et il règne une incertitude générale chez les scientifiques. Le manque de compréhension des coûts économiques utilisés pour la prise de décisions et les jugements de valeur qu'on porte implicitement dans l'analyse économique font obstacle à la communication entre les intervenants du secteur de la santé publique et ceux du secteur économique. De plus, les structures organisationnelles peuvent nuire à l'utilisation efficace des indicateurs. Les auteurs analysent aussi la proposition de l'Organisation panaméricaine de la santé visant l'amélioration des communications sur les indicateurs au moyen du réseautage des technologies de l'information pour faciliter les échanges entre les gestionnaires de programmes et les décideurs à l'échelle nationale et régionale. L'objectif du projet est d'améliorer les conditions pour la prise de décisions. Le problème de choléra au Pérou est utilisé comme un exemple à illustrer le besoin de la meilleure communication.

Correspondence: Dr. Joan Aron, Science Communication Studies, 5457 Marsh Hawk Way, Columbia, Maryland, 21045, U.S.A., Tel: 410-740-0849, Fax: 410-964-3598, E-mail: joanaron@mmscnet.org
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This paper examines problems of assessment and decision-making that result from poor communication of indicators among the disciplines of public health, the physical sciences, and economics. The mere production of a particular set of indicators is not sufficient. It is necessary to understand and enhance the process for their utilization in decision-making.

Climate and health indicators

The World Health Organization (WHO) has developed a DPSEEA conceptual framework for environmental health indicators: driving force (D), pressure (P), state (S), exposure (E), effect (E), and action (A).[1] However, decision-makers face confusion about the indicators at different steps in the DPSEEA framework and the expression of scientific uncertainty about the underlying physical processes. Communication across multiple disciplinary perspectives is necessary to ensure that decision-makers can understand indicators and develop appropriate responses. Examples drawn from climate impacts related to hurricanes, El Niño events and glacial retreat in the Americas are presented.

Hurricanes

The impacts of hurricanes depend on the characteristics of atmospheric events as well as the vulnerability of affected populations and infrastructure, factors often poorly understood. For example, great hurricane-related economic losses in the U.S. during the early 1990s were attributed in a U.S. Senate report to more frequent and severe storms. Hurricane Andrew in 1992 notwithstanding, the period of 1991-1994 was in fact relatively quiet.[2] What had changed is that development in hurricane-affected areas had placed more population and infrastructure at risk, a fact not emphasized in that report.

The impacts of Hurricanes Georges and Mitch can be partially attributed to increased societal vulnerability as well. The Director of the Pan American Health Organization (PAHO) stated that "those persons who lost the most had the least to lose"[3] in reference to these events. Many participants of the fourth Conference of the Parties to the United Nations Framework Convention on Climate

TABLE I
Standard Methods for Assessing Economic Value in Health Programs and Challenges in their Interpretation

Technique	Purpose	Challenges / Benefits
Cost-Benefit Analysis Uses either: Human Capital Theory (return on investment = individual's production) Welfare Economics (what consumers are willing to sacrifice to have a program)	Determine if investment in a program is worthwhile	• Many benefits in health are not in market system • Assignment of $ is controversial • Need to aggregate measures of costs and benefits across time periods for long-term processes
Cost-Effectiveness	Determine least expensive way to achieve goal	• Aggregate effects of mortality and morbidity into a single measure of quality of life (QoL) • Valuation problem for quality-adjusted life year • No consensus for QoL exists as indicator of cost-effectiveness • Need to aggregate measures of costs and benefits across time periods for long-term processes
Multiple Criteria	Seeks to make tradeoff between factors more explicit	• May produce too many options • Cost of assembling and educating stakeholders may be high • Tradeoffs might be represented inconsistently in different groups
Standardization	Often the goal for analyses	• Disguises ethical conflicts

Change in Buenos Aires declared that the effects of Hurricane Mitch were a harbinger of the dangers of global warming. Yet the reality is that action needs to be taken against poverty, poor land-use practices and inadequate preparedness regardless of global warming.[4]

El Niño Events

Climate-sensitive sectors are strongly affected by El Niño events in the Americas. The process is very complex and extends over many months.

Despite some typical patterns, each El Niño event develops differently. Indicators of stages of these events have great potential value for monitoring and understanding their variability. However, the use of indicators for many different aspects of these events is a tremendous source of confusion. For example, during the major El Niño event of 1997-1998, reports of successful forecasting coexisted with reports of major errors. Even if a forecast is successful in climatological terms, it may not be useful in making decisions to mitigate impacts because it is difficult to predict the impact of El Niño on weather at very local scales.

The communication to decision-makers must explicitly address indicators for four linked domains. They are: Pacific sea surface temperatures, reflecting physical processes at the core of El Niño events, although some regions may also be affected by changes in the Atlantic and Indian Oceans; seasonal climate, usually expressed over a broad region; specific outcomes in the health sector; and actions that can be taken to mitigate impacts. A challenge throughout is the uncertainty inherent in each of these domains.

Glacial Retreat

A large part of the population in Latin America depends on the hydrological cycle in mountains. Mountains provide the sources of major rivers, such as the tributaries of the Amazon. However, valley glaciers are receding in Latin America and the rest of the world. Deglaciation can augment streamflow in the short run (as the glacier melts) and reduce streamflow in the long run, disrupting ecosystems and social organization. Current projections of the impact of global climate change anticipate both an increase in average global surface temperature (melting glaciers) as well as an increase in precipitation (possibly adding to glaciers). The balance between these two processes is the subject of ongoing research. In this case, decision-makers and scientists should establish a dialogue and review the potential indicators of change. Scientists can provide more climatological and hydrological information as research progresses. Decision-makers can provide needed input on potential social impacts and develop indicators over time. Limitations in scientific prediction do not necessarily prevent useful societal responses.

Economic indicators

Decisions depend not only on assessments of risks to public health but also on estimates of costs of interventions and impacts. The fundamental problem is that resources are scarce. The goal of economic analysis is to provide insight about allocating scarce resources efficiently. However, methods for economic valuation make assumptions and value judgments that are not always explicit. An indicator that may look straightforward may contain objectionable assumptions. Table I summarizes standard methods used in assessing economic value and some of the associated challenges inherent in their interpretation.

Organizational processes

Organizational processes may inhibit the effective use of indicators. This section provides a summary of perspectives on problems in organizational linkages between scientists and decision-makers.

Surprises

Some surprises may be due to uncertainties inherent in the complexity of social and environmental phenomena. Other surprises are due to the ways scientific data are presented to and used by decision-makers. Even gradual phenomena may generate surprises[5, pp 44-45] due to habituation to warnings and the short time scale for political decisions.

Embedded Assumptions

How scientific bureaucracies control information and embed hidden assumptions in data analysis has been explored in applications of geographic information systems (GIS). The most obvious way in which an analysis of environmental equity can be biased is in the selection of data, since most studies rely on secondary data sources collected by government agencies that are laden with social norms.[6] Databases may also have errors such as census undercounts. General-purpose interfaces introduce bias if they are not well suited to a particular need.[7]

Expertise and the Policy Cycle

Political scientists typically divide the policy process into four stages: agenda setting, policy formulation, policy implementation and policy evaluation. Scientific expertise does not usually drive an agenda, but works to provide legitimacy for it and is generally recognized as contributing tools to the analysis of decisions during the formulation of policy. The use of expertise is limited by the political constraints surrounding a decision. Decision-makers are subject to requests from special interests, bureaucratic demands, and short-term political pressures. Science and expertise can be used to bolster a decision made for other reasons. Moreover, when there are underlying value differences between conflicting parties, more data may actually generate more conflict as information is used selectively to support favoured positions.[8] In translating policy into practice, "experts play a key role in providing specificity to vaguely worded legislative mandates."[9] A policy that calls for "an adequate margin of safety" cannot implement itself. However, if political obstacles can be overcome, scientific difficulties remain in sorting out causal effects among multiple influential factors.

Future work by the Pan American Health Organization

The effective use of indicators in environmental health decision-making depends on establishing a good environment for making decisions. Individuals from multiple disciplines need to communicate and develop a shared understanding of the issues. The Division of Health and Environment at PAHO has developed information technology to access information. Future efforts will focus on enhancing networks of people who can utilize the new technology. The case of cholera in Peru illustrates the need for enhanced communication in using indicators for environmental health decision-making.

In January 1991, a major cholera epidemic started in the coastal area of Peru and eventually spread throughout Latin America.[10] The epidemic was preceded by scattered cases of cholera in several coastal cities, including Trujillo, with the earliest case detected on October 23, 1990.[11] Why did cholera return after a century? According to Bell and Wilson,[12] government officials in Peru decided to stop chlorinating drinking water after they received warnings in the early 1990s about the cancer risk posed by trihalomethanes (THMs) as byproducts of chlorination of drinking water. They claim that Peru had a poor institutional infrastructure that could not effectively utilize a risk assessment generated by the U.S. Environmental Protection Agency (EPA).[12] We claim that the essential issue is one of poor characterization of the decision-making environment in combination with poor communication about environmental health decisions in both developed and developing countries.

The implication of the U.S. EPA risk assessment as the cause of the cholera epidemic in Peru first appeared in the international scientific press late in 1991.[13] In Anderson's scenario, the decision to stop chlorinating many wells occurred in Lima, Peru in the 1980s after the U.S. EPA promulgated in 1979 the total THM standard of less than 0.10 milligrams per liter for U.S. community water systems that serve at least 10,000 people.[14] Anderson's article has been used to argue that the decision not to chlorinate was the cause of the cholera epidemic in Peru.[15, p.81] However, Anderson[13] presented opposing points of view about the influence of the THM assessment. Frederic Reiff, PAHO's regional director for water quality, stated that the decisions "may have been based more on the practical and economic difficulties of chlorination than on analysis of the risks". Robert Clark, director of the EPA Drinking Water Research Division, added that he thought Peruvian officials "were simply using the EPA's position, so they could turn around and point the finger at us and say, 'Well, they told us not to.'" Such statements strongly suggest the need for a better characterization of how water treatment decisions in Peru are made. Discussion of an assessment does not mean that it determines an outcome.

Salazar-Lindo and colleagues[16] provide more detailed information on the role of chlorination in Peru as a barrier to this spread of cholera. Their study investigated the water supply systems of Trujillo and Iquitos, both of which were affected by the 1991 epidemic. Trujillo lies along the arid coast of Peru and relies on groundwater obtained from 43 drilled wells. Iquitos is situated in the jungle and relies on water pumped up from a river below the city. Before the cholera epidemic, engineers in charge of the Trujillo system believed the groundwater was pure and did not require chlorination and they were also concerned about the carcinogenic risk of chlorination. The system in Iquitos suffered from poor design and management and chlorination was applied irregularly at the treatment plant. Local differences in sources of water – groundwater versus surface water – are important. The lack of chlorination was an explicit decision only where groundwater appeared to be pure. This suggests that the decision about chlorination in Trujillo did not depend on carcinogenic risks, but rather that knowledge of carcinogenic risks buttressed a decision made for other reasons. It also appears more generally that operational and fiscal difficulties played an important role in the lack of chlorination in Peru.

It is critical to examine the risk assessment employed by the engineers in Trujillo and ask who else agreed with them – were there other indicators of risk that were ignored? In studies of unexpected events, Glantz et al.[5, p.12] stress the importance of asking who is surprised. It is likely that opinions about the need for chlorination of the public water supply in Trujillo before 1991 varied. If disagreement can be confirmed, then one should ask how one view prevailed and how better communication can improve the quality of decisions. Comparisons among the Peruvian coastal cities first to experience the return of cholera would be especially informative.[11]

Cholera transmission in Peru has also been linked to an aquatic reservoir of the cholera vibrio and the warming of ocean waters during El Niño events.[10] Current understanding of the joint impact of climatic influences and chlorination policies is limited. Studies of cholera in Peru that focus on the aquatic reservoir and El Niño do not mention the debate about chlorination in Peru.[10,11] The decision not to chlorinate has been used to dismiss the influence of climate.[15] Some reports (e.g., World Resources Institute[17,pp 22-23]) are atypical in addressing both the decisions about chlorination in Peru and aquatic reservoirs of the cholera vibrios and El Niño.

A comparison of the first and second years of cholera transmission in Trujillo demonstrates the complexity. In 1991, 75% of the cases occurred within the first eight weeks of the epidemic, the pattern typical of coastal cities.[16] Transmission appeared to be largely controlled by intensive efforts to chlorinate the sources of water and to persuade the population to disinfect water before drinking; a pattern suggestive of a common-source outbreak. In 1992, however, the number of cases was smaller and the appearance of cases was more spread out in time, raising questions about exposures and the effectiveness of previous control efforts. Work in Nukus, Uzbekistan demonstrates the importance of water pressure, a secure system, and the presence of a filtration system to remove particulate matter, in preventing diarrheal diseases related to water supplies.[18,19] The water system managers in Trujillo did not maintain water pressure in the system or monitor water quality on a regular basis.

The reemergence of cholera in Peru coincided with an extended El Niño pattern, conventionally designated as the period 1991-1995.[17, p. 23] However, the classification of that time period is contentious.[20, pp.84-85] In the western tropical Pacific (Niño 4 indicator), warmer ocean temperatures persisted from 1990 through 1995, consistent with one long El Niño event. In the eastern tropical Pacific near Peru, Ecuador and the Galapagos Islands (Niño 1 and Niño 2 indicators), the ocean temperatures peaked three times during that period, suggesting three distinct El Niño events; the first and largest peak in ocean temperature occurred in late 1991 and early 1992. Local El Niño indicators need to be linked to local weather conditions, which in turn need to be linked to specific modes of disease transmission and specific actions for intervention.

The potential use of forecasts of El Niño in cholera prevention depends on identifying activities that should be responses to specific forecasts. One major difficulty is that El Niño has broad regional impacts but inconsistent local impacts. In preparation for the 1997-1998 El Niño event, President Fujimori of Peru made great investments in physical mitigation based on the assumption that the event would unfold as in 1982-1983; however, the 1997-1998 event turned out to be most similar to the event of 1925-1926.[21, p.14] Because the details are so hard to predict, Peru should always be readying itself on a national basis.[21] Preparations for floods related to El Niño must also be integrated into overall plans to mitigate the impact of natural disasters on drinking water and sewerage systems.[22] Communication is needed to coordinate disaster relief, infectious disease control and water system management.

The example of cholera in Peru has demonstrated the complexity of the decision-making environment and the factors affecting the control of disease. In the story of chlorination in Peru, it is striking that multiple influences are often presented but clearly ignored in favour of a particular factor. Understanding why multiple influences are ignored deserves further inquiry. The challenge is to communicate indicators that can characterize these interactions. The importance of these issues extends far beyond Peru; cholera is one of the few bacterial diseases that can still cause pandemics[10] and the U.S. EPA's assessment of the carcinogenic risk due to chlorination is thought to "have induced many authorities in developing countries to reduce or even abandon the use of chlorine."[23,p.29]

CONCLUSION

Improved cross-disciplinary communication is needed to promote the effective use of indicators in making decisions. Cross-disciplinary communication has to address the joint influences of multiple indicators, different types of analysis for economic factors, and organizational barriers to informed decision-making.

As PAHO develops its plans for using information technology to support networks of decision-makers at the local level, it will be faced with many questions about the scope of information and uncertainty. The lesson learned from the U.S. acid rain assessment is that "there must be widespread agreement on what questions are being asked, why they are important, what counts as answers to them and what the social use of these answers might be."[24] PAHO should work closely with local decision-makers to ensure that they can make effective use of new networks.

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Modern Information Technologies in Environmental Health Surveillance

An Overview and Analysis

Yvan Bédard, PhD[1]
William D. Henriques, PhD, MSPH[2]

ABSTRACT

In recent years we have witnessed the massive introduction of new information technologies that are drastically changing the face of our society. These technologies are being implemented en masse in developed countries, but also in some pockets of developing nations as well. They rely on the convergence of several technologies such as powerful and affordable computers, real-time electronic measurement and monitoring devices, massive production of digital information in different formats, and faster, wireless communication media. Such technologies are having significant impacts on every domain of application, including environmental health surveillance. The current paper provides an overview of those technologies that are having or will likely have the most significant impacts on environmental health. They include World Wide Web-based systems and applications, Database Management Systems and Universal Servers, and GIS and related technologies. The usefulness of these technologies as well as the desire to use them further in the future in the context of environmental health are discussed. Expanding the development and use of these technologies to obtain support for global environmental health will require major efforts in the areas of data access, training and support.

RÉSUMÉ

Au cours des dernières années, on a observé l'arrivée massive de nouvelles technologies de l'information qui ont changé radicalement la société. Les technologies sont mises en place à grande échelle dans les pays développés et aussi dans certaines petites régions des pays en développement. Elles reposent sur la convergence de plusieurs technologies telles que des ordinateurs puissants et à coût abordable, des dispositifs électroniques de mesure et de surveillance en temps réel, la production massive d'information numérique en divers formats, et de moyens de communication sans fil plus rapides. De telles technologies ont de grandes répercussions sur chaque domaine d'application, y compris la surveillance de l'hygiène de l'environnement. L'article présente un aperçu des technologies qui ont ou qui auront probablement les impacts les plus importants sur l'hygiène de l'environnement, entre autres les systèmes et les applications basés sur le World Wide Web, les systèmes de gestion de base de données et les serveurs universels, ainsi que les SIG et les technologies connexes. Les auteurs se penchent sur l'utilité de ces technologies et sur le désir d'y avoir davantage recours à l'avenir dans le contexte de l'hygiène de l'environnement. Pour accroître la mise en place et l'utilisation de technologies visant à dresser le portrait de l'hygiène de l'environnement dans le monde, il faudra améliorer considérablement l'accès aux données, la formation et le soutien.

1. Centre for Research in Geomatics, Université Laval, Quebec City, Québec
2. GIS Coordinator, Agency for Toxic Substances and Disease Registry, Division of Health Assessment and Consultation, Atlanta, GA
Correspondence: Dr. Yvan Bédard, Centre for Research in Geomatics, Université Laval, Quebec City, Québec G1K 7P4, E-mail: yvan.bedard@scg.ulaval.ca

Recently, the world has seen the introduction of numerous new information technologies (IT) that are having significant impacts on society. Many authors speak of a communication revolution as important as those following the invention of the printing press, radio and television. As a result of this revolution, new expressions such as 'Global Village', 'Information Society', and 'Digital Earth' have been introduced to describe this new connectedness we experience. These new technologies are being implemented extensively in developed countries and in isolated pockets of developing nations and are having major impacts in such areas as environmental health surveillance. The aim of the present paper is to give an overview of technologies that are having or will likely have the most important impacts in environmental health research and practice.

Overview of modern information technology for environmental health surveillance

World Wide Web

The massive penetration of the internet and the World Wide Web (W3) in today's society has created new opportunities to provide/access information and services. For the first time, a massive amount of information and services are available immediately worldwide 24 hours a day. The most important opportunities offered today include:

a) E-mail (electronic mail): The most widely used application on the internet, used to send/receive messages, documents and other files from any location.
b) Web sites: Where an organization or individual gives access to "web surfers" to static and limited information or massive and dynamic information. The best user interfaces are designed for easy navigation using hyperlinks (clickable links to other parts of the site or other web sites) and other formats. When an organization restricts a part of its web site to internal employees, it becomes an "intranet", and when they add access to selected external clients or partners, it becomes an "extranet".
c) Portals: Web sites that offer a large array of well-organized and indexed information, search engines and customizable services such as weather

forecasts, user-selected sport news, etc. (e.g., Yahoo). When a portal focusses on a precise field of information (e.g., environmental health), it is called a vertical portal, or "vortal".

d) E-commerce: Some web sites offer electronic commerce allowing an organization, such as a retail store, to sell products directly via the web. Among these sites, one finds digital libraries that provide users with searchable and downloadable catalogues of digital documents (e.g., reports, datasets, maps and satellite images).

e) The web also offers technologies for distance learning and workgroups. These usually involve static or interactive multi-point communication capabilities such as textual communication, group chatting, whiteboarding, group calendaring, etc. Specialized software is required for the host organization only (except for a facultative on-line web camera).

Additionally, there are a few general-purpose web sites dedicated to facilitate searching on the web and thousands of specialized search sites. Metasearch sites are sites that make simultaneous use of several search sites and present the results to the user in an organized format. To benefit from the internet and W3 technologies, a user needs access to an ISP (Internet Service Provider), an electronic address and an internet connection. To offer such services to others, one must add a web server and specialized software (firewall) to these technical requirements.

DBMS and Universal Servers

DBMS (Data Base Management Systems) include tools such as Oracle DBMS, SQL-Server, Informix, Sybase, DB2, Access, etc. This family of tools is 30 years old and has attained a high level of commercial maturity, especially with the market lead of the relational approach developed over the last 20 years. Relational DBMS allows one to define a database structure, feed it with simple data (a string of characters, numbers, dates or boolean values), verify its integrity, manipulate the data, query them and build automatic reports.[1] They can be accessed simultaneously by several, or even thousands, of users without crashing or corrupting the data. These data can be stored in a unique site or distributed over several sites. Access to the data can be direct, via application-built graphical user interfaces, or via the web.

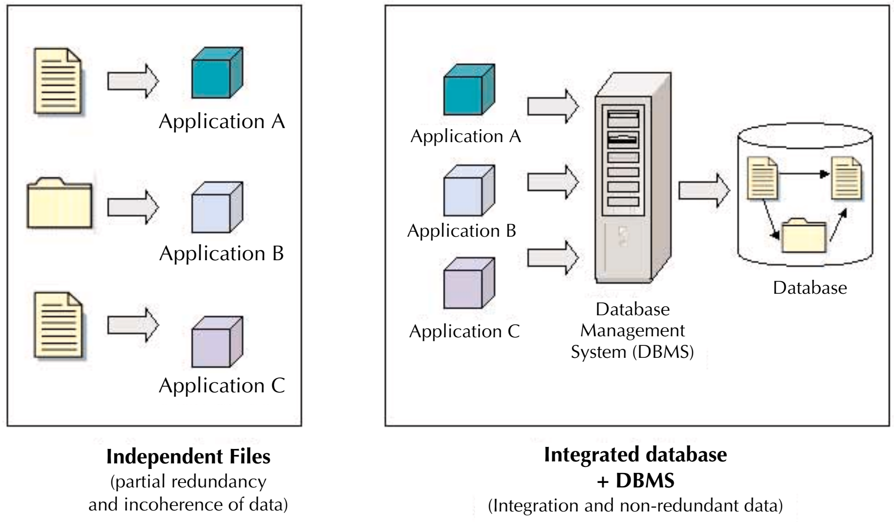

Figure 1. Independent files vs integrated database + DBMS

With the demand-driven influence of the media-rich web as well as the push-driven influence of the multimedia-capable object-oriented DBMS appearing in the 1990s, there has been an evolution of Relational DBMS into hybrid Object-Relational DBMS, or Universal Servers (e.g., Oracle 8i and Cartridges, Informix with Datablades). These are called "universal" because they are not restricted to the traditional types of data found in DBMS and also have the added capability of storing, manipulating and querying multimedia information. Thus, today's DBMS are well adapted to the web revolution.

Data Warehouses and the Latest Decision Support Tools

While DBMS were created to bring coherence among previously disparate, independent, redundant and application-specific data files (Figure 1), most organizations have implemented databases in a way that has created isolated database islands. There has been an evolution from having independent and redundant files to independent and overlapping databases. This is considered an improvement though as the overlap and coherence problems have become easier to manage. Nevertheless, the situation still lacks the unified view of a system where data coming from different databases are organized and ready to rapidly provide strategic, synthesized and aggregated information for high-level decision-making.[2] Data warehouses which "provide a unified view of dispersed heterogeneous databases in order to efficiently feed the decision-support tools used for strategic decision making" have been designed to address this issue.[3] To achieve this, the warehouse must import, in read-only and batch modes, subsets of the source database (called legacy systems) and process/integrate them so that the resulting information to be stored in the warehouse is consistent and properly aggregated.[4]

When data are updated in the legacy systems, the new information is added to the warehouse without replacing previous data allowing them to support the analysis of trends over time, a key element needed for decision-making.[5] Consequently, data warehouses are considered the main source of information for knowledge discovery and business intelligence.

Data warehouses differ from traditional databases in that they are designed to support small volumes of long aggregation-oriented strategic-level transactions involving large volumes of data. To achieve these opposing objectives that cannot be met in a single database when the volume of data becomes large, two different database designs (and sometimes technologies) are used: the object-relational design of traditional DBMS for transaction-oriented operations and the multidimensional design of data warehouses for analysis-oriented operations and knowledge discovery (i.e., decision-support; e.g., Red Brick, Essbase and Oracle Express).

When an organization-wide data warehouse is not needed, one may use the same

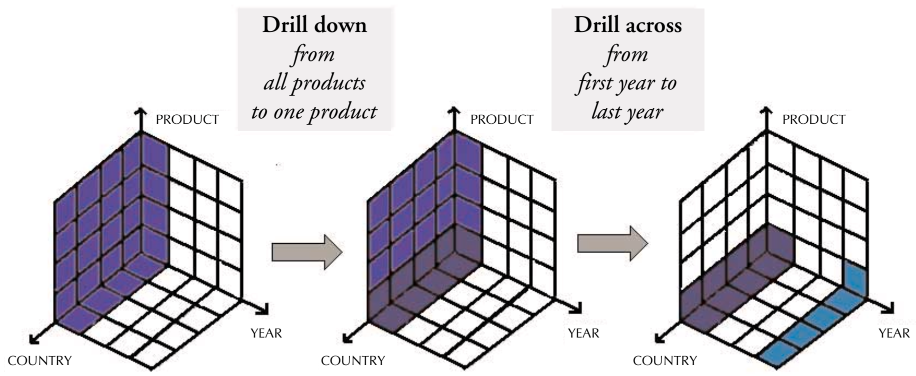

Figure 2. OLAP navigation

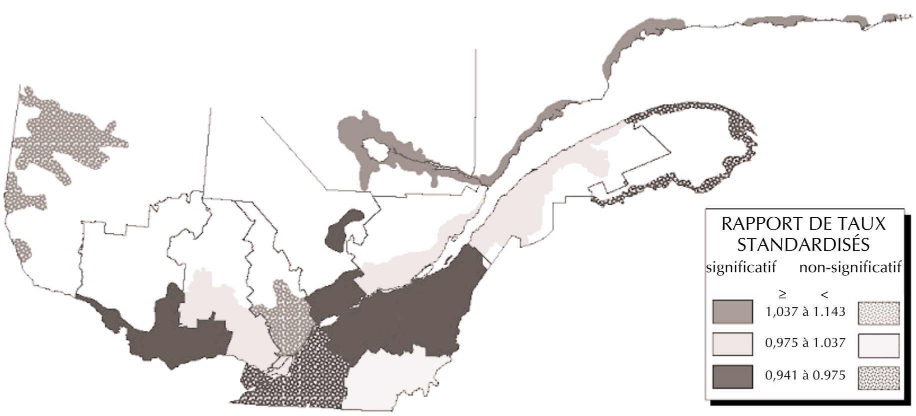

Figure 3. Example of a screen copy displaying a thematic map (cancer for the province of Quebec)

technology to build a focused, specialized, domain-specific mini-warehouse extracting data from a subset of legacy systems to develop more summarized information in a mini-warehouse called a datamart. We regularly find several datamarts in an organization built on top of unique enterprise-wide data warehouses to avoid another level of isolated information island. In such systems, the datamarts and data warehouse are designed so that the datamart offers subject-oriented, more highly aggregated information for a specialized view with faster data access than in the warehouse approach.

In order to support the extraction of useful knowledge from the data warehouse/datamart, one needs a decision-support tool such as Query and Report builders, On-Line Analytical Processing software (OLAP) and Data Mining tools.

a) Query and Report Builders: these tools (e.g., Impromptu, Crystal Report) facilitate the creation of queries and reports by replacing the standard technically driven SQL interface (Structured Query Language) by a more intuitive user-interface, usually based on natural language (e.g., plain English) or better query/report-driven graphical interfaces.
b) OLAP: the most popular category of decision-support tools providing unique capabilities to explore massive amounts of data in a rapid, intuitive and interactive way. Such ad hoc discovery-driven exploration of data relies on the multidimensional nature of the warehouse data structure (called data cube) where the user can go directly from detailed levels of information to more aggregated/summarized levels of information (drilling down and rolling up) (see Figure 2) as well as navigating from one category of information to another category (correlating, filtering, slicing them, etc.) (examples are Powerplay and Business Objects).
c) Data Mining: this category of knowledge discovery packages aims at automating the search for hidden patterns, correlations or trends in large data cubes and to automatically make predictions based on historical data. The "automatic" nature of the exploration methods leads to the discovery of unexpected and complex patterns and accelerates the exploration of large warehouses. To achieve this, they use complex techniques such as neural networks, decision trees, genetic algorithms, rule induction and nearest neighbour calculations.

It is becoming more common to find these technologies embedded in statistical packages and DBMS thus improving their decision-support qualities. Although several decision-support products are third-party add-ons to DBMS or to specialized warehouse/marts engines, today's trend is to find the multidimensional capabilities as well as the decision-support front-ends built into major universal servers. Finally, it is possible to make data warehouses and datamarts accessible through the web with browser-based query and report builders as well as EIS (Executive Information Systems, i.e., dashboard-like read-only reactive reporting tool).

Geographic Information Systems (GIS) and Related Technologies

Much of the information that organizations maintain includes geographic elements such as a street address, postal code, county, province/state, or map location specified by geographic coordinates. In the early 1980s, digital mapping converged with database management systems (DBMS) giving rise to the first commercial Geographic Information Systems (GIS) such as ArcInfo and Intergraph MGE. This has allowed organizations to relate tabular information to locations on digital maps and produce thematic maps (Figure 3). Rapidly, spatial analysis functions have been added and from the mid-80s to the mid-90s, capabilities such as buffering of spatial data layers to result in demographic profiles within a distance from a feature of interest, spatial intersection to identify areas suitable for the proliferation of a disease vector, and network analysis (e.g., shortest path, routing, defining the zones covered within a given timeframe of traveling) were developed. Coupled with location-gathering technologies such as global positioning systems (GPS), computer mapping and spatial analysis will be the next revolution in computational technologies affecting the way in which we examine data for environmental and heath surveillance.

The mass market penetration among larger organizations and upper-end products, in relation to the capability of universal servers to manage geographic data and to display maps with low-cost viewers in a client-server architecture, is having a major impact on the market (e.g., ArcView, Geomedia and MapInfo).

A similar phenomenon is taking place with geographic web servers offering web-mapping capabilities (Figure 4). Servers (e.g., Geomedia WebMap, MapXtreme, MapGuide, etc.) are used for various types of applications (address locating, distance learning, trip planning, etc.) and to enrich traditional web technologies. Two examples of the latter are 1) geographic digital libraries, which allow one to access, obtain and download digital maps, aerial photographs and satellite images from a government or e-commerce web site, and 2) location-commerce (or l-commerce), which provides custom maps showing locations of user-requested services and directional information.

Finally, the GIS community is moving towards internationally accepted open-standards (cf. ISO and OpenGIS Consortium), interoperability solutions (e.g., OGDI, the Open Geospatial Data Store) and the development of very efficient geographic data fusion tools (e.g., FME, the Feature Manipulation Engine from Safe Software) allowing one to integrate/process geographic data from diverse sources. As a result of these advances, the first projects of spatial data warehouses, spatial OLAP and spatial data mining are moving out of research labs and into the applications market. The GIS community and its technologies have become part of the information technology mainstream.

Overview of environmental health surveillance needs regarding information technology

A drastic improvement in computer technology has occurred over the past 20 years.

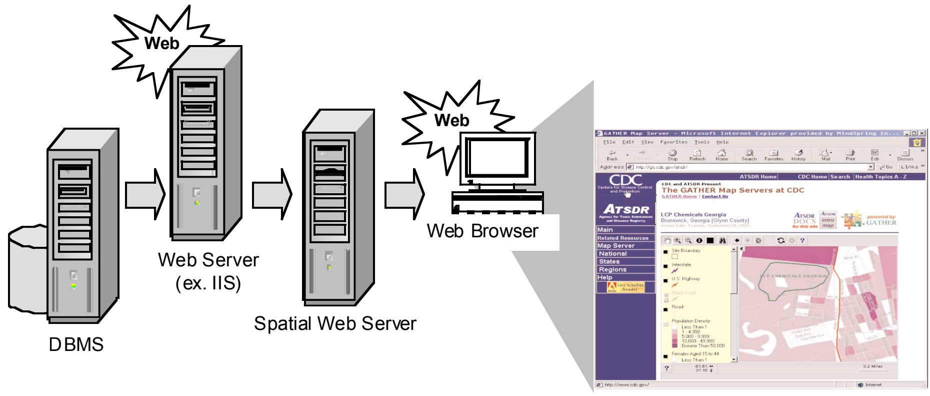

Figure 4. Example of a spatial web server, the GATHER map server at CDC

More information is available to more people eager to learn of the impacts of environmental pressures on public health. Databases allow access to annual summaries of such things as chemical emissions information compiled through the US Environmental Protection Agency's Toxic Release Inventory.

While this information is useful, the reporting of sheer volumes of chemicals is not enough. A more suitable measure of the impact of chemical volumes is needed utilizing knowledge of compound toxicity. An interface that links time- and volume-based information on chemical emissions to an algorithm that considers the weighted risk to adverse health effects of each substance over a geographic area is a tool that is technologically feasible, but requires the convergence of disciplines. The technological challenge is to develop tools that convert extensive databases containing existing environmental data in relational database systems (RDBMS) into maps that depict risk of adverse health impacts to people in a specific geographic area (e.g., Figure 5). Linking toxicity information with concentration data, we can develop maps that more closely depict geographic areas of potential environmental health concern. While this simplistic example uses an approach of querying source information (ATSDR's HazDat database) to map only those sites that fulfill specific criteria, it fails to consider additional sources of human exposure to environmental contamination. As additional information is added to gain a more comprehensive view of the environmental impact of chemicals, the picture becomes more complex. Reporting volumes of chemicals dispersed into the environment is useful, but tools are still needed to summarize and categorize (e.g., heavy metals) this information over a geographic area and by target organ system (e.g., neurotoxins). The emergence of computational tools that take what we know about individual chemicals and convert this information into an interactive map describing areas of risk by summarizing and weighting data will provide a new view that assists the lay person in determining the impact of the industrial world on the health of their community. User-friendly databases are being constructed in many countries and many examples are given in a detailed study by Catelan et al.[6] Leading-edge applications and user interfaces based on spatial data warehousing and spatial OLAP, such as the SPHINX (Alberta) and ICEM-SE (Quebec) projects, will provide a tool that gives access to aggregated and detailed information as well as both outside and in-house information (given proper access rights) in both aggregated and single datasets.

Applications, benefits and resources required

As our world becomes increasingly industrialized, populations that are more susceptible to adverse effects of environmental degradation will need refuge. The elderly, women of reproductive age and youth have a right to know where levels of pollution exceed what is considered to be "safe". Once identified, interim health protection measures must be put in place for these populations, as chemicals will persist in the environment long after the beginning of clean-up efforts. A more practical approach to health protection can be taken once we examine all regional contributions to chemical exposure, not only those of

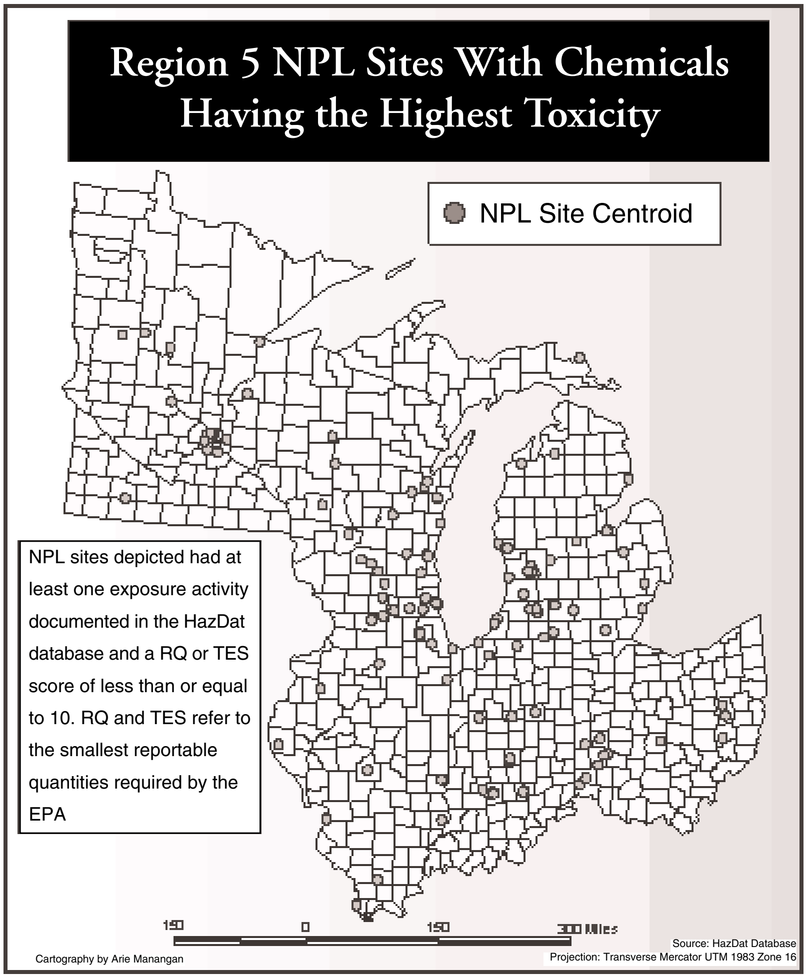

Figure 5. ATSDR's HazDat database was queried to identify only those sites with documented off-site exposure activities and containing substances considered most toxic.

industrial origin. Resulting information could influence urban planning by considering the relationships between environmental pollution sources and behaviour and geographic formations.

Challenges for successful implementation and suggestions for future orientations

Assessing such things as the dose of a compound that may result in an adverse health effect to humans is rarely an easy task. Computer networks and legacy mainframe systems contain billions of records of analytical samples collected at hazardous waste sites that document the levels of priority pollutants found in air, water, and soil. Rather than considering the individual toxicity of compounds at the parts-per-billion level, it may be more prudent to consider the relative toxicity of compounds (possibly to specific target organs) as an approach to weighing toxicity of chemicals over a broad geographic area. We can enhance the traditional epidemiological studies by taking into account the possibilities offered by modern GIS, such as spatial statistics and geographic overlays with other datasets (e.g., exposure modeling results, sociodemographics, land use, topography), to better qualify exposure and risk levels. These areas can then be investigated in greater detail using more detailed health and environmental information in legacy systems.

However, when one wants to identify the biggest challenges to integrate such modern IT in the day-to-day work of environmental health specialists, one must look at the activities related to data access, data usability assessment and data standardization.[7] Knowing what data exist where remains a challenge as well as obtaining these data (costs, confidentiality) and transforming them into a usable format (restructuring, recoding, validating, aggregating, geocoding, etc.). Other major challenges identified by Gosselin et al.[7] include the provision of more training (both in formal and informal settings, including having access to technical support) and finding adequate funding to sustain and build capacity for the use of evidence-based tools built with modern information technologies. The real challenges ahead of us are more administrative/political than technological, more driven by data finding/access difficulties than by the technology and more about the usability of systems and adequate training/support than about the technology.

CONCLUSIONS

Technology is rapidly changing the type and amount of information that is accessible to specialists and the public. New technologies are providing the necessary tools for decision-making and analysis. In the near future, we will be able to find simple responses to simple questions such as the best place to raise a family, report on local and regional health statistics for this location, and provide directions to surrounding health services. This will be done with information that exists today, but using modes of interaction that we are just beginning to develop.

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Indicators of Ocean and Human Health

Eric Dewailly, MD, PhD[1]
Chris Furgal, PhD[1]
Anthony Knap, PhD[2]
Jennifer Galvin, BS, MPH[2]
Dan Baden, PhD[3]
Bob Bowen, PhD[4]
Michael Depledge, PhD, DSc[5]
Linda Duguay, PhD[6]
Lora Fleming, MD, PhD, MPH[7]
Tim Ford, PhD[8]
Fredricka Moser, PhD[9]
Richard Owen, PhD[1]
William A. Suk, PhD, MPH[10]
Umit Unluata, PhD[11]

ABSTRACT

The interactions between humans and the ocean are significant, and necessitate more comprehensive study on an international scale. The world's oceans provide great health benefits to humans ranging from food and nutritional resources, to recreational opportunities and new treatments for human disease. However, recently, human health effects from exposure to substances present in the marine ecosystem such as synthetic organic chemicals (e.g., chlorobiphenyls, chlorinated dioxins and some industrial solvents), polycyclic aromatic hydrocarbons (PAHs), metals (both introduced and anthropogenic), marine toxins, and pathogens have been recorded and are of great concern. This paper reviews our state of knowledge of the interactions between oceans and human health and proposes indicators and a research strategy to investigate and monitor these relationships more closely. Four approaches to gathering information on indicators included here are: biomarkers; cellular pathology; physiological and behavioural responses; and changes in populations. All hold the potential to enhance our understanding of marine environmental quality and far-reaching effects on human health. Monitoring systems that include the rapid assessment of contaminants in the ecosystem and subsequent risk to human populations, with appropriate internationally distributed data bases, need to be developed and validated. Such tools would provide early detection of potential environmental threats, and enhance the ability to prevent human illness.

RÉSUMÉ

Les interactions entre les humains et les océans sont importantes, et il faut en faire une étude plus approfondie à l'échelle mondiale. Sur le plan de la santé, les humains tirent grandement profit des océans, que ce soit de la nourriture et des ressources nutritionnelles, des activités récréatives et de nouveaux traitements contre les maladies. Cependant, on a signalé récemment, et on se préoccupe beaucoup, des effets sur la santé liés à l'exposition aux substances toxiques présentes dans l'écosystème marin comme les produits chimiques organiques de synthèse (p. ex. les chlorobiphényles, les dioxines chlorées et certains solvants industriels), les hydrocarbures aromatiques polycycliques (HAP), les métaux (d'origine naturelle et anthropique), les toxines marines et les agents pathogènes. Les auteurs examinent l'état des connaissances sur ces interactions et proposent des indicateurs et une stratégie de recherche pour les étudier et les surveiller de plus près. Ils mentionnent quatre approches pour la cueillette de renseignements sur les indicateurs : les biomarqueurs, la cytopathologie, les réactions physiologiques et comportementales ainsi que les changements dans les populations. Ces approches peuvent améliorer la compréhension de la qualité de l'environnement marin et des effets lourds de conséquence pour la santé humaine. Il faut construire et valider des réseaux de surveillance qui permettent de mesurer rapidement les contaminants dans un écosystème et d'en évaluer les risques pour la santé humaine; ces réseaux doivent être reliés à des bases de données à l'échelle mondiale. De tels outils faciliteraient la détection précoce de menaces potentielles pour l'environnement et amélioreraient la prévention des maladies chez les humains.

1. Laval University, Quebec
2. Bermuda Biological Station for Research, Inc., St. Georges, Bermuda
3. University of North Carolina, Wilmington, NC
4. University of Massachusetts, Boston, MA
5. University of Plymouth, Plymouth, UK
6. Wrigley Institute, University of Southern California
7. NIEHS Marine and Freshwater Biomedical Sciences Center, University of Miami, Miami, FL
8. Harvard School of Public Health, Boston, MA
9. US State Department, Washington, DC
10. National Institutes of Health, Research Triangle Park, NC
11. Intergovernmental Oceanographic Commission, UNESCO, Paris, France

Much of the text of this paper forms the basis for another paper published in *Environmental Health Perspectives*.[1] The focus of the current paper is on the meeting discussions and conclusions regarding indicators for ocean and human health.

Correspondence: Chris Furgal, Public Health Research Unit, CHUQ - Pavillon CHUL, 2400 rue d'Estimauville, Beauport, QC G1E 7G9, Tel: 418-666-7000 ext. 555, Fax: 418-666-2776, E-mail: christopher.furgal@crchul.ulaval.ca

This paper is the result of a NIEHS-funded conference held in Bermuda in November, 2000 to discuss indicators of ocean and human health. The conference brought together international experts in the areas of marine ecosystem and human health. The result was a list of indicators for aspects of ocean and human health, identification of research needs and the development of an approach to deal with these issues. What is presented here is the discussion relating to environmental health indicators relevant to marine environments.

At present, it is estimated that 60% of the world's population lives in coastal areas and human population growth in coastal zones is about twice that of the global rate. This settlement pattern has exacerbated the rate of change in coastal systems and has already placed the goal of "sustainable development" out of reach for some regions. The world population is estimated to increase from about 5 billion (at present) to 8.3 billion by 2025, with 90% of this growth occurring in subtropical and tropical countries. At the same time, over 2 billion people world-wide rely on seafood as a major source of protein in their diet and global seafood consumption continues to increase.[2]

There are many potential sources of contamination of the marine system. Only a subset of these are of specific concern to the issue of Ocean and Human Health. As determined by the conference participants, priority issues include: persistent organic pollutants (POPs), a few specific heavy metals, algal toxins, pathogens, pharmaceuticals and possibly genetically modified organisms. Routes of human exposure to marine products include ingestion, dermal exposure and inhalation. The largest concern for public health is the ingestion of contaminated seafood, putting those humans who ingest large quantities of seafood at greatest risk.

Persistent organic pollutants (POPs)

POPs are a loosely defined group of substances which, aside from petroleum hydrocarbons and polyaromatic hydrocarbons, include all synthetic substances that result from industrial activities. The introduction of POPs to the marine environment arises from direct discharge (point sources), discharge to municipal sewage systems or rivers, and venting to the atmosphere. These compounds are best classified in terms of their a) toxicity, b) persistence, c) tendency to bioaccumulate, d) bioavailability, and e) source functions (size and nature of the land-based sources). Current scientific knowledge of these compounds is still limited and new compounds continue to be identified. Polynuclear aromatic hydrocarbons (PAHs) are derived from thermal transformations of fossil fuel, primarily petroleum. Some are formed by natural low temperature metamorphic processes. The primary human health concerns related to these substances deal with their carcinogenicity.[3] They enter the marine system through municipal or industrial effluents or via atmospheric pathways from industrial emissions, through exhaust fumes of internal combustion engines or from domestic heating systems and humans are exposed to these substances primarily through food chain consumption.

Most POPs have been linked to possible endocrine-disrupting functions and there are links between herbicide exposure and reduced sperm counts in males living in agricultural regions. Human exposure to POPs occurs primarily through ingestion of contaminated foods, often procured directly from the environment (e.g., small traditional fishing communities, etc.) and results in a variety of effects. PCBs, for example, have a variety of effects on human reproduction, neurobehavioural development, liver function, birthweight, immune response, as well as having carcinogenic properties. Studies in Arctic populations have linked fetal cord blood PCB concentrations with low birthweight, small head circumference, and immunosuppression.

Despite the fact that the POP "DDT" was banned in the U.S. and Europe in 1972, it is still being used worldwide for malaria control and is of concern for human health. The International Agency for Research on Cancer (IARC) considers DDT to be "possibly" carcinogenic. DDT is regarded as an estrogen mimic and DDE as an androgen receptor antagonist. Subacute levels of exposure show effects on the central nervous system (CNS) of humans while studies continue on the effects of neonatal POPs exposure in the Arctic.[4] There is little information on the transfer through the marine food web of other organochlorine pesticides and their effects on humans.

Metals

Trace metals comprise all metals and metalloids in the marine environment. It is important to distinguish between the introduction of trace metals from anthropogenic activities and those from natural weathering processes. Although sources of trace metals in the marine environment are numerous and diverse (elevated trace metal levels accompany almost every type of effluent), there is little evidence of widespread adverse biological effects posed by metals in seafood other than risks to human health.[5] Elevated metal levels in seawater are unlikely (other than in the immediate vicinity of sources) due, in most cases, to their rapid removal by adsorption to suspended particulate material. In the case of certain organo-metallic complexes/compounds, the situation is quite different. Tributyl-tin (used as a constituent in anti-fouling paints on boats) and methyl mercury (formed by the microbial methylation of mercury) are two highly toxic compounds which have been responsible for well-recorded marine pollution incidents. The basis of toxicity for these substances lies in their forms of speciation. Thus, special attention may be required to identify specific forms of other trace metals in the future. Mercury is used in a wide range of industrial processes and mining practices. Once released into anoxic environments, it can be rapidly methylated by bacteria. Methyl mercury (MeHg)is highly lipophillic and is biomagnified in the environment.[6] The half life of MeHg is 60-120 days in humans and up to 2 years in fish. MeHg causes cytotoxic, kidney and brain damage, with concentrations of 1-2 mg/kg in brain tissue producing neurotoxic effects. Fetal exposure to MeHg is of great concern and as expected, individuals who consume seafood have the highest concentration of MeHg in their tissues. Environmentally chronic exposures have been reported in fishing populations in Amazonia, Coastal Peru, Seychelles, Faroe Islands, the Arctic and in New Zealand.

Cadmium (Cd) can also bioaccumulate in the environment, however its uptake by humans is affected by the uptake of lead (Pb). IARC has labelled Cd as a group 1 carcinogen. The major health risk associated with cadmium is nephrotoxicity (proteinuria and renal failure). Environmental exposures to Pb have been linked to poor neural development in children, however there are no documented cases of lead poisoning related to a marine source. Arsenic is also a highly toxic metal, however, as with Pb, no known arsenic poisonings have occurred as a result of marine exposures or consumption of seafood. Both lead and arsenic occur in marine sediments as a result of industrial discharge. Like mercury, arsenic can be converted to more lipophillic and toxic methyl forms. The effects of these metals on the ecological health of the marine environment are not yet well known.

Harmful algae blooms

Algal toxins are compounds that are produced by marine organisms on a large-enough scale to induce adverse effects on communities of higher marine organisms.

In turn, humans may be exposed through consumption of seafood or through occupational or recreational exposure to the toxins, primarily through dermal contact. In the case of *Gynmodinium breve* (Florida Red Tide) and *Pfiesteria*, transfer to humans can occur through inhalation of aerosols containing the toxin. Algal toxin outbreaks are mainly confined through transfer from dinoflagellates and marine phytoplankton. Currently, there are about 2,000 species of dinoflagellates identified, of which about 60 species cause red tides and about 30 produce biotoxins. Of the 5,000 known species of phytoplankton, approximately 80 are toxic.[7] There is strong evidence that certain blooms of phytoplankton-producing toxins are induced or sustained as a result of anthropogenic destabilization of the marine ecosystems (e.g., eutrophication).

It is virtually impossible to accurately assess health risks from exposure to marine toxins as very little data exist on their transfer through the coastal food web. Different toxins have different effects. Exposure to the aerosolized neurotoxin of *Physteria* has been linked to nausea, respiratory problems and severe memory loss.[8] Twenty types of paralytic shellfish poison (PSP) toxins are currently identified, of which saxitoxin is the major toxin. Primary symptoms of exposure are paresthesias and paralysis. The neurotoxic shellfish poison (NSP) toxin – brevetoxin – is easily aerosolized and inhalation by humans can lead to respiratory infection, coughing and bronchiospasms. Exposure to the asptoxin – domoic acid – can lead to seizures, coma, amnesia and formation of lesions in the brain. The diarrheic shellfish poison (DSP) toxin – Okadaic acid – is probably the most widespread marine toxin illness attributable to seafood consumption[9] and exposure to the toxin leads to gastrointestinal symptoms. The ciguatera fish poison (CFP) toxin – Ciguatoxin – has been documented in up to 400 species of fish and is responsible for more than half of all reported seafood-related illnesses (~50,000 reported cases/year). Like other types of seafood poisoning, it is felt that many cases go unreported. Variations in symptoms from exposure to ciguatoxin occur geographically. In Polynesia, CFP symptoms are usually neurologic, while in the Caribbean the initial symptoms include gastroenteritis and cardiovascular problems. Ciguatera toxin has also been linked to premature labour and spontaneous abortions.

Microbial risks

Pathogens in the marine environment are a significant human health concern, both because of exposure through consumption of contaminated seafood and through occupational and recreational exposures. The primary sources of human pathogens are untreated human and animal wastes, although transmission can occur between swimmers or, potentially, from seabirds or other wildlife. One of the major causes of reported seafood illnesses is the consumption of raw shellfish contaminated by sewage. Routes of human exposure to pathogens include consumption of seafood, direct ingestion of seawater, and dermal exposure to both water and sediments.[10] Among the microbial agents related to seafood-borne illnesses, viruses are the most common form of infection, followed by bacteria and finally the protozoa. The major vectors of viral infection are marine bivalves such as oysters and clams. The potential human health effects are numerous and dependent upon the specific virus.

In contrast to our understanding of microbial agents in the marine environment, there is very little known about the protozoa. *Cryptosporidium sp.* have been found to accumulate in shellfish, but to date there are no reports of outbreaks associated with seafood consumption. *Giardia* and *Entamoeba* gastritis have been epidemiologically linked to scuba diving in sewage-contaminated waters. In general, there appears to be an increase in infections (e.g., gastrointestinal, dermal, respiratory, eye, ear, nose and throat infections) among individuals recreationally and occupationally exposed to seawater. Children are at greater risk of contracting these infections and the potential economic consequences are significant.

Pharmaceuticals include all substances used in preventing and treating human and animal diseases. The major conduit of pharmaceuticals into the marine environment is via the municipal sewage system, or in the specific case of aquaculture, by their direct and intentional introduction into fish enclosures. The concerns regarding these substances in the marine environment are considerable as the use of aquaculture increases worldwide, with a consequent reduction in genetic diversity among fish. This in turn results in an increased need for more pharmaceutical use in the future. There is no conclusive evidence of significant adverse effects in coastal waters, but research in this area is continuing, with some limited information on potential endocrine-disrupting effects.

ENVIRONMENTAL AND HUMAN HEALTH INDICATORS

The marine environment

In the past, measures of concentrations of contaminants and changes in community structure were used to indicate the state of ecosystem health. However, such high-level responses are generally too complex and far removed from causative events and are manifestations of damage rather than predictive indices. Detection of lower-level changes (molecular, cellular, physiological and behavioural responses) which underlie higher-level effects and for which causality can be established, may provide a better early warning of impending environmental damage. Individual and sub-individual responses may also be amenable to detection by automated monitoring systems. Four approaches to gathering information on indicators are suggested: biomarkers, cellular pathology, physiological and behavioural responses, and changes in populations. All hold the potential to enhance our understanding of both marine environmental quality and consequential effects on human health. Tables I to V outline available and needed indicators and data for each of the 5 following priority issues for ocean and human health interactions: seafood consumption, POPs, heavy metals, pathogens and harmful algae blooms.

Our knowledge of distress signals has grown substantially in the past decade, often drawing from the reservoir of our knowledge of humans and rodents. The use of biomarkers (indicators) in marine environmental toxicology is increasing and their potential power is significant: they hold the prospect of being not only diagnostic predictors of pathological change, but also biomarkers of exposure for specific classes of toxic chemicals (xenobiotics) and certain trace metals. This latter type of biomarker has the potential to provide rapid

TABLE I
Priority Issue: Seafood Consumption

	External Exposure	Internal Exposure	Early Human Response	Disease	Death	Action
Available Data	Levels of priority chemicals in consumed fish spp.	Fish fatty acid profile (N-3/N-6) among consumers				
Research Needed	*			Seafood eaters disease profile		

* For all indicators, need cheap, fast, easy and transportable testing methods

TABLE II
Priority Issue: POPs (Pesticides, PCBs/PCDD/HCB)

	External Exposure	Internal Exposure	Early Human Response	Disease	Death	Action
Available Data	• Levels of priority chemicals in consumed pelagic and deep sea fish spp. • Levels of priority chemicals in seafood spp consumed * Emphasis on predator and fatty spp.	• Measurement in lipophillic tissue and fluids of consumers (fat, milk, plasma, maternal cord blood)	• Endocrine markers • Immune markers • Neurotoxicity markers • Genotoxicity markers	• Birth defects registry		
Research Needed	• Standard seafood consumption questionnaire • Identification of new contaminants • Biological activity assessment (in vitro receptor assay)			• Childhood infection • Reproduction problems • Cancer	• Death certificate (cancer)	

TABLE III
Priority Issue: Heavy Metals

	External Exposure	Internal Exposure	Early Human Response	Disease	Death	Action
Available Data	• Hg levels in tuna (global) • Metal levels in bivalve spp.	• MeHg in consumers (hair, blood) • Cd in consumers (24 hr. urine)	• Cd in consumers (beta2 microglob)			
Research Needed	• Se levels in seafood		• Hg effects measurements	• Cd, Hg (blood pressure)		

TABLE IV
Priority Issue: Pathogens

	External Exposure	Internal Exposure	Early Human Response	Disease	Death	Action
Available Data	• Coliform counts (water, seafood) • Bivalve data on pathogen incidence			• Registry • Cholera incidence • Salmonella incidence • Shigella incidence	• Death certificate review	
Research Needed		• Identify pathogens for marine environment		• Increase registry • Rapid test pathogens	• Increase registry	

TABLE V
Priority Issue: Harmful Algae Blooms

	External Exposure	Internal Exposure	Early Human Response	Disease	Death	Action
Available Data	• Shellfish poisonings incidences • Dinoflagellates incidences			• Reportable disease incidence (specific, U.S., Canada, Japan)		• Outbreak investigation
Research Needed	*	• Compound and metabolites indicators	• Biomarkers of effects (cigu., NSP, ASP)	• Improve surveillance • Follow up chronic diseases		

and less costly alternatives to routine chemical analytical screening. Chemical analytical efforts can then be focused on more specific fingerprinting work, thereby helping to elucidate the link between cause and effect.

Potential marine biomarkers (indicators) include alterations in intercellular membranes (e.g., endoplasmic reticulum, lysosomes, endosomes, transport vesicles), genotoxicity (e.g., oxidative adducts, micronuclei), specific proteins or enzymes (e.g., metal-binding proteins, stress proteins, oncoproteins, cytochrome P-450s, multi-drug resistance proteins) and inhibition of cholinesterase by neurotoxins (e.g., organophosphates, carbamates). Some of these biomarkers, such as membrane changes and stress proteins, are indicative of cell injury and potential damage to health while others, such as DNA adducts, cytochrome-P450 (e.g., CYP1A and Ethoxyreorufin O-Deethylase (EROD), multi-drug resistance (MDR) protein and metal-binding proteins), can be indicative of exposure to certain classes of xenobiotics and metals.

The use of molecular and cellular biomarkers coupled with cellular pathology (histopathology) provides another clue as to the source of the specific environmental problem. Histopathological change can be easily and accurately quantified using microstereological procedures applied to tissue sections. These data can then be correlated with both cell injury processes and abnormalities in physiology. Linking these measurements with physiological and behavioural responses, and the more traditional population and community monitoring, will provide a set of early and long-term warning systems for the environment.

Human health

It is clear that challenges remain in order to develop a better understanding of the connection between the marine environment and human health. Environmental changes do have an impact on human health and it is important to identify which indicators have enough sensitivity and specificity to be able to detect these changes. It is unlikely that human mortality and morbidity registries alone could help to monitor environmental changes, as most chronic human diseases are multifactorial and involve genetic, lifestyle and environmental factors. It is therefore also unlikely that cancer registries or mortality rates will provide a useful indication of changes for ocean-related illnesses as there are issues regarding specificity, and the delay between the exposure to environmental risk factors and cancer is long (10-20 years). However, morbidity registries on acute diseases such as marine toxin poisonings and other seafood-borne diseases, which are mandatorily declared in most countries, could provide useful information on any incidence changes over time. As there is acceptance that these diseases are largely under-declared, there is an urgent need to improve and validate these surveillance systems. Health registries are also very useful to monitor short-term events such as pregnancy, and pregnancy complications such as low birthweight, congenital malformations, etc.

Specific clinical effects related to contaminants have been the subject of numerous and recent epidemiologic studies. In low-dose exposed general populations, only subtle effects are expected to occur. For Pb and Cd, epidemiologic studies and animal experiments provide sufficient data to set thresholds for human exposure. There is a general consensus that 10 mg/dl is the maximum Pb blood concentration accepted for children. In this case, measuring blood Pb in a group of children is a relatively easy, cheap, validated and manageable biomarker to assess both exposure and risk in children. However, for most ocean-related contaminants such as MeHg and POPs, results from epidemiological studies are more contradictory. Cohort studies in Michigan[11] and North Carolina[12] provided some discrepancies on neurobehavioural changes in children who were prenatally exposed to PCBs. Conflicting results were also reported on neurological impairments in children who were exposed to MeHg during their fetal life. A study in the Seychelles did not report any deleterious effects,[13] whereas a cohort study in the Faroe Islands did.[14] There may be many reasons for these discrepancies, including differences in methods, exposure mixtures, nutritional interactions and genetic susceptibility.

Unfortunately, cohort studies are extremely expensive and require large multidisciplinary scientific groups. In addition, new xenobiotics or metabolites are regularly identified by analytical chemists and it is unlikely that epidemiologists will be able to react in a timely manner. To complement standard disease registries and epidemiological cohort studies, scientists have tried to develop early response biomarkers to detect any reversible or irreversible biological effects. Potential early warning signal markers deal with the immune system (cytokines, cell markers, antibody response to immunization, etc.), endocrine activity (hormones such as sexual or thyroid), genotoxicity (DNA and protein adducts for POPs), and enzyme induction (CYP-450 1A2 and EROD activity using Caffeine Breath Tests for POPs). Some biomarkers are already in use (ALAD for Pb, b2-microglobuline for Cd) but most still need to be validated. Major challenges to their applicability are a lack of sensitivity and specificity. A great deal more work needs to be done to link the health of the marine environment to human health, and to identify and select the best indicators of this relationship.

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Environmental Health Surveillance: Indicators for Freshwater Ecosystems

Robert D. Morris, MD, PhD[1]
Donald Cole, MD, MSc[2]

ABSTRACT

The relationship between the health of human populations and the state of the ecosystems in which they live is profoundly complex. As most environmental indicators relevant to human health depend on evidence of a direct cause and effect relationship, there are few indicators of the less direct consequences of environmental degradation on human health. Indicators of the direct consequence of contaminants in freshwater ecosystems on human health are highlighted in this paper and candidate indicators for environmental health are provided. Many of the indicators included here are from the State Of the Lakes Ecosystem Conference (SOLEC) program. SOLEC conferences in the past (1994 and 1996) examined the state of various components of the ecosystem through the use of ad hoc indicators, and provided subjective assessments of certain environmental conditions. At SOLEC 98, a comprehensive suite of 80 Great Lakes ecosystem health indicators was presented for review, refinement and acceptance. Candidate indicators for freshwater systems and environmental health presented here are organized following the "Pressure-State-Response" framework and cover the areas of drinking water, recreational water, freshwater food sources, and the availability of freshwater for economic activities.

RÉSUMÉ

La relation entre la santé des populations humaines et l'état des écosystèmes où elles vivent est très complexe. Même si la plupart des indicateurs environnementaux liés à la santé humaine dépendent de la démonstration d'une relation directe de cause à effet, il existe néanmoins quelques indicateurs des conséquences moins directes de la dégradation de l'environnement sur la santé humaine. Les auteurs traitent des indicateurs des effets directs des contaminants dans les écosystèmes d'eau douce sur la santé humaine et proposent des indicateurs d'intérêt potentiel pour l'hygiène de l'environnement. Nombre de ces indicateurs sont tirés du programme de la Conférence sur l'état des écosystèmes lacustres (CEEL). Les conférences CEEL de 1994 et 1996 ont porté sur l'état de diverses composantes des écosystèmes à partir d'indicateurs ad hoc et ont fourni des évaluations subjectives de certaines conditions environnementales. Lors de la CEEL 1998, on a présenté une série exhaustive de 80 indicateurs de l'état de l'écosystème des Grands Lacs en vue de les examiner, les raffiner et les approuver. Les indicateurs potentiels pour les écosystèmes d'eau douce et l'hygiène de l'environnement présentés dans cet article sont organisés d'après le cadre Pression-État-Réaction et couvrent les secteurs de l'eau potable, des eaux utilisées à des fins récréatives, des sources de nourriture en eau douce et de la disponibilité de l'eau douce pour des activités économiques.

1. Tufts University, School of Medicine, Boston, MA
2. University of Toronto, Faculty of Medicine, Toronto, ON
Correspondence: Dr. Robert D. Morris, Tufts University, School of Medicine, 136 Harrison Avenue, Boston, MA 02111 U.S.A., Tel: 617-636-7000, E-mail: robert.morris@tufts.edu

Contaminants in the Great Lakes can cause disease in humans because we drink or wash in contaminated tap water, because we ingest contaminated food, or because we swim in contaminated water. In suggesting indicators for environmental health, this paper considers each of these routes of exposure. As most health outcomes have multiple potential sets of causal factors, outcome indicators are of limited value and do not permit any direct inferences with respect to effects from environmental exposures. Nonetheless, those outcomes that are routinely recorded by state, provincial and federal agencies are relatively easy to track and unusual spatial and temporal distributions of disease may suggest emerging problems. Trends in disease rates may provide evidence relevant to interpretation of trends in contamination and thus some are included here. We also consider the less direct relationships between health and the environment such as those related to economics and food supplies in the Great Lakes basin. Finally, we delineate structural indicators that reflect the status of programs to protect human health from these risks.

DRINKING WATER

Overview

Few areas of environmental health have received as much attention for as long a time as the health risks related to drinking water. Contaminants may enter water supplies at many points before reaching the tap. The types and quantities of contaminants in drinking water at the point of consumption differ depending upon whether they result from contamination of the source water, arise as a consequence of treatment processes, or enter as the water is conveyed to the user.

Source water contaminants and associated health risks

Precipitation falling on the Great Lakes Basin literally washes over the air and the watersheds of the Lakes delivering a solvent load that contains, at some concentration, every chemical produced in the basin together with the pathogens that infect its human and animal inhabitants. Contaminants of concern are those that are either sufficiently potent to pose risks at extremely low concentrations or capable of causing local contamination at high concentrations. These contaminants may enter the water from naturally occurring sources of toxic elements, industrial discharges, agricultural runoff or domestic municipal waste discharges.

Naturally Occurring Chemicals and Pathogens

Naturally occurring chemicals, such as arsenic[1-3] and radon,[4,5] are established carcinogens that can pose significant health risks. These are primarily a concern for groundwater supplies and do not appear to pose a documented problem in the water of the Great Lakes. Furthermore, naturally occurring chemicals do not provide a useful indicator with respect to the State of the Lakes since their presence is usually independent of anthropogenic activities. Pathogens and algal toxins may enter source water from sources that are not a direct consequence of human activity (e.g., giardia). There is no clear evidence of health effects from exposure related to these contaminants in the Great Lakes, but they pose a plausible risk that should be considered in the development of indicators.

Agricultural Runoff

Farm runoff containing agricultural chemicals and manure may lead to local or regional contamination of source waters with pesticides, fertilizers and pathogens. Agricultural activities may also result in nutrient loading and suspended silt loads in the Lakes that can have secondary effects related to human health.

Most pesticides have documented effects on human health, but there is little evidence to determine whether long-term exposure to the low levels found in drinking water has significant health consequences. Water utilities regularly test for heavily used chemicals and highly toxic chemicals as specified by the EPA and Health Canada. It is possible that an index could be developed based on these data.

Nitrates in drinking water have the well-documented capacity to cause methemoglobinemia ("blue baby syndrome"). There is also limited evidence indicating that nitrates may have other effects.[6-8] Given that the presence of nitrates in surface water in rural areas is likely to be strongly correlated with the presence of animal wastes, the nitrate link should be interpreted cautiously.[9] Their levels are routinely monitored in drinking water and could provide not only a measure of potential risk associated directly with nitrates, but also an indicator of agricultural runoff.

Agricultural runoff can also contain a number of significant pathogens. Of particular concern are *Cryptosporidium* and E. coli:157. *Cryptosporidium* oocysts are resistant to chlorine disinfection and have caused many waterborne outbreaks. Routine monitoring for *Cryptosporidium* is limited and relies on insensitive methods, but more regular monitoring with more sensitive methods is likely to be required in the near future. Also, routine monitoring data for fecal coliform should identify possible contamination with this organism.

Industrial Discharges

Industrial waste includes a vast number of chemicals about which it is difficult to draw general conclusions about the risks they pose. Elevated cancer risks are difficult to detect because of the relatively low incidence of site-specific neoplasms and the small size of exposed populations in most situations.[10] However, some studies have found evidence of positive associations between some compounds in drinking water and some forms of cancer.[11-13] The wide variety of chemicals present in hazardous waste sites, the difficulties in assessing exposure, the obstacles to establishing links between exposure and cancer even when links are present, the small size of exposed populations and the uncertainties concerning future risks make it difficult to define an ideal indicator of risk associated with this group of chemicals. Currently, water utilities in Canada and the U.S. monitor a subset of these chemicals that could provide the basis for any such indicator.

Contaminants from Sewage

Municipal sewage, in treated effluents or in untreated combined sewer overflows, poses an obvious risk related to human pathogens, especially during periods of low flow when treated waste can constitute a substantial portion of the water entering the Lakes. This waste can include any pathogen present in the population including bacteria, viruses, or protozoa. Routine monitoring for pathogens is often limited to 3 indicators. Total coliform is used primarily to indicate the effectiveness of the disinfection at the treatment plant. Fecal coliform provides an indicator of contamination with fecal matter in the source or treated water and turbidity provides an indicator of filter effectiveness and is a surrogate for the presence of viruses and protozoa in the effluent.

Municipal sewage can also contain chemical contaminants as industrial wastewater is often combined with domestic waste entering the sewage system. It has recently been recognized that pharmaceutical products can contaminate domestic and hospital waste and may pose threats to ecological and human health. However, there is little hard data documenting this effect and immediate monitoring is not required, but the existence of data may provide a useful indicator with relevance to public health in the future.

Contaminants introduced during water treatment

Modern drinking water treatment relies on a variety of chemicals. There is little evidence that any of these chemicals pose a significant health risk with the singular exception of chlorine. The introduction of chlorination for the treatment of drinking water in the early 1900s dramatically reduced mortality from waterborne pathogens. Ironically, it may now account for a substantial portion of the residual health risks associated with drinking water. Since it was first recognized that chlorinated drinking water contained chlorinated organic compounds, particularly chloroform, a known carcinogen,[14,15] more than 30 epidemiological studies have examined the association between cancer and chlorination by-products. These studies provide evidence of an association between chlorination by-products and bladder cancer and suggest a risk of colorectal cancer,[16-18] among others. There is also emerging evidence to suggest that chlorination by-products may be associated with adverse reproductive and developmental outcomes such as low birthweight, congenital anomalies, and spontaneous abortion. In sum, the available studies generally support the notion that chlorination by-products pose risks to human health. The precise characterization of these risks is somewhat less clear. The broad category of chlorination by-products includes many different compounds and the specific compounds associated with the apparent health risks have not been clearly identified.

Utilities routinely monitor for total trihalomethanes as an indicator of chlorination by-products and they will soon be required to monitor for the trichloracetic acids as well. Also, the amount of chlorine added is a useful indicator of both the quality of the treated water and the potential for formation of by-products.

Indirect effects of drinking water contamination

Reductions in drinking water quality may have consequences beyond the direct health effects of the contaminants. Many industries require extremely high quality water, particularly in the high technology sector. Contamination of the water supply may require introduction of filtration equipment, may cause operational problems for filters already in use, and, in extreme cases, may cause some industries to relocate or decide not to locate in such ecosystems as the Great Lakes Basin. The associated economic effects could have ramifications for public health in the affected areas. Contamination of the water supply may also erode public confidence in the water supply and lead to the increased use of bottled water and water filters. Both alternatives have implications for health and the environment including increased pollution from bottle manufacturing, increased pollution from transport of bottles, increased exposure to chemicals leaching from bottles, increased solid waste, and, for water from outside the region, the loss of money from the local economy. Possible indicators for drinking water and health are included in Appendix 1.

RECREATIONAL WATER

Bathing in recreational water poses a well-documented risk of disease, primarily due to microbial contamination. Chemical contamination can pose a risk at locations that are close to toxic chemical sources, but public swimming facilities are not generally placed in such locations. At present, most of the testing of bathing beaches is limited to tests for fecal coliform during the swimming season.

In 1986, the US EPA recommended that criteria for recreational use of freshwater be based on testing for E. coli or enterococci rather than fecal coliform. This was based on data indicating that fecal coliform was not a good surrogate for the combined health risk from pathogens in ambient water. Despite this recommendation, many jurisdictions continue to use fecal coliform for monitoring of recreational water.

The accessibility of freshwater swimming beaches may also have indirect effects on human health. Increased accessibility can have benefits related to the physical as well as psychological benefits of swimming in the Lakes. The number and accessibility of beaches can also have effects relating to the desirability of these beaches for summer recreation. The population density of the Great Lakes Region and the limitations on availability of beaches near population centres can create a variety of pressures with implications for health including development of vacation homes and resorts, increased traffic with its associated air pollution and automobile injuries, and the increase in boat activity in the vicinity of beaches. Possible indicators for recreational water are presented in Appendix 1.

FRESHWATER FOOD SOURCES

Contaminant risks

Considerable work has been carried out in the Great Lakes and St. Lawrence River basins to document human exposure to chemical contaminants and estimate its impact on human health. Several indicators related to such exposure are included in the SOLEC documentation.

Most directly related to the environment are measures of contaminants in various media. SOLEC indicator #118 describes concentrations in offshore waters of the IJC priority toxic chemicals. Most are persistent and bioaccumulative as well as toxic (PBT). Important at an ecosystem level, most of these PBTs are removed by water treatment facilities and the amount of water humans directly consume from freshwater systems is sufficiently small to place a lower priority on them as indicators of potential human health impact.

Second are measures of contaminants in freshwater food sources that bioaccumulate toxins and that humans consume. This includes a wide array of fish caught and eaten in the Great Lakes (i.e., pressure indicator # 4083 of SOLEC). Additionally, some measures of other species (e.g., SOLEC pressure indicator #115 on contaminants in colonial nesting birds) may be relevant given the consumption of bird eggs in some areas, e.g., North shore of the St. Lawrence. PCBs and mercury have been the most common consumption-limiting contaminants, followed by dioxins, toxaphene, and mirex/photomirex in different Great Lakes. Such levels have been used in exposure estimation for epidemiological studies of neurodevelopmental and reproductive impacts among humans which have contributed (along with animal research) some of the most important findings to our state of knowledge on these issues.

Third are estimates of total intakes of contaminants from all sources (including water and freshwater food sources) by people with different activity profiles. Included as part of SOLEC pressure indicator #4088, such estimates have a long history in risk assessment activities.

Fourth are the most direct indicators of human body burden or accumulated dose of persistent contaminants, to which freshwater food sources may contribute. SOLEC #4177 subsumes a number of such measures. DDE and PCB levels in breastmilk, dioxin levels in plasma/serum and mercury in hair/whole blood are among the most frequently cited measures. The latter two have the greatest human health relevance given the relatively less disputed nature of their human health impacts and the fact that human levels are of the same order of magnitude as subtle effects in other species. Ways of more easily monitoring such levels in human populations on an ongoing basis need to be developed.

Finally, geographic patterns and trends in disease incidence are also included in the suite of SOLEC human health indicators (#4179). However, such attribution depends on better estimates of population exposure and dose than are usually available on a geographical basis. At present, risk assessment-based estimates are likely a better guide to human health impacts attributable to chemical contaminant exposures from freshwater sources than geographically based disease burden measures. Appendix 1 presents possible indicators for contaminant risks posed by freshwater food sources.

Health benefits

Anglers, hunters and clients of commercial operations can eat fresh food procured from freshwater lakes, rivers and streams, subject to local regulations. The Canada Health Monitoring survey estimated that almost half of Ontario residents sampled had eaten sport fish from Ontario at least once per year, while 5% reported at least weekly consumption. Similar estimates were made (42% and 7% respectively) during shoreline surveys of fishers in five Ontario Areas of Concern (AOCs) during the summers of 1995-1997.[19] Consumption of aquatic waterfowl[19] and other freshwater species (e.g., turtles, frogs, muskrat) were also reported, though much less frequently.

Fishers reported the value of fresh fish based on its perceived superior quality, its contribution to their ability to provide for themselves, and the economic advantages of being able to procure food from the environment.[19] Each of these benefits are important within broader social notions of 'health', however are difficult to measure with direct questionnaire measures, making their conversion into indicators difficult.

Quantification of potential nutritional benefits through dietary record measures has been carried out among frequent consumers in the Montreal area and Ontario AOCs.[19] Both studies indicated that sport fish consumption was associated with lower percentages of energy intake as fat, higher protein and iron intakes and higher plasma concentrations of omega-3 essential fatty acids (FA). Each of these associations can be regarded as health benefits. Although the epidemiological debate around fish consumption and heart disease continues, increased omega-3 FA intakes are important for both reproductive-developmental benefits and cardiovascular risk reduction (Toxicology Excellence for Risk Assessment, personal communication with expert panel member, Judy Sheeshka). Yet such nutritional assessment work is relatively labour-intensive if more precise intake or biological measures are required for benefits assessment. Alternatively, work on nutrient composition could be carried out for common species/location mixes. However, omega-3 fatty acid composition data, for example, are available only on some Great Lakes species, and various environmental and food availability factors affect such composition. Indicators for the health benefits associated with freshwater food sources are presented in Appendix 1.

AVAILABILITY OF FRESHWATER FOR ECONOMIC ACTIVITIES

Water resources and their utilization for navigation, hydroelectric power generation, fisheries and agriculture have historically been important policy concerns. In extreme cases, environmental and economic disasters with subsequent health impacts have occurred elsewhere in the world because of massive withdrawals of water primarily for irrigation, e.g., the Aral Sea in Uzbekistan.[20,21] Although the water resource situation is not as dramatic in the Great Lakes Basin, concern about the continuing availability of water has stimulated estimates of use and consumption.[22] Such work considers draws by industry and agriculture, among the former being massive quantities that cycle through nuclear generating stations.

Given the historic importance of water resources, the current suite of SOLEC indicators cover a variety of concerns. Water level fluctuations (SOLEC #4861) are included in both coastal wetland and nearshore terrestrial sections. The role of nearshore waters and coastal wetlands as essential areas for maintenance of the diversity and production of fish, and hence both the recreational and commercial fisheries on the Great Lakes, are reflected in a number of indicators (e.g., SOLEC #8). Related are indicators that measure aspects of fish that would detract from economic human uses (e.g., deformities/eroded fins/lesions/tumors in coastal wetland fish - SOLEC #4503).

As the IJC[22,p.26] has stated, "Water quantity and water quality are inextricably linked...In many areas, poor water quality continues to impair the potential uses of the Great Lakes." The extent to which such poor freshwater quality impacts on economic prosperity (SOLEC #7403) may be hard to estimate, yet for sustainable livelihoods such impacts must be addressed.

Whether to include this group of indicators as estimates of health impacts, is an open question. On one hand, their inclusion would reflect the broad 'ecosystem and social system sustainability for health' perspective. Yet doing so would rapidly expand the nature of indicators well beyond the traditional areas of expertise of most environmental health personnel and potentially duplicate work being done by other groups. We have not included such indicators in our short list, based primarily on the latter consideration and the need for focus on those indicators in an environmental surveillance system where health professionals can most push an agenda forward. Indicators of economic activities related to freshwater are presented in Appendix 1.

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(continues on page S44)

Appendix 1

Proposed Indicators

INDICATORS FOR DRINKING WATER

Possible Indicators
SOLEC indicator #4175
* (for all SOLEC indicators see http://www.on.ec.gc.ca/solec/indicators2000-e.html)

Indicators of Exposure
Microbial
- Treated water fecal coliform
- Raw water fecal coliform levels
- Treated water turbidity

Gaps – Specific pathogens are not routinely measured. Include measures of *Cryptosporidium* and viruses as they become more available.

Chemical
- Treated water THMs
- Treated water HAAs
- Amount of chlorine used
- Recorded violations of federal drinking water regulations for other chemicals

All measurements should include max. and average levels / location. Treated water indicators should include the number of non-zero days or days in violation of existing standards. Combined indicators can be generated by calculating a weighted average with weighting based on the population served.

Gaps – Data on specific byproducts, particularly brominated by-products. Measurements of specific regulated chemicals vary in frequency and exact measurements are not routinely available unless a violation occurs.

Outcomes
- Incidence of cancer for common sites
- Rates of birth defects
- Counts of physician visits for gastroenteritis
- Population antibody levels to specific pathogens such as *Cryptosporidium*

Indirect Effects
- Total bottled water consumption in the region
- Proportion of bottled water from outside the region
- Number of bottles produced
- Sales of household water filters

Gaps – It is not clear that sales data for bottled water or water filters are routinely available.

Pressure
- Total volume of sewage discharged into the basin by treatment category
- Total volume of combined sewer overflows
- Use of agricultural chemicals in the basin by type
- Livestock density in the basin
- Total water use throughout the basin / Total flow from streams in the basin
- Aquifer use/Recharge rate
- Public vs. Private ownership of riverbanks and other key watershed land

Gaps – Combined sewer overflows are difficult to quantify and such data may not be routinely available.

INDICATORS FOR RECREATIONAL WATER

Possible Indicators
SOLEC indicator # 4081

Exposure
Until measures of coliform become more standardized, an indicator should integrate the three measures and should take into account the frequency of testing and the population served by the beach. Measurements for other pathogens should also be integrated into this indicator.
- Fecal Coliform levels
- E. Coli levels
- Enterococci levels
- Other pathogen data should be tracked (e.g., *Cryptosporidium,* Giardia, caliciviruses and rotavirus)
- Beach closings

Gaps – E. Coli and Enterococci are not routinely measured.

Outcomes
- Administrative records of medical care for gastroenteritis (as discussed for drinking water)
- Reports of swimming-related outbreaks

Gaps – Better data on the relationship between contamination of freshwater and infectious disease in swimmers needed.

Indirect Effects
- Miles of swimmable beach
- Population-weighted average of miles to nearest beach for major cities in the basin

Pressure
Indicators of pressure for drinking water as described above would also serve as indicators for recreational water.

INDICATORS FOR FRESHWATER FOOD SOURCES

RISKS
Possible Indicators: Available (A) & Gaps (G)

Pressure
- Multiple SOLEC indicators, e.g., waste water pollutant loading #7059 (mostly A)
- Estimated contaminant loadings to water (A for each Great Lake, e.g., SOLEC #117)
- Contaminant levels in water (SOLEC #118) and sediments (A for most PBT substances, e.g., mercury, DDE)

Exposure
- Population frequency and amount of freshwater sport fish and other wild food consumption, with species/location/size data (Sparse/partial A for fish, G for other wild foods, e.g., duck, muskrat)
- Contaminant levels in most frequently consumed species/locations of fish and wildfowl (Partial A; G – need for concentration on species-locations of most relevance based on human consumption data and standardization of methods, uneven coverage for other wild foods)
- Estimated contaminant intakes for different population groups (Partial A, often at broad federal or specific local risk assessment level)
- Contaminant levels in fat, serum/ plasma/blood, breastmilk, hair or other tissues (Partial A, G – not as location specific or as regular as desirable in most jurisdictions)

Outcome
- Risk assessment-based calculations of impact (Partial A. G – provincial/state or local health agency capacity to do such estimates on more local basis)

Response
- Clean-up programs to reduce contaminant loads in freshwater food sources (A though currently not adequate – G)
- Involvement of fishers in restoring and maintaining freshwater food resources (G)
- Presence of advisory programs with regard to relative levels of contamination in sport fish (A. Risk dialogue with fishers to improve fish consumption choices, e.g., Fish and Wildlife Nutrition Project, 2000,[19] chapter G) currently inadequate – G)

HEALTH BENEFITS
Possible Indicators: Available (A) & Gaps (G)

Pressure
- Multiple SOLEC indicators of pressures on fish or wild food populations (A, e.g., SOLEC #72)

Availability/Exposure
- Multiple SOLEC indicators on viability of sport fish and waterfowl populations (A, e.g., # SOLEC 8)
- Population frequency and amount of freshwater sport fish and other wild food consumption (Partial A for fish, G - not for other wild foods)
- Nutrient composition of wild foods with regard to human needs. (Partial A. G – re a number of species/locations of considerable human consumption)

Outcome
- ‘Benefit’ modeling incorporating data on consumption and nutrient composition to estimate positive impacts

Response
- Several responses (both currently A and G) identified for each indicator above
- Involvement of fishers in restoring and maintaining freshwater food resources (G)
- Dialogue with fishers to improve fish consumption choices (e.g., Fish and Wildlife Nutrition Project, 2000,[19] chapter G) currently inadequate – G)

INDICATORS FOR AVAILABILITY OF FRESHWATER FOR ECONOMIC ACTIVITIES

Possible Indicators: Available (A) & Gaps (G)

Pressure
- Multiple SOLEC indicators, e.g., waste water pollutant loading #7059

State
- Multiple SOLEC indicators, e.g., economic prosperity indicator #7403 could be disaggregated for sectors of interest such as the recreational fishery

Response
- Multiple SOLEC indicators, e.g., integration of sustainability principles across landscapes’ #35

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Indicators of Environmental Health in the Urban Setting

Trevor Hancock, MB, BS, MHSc

ABSTRACT

The North American population is approximately 80% urbanized and spends almost 90% of the time indoors. Accordingly, the built environment is the most important – one might almost say "natural" – human environment. Urban settlements incorporate within their boundaries natural ecosystems of plant and animal life (often highly adapted to the urban environment), and are in turn incorporated within wider bioregions and global ecosystems. But urban settlements are not just built and natural physical environments, they are social, economic, cultural and political environments; the whole constitutes an urban ecosystem. These ecosystems have profound implications for the physical, mental, social, emotional and spiritual well-being of their human inhabitants, as well as for human beings remote from these urban ecosystems. Therefore, this paper discusses urban ecosystems and human health and presents a framework for indicators of environmental health in the urban setting based on such an understanding. The concepts of environmental viability, ecological sustainability, urban livability, community conviviality, social equity, and economic adequacy are discussed in relation to human health and are used to organize proposed candidate indicators for urban ecosystems and public health.

RÉSUMÉ

En Amérique du Nord, environ 80 pour cent de la population vit en milieu urbain et passe presque 90 pour cent du temps à l'intérieur. En conséquence, le milieu bâti est le plus important environnement humain – on pourrait presque dire de lui qu'il est « naturel ». Les milieux urbains comprennent des écosystèmes naturels de plantes et d'animaux (souvent fortement adaptés à l'environnement urbain) et font aussi partie de plus grandes régions biogéographiques et d'écosystèmes planétaires. Cependant, de tels milieux sont non seulement des milieux bâtis et des environnements naturels et physiques, mais ils constituent aussi des milieux sociaux, économiques, culturels et politiques, dont l'ensemble forme un écosystème urbain. Ils sont intimement liés au bien-être physique, mental, socio-émotionnel et spirituel des habitants ainsi qu'à celui des humains qui vivent loin de ces milieux. L'auteur traite donc d'écosystèmes urbains et de santé humaine et présente un cadre pour des indicateurs de l'hygiène de l'environnement en milieu urbain qui est basé sur ces considérations. Il analyse les concepts de viabilité de l'environnement, d'écosystèmes durables, d'habitabilité des milieux bâtis, de convivialité des collectivités, d'équité sociale et de cadre économique adéquat en rapport avec la santé humaine et s'en sert pour organiser les indicateurs potentiels de santé publique dans des écosystèmes urbains.

Health Promotion Consultant, Victoria, BC
Correspondence: Dr. Trevor Hancock, 4394 Lochside Drive, Victoria, BC V8X 2C9

THE URBAN ECOSYSTEM AND HUMAN HEALTH

Today, the built environment is the most significant human environment. Globally, half of humanity now lives in urban settlements, while Europe and North America is 80% urbanized. These urban settlements have a disproportionate impact on the natural environment, consuming 75% of the world's resources and producing most of its waste.[1]

In North America, humans spend approximately 90% of their time indoors and a further 5% in cars, leaving only 5% of the time when they are outdoors.[2] And since they are 80% urbanized, this means that much of the time spent outdoors is nonetheless spent within the confines of the built urban environment. The amount of time that North Americans spend outdoors in a natural (or mainly natural) environment may be as little as 1%.

The urban settlement can be viewed as a human ecosystem – an ecosystem largely created by and inhabited by humans and consisting of both the built and human-modified physical environment and the social, economic, cultural and political environments that humans have created. As such, an urban ecosystem can be identified as a dynamic complex of human, plant and animal communities situated within a given urban environment (based on IDRC's definition of an ecosystem in its "Ecosystem approaches to human health" program - www.idrc.ca).

It is also important to recognize that these human-created urban ecosystems exist within a larger frame of reference – the bio-regional and ultimately planetary natural ecosystems. While much of humanity may spend the majority of their time indoors and in an urban setting, it is natural ecosystems, not urban ones, that constitute the fundamental life support systems for humanity. The social and economic development that has been at the root of improved population health, first in the industrialized world and now globally, is built upon those natural ecosystems, their resources and the "free" eco-services they provide. Human health cannot be maintained if ecosystem health is not sustained.[3] Any selection of indicators of environmental health in the urban setting must reflect and incorporate these complexities and relationships.

Urban ecosystem health

Just as the health of natural ecosystems is measured in part by the health of the diverse microbial, plant and animal populations of which they are composed, and the level, quality and extent of the dynamic processes of the ecosystem, so too can the health of the human ecosystem be assessed in terms of the health of its population and the level, quality and extent of its dynamic social and natural processes.

Urban health thus has at least four distinct meanings:

- the health of the urban settlement in terms of the quality of its built environment;
- how well it functions socially as a community;
- how it functions biologically as an ecosystem (including the health of the biotic community of plant and animal life within and beyond the urban ecosystem); and
- the health status of the human population that lives within the urban ecosystem.

This suggests at least six dimensions to the concept of urban ecosystem health:[4]

1) the quality of the urban physical environment (air, water, soil);
2) the quality of the built environment;
3) the impact of the urban ecosystem on the wider natural ecosystems;
4) the health of the urban community as a social entity;
5) the health of the biotic community;
6) the health status (physical, mental, emotional and spiritual) of the urban human population.

A framework for indicators

The model shown in Figure 1 is based on a healthy community model that has been in use for approximately a decade[5] and that has recently been expanded.[6] The basic framework links community sustainability and well-being (community, environment and economy) while paying attention to the links between these three spheres. It also focuses attention on the desired outcome – health – at the centre. The three spheres and their overlaps describe six qualities of a community that contribute to health:

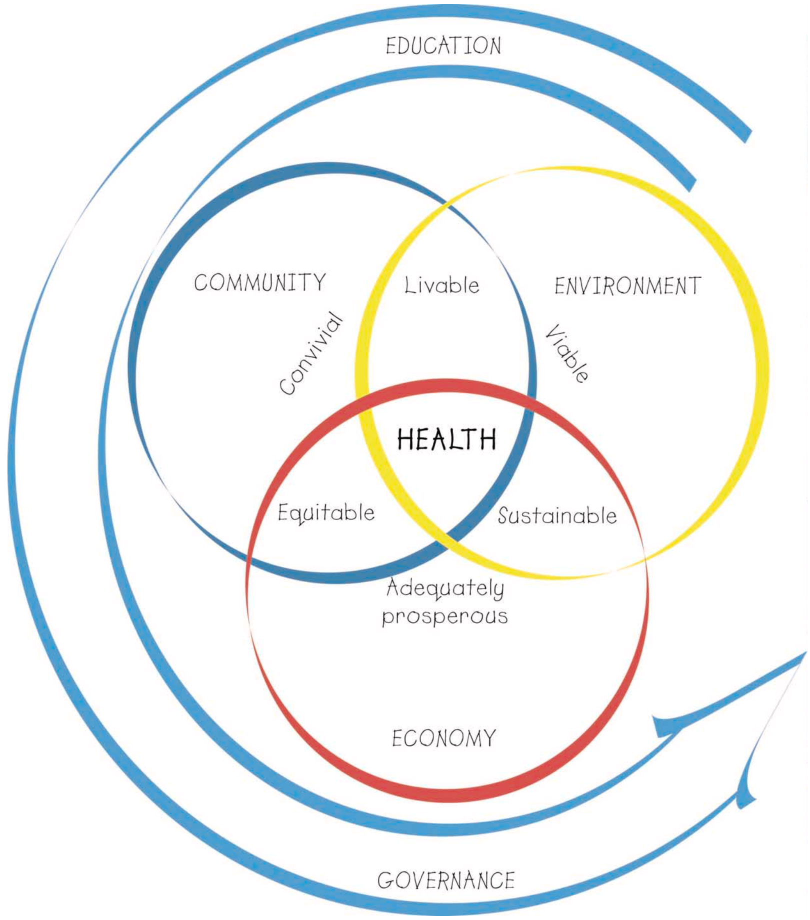

Figure 1. Healthy Community Model[6]

- **Environmental viability:** the quality of the community's local environment;
- **Ecological sustainability:** the impact of the community on the wider bioregional and planetary ecosystems;
- **Urban livability:** a high quality built environment that is safe, pleasing and encouraging of conviviality;
- **Community conviviality:** concerned with the community's social well-being;
- **Social equity:** even distribution of power, resources and the benefits of the economy, and all members are treated with fairness and justice;
- **Economic adequacy (or well-being):** having a level of prosperity sufficient to ensure that basic needs for all are met.

The two key drivers of processes of change that have been added to the model are education and governance. These elements, when in place and working well, independently enhance human health as well as increase the likelihood that individual, community and political decisions in the three spheres and their overlapping areas of concern will result in the outcome of improved health.

INDICATORS OF HUMAN AND URBAN ECOSYSTEM HEALTH

This paper uses the indicator sets developed by Hancock, Labonte and Edwards[6] as a starting point in proposing a set of indicators that can measure the six identified components of urban ecosystem health, the processes that influence it, and the outcome in terms of human and biotic community health. These indicators are organized based on the model (Figure 1) and the OECD's pressure/state/response framework.

"Pressure" indicators

These are indicators of the determinants of health for the biotic and human communities.

Viable Urban Environments and Health

In this context, a viable urban environment is one that does not poison or otherwise harm or kill either the human or the biotic communities of the city. This requires clean air, water, soil and food.

Outdoor air quality is a persistent problem in almost all major cities, due to pollutant emissions from energy generation, industrial, commercial and residential activity and transportation emissions. Ground-level ozone, particulate matter (especially $PM_{2.5}$), acid aerosols and air toxics (e.g., benzene and PAHs) are the main pollutants of concern, although the long-range transportation of many of these pollutants, heavy metals and persistent organic pollutants (POPs) is also a significant problem. Indoor air quality is a growing concern as well, especially since most urban dwellers today spend the vast majority of their time indoors. Key indoor contaminants of concern include NO_x, VOCs, environmental tobacco smoke (ETS), carbon monoxide and moulds.

Water pollution from human or animal excreta and chemical wastes is a major problem. While the vast majority of urban dwellers in the developed world today have access to a safe supply of piped drinking water, for those who do not, provision of safe piped water supplies remains a priority and its absence can result in infectious diseases as well as conditions arising from chemical contamination, including contamination resulting from water treatment itself (e.g., ref. 7). In addition to drinking water, urban dwellers have a need for recreational waters for swimming, fishing, boating and other activities. Microbiological pollution of beaches and rivers directly threatens the health of bathers and indirectly threatens the mental and social well-being of many others by denying them a valuable recreational resource. Further, chemical or heavy metal contamination may make hazardous the consumption of fish caught by both commercial and recreational fishers.

Soil pollution in cities is primarily linked to contaminated dustfalls from industrial sites (e.g., lead from smelters) and spills, leaks and other sources of contamination from current or old industrial sites. These tend to be localized conditions but the affected populations, as usual, tend to be the poorer sections of the communities living in close proximity to these sites. Children are particularly vulnerable due to their increased exposure to contaminated soils and housedusts, while all segments of the population – but especially women of child-bearing age – may be at risk from vegetables grown in the contaminated soils of their local community.

Urban communities are not only recipients of pollution from elsewhere, they are also significant contributors to local, regional and global pollution. The extent to which the city produces both toxic products and toxic wastes is a measure of the viability as well as the sustainability of the urban ecosystem.

Potential indicators of viable environments are presented in Table I.

Sustainable Urban Environments and Health

In order to ensure the health of future generations of its citizens, a healthy city must also be environmentally sustainable. Ideally, this would mean that the city could meet all of its resource needs and handle all of its wastes within its own confines, or at least within its own hinterland. But given the size of modern cities, and given that their hinterland now encompasses much of the world, this is neither feasible nor realistic.

For our purposes, at the very least, a sustainable city should be reducing its contribution to the four forms of global change that affect human health (as noted by Davies and Hancock)[8]: climate and atmospheric change, pollution and ecotoxicity, resource depletion, and loss of habitat and biodiversity. It should know what its ecological footprint is and be attempting to reduce both its total and per capita impact on the ecosystem.

Energy use and conservation is an area of common concern, both because of the local and downwind air pollution resulting from combustion of fossil fuels and because of the release of huge quantities of CO_2. The health effects of global warming are likely to be very significant, even if remote in time and difficult to quantify at present.[9,10] Thus efforts to reduce energy consumption and CO_2 emissions are likely to be beneficial to human health.

Efforts to improve energy efficiency in the heating of buildings may also have beneficial health effects. However, because indoor air pollution can be increased by sealing buildings more tightly and reducing the intake of fresh air, it is important to strike a balance and to use new approaches such as "green" or naturally ventilated buildings to reduce heating and cooling requirements, as well as reducing the use of toxic materials in the construction, furnishing and operation of buildings.

In addition to contributing to climate and atmospheric change, urban environments contribute extensively to pollution and ecotoxicity, use both renewable and non-renewable resources, and contribute to the loss of habitat and biodiversity. Among the renewable resources that cities deplete are fresh water, farm lands (both by paving them over with urban sprawl and by their heavy demand for food, which can often only be met through unsustainable farming practices), forest products (notably lumber and paper) and fisheries. Also, cities consume huge quantities of non-renewable resources such as fossil fuels, metals and minerals. An assessment of the per capita consumption of these key resources and of loss of habitat and biodiversity is an important measure of the sustainability – or unsustainability – of an urban ecosystem.

Potential indicators for the environmental sustainability of urban ecosystems are presented in Table I.

Livable Urban Environments and Health

Livability has a great deal to do with social as well as physical conditions and the interplay between those two elements in the "settings" within which people lead their lives.[11] At its most basic, livability refers to the quality of the housing stock and such fundamental physical infrastructure as water and sewage supplies, roads and public transportation systems and other infrastructure that make it possible for people to lead healthy lives and access the city's amenities and services. An important aspect of livability is the extent to which noise, litter and dirt make the urban environment unpleasant, even stressful and harmful to health.

Livability also refers to how safe the community is, in terms of the prevention of accidental injuries arising from unsafe housing and other buildings, transport-related accidents, and other sources of fires, explosions, leaks and spills, and various forms of crime. Further, the very important issues of traffic and urban design which influence urban health must be considered here as well. Traffic contributes to health problems (e.g., air pollution) and detracts from many aspects of conviviality, and urban design must incorporate such things as the need for equitable access to, and efficient operation of public transportation.

Livable environments move beyond meeting the basic needs and defensive measures intended to ensure safety and security to look at ways in which the built environment can be a lively, diverse, stimulating, aesthetically pleasing environment which, in turn, help create an environment that promotes health and well-being.

Potential indicators of livable environments are presented in Table I.

Convivial Urban Environments and Health

In a convivial community, people live well together, they provide social support, they address problems and settle differences amicably, they participate fully in the life of their community. Such communities have high levels of social capital[12] and social cohesion. Such conviviality results from both the informal social networks that make up the community and from the formal social support system provided by the state in the form of social security and human services. One aspect of place-based social support is a sense of neighbourliness and a sense of neighbourhood or place, which is a factor in both "community resilience" and "community competence", both of which are associated with improved health status.[13]

Potential health indicators in this area are presented in Table I.

Equitable Urban Environments and Health

Inequalities in health, wealth, power and resources are inherent in the human condition. Some of those inequalities are relatively fixed, rooted as they are in biological differences such as gender, age, genetic inheritance and so on. But many other inequalities are rooted in inequitable (unfair or unjust) access to wealth, power, resources and other determinants of health. Reductions in inequalities in health that are rooted in such inequitable circumstances are dependent upon addressing social and economic inequity.

The results of such factors as social, economic and environmental injustice (e.g., the poor live downhill, downwind or

TABLE I

Suggested Indicators of Urban Ecosystem Health (* = possible key indicators)

General	Specific Examples
Viability	
Outdoor air quality*	O_3, PM_{10}, $PM_{2.5}$; acid aerosols; air toxics
Indoor air quality	ETS; VOCs; NO_x;
Drinking water quality*	Microbial and/or chemical
Recreational water quality*	Fecal pollution of near-shore recreational waters
Contaminated sites*	# of contam. sites/100,000
Production of toxic*	
–products	Pesticide production, other?
–wastes	Toxic wastes – which ones?
Food chain contamination*	Dioxin/other POP/heavy metal dose in a standard food basket or Chemical contaminant in edible fish tissue
Sustainability	
Energy use*	Total energy use/capita
–fossil fuel use*	Total fossil fuel use/capita
CO_2/GHG emissions*	Total and per capita emissions
Resource consumption	
–renewable	Fresh water, wood, agricultural land, fish, etc. (consumption/capital)
–non-renewable	Fossil fuels, metals, minerals
Ecological footprint*	Total and per capita
Livability	
Environmental hygiene	
Housing quality*	Fitness for human habitation, Building/Safety Code violations
Hygiene	Litter, waste management
Noise	Noise levels, complaints
Community safety	
Road quality	MVAs due to poor road quality –# of occurrences, # of people affected
Fires, explosions, leaks and spills*	
Crime rates*	Violent crimes, sexual assault, robbery, etc., as well as fear of crime, feeling of safety
Traffic	
Traffic management	Traffic calming, traffic-free areas, etc.
Public transportation*	Modal split, accessibility
Pedestrian-friendly	Walkability Index
Urban design	
–appeal/pleasing	
–diverse/stimulating	
Conviviality	
Social support	
–social networks	
–formal social support services	
–sense of place/neighbourhood	
Prosperity	
Diverse economy	Proportion of workforce in top 10 employees
Quality of workforce and Quality of Work Life	QWL indicators
'Green' business*	"Green" business as % of total, or # of start-ups
Economic activity	GPI
Biotic Community Status	
Presence, number and diversity of key species*	Reproductive success, congenital anomalies, cancer
Health of ecosystems such as wetlands*	
Health of key indicator species*	
Contaminant levels at top of food chains*	Key POPs in raptors, pike, humans, etc.
Human Health Status (see Table II)	
Mortality	
Morbidity	
Positive health	
Information	
Data collection systems*	
Data available to the public*	
Education/awareness	
School curriculum*	
Media content*	
Citizen involvement	
Number of community groups	
Status and role of community groups	
"Round Tables"*	
Government decisions	
Commitment of resources*	
Presence on Council agendas	
Legislative measures	

downstream) can be found in the inequalities in health status that exist within and between urban ecosystems. The implication for indicators of environmental health is that we need indicators that can identify inequity in general and environmental and health inequities in particular.

Such indicators include
- economic disparity (e.g., levels of poverty, hunger, homelessness and access to affordable housing);
- measures of social discrimination and exclusion from services, resources and power;
- indicators of environmental injustice (e.g., proximity to industrial or waste sites);
- health status measures that can be disaggregated on a geographic and social basis to identify and highlight inequalities.

Urban Prosperity and Health

Jane Jacobs[14] has argued that cities are the economic engines and the true generators of the wealth of nations. Urban ecosystems must generate enough wealth to ensure that the fundamentals of good health such as safe water, food, environmental hygiene, safe disposal of wastes, universal education and other basic human services, and the fundamental processes of governance can be ensured for all. Beyond that, two important measures of the urban economy are its diversity and adaptability. The latter quality is dependent in part upon the quality of the workforce, as well as the adequacy of the (lifelong) education and the human resource development policies of the city and its public and private sectors.

One important new dimension of urban economies that is of enormous significance for the environment and health is the extent to which local businesses are environmentally responsible and, even more profoundly, the extent to which new "green" businesses are developing. New measures of economic output such as the Genuine Progress Indicator or GPI,[15] which attempt to both exclude environmentally, socially and health damaging economic activities and include a variety of non-monetized socially beneficial activities (such as child rearing, volunteer work, growing one's own food, etc.), provide an accurate and useful guide to the true "wealth" of a city and should be included here.

Proposed indicators of these issues are presented in Table I.

"State" indicators

Indicators of the status of the urban ecosystem fall into two categories which can be considered as the output of both the determinants of health (pressure indicators) and the effectiveness of the processes of governance (response indicators). The two output or state indicator categories are the health of the biotic community and the health of the human population.

Biotic Community Status

The urban ecosystem contains within it a vast range of living organisms. The health of this biotic community and its organisms is a reflection of the viability of the urban ecosystem, and the overall health of the urban ecosystem and its suitability as a habitat for humans. A wide variety of indicators of biotic community health are available and some are listed in Table I (for more examples, see www3.ec.gc.ca/cehi/en/indic_e.htm).

Human Health Status

From an anthropocentric perspective, human health status is the ultimate measure of success. One of the challenges we face is making clear and explicit links between environmental problems and human health. Nonetheless, a number of health outcomes related to key environmental factors in urban ecosystems can be proposed and these are shown in Table II. These fall into the categories of mortality (e.g., respiratory diseases related to outdoor and indoor air pollution), morbidity (e.g., food-borne infectious diseases), and positive health measures (e.g., self-reported health and life satisfaction).

"Response" indicators

Faced with evidence of damaged or threatened environments or evidence of actual, perceived or threatened harm to human health, cities and societies respond. Both pro-active and reactive responses are aspects of our processes of governance. The making of choices and decisions depends upon a number of factors as discussed below. Potentially key response indicators at a general level are listed in Table I.

Information

It is essential that there is an information system in place that can collect the requisite data on a routine basis, link that data to other information systems and present the data to the public and to decision-makers. One important, and often limiting, challenge is that data are often not easily available routinely at the city level. Even when they are, it is even less likely that the sampling method and sample size regularly allow for disaggregation to the neighbourhood level.

Education and Awareness

Perhaps the most important prerequisite for action on environmental health hazards is public awareness of the issues, which fuels public concern and social and political action. Such awareness needs to begin in school; in the 21st century, children need to have a full and broad-based understanding of local and global environmental issues and of the importance of ecosystem health as the underpinning of social and economic development. Not only do these children grow up to be environmentally aware adults, they also help to raise the environmental awareness of today's adults.

A second key component of environmental awareness is the attention paid to this subject by the media. The extent to which local and national print, radio, TV and e-media cover environmental issues and the relative importance – as well as any 'bias' they display – are important indicators.

Citizen Involvement

While the key to an active citizenry is information, education and awareness, that awareness has to be translated into action. Concerned citizens, acting as individuals, as community groups or through environmental NGOs, have played a crucial role in addressing environmental issues both locally and globally. Citizen involvement in environmental issues is one important aspect of a civil society.

Governance

Governance is the process by which we as a society or a community make choices and decisions. This process involves not only the government but a wide array of other stakeholders that constitute a civil society, including business, citizen groups and NGOs, labour, the charitable sector, etc. One measure of the process is whether or not there is a forum (or several fora) that bring together these often competing interests in an attempt to find consensus and a common approach.

Ultimately, the test is whether, as a result of this process, local, state/provincial and federal governments give environmental health the priority it deserves. This is shown through their commitment of resources, the passage of legislation and the enforcement of such legislation.

PROPOSED INDICATORS

The biggest challenge in developing indicators is to select from the many hundreds if not thousands of potential indicators that are available. For the purposes of this exercise, the indicators set for urban ecosystem and health must include measures of:

- exposure to priority substances (air, water, soil, foodchains)
- urban living conditions (physical, social, economic)
- services and programs for health protection
- health effects (acute, chronic, physical, mental, behavioural)

at various scales, in particular to permit intra-urban comparisons (spatial and non-spatial). Of course, not every indicator can or should meet all of those criteria; rather the point is to select a battery of indicators that among them provide good coverage of these requirements (for a further discussion of indicators criteria, see Hancock, Labonte and Edwards,[6] or Eyles and Furgal – this issue[16]). In an attempt to focus the list provided here, a set of potential "Key Indicators" are denoted with an asterix in Tables I and II.

TABLE II
Suggested Human Health Status (Outcome) Indicators (* = possible key indicators)

Determinant (Pressure) Indicator	Human Health Status (Outcome) Indicator
Outdoor air quality*	• Asthma and other respiratory or cardiovascular mortality and morbidity related to key air pollutants • Excess mortality and morbidity during pollution episodes
Indoor air quality	• Asthma, "sealed building syndrome"
Drinking water quality*	• Water-borne infectious disease mortality and morbidity (giardia, E. Coli, cryptosporidium, etc.)
Recreational water quality	• Outbreaks of G-I or skin infections or otitis externa
Toxic contaminants*	• Cancers linked to pesticides and POPs (e.g., childhood brain cancer, lymphomas, etc.) or to disinfection by-products (bladder cancer) • Tissue levels of key contaminants
Global warming	• Heat-related mortality • Insect-borne disease rates (e.g., malaria, dengue fever, encephalitis, etc.)
Unsafe/poor quality housing*	• Mortality and morbidity from fires, accidents, etc., related to unsafe housing • Anxiety, stress, depression due to poor housing
Roads/transportation*	• MVA mortality and morbidity
Toxic fires, spills, leaks and explosions*	• Mortality and morbidity associated with such incidents
Crime*	• Mortality (homicide) and morbidity due to assault, sexual assault, robbery with violence, etc. • Fear of crime, violence; not feeling safe
Noise*	• Sleep disturbance or other stress due to noise
Social support*	• Anxiety, depression secondary to loneliness, isolation
Environmental injustice*	• Inequalities in mortality and morbidity linked to environmental causes
Quality of working life	• Mortality and morbidity related to occupational injury and disease • Workplace stress, satisfaction with work life

Gaps in indicators

The biggest problem with many of these indicators will be their availability at the county or city level, and even more problematically at the neighbourhood level. This latter issue may make assessment of inequity in environmental, social, economic or health status terms difficult, if not impossible. Another problem may be the availability of an assessment of food chain contamination and the levels of POPs in the tissues of top predators and humans. Yet such data are essential if we are to assess and track the exposure of humans to these toxic substances.

Many other indicators suggested in Tables I and II were not considered for inclusion in the list of key indicators, whether because they are not routinely collected, because there is no generally agreed-upon measure, or because the relationship between environmental conditions and health status is not well established.

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A Strategy for Developing Environmental Health Indicators for Rural Canada

Raymond W. Pong, PhD[1]
J. Roger Pitblado, PhD[1,2]
Andrew Irvine, MA[3]

ABSTRACT

Our understanding of and ability to describe rural health conditions can be considerably enhanced by the use of rural health indicators which allow us to compare rural and non-rural areas or areas differentially located on the urban-rural continuum in terms of various health conditions. However, while health indicators abound, there are very few that can be used to describe the health conditions of rural Canada. This paper discusses the concepts of health in a rural context and adopts a broad definition of health that goes beyond the mere absence of disease or impairment. We propose five broad categories of health indicators: health status indicators, health determinant indicators, health behaviour indicators, health resource indicators, and health service utilization indicators. The most commonly used health indicators in Canada and the datasets from which they are derived are examined in order to assess their applicability to "communities" or "regions". This review highlights the strengths and limitations of various datasets and indicators and their applicability to the "community" and "regional" scale for rural environments. Finally, challenges in data availability and use are discussed as they relate to rural health indicator development.

RÉSUMÉ

Le recours à des indicateurs de santé en milieu rural, qui permet de comparer les régions rurales et les régions non rurales ou des régions situées en des endroits distincts d'un même grand territoire, peut améliorer grandement la compréhension de l'état de santé en milieu rural. Toutefois, alors que les indicateurs de santé sont nombreux, très peu peuvent servir à décrire l'état de santé des régions rurales au Canada. Les auteurs analysent les concepts de la santé en milieu rural et optent pour une définition large de la santé, qui dépasse la simple absence de maladies ou de déficiences. Ils proposent cinq grandes catégories d'indicateurs de santé : des indicateurs de l'état de santé, des indicateurs des déterminants de la santé, des indicateurs des comportements liés à la santé, des indicateurs des ressources en santé et des indicateurs de l'utilisation des services de santé. Ils étudient les indicateurs de santé les plus utilisés au Canada et les ensembles de données dont ils découlent afin d'en évaluer l'applicabilité aux collectivités ou aux régions. L'étude souligne les avantages et les limites de divers ensembles de données et d'indicateurs et compare leur applicabilité aux milieux ruraux à l'échelle de la collectivité et de la région. De plus, les auteurs traitent des problèmes de disponibilité et d'utilisation des données en rapport avec l'élaboration d'indicateurs de santé en milieu rural.

1. Centre for Rural and Northern Health Research, Laurentian University, Sudbury, ON
2. Department of Geography, Laurentian University
3. Ontario Ministry of Health and Long-Term Care, formerly a Senior Researcher with the Centre for Rural and Northern Health Research, Laurentian University

Correspondence: Dr. Raymond Pong, Research Director, Centre for Rural and Northern Health Research, Laurentian University, Ramsey Lake Road, Sudbury, ON P3E 2C6, Tel: 705-675-1151, ext. 4357, Fax: 705-675-4855, E-mail: rpong@laurentian.ca

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A set of commonly used rural health indicators does not exist in Canada. In particular, there are very few rural health indicators that are of an environmental nature. Some very useful rural health-related data, such as data on agricultural injury, do exist. But, to date, there have been few attempts to examine the feasibility of turning such data into health indicators. As far as we are aware, a recent study by the present authors, *Assessing Rural Health: Toward Developing Health Indicators for Rural Canada*,[1] represents the first attempt at examining the feasibility of developing rural health indicators in a systematic manner and for the whole of Canada. Although the initial focus of *Assessing Rural Health* was not on environmental health indicators per se, it did discuss some of the issues that are relevant to the focus of this publication.

Depending on how "rural" is defined, about a quarter to about a third of the population and well over 90% of the land mass in Canada are rural. That rural communities differ from urban and suburban communities in many respects has been extensively documented. There are considerable rural-urban differences in health status, health behaviour, health-resource availability and health-service utilization.[2-8] Generally speaking, the rural population has poorer health status, lower life expectancy, higher accident and injury rates and higher levels of disability. Even the widely held image of a clean, wholesome rural environment has been shattered by the recent water-contamination tragedies in Walkerton and North Battleford. To improve rural health, it is necessary to document the health conditions of rural communities and populations. Rural health indicators are a means to this end. Similarly, rural environmental health indicators allow us to assess the state of the environment and its potential impact on health in rural areas.

The central question for our present task is: *Can environmental health indicators for rural Canada be readily developed given the types and nature of health and related datasets at our disposal?* In order to answer this question, we need to address several conceptual and methodological issues. Although the terms "health", "environment" and "rural" are used frequently in daily conversations, they are not clear-cut concepts. In fact, there are no universally agreed-upon definitions. Since how we understand these concepts affects the way rural environmental health indicators are developed, it is necessary first of all to discuss what they mean. Because the concepts of environment and health indicators have been discussed elsewhere in this publication,[9,10] we focus here on rural. Much of the following discussion is on the broader issue of developing rural health indicators, of which rural environmental health indicators are a subset.

First step: Linkages to rural people, communities and regions

From a pragmatic point of view, a key step in the development of health indicators rests in our ability to link our indicator and risk factor measures with our target populations. In the context of this paper, we must then be able to distinguish between rural and non-rural populations. This leads to the inevitable question: "What is rural?" It has been noted that there are almost as many definitions of rural as there are researchers.[11] Fitzpatrick and LaGory[12] are right in pointing out that all human action takes place in geographic space and this geographic space is more than a physical container; it is also a social and cultural phenomenon. As a result, some definitions of rural are derived from cultural and social manifestations of rural communities. However, for the purpose of developing rural health indicators, such definitions of rural are not useful. Health indicators are typically derived from available secondary data which can rarely be aggregated or disaggregated on the basis of social and cultural characteristics.

One of the most desirable linkage tools is the use of postal codes. Wilkins[13] discussed the potential of using this approach for health studies, while Sanmartin and Snidal,[14] among others, employed postal codes to examine rural physician characteristics. In these studies, rural postal codes were readily recognizable because they had "0" in the second position in the 6-character postal code. While this use of "0" for rural may have been useful in the past, it is becoming less so as Canada Post reorganizes postal codes in such a way that they are not correlated with any commonly accepted rural-urban designation. Even so, the postal code conversion files provided by Statistics Canada enable us to link them with standard census geographical units such as Enumeration Areas (EAs), Census Subdivisions (CSDs), Census Divisions (CDs) and so on. Almost everybody knows his/her postal code, whereas few people know their EA, CSD or CD.

When examining the geographic distribution of Canadian physicians, Pitblado and Pong[15] have maintained that access to unaggregated data that can subsequently be aggregated without the limitation of predefined geographical units is the most desirable, since there is not a universally agreed-upon definition of rural. Postal codes can be aggregated to form larger geographical units for the purpose of constructing rural health indicators. Commenting on spatial analysis, Gilbert[16] has arrived at a similar conclusion. He has recommended the use of the unit postcode area in the United Kingdom as the basic building block of spatial statistics because of the relatively small area it covers and the geography of population and economic activities it reflects.

For researchers who do not work in government, perhaps the greatest disadvantage with using postal codes centres around the problem of access. There are access restrictions due to confidentiality/privacy matters. More commonly, researchers must use aggregated data and therefore must define rural based on given parameters of existing administrative datasets. From our perspective, this means dealing with aggregations that can be called communities or regions.

We believe there are two major approaches to achieving a functional definition of rural at this level: the "rural and small town Canada" designation of Statistics Canada and their modification of the scheme developed by the Organization for Economic Cooperation and Development (OECD). Both approaches have a fairly long history of usage and are, therefore, relatively familiar to researchers. And both can be used as a basis for record linkages with respect to many datasets that can be employed to generate health indicators for Canada's rural population.

Useful discussions of the development and applications of these terms can be found in Bollman[17] and the most recent summary of these approaches can be found in du Plessis et al.[18] In brief, "rural and small town Canada" is particularly applicable to communities, i.e., where people live. In the parlance of the Census, rural-and-small-town communities are Census Subdivisions that are located outside the predominantly urban areas known as Census Metropolitan Areas (CMAs) and Census Agglomerations (CAs).

OECD defines a "community" as rural if the population density is less than 150 persons per square kilometre. Statistics Canada, in contributing to the work of OECD, applies this definition of rural using the Census Consolidated Subdivision as the community.[18,19] CDs are used to equate with the OECD term "region." Regions are classified as "predominantly rural" if more than 50% of the population lives in rural communities; "intermediate" if 15% to 50% live in rural communities; and "predominantly urban" if less than 15% live in rural communities. Additional classes have also been added to recognize the diversity of rural and remote areas of Canada: metro-adjacent subregions, non-adjacent subregions and northern hinterland subregions.

The ability to identify "regions" is important for the development of rural health indicators. This is because, in many instances, health dataset records do not provide sufficient geographical information to identify communities. The next closest level is the region. There is an advantage in using regions expressed as CDs. In many provinces, public health units, health planning regions, or health authorities have been established for the purposes of health care planning and/or delivering health services. These administrative or planning entities are often coterminous with one or more CDs.

Examples of rural health indicators

In *Assessing Rural Health*,[1] a series of health indicators were provided along with various definitions or geographical designations of rural. Here, two examples, both using data from the Census of Agriculture, are presented for illustrative purposes. For other examples of rural health indicators and the data sources from which they are derived, see *Assessing Rural Health* (the website address for this report is identified in the References section of this paper).

Example 1: Incidence of Farm Injuries

Source: 1996 Census of Agriculture[20]

Raw Data: Counts of farm operators by sex reporting farm-related injuries requir-

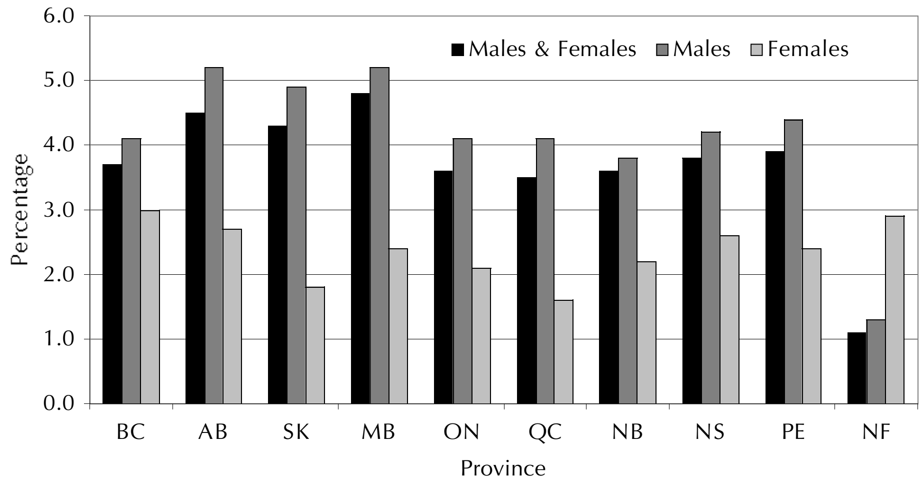

Figure 1. Proportions of farm operators reporting farm-related injuries.

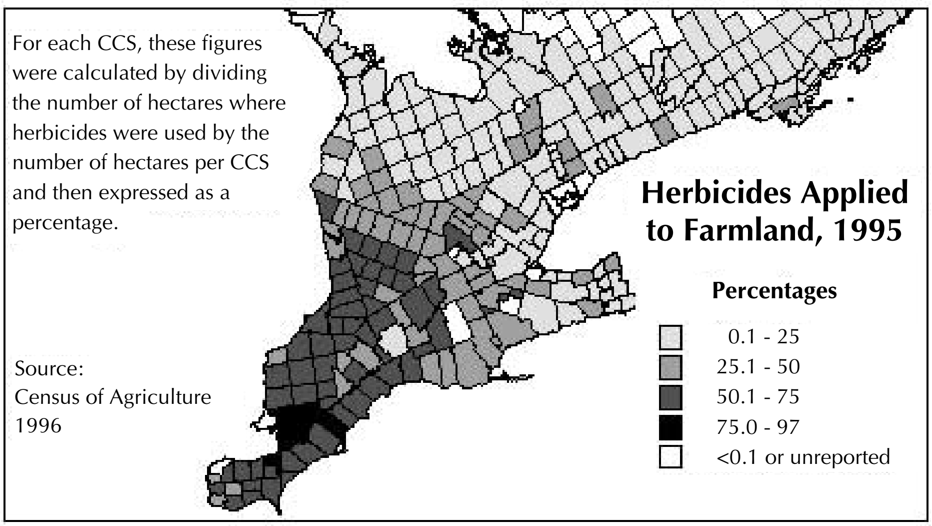

Figure 2. Map of herbicide application to southwestern Ontario farmland in 1995.

ing professional medical attention per province.

Results: Figure 1 shows a count of farm-related injuries by sex for each province.

Discussion: Since the vast majority of farms are located in rural areas, it made little sense to compare the number of farm injuries in rural and urban areas, thus farm-related injuries were examined by province and sex only. While Figure 1 shows that there are indeed provincial and sex-related differences in the percentage of farm-related injuries, the results are not particularly revealing. More could be learned from a subprovincial analysis. Further work should look at whether the Census of Agriculture can be used at finer levels of geography. Future analysis should also focus on deriving rates of trauma, controlling for differences in population, and on making results more comparable between different rural regions within a province.

Example 2: Herbicide Application

Source: 1996 Census of Agriculture[20]

Raw Data: Counts of hectares applied with herbicide per Census Consolidated Subdivision. The 1996 Census of Agriculture provides counts of the farm areas (hectares) where herbicides, insecticides and fungicides have been applied. This variable was not split into a rural/urban dichotomy, as it is obvious that herbicide/pesticide-use rates are much higher in rural areas.

Results: For illustrative purposes, the analysis has been done for southwestern Ontario where farming is the predominant economic activity (see Figure 2).

Discussion: Herbicide application does show spatial variation in southwestern Ontario. It increases from east to west, which is to be expected since the high-intensity farming areas are located in the western part of southwestern Ontario. With such information, it may be possible to further examine whether there is an equivalent east-west gradation of certain health problems associated with rates of herbicide applications.

Next steps

In order to improve rural health, one of the first steps that need to be taken is to understand and be able to describe rural health conditions. Our understanding of and ability to describe rural health conditions can be considerably enhanced by the use of rural health indicators which would allow us to compare rural and non-rural areas or areas differentially located on the urban-rural continuum in terms of various health conditions such as environmental quality and impact. However, while health indicators abound, there are very few that can be used to describe the health conditions of rural Canada.

Our recent review[1] of three major publications on health indicators – *Report on the Health of Canadians* (Health Canada), *Statistics Canada Health Indicators Database* (Statistics Canada) and *Community Health Indicators: Definitions and Interpretations* (Canadian Institute for Health Information) – shows that the bulk of the indicators are derived from a limited number of datasets. With the exception of the datasets from the Laboratory Centre for Disease Control (Health Canada), it is possible to assign records contained in most of the other datasets to either communities or regions. Although it is possible to assign records from the National Population Health Survey to communities or regions, the sample size is generally too small to permit subprovincial analysis. Unfortunately, this is true of most of the survey-based datasets we have examined.

Although there is a growing interest in the determinants of health, there are relatively few indicators of health determinants. In particular, as Pengelly et al.[21] have pointed out, there are few indicators of environmental status. As well, there are many datasets (e.g., Survey of Income and Labour Dynamics and the Canadian Agricultural Injury Surveillance Program database) that do not appear to have been well exploited. Such datasets may be useful for generating health indicators, particularly health determinant indicators.

There are also practical or logistical problems that have made rural health indicator development difficult. For instance, the Laboratory Centre for Disease Control has many datasets on notifiable diseases, but such data are only available at the provincial level. Subprovincial data are needed for generating rural health indicators. In order to obtain subprovincial data on notifiable diseases, one has to obtain permission from each province – a cumbersome and time-consuming process. There are other problems, such as the cost associated with obtaining data at the subprovincial or subregional level. For instance, Statistics Canada has made available, free of charge, a large amount of data through the Data Liberation Initiative. However, most of these data are at a high level of aggregation. To obtain lower-level data, one has to make special data requests which must be paid for. This often discourages rural health indicator development.

To facilitate the development of rural health indicators, including rural environmental health indicators, we propose the following:

First, the two rural health indicators shown above are meant to indicate what is feasible. The next logical step is to construct a broad array of rural health indicators, including rural environmental indicators, relying on national and provincial datasets that are publicly available and using the methodological approaches we have suggested. Some of the indicators may not be very satisfactory because of the way rural is defined or operationalized in some datasets. However, it should be seen as another step in a long journey toward a better understanding of rural health.

Second, on the basis of the above, it should be possible to construct health profiles of rural Canada. According to Hansluwka,[22] in health indicator research, there is a shift away from relying on individual indicators toward the "characteristic" approach by organizing the information into a health profile. We should be able to use a series of health indicators, including environmental health indicators, to paint a composite picture of the health conditions of rural Canada.

Third, the development of rural health indicators will not progress very far unless health surveys, administrative databases and other datasets begin to include appropriate geographic information that could be used to differentiate between rural and non-rural or regions of varying degrees of "ruralness." This is particularly important since rural Canada is not a homogeneous entity.[23] The availability of postal code information would allow researchers to configure geographic units of analysis in whatever ways they want. Postal codes can be aggregated in many ways, making them useful building blocks.

Closely related to this is the issue of data release. We understand the reasons (e.g., issues of statistical reliability and protection of privacy) for the suppression of data release for small areas. However, this practice puts rural Canadians at a disadvantage. Sparse population is an inherent characteristic of rural Canada. Data suppression due to small numbers will inordinately and adversely affect the information that can be garnered for studying rural health issues. Some means must be found for the release of these small numbers. Otherwise, we will continue to be forced to employ health indicators that are inevitably weighted or biased toward urban populations.

Fourth, as pointed out earlier, very few environment-related rural health indicators are presently available in Canada. At the 1999 National Consensus Conference on Population Health Indicators, which was hosted by the Canadian Institute for Health Information,[24] several health indicators related to environmental factors were identified for potential future development. These are exposure to second-hand smoke, air quality, water quality, toxic waste and ecological footprint. We believe that given the large amount of health- and environment-related data collected by federal and provincial/territorial jurisdictions, many more rural environmental health indicators can be developed.

Finally, another priority task that has been identified by the International Joint Commission is the harmonization of indicators between jurisdictions. Since countries collect health and environmental data in different ways and for different reasons, the ability to use such data to generate comparable health indicators, other than the most basic ones such as infant mortality and life expectancy, is a major challenge. Furthermore, for political and administrative reasons, different countries may define "rural" in dissimilar manners, making it even more difficult to compare rural health indicators. This is an issue that needs further exploration and discussion.

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Sentinel Human Health Indicators: To Evaluate the Health Status of Vulnerable Communities

Heraline E. Hicks, PhD
Christopher T. De Rosa, PhD

ABSTRACT

The presence of toxic substances in the Great Lakes (GL) basin continues to be a significant concern. In the United States, some 70,000 commercial and industrial compounds are now in use. More than 30,000 are produced or used in the Great Lakes ecosystem. These substances include organochlorines (e.g., polychlorinated biphenyls (PCBs), dioxins, furans, dieldrin, etc.), heavy metals such as methylmercury, and alkylated lead, and polycyclic aromatic hydrocarbons (e.g., benzo[a]pyrene). The IJC has identified 42 locations in the GL basin of the United States and Canada as Areas of Concern (AOCs) because of high concentrations of these toxic substances. In 1990 the U.S. Congress amended the Great Lakes Critical Programs Act to create The Agency for Toxic Substances and Disease Registry (ATSDR) Great Lakes Human Health Effects Research Program (GLHHERP) to begin to address these issues. This program characterizes exposures to contaminants via consumption of GL fish and investigates the potential for short- and long-term adverse health effects. This paper reviews the GLHHERP program and indicators established to monitor and address the risks posed by these substances to vulnerable populations in the Great Lakes ecosystem.

RÉSUMÉ

La présence de substances toxiques dans le bassin hydrographique des Grands Lacs constitue encore une préoccupation importante. Aux États-Unis, on utilise quelque 70 000 composés chimiques à des fins commerciales et industrielles. Plus de 30 000 d'entre eux sont produits ou employés dans l'écosystème des Grands Lacs. Les composés organochlorés (p. ex. les diphényls polychlorés [BPC], les dioxines, les furannes, la dieldrine, etc.), les métaux lourds comme le méthylmercure, ainsi que l'alkylplomb et les hydrocarbures aromatiques polycycliques (p. ex. le benzo[a]pyrène) en font partie. La CMI a désigné 42 endroits dans le bassin des Grands Lacs aux États-Unis et au Canada comme secteurs préoccupants en raison de la présence de fortes concentrations de ces substances toxiques. Aux États-Unis, le Congrès a modifié en 1990 la Great Lakes Critical Programs Act en vue de créer l'Agency for Toxic Substances and Disease Registry, responsable de l'application du Great Lakes Human Health Effects Research Program (GLHHERP), et qui a commencé à régler les problèmes causés par les substances toxiques. Le GLHHERP définit les expositions aux contaminants liées à la consommation de poissons provenant des Grands Lacs et se penche sur leurs effets nocifs à court et à long terme. Les auteurs examinent le programme GLHHERP et les indicateurs retenus pour surveiller et contrer les risques que posent de telles substances pour les populations à risque de l'écosystème des Grands Lacs.

U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia
Correspondence: Heraline Hicks, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road NE, M/S E-29, Atlanta, GA 30329-4027, Tel: 404-639-6306, Fax: 404-639-6315, E-mail: heh2@cdc.gov
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The Great Lakes contain some 5,500 cubic miles of water, covering 94,000 square miles and have a shoreline of over 10,000 miles. They are the largest system of fresh surface water on earth, comprising roughly 18% of the world supply. Approximately 10% of the U.S. population and 25% of the Canadian population live in the region.[1] For over 200 years, the Great Lakes basin has been used as a resource for industry, agriculture, shipping, and recreation. By the early 1960s, eutrophication, overfishing, and the widespread presence of toxic substances had all contributed to a decline in the environmental quality of this basin. The physical nature of the basin and the long retention time of chemicals in the lakes combine to make this huge freshwater resource a repository for chemicals and their by-products. Despite their size, the lakes are especially sensitive to pollution. Less than 1% of their total volume flows out of the St. Lawrence River each year, leaving toxic substances to accumulate in the sediment.[2]

Results from epidemiologic investigations suggest that adverse human health effects, i.e., reproductive, developmental, behavioural, neurologic, and immunologic, may result from exposure to Great Lakes pollutants.[3-5] Given the implications of this association, the U.S. Congress amended the Great Lakes Critical Programs Act in 1990 to investigate this human health concern.

The Agency for Toxic Substances and Disease Registry (ATSDR) Great Lakes Human Health Effects Research Program (GLHHERP) was initiated in 1992, and is designed to characterize exposure to contaminants via consumption of Great Lakes fish, and investigate the potential for short- and long-term adverse health effects. In implementing this program, ATSDR identified 1) a research strategy and 2) a suite of indicators to determine human risk from exposure to Persistent Toxic Substances (PTSs) in the Great Lakes basin.

Research strategy

ATSDR's GLHHERP is a strategy based on the five traditional elements of disease prevention: 1) identification of a pattern of disease or other adverse health effects, 2) evaluation of the causal factors potentially contributing to these patterns of disease and adverse effects, 3) interventions to control or mitigate the causal factors, 4) dissemination of information, and 5) development of an infrastructure.[6] This research strategy has been endorsed by the Council of Great Lakes Research Managers and has been adopted by the International Joint Commission (IJC) as a framework for the study of human and ecosystem health in the Great Lakes basin.

Indicators of potential risk

The research program has identified a set of indicator categories to determine risk. They include 1) vulnerable, i.e., susceptible populations, 2) exposure, 3) pathways of exposure, 4) sensitive human health end points, 5) body burden levels, 6) sociobehavioural data, 7) sociodemographic data, and 8) knowledge of health advisories. Taken together, these indicators categories assess the potential for adverse human health effects from exposure to PTSs in the basin. What follows is a brief description of each category.

Vulnerable Populations

Several human populations who may be at particular risk because of exposure to Great Lakes pollutants via fish consumption have been identified. Predisposition to toxic injury in these populations can be due to behaviour, nutritional status, physiology, or other factors. These populations include subsistence fish anglers, American Indians, Asian Americans, pregnant women, fetuses, nursing infants whose mothers consume contaminated Great Lakes sport fish (GLSF), young children, the elderly, the urban poor, and those with compromised immune function.[7]

Exposure

In the United States, some 70,000 commercial and industrial compounds are now in use and more than 30,000 are produced or used in the Great Lakes basin. The "critical Great Lakes pollutants" identified by the IJC are polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethane (DDT), dieldrin, toxaphene, mirex, methylmercury, benzo[a]pyrene (a member of a class of substances known as polycyclic aromatic hydrocarbons [PAHs]), hexachlorobenzene (HCB), furans, dioxins, and alkylated lead. They are persistent, and many are lipophilic so that they bioaccumulate in biota and biomagnify up the food web.[2,8] The ATSDR GLHHERP focused on these 11 critical pollutants as well as other toxic chemicals of concern, e.g., arsenic, cadmium.

The IJC has identified 42 "Areas of Concern" (AOC) in the United States and Canada in which toxic substances exceed limits or guidelines of the U.S.-Canada Great Lakes Water Quality Agreement. Thirty-one of these 42 areas are within the borders of the United States.[9]

Pathways of Exposure/Body Burden Levels

Potential pathways of human exposure to Great Lakes pollutants include inhalation of air; ingestion of water, foodstuffs, or contaminated soil; and dermal contact with water or airborne particulates. Analyses indicate the majority of human exposure to chlorinated organic compounds (80-90%) comes from food, a lesser amount (5-10%) from air, and minute amounts (less than 1%) from water.[10]

Most available data on human exposure to toxic substances in the Great Lakes come from analyses of contaminant levels in drinking water and sport fish. Investigators have also demonstrated that blood serum levels of these contaminants are significantly increased in consumers of Great Lakes sport fish compared to people who do not eat such fish or who consume very small amounts.[11]

Sensitive Human End Points

Exposure to contaminants via consumption of Great Lakes fish over an extended period of time allows for continuous exposure that may increase the potential for adverse human health effects. The program has identified sensitive human health end points to be assessed which included behavioural, reproductive, developmental, neurologic, endocrinologic, and immunologic measures. Future assessment may examine genetic end points if warranted by the research findings.

Sociobehavioural and Sociodemographic Data

The Health Belief Model (a model for the value expectancy theory) has been used to examine why people do or do not take preventive actions to reduce their risk. According to this theory, how people think and respond to risk largely depends on their health beliefs and knowledge of the risk, weighed against the barriers and benefits of taking preventive action.[12] Motivation to comply with health advisories includes value of health, and structural and demographic variables; these variables influence individual health beliefs and preventive behaviours.[13] Structural variables can include knowledge of a disease or hazard. Demographic variables can include age, gender, ethnicity, income, and education.

Knowledge of Fish Advisories

A thorough understanding of the target audience is necessary to effectively communicate risk through fish advisories. Communicating risk can increase the likelihood and willingness of a population to adhere to advisories. Therefore, the research program also chose to assess the knowledge and awareness of fish advisories in vulnerable populations.

Research findings

The Great Lakes Human Health Research Program has made significant progress in identifying, evaluating, and reporting public health findings through the use of the listed indicators. These findings indicate the following:

Exposure Data

- Communities of concern are still exposed to PTSs including PCBs, dioxins, furans, chlorinated pesticides, i.e., DDT, and mercury.[14-21]
- Levels of some contaminants in Great Lakes sport fish are above the advisory limits set by state and federal governments.[19,22]
- Residents in the basin ate more fish than that estimated for the U.S. population.[14,18,20,23]
- Sport fish-eaters consume 2-3 times more fish than the general U.S. population.[14,16,18,20,24]
- Fish consumption appears to be the major pathway of exposure for some PTSs.[15,20]
- Body burden levels of some PTSs in vulnerable populations are 2 to 4 times higher than those of the general U.S. population.[14,16,18]
- A significant trend of increasing body burden is associated with increased fish consumption.[14,20,25]

- Men consume more fish than women; men and women eat Great Lakes sport fish during most of their reproductive years.[14,20,21,23,26]
- Maternal consumption of Lake Ontario Great Lakes fish increases the risk of prenatal exposure to the most heavily chlorinated PCBs.[15]

Sociobehavioural and Demographics Data

- An estimated 4.7 million people consumed Great Lakes sport fish in a given year; 43.9% of the respondents were women.[27]
- Knowledge of and adherence to health advisories for Great Lakes sport caught fish vary across different populations.[20,26,27]
- Fifty percent of respondents to the survey who had eaten Great Lakes sport fish were aware of the health advisory for fish, and awareness differed significantly by race, sex, educational level, fish consumption, and state of residence.[27]
- Ninety-seven percent of American Indian men were aware of local advisories against consuming Great Lakes sport fish, however 80% of the men ate fish.[20]
- Eighty percent of minorities who had eaten Great Lakes sport fish were unaware of the fish advisory, and awareness was especially low among women.[27]
- Fish is an essential component of diets of minority populations and American Indians; they consume fish that tend to have higher levels of contaminants.[20,26]

Health Effects

- Conception rate and the incidence of a live birth are lower in some women who are sport fish consumers.[23]
- An association was found between men who consumed large amounts of sport fish and the risk of delayed conception in their spouses.[24]
- Significant menstrual cycle reductions were indicated in women who reported consuming more than 1 meal per month of contaminated Great Lakes sport fish.[28]
- In the Oswego Newborn Study, neurobehavioural and developmental deficits have been observed in newborns (12 to 24 hours after birth and again 25 to 48 hours after birth) of mothers who consumed approximately 2.3 meals per month of contaminated Lake Ontario fish.[21]
  - ◆ Significant relationships were identified between the most highly chlorinated PCBs performance impairment on the habituation and autonomic tests of NBAS (neurobehavioural assessment scales) at 25-48 hours after birth. No significant relationship was found between PCBs of lesser chlorination, DDE, hexachlorobenzene, mirex, lead or mercury on any NBAS performance test.[29]
  - ◆ Initial test results for memory, verbal, and perceptual performance among 3 years old in the Oswego study indicate their score is lower than children from mothers who consumed low amounts or no GL sport fish.[30]
  - ◆ The relationship between prenatal exposure to PCBs and performance on the Fagan Test of Infant Intelligence (FTII) was also assessed in the Oswego infants at 6 months and again at 12 months. The results indicated a significant relationship between exposure to PCBs and poor performance on the FTII. No significant relationship was found between exposure to DDE or methylmercury on any tests of the FTII.[31]
- Self-reported liver disease, diabetes, and muscle/joint pain may be associated with exposure to PCBs and other contaminants via fish consumption.[32]
- PCB concentrations were significantly associated with poorer pegboard performance (a test to evaluate visual motor coordination and spatial orientation).[33]
- PCBs and dichlorodiphenyl dichloroethene (DDE) were markedly elevated in an adult fish-eating cohort. Exposure to PCBs, not DDE, was associated with lower scores on several measures of memory and learning.[34]

Success stories

The significant research findings from the ATSDR GLHHERP have resulted in a number of success stories by using different public health strategies, e.g., regulatory and community-based. For example, recent health findings were instrumental in the implementation of a Uniform Great Lakes Sport Fish Advisory used by all 8 Great Lakes states as well as other states. As well, among a population of high fish-consuming American Indian men, the ATSDR used various risk communication strategies to make them aware of the risks of consuming contaminated fish.[35] As a result, the men reduced their consumption rate from an average of 98 meals per year to 28 in the first year of the study and even lower during the second year. A reduction in consumption led to lower PCB serum levels. A similar trend was also found among women of this group.[20,36]

Public health implications

The levels of pollutants in the environment have declined dramatically since the 1970s and 1980s, however, more recent trends are less clear, indicating a possible plateau as well as an increase in pollutants from outside the basin via atmospheric transport. However, there is a success story in that regulatory agencies, health agencies and industry have all worked together to put technologies in place to reduce emissions into the environment. Despite this, the body burden levels of some PTSs in vulnerable populations are still 2 to 4 times higher than those of the general U.S. population. We also recognize that body burdens of key pollutants in the general population have been identified at levels that are within an order of magnitude that produces health effects in experimental settings.[37]

It is clear that vulnerable populations are at risk for adverse health effects because of elevated exposures as well as possibly intrinsic physiological sensitivity. Nursing infants, subsistence and sport fishermen, and the elderly are among these vulnerable groups. The nursing infant may experience exposure rates anywhere from 40 to 50 times that of the general population.[38] Therefore, the developing fetus is intensely sensitive to the effects of these chemicals during certain critical "windows" of development. If these chemicals are endocrine disruptors, these effects may have transgenerational impacts. These identified health end points in the GLHHERP constitute sensitive as well as sentinel indicators for assessing human health status in vulnerable communities.

Another complication is the possibility that these subtle effects are occurring on a wide-scale basis and in populations where the effects resist conclusive demonstration through epidemiologic methods. The tobacco experience suggests it may be impossible, or nearly impossible, to have absolute consensus on the issue of causality. But in terms of public health practice, Gilbertson[39] has posited that the weight of evidence be used as a causality surrogate to address the challenges posed in moving from science to service. Nevertheless, even in the face of that uncertainty, society is confronted with potential public health issues that must be addressed.

The public health case for action is based on the shift in the distribution curve of a measure of functional capacity such as IQ. If the population as a whole is affected, the proportion of the population that falls into the gifted and handicapped categories is significantly altered. The public health implications of such a shift are profound. A recent re-examination of 212 children from the Lake Michigan Maternal/Infant Cohort Study indicated neurodevelopmental deficits assessed in infancy and early childhood still persist at age 11.[40] The study results indicated that the most highly exposed children, those with prenatal exposures equivalent to at least 1.25 µg/g in maternal milk, 4.7 ng/milliliter in cord blood, or 9.7 ng/milliliter in maternal serum:

- were three times as likely to have low average IQ scores ($p<0.001$);
- were twice as likely to be at least 2 years behind in reading comprehension;
- have poorer short- and long-term memory; and
- have difficulty paying attention.

These intellectual impairments are attributed to in utero exposure to PCBs; and concentrations of PCBs in maternal serum and milk at delivery in this study were slightly higher than in the general U.S. population. Because of these findings, the case for action is also based on the rights of individuals and communities to know the risks to which they are exposed. Given such effects on fetal development, one must ask, "Has the fetus become the unfortunate mining canary for human exposure to toxicants in the environment?"[17]

The Great Lakes research program has already initiated steps to reduce the impact of these findings. The program has emphasized disease prevention through mobilization of the research community to pursue appropriate public health interventions, and communication efforts for defined populations and vulnerable communities.

CONCLUSIONS

Given the significant implications of these research findings, the critical importance of primary prevention is apparent. This entails both pollution prevention as well as the model of disease prevention as key strategies to interdict exposure pathways. In addition, we must consider the health benefits gained from fish consumption while also evaluating the potential health implications. The counter-balancing risks and benefits pose a significant challenge in the development of health education and risk communication, as well as in assuring the best science is responsibly and rapidly translated into public health practice. Despite these challenges, pollution prevention strategies remain the key to reducing toxic chemical exposures.

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Indicators in Environmental Health: Identifying and Selecting Common Sets

John Eyles, PhD, FRSC[1]
Chris Furgal, PhD[2]

ABSTRACT

In association with the proposed goals of the conference, this paper is presented to support the conference discussions on environmental health indicators by providing background on indicators for environmental health and their identification, selection, organization and use. This paper discusses the purpose of indicator use, frameworks used to organize indicators and the common types of indicators in use in monitoring programs today. It proposes a process for the identification and selection of indicators within the different environments, stressing the importance of clear goal definition and scientific and use-based criteria selection to support decisions. Finally, the paper suggests methods by which to organize and limit the number of indicators retained within a program, and the development of a potential "core" of indicators common to many environments and geographical scales.

RÉSUMÉ

En lien avec les objectifs de la conférence, l'article alimente les discussions sur les indicateurs de l'hygiène de l'environnement en présentant le cadre de tels indicateurs et de leur choix, leur organisation et leur utilisation. Les auteurs analysent le but du recours aux indicateurs, les cadres servant à leur organisation et les types courants d'indicateurs qui sont utilisés de nos jours dans les programmes de surveillance. Ils suggèrent une méthode de détermination et de choix des indicateurs dans divers milieux, en insistant sur l'importance de définir précisément les objectifs ainsi que les critères scientifiques et ceux qui sont fondés sur l'utilisation et qui servent à justifier les décisions. Enfin, l'article propose des méthodes pour organiser les indicateurs retenus dans le cadre d'un programme et en limiter le nombre et pour définir un groupe potentiel d'indicateurs communs à nombre de milieux et d'échelles géographiques.

1. McMaster Institute of Environment and Health, Professor, School of Geography and Geology, McMaster University, Hamilton, ON
2. Public Health Research Unit, CHUQ Research Centre, Beauport, QC
Correspondence: Chris Furgal, Public Health Research Unit, CHUQ - Pavillon CHUL, 2400 rue d'Estimauville, Beauport, QC G1E 7G9, Tel: 418-666-7000 ext. 555, Fax: 418-666-2776, E-mail: christopher.furgal@crchul.ulaval.ca

Why monitor and develop surveillance systems?

Monitoring and surveillance are important aspects of public health practice. They involve the collection and analysis of routine measurements aimed at detecting changes in the environment, the health status of populations, or both. Further, they can involve continuous or periodic measurement of the effect of an intervention on the health status of the population, the environment, or both. Finally, they can provide overseeing of activities to ensure that things are going according to plan.[1] Surveillance is a key task in many governmental organizations charged with ensuring the health and well-being of the population and/or environment (see Eylenbosch and Noah[2]). These activities are particularly important in ecosystems, such as the Great Lakes, where the link between society and environment (or human health and ecosystem health) is particularly acute. These ecosystems are a source of potential hazards as well as a fundamental condition for human well-being (see Cole et al.[3]) and thus their monitoring and surveillance are critical.

Valuing measurement and monitoring

Monitoring and surveillance are purposeful human activities, closely related to the goals and values of the societies in which they are embedded. They are measurement devices that inform on what society deems important enough to monitor. Yet measurement is only one way of conceptualizing and categorizing phenomena of interest (see Fortin,[4] City of Toronto,[5] Hancock et al.,[6]). As Alonso and Starr[7] note, for such things as official statistics, measurements reflect presuppositions and theories about the nature of society being shaped by social, political and economic interests. Thus, data from monitoring are only meaningful when they are interpreted.[8] As Allen and Hoekstra[9] note, measurement has to wait for a definition – normatively and scientifically derived – of what is to be quantified. It is important therefore to ensure that monitoring systems are broad-based, including local studies, qualitative findings and community stories. It is important to note that monitoring is meant to provide information to think about and conceptualize an issue, to chart progress toward desired change, to provide a basis for empowerment and to identify the needs and capacities of, for example, the

Great Lakes populations. It represents a larger body of information than simply the data it provides and thus some consideration for a variety of forms of information must be considered where appropriate (e.g., inclusion of community stories allows people to speak in their own words and use their experiences as the basis for action). Yet, counting is societally important. As Stone[10] points out, what is measured is political in that it is based on decisions about categorizing, inclusion-exclusion criteria; it implicitly creates norms; it is used to tell 'stories'; it makes the complex apparently simple and precisely defined; and it creates political communities. Furthermore, numbers have tremendous salience in western culture and monitored, quantified data are usually given precedence over all other (see Porter[11]; Eyles[12]).

All monitoring is thus important and its specificity must come from the value it provides in moving towards desired changes. And while it is increasingly recognized that evidence often plays a small part in decision-making, we concur with Innes[13] that monitoring will be valued in policy decisions if it is theoretically sound and meshed in publicly understood concepts (e.g., stories to support surveillance outputs); is developed and overseen by people representing a variety of interests and processes; utilizes a careful process to ensure public exposure and policy attention (i.e., the timeliness and relevance of the system); and institutionalizes data collection to protect it from special interests.

Framework Components

<table>
<tr><td></td><td colspan="3">Pressure</td><td colspan="2">State</td><td>Response</td></tr>
<tr><td>Issue</td><td>Indirect Determinant</td><td colspan="2">Direct Determinant</td><td colspan="2">Health Status</td><td>Response</td></tr>
<tr><td>Driving Force</td><td>Pressure</td><td>State</td><td colspan="2">Exposure</td><td>Effects</td><td>Actions</td></tr>
<tr><td></td><td>Pressure</td><td colspan="2">External Dose</td><td colspan="2">Internal Dose
Effects
Death</td><td>Actions</td></tr>
<tr><td>Condition</td><td colspan="5">Stress</td><td>Response</td></tr>
</table>

Figure 1. Examples of Frameworks for Indicator Organization. Sources: OECD,[17] von Schirnding,[18] Environment Canada, WHO[42]

INDICATORS AND THEIR USE

Monitoring through indicators

With increasing knowledge and understanding of various forms of environmental degradation and pollution and their impacts on human health, there has been increased emphasis on government initiatives to manage and, where possible, minimize these impacts. Subsequently, more attention has been given to tracking processes such as benchmarking and status reporting (i.e., State of the Environment) to provide information for evidence-based decision making. As this task is daunting, measurements that are indicative of the relationships and impacts of concern and of specific interest to individuals are chosen as "indicators" of the status of these relationships and their outcomes. Indicators provide clues to matters of larger significance or make perceptible a trend of phenomenon not immediately detectable and thus their significance extends beyond what is measured. For environment and health, the International Joint Commission[14] outlines five such examples of common uses for environmental indicators. They are:

- Compliance Indicator: assessment of current condition of environment;
- Change Indicator: to document trends or changes;
- Early Warning Indicator: to anticipate hazardous conditions before impacts occur;
- Diagnostic Indicator: to identify causative agents to specify appropriate action;
- Relational Indicator: to identify interdependence between indicators.

Briggs et al.[15] state that environmental health indicators are *"an expression of the link between environment and health, targeted at an issue of specific policy or management concern and presented in a form which facilitates interpretation for effective decision making"*. Despite the numerous definitions in the literature, common characteristics exist among them. Indicators summarize some aspect of a relationship within a phenomenon in a way that can support specific program goals. They are indicative of something based on previous knowledge, experience, or understanding of the relationship between the indicator and the phenomenon studied. Thus, by definition, indicators reflect the conceptual bias of the model on which they are based.[16] Despite these confounding factors, they can provide information in an accessible, and understandable way. However, as Innes[13] states, *"more is required to inform policy than simply producing academically certified data and handing it to policy makers"*.

Frameworks of understanding systems

To be useful, the models and biases underlying indicators must be defined. One of the most recognized of these models or "frameworks" is that of the "pressure – state – response" model put forth by the OECD.[17] This model is based on the understanding that certain pressures on a system (e.g., release of toxic substances in the environment) cause certain forms of stress on components within the system (e.g., pollution of organism tissues or compartments of air, soil or water), influencing their status (e.g., levels of substances in organisms, or environmental compartments) which then elicits various forms of response (e.g., organism mortality). From this basic model, a number of others with varying levels of specificity have been derived (Figure 1). Whether the interest of a monitoring program is to look in greater detail at the factors leading to the pressure on the system (what von Schirnding[18] calls "driving forces"), at the states or responses within the system (e.g., external dose, internal dose and effect at the organism, cellular or molecular level), or at actions taken to combat negative impacts (e.g., government emission control legislation), is determined by its goals and ultimate purpose (see Kjellstrom and Corvalan[19]).

Different types of indicators exist to help monitor pressures, responses, and actions. Traditional indicators of individual health have included measurements of morbidity and mortality as they are "objective" representations of the status of a population. In a simplified sense, objective measures are based on counts of behaviour and conditions associated with a particular situation.[20] However, often there is interest and value in investigating subjective measures, such as self-reported notions of health and well-being, as they can indicate deteriorations or improvements in well-being encompassing a number of often hard to measure factors. In a simplified sense, subjective indicators are based on reports people make about their feelings, attitudes and evaluations.[20] Many criticize subjective measurements for their obvious potential interpersonal variability, however Andrews[21] argues that well-constructed subjective measures can show high levels of validity and reliability, and Hancock et al.[6] argue that subjective indices are good for an index of change, but that the confounders to any data must be investigated and identified.

In addition to the objectivity of indicators, one must consider whether the phenomenon of interest is being investigated from a positive or negative perspective. Traditional measures of health, such as rates of disease and life expectancy, are more indices of illness and death than health or well-being and are considered to be negative measures of health. This presence/absence of disease approach is also common in toxicology and epidemiology research on human exposure, health consequences, and outcomes and is used analogously in ecosystem health.[16] Positive aspects can be identified, but are often associated with well-being and are often difficult to measure succinctly. Four ways in which health has been defined positively are:

1. That which enables people to achieve maximum personal potential;[22]
2. Ability to adapt to new or changing circumstances;[23]
3. A state of complete physical and social well-being and not merely absence of disease or infirmity;[24]
4. State of optimum capacity of individual for effective performance of tasks and duties for which they have been socialized.[25]

Just as health is complex, so is the concept of environment. "Environment" and "ecosystem" are multi-faceted and potentially complex entities unto themselves and it must be clearly identified what exactly the focus of these concepts is if a set of indicators is to be successful in achieving the desired focus (for a discussion and definitions of these terms, see Cunningham and Saigo,[26] Haskell et al.,[27] Woodley[28]; for a discussion of the concepts and definitions of health, see Aggleton,[29] Eyles et al.,[16] Cole et al.,[30] Hancock et al.[6]).

Indicators can measure aspects of health or environment, for example, at different scales (e.g., individual, local, regional, national or global). However, consideration must be given to the level at which an indicator is grouped when interpreting the data and making decisions based on this information. Often indicators built upon aggregated data (e.g., a specific indicator for health status at the municipal level) may hide inequalities at smaller scales included in the aggregate information (e.g., significant differences between groups of individuals in the municipality). For example, Canada boasts one of the highest life expectancy rates in the world, but this hides high mortality rates in some Aboriginal communities. Vogel[31] suggests when dealing with communities and individuals, it is better where possible to deal with individual-based data rather than aggregated data, as interpretations at one level of grouping can influence the validity of data at another. For these reasons, consideration must be given to building aggregates from individuals where possible, to ensure sensitivity at the individual level. Again, the level of aggregation required among indicators relates to the goals and objectives of the monitoring and surveillance program and should be considered in indicator identification, selection, or development.

INDICATOR IDENTIFICATION AND SELECTION

Criteria for indicator selection: Selecting the "right" ones

The possible array of indicators for environment and health remains overwhelming. What is necessary to keep in mind is the purpose of indicator selection and the fact that any such selection will appear, for other purposes, incomplete. It will also be temporary, reflecting our state of knowledge and ability to act at any one time. We present here some of the criteria used to select indicators from the many that exist for monitoring purposes within a surveillance program. Each program will have its own set of criteria, but some are common and should be included in most, if not all cases. We concur with the review and organization of criteria present in the literature by Eyles et al.[16] in which these criteria are separated into two basic forms: scientific-based and use-based.

Scientific Criteria

Scientific criteria are generic to the issue of scientific quality and include:

1. Data availability and suitability: is it already collected? what was the original intent?
2. Indicator validity, which includes:
   - Face validity: is it a reasonable measure?
   - Construct validity: does it describe what it claims to?
   - Predictive validity: does it correctly predict a situation?
   - Convergent validity: do many measures collected or structured in different ways move similarly?
   - Content validity: what is the fit between the indicator and the object being observed?
   - Theoretical and empirical validity: is it an important health determinant or dimension?
3. Indicator representativeness: the indicator's appropriateness to represent a specific dimension.
4. Reliability: measured by consistency over a number of repetitions.
5. Ability to disaggregate: those indicators that are able to be broken down into other variables telling us much more than the single measure it represents.

Those criteria presented here are the most commonly identified and what we consider to be representative of a reasonable degree of indicator scientific quality. This list includes those criteria covered by others (e.g., Eyles et al.,[16] Eylenbosch and Noah,[2] Hancock et al.,[6] von Schirnding[18]) although slightly rephrased.

Use-based Criteria

The development and selection of use-based criteria depend on the goals of the indicator application or surveillance program within which they are used. Use-based criteria present in the literature vary from the general (e.g., are they feasible to collect?) to the very specific (e.g., what is the valency of the indicator (potential to carry political and social punch)). As Eyles et al.[16] state, as much clarity as possible is required in the relationship between the indicator and the purpose for which it is used. Some of the commonly reported use-based criteria include:

1. Feasibility (are they already collected, and if not, how feasible is it to collect new information);
2. Resonance with audiences (importance of the indicator measurement to those affected);
3. Gameability (the ability of the indicator to be manipulated for those with something to gain);
4. Manageability (a manageable number is needed to attain specified goals yet not be too large to comprehend and manage mentally);
5. Balance (a balance among all phenomena of interest should be represented);
6. Catalyst for action (those that act as a catalyst to action of one form or another).

There exist variations to these in the literature. Some lists include such things as indicator sensitivity, understandability by the press and policy-makers, cost-effectiveness, minimal environmental impact to collect, audience interpretability, population applicability, etc. (Hancock et al.,[6] USEPA,[32] IJC[14]). Regardless of the specific criteria developed and used, a close relationship between the criteria and the goals set for the use of the indicators is paramount. The criteria selected reflect these goals and help retain indicators to meet them (for an example of a composite of these scientific and use-based criteria, see Rump[33]).

In applying these criteria, we should note that applying the use-based ones may well appear to compromise the scientific ones. But if a particular phenomenon requires special surveys or studies to be carried out at several points in time, then its scientific salience must be set against practical issues such as cost, timeliness, interpretability.

TABLE I
Procedures Used to Combine Indicators

Statistical Methods	Conceptual Methods	Ad Hoc Methods
1. Correlation analysis	1. Expert judgement	1. Indiscriminate selection (e.g., selection of all available data in a content area)
2. Regression analysis	2. Theory	2. Opinion (public)
3. Factor analysis (of various kinds)	3. Logical analysis (e.g., cluster analysis)	3. Addition and equal weighting
	4. Linguistic analysis	

Source: Amended from Rossi and Gilmartin (1980), as in Eyles[20]

Criteria for combining indicators into composites

In addition to selection through the use of specific scientific or use-based criteria, the number of indicators retained can be decreased, in some instances, by developing composite indicators. Composite indicators can group similar data (e.g., concentration of total airborne metal pollutants as compared to concentration of airborne Pb), or through calculation create a "new" indicator (e.g., Quality of Life calculations). These composites carry with them new meaning and represent more than the individual indicators used to create them. Often they are created exactly for that intent, as they carry more "weight" in decision-making processes than their individual components (e.g., QoL or Human Development Index) and are interpreted as being more "meaningful" in comparison across jurisdictions, boundaries, etc. (e.g., air quality index). Eyles[20] reviews procedures used to combine indicators into composites or indices in his review of social indicators (Table I). In any case, caution should be taken in compiling and retaining information in composites without specific reasoning as data compiled as composites are more complex to verify and disaggregate.[18]

Limits to information processing

With an increasing interest to construct, identify and agree upon common indicators that might be utilized throughout many jurisdictions or political boundaries and covering a range of concerns, some consideration for the appropriate number of indicators to use to study any one phenomenon is required. Ideally, the minimum number to be used would be the minimum number needed to meet any targets or established program goals.[2] As this is difficult if not impossible to determine, some consideration for the limits to human comprehension or cognizance is useful. From psychological studies, Miller[34] identified a limit of 7 ± 2 as the "magic" number for humans, a limit of our processing abilities. Hancock et al.[6] argue that conceptual systems are too simple and small (e.g., less than 6), but too many indicators (greater than 30) makes it difficult to manage. Therefore it is suggested that a small number of categories with a small number of indicators in each be retained and then a core selected as a balance from all of the categories. Among those selected, a balance of positive and negative, subjective and objective indicators should be included.

Sentinel events and stories

The need to reduce indicators is particularly pertinent for health indicators with an environmental linkage because of the diverse and complex subject matter, ranging potentially from radon and cancer to fear of contaminant burden and psychosocial health. One practical way of reducing this number is through using sentinel health events (see Rothwell et al.,[35] Mullan and Murthy,[36] Seligman and Frazier[37]). Such events serve as a warning signal, pointing to cases of disease or illness that seem out of the ordinary and that can be potentially linked to an external factor. In this way, such events can be used to assess the stability or change in health levels of a population.[1] In Seligman and Frazier's words,[37, p.16] a sentinel health event is then "a case of unnecessary disability, or untimely death whose occurrence is a warning signal…". It is of course possible to identify sentinel events for environmental integrity or stress, e.g., the disappearance of particular species (see Rothwell et al.[35] for potential indicators of sentinel events for environmental chemical exposures).

By definition, sentinel health events are concerned with death and disease states. If a definition of health is broadened to the

TABLE II
Criteria for 'Assessing' Sentinel 'Stories'

Criteria	Definition	Assumptions	Strategies/Practices to Satisfy Criteria
Credibility	• Authentic representation of experience	• Multiple realities • Causes not distinguishable from effects • Empathetic researcher • Researcher as instrument • Emphasis of the research endeavour	• Purposeful sampling • Disciplined subjectivity/bracketing • Prolonged engagement • Persistent observation • Triangulation • Peer debriefing • Negative case analysis • Referential adequacy • Member checking
Transferability	• Fit within contexts outside the study situation	• Time and context-bound experiences • Not responsibility of 'sending' researcher • Provision of information for 'receiving' researcher	• Purposeful sampling • Thick description
Dependability	• Minimization of idiosyncrasies in interpretation • Variability tracked to identifiable sources	• Researcher as instrument • Consistency in interpretation (same phenomena always matched with the same constructs) • Multiple realities • Idiosyncrasy of behaviour and context	• Low-inference descriptors, mechanically recorded data • Multiple researchers • Participant researchers • Peer examination • Triangulation, inquiry audit
Confirmability	• Extent to which biases, motivations, interests or perspectives of the inquirer influence interpretations	• Biases, motivations, interests or perspectives of the inquirer can influence interpretation • Focus on investigator and interpretations	• Audit trail products • Thick description of the audit process • Autobiography • Journal/notebook

Source: Lincoln and Guba,[38] Baxter and Eyles[39]

illness experience and its positive aspects in human potential and well-being, such indicators may be supplemented with 'sentinel stories' which can illustrate both the adverse effects of the environment for health and the role it plays in enhancing well-being. We suggest the application of qualitative research criteria (see Lincoln and Guba,[38] Baxter and Eyles[39]), especially those of credibility, transferability, dependability, and confirmability (see Table II), all of which ensure the scientific adequacy and trustworthiness of the stories (see Eyles et al.[40] for a description of sentinel story assessment).

CHOOSING A CORE SET

A common process for consensus and influence

Given all of the above, is it possible to choose a core set of indicators? A two-staged process for indicator identification and selection was used by Gosselin et al.[41] in their "Indicators for Sustainable Society". Indicators were first selected based on a variety of criteria including both scientific and use-based criteria tailor-made for the purposes of measuring aspects of sustainability within societies. A stakeholder-based scoring system was used to reduce the final number of indicators retained based on the criteria and their balance among phenomena of interest within the program.

It remains to be decided whether such a process is acceptable for establishing indicators for other ecosystem and large bio-regions. At the very least, discussion and agreement on both the process of establishing indicators and the process of establishment itself are required. With respect to the process, those involved must agree on the 'terms of engagement', i.e., who may speak with respect to indicators for specific environments; will those be discussed before core indicators for the whole ecosystem; how will consensus be achieved; etc.

With respect to establishing indicators themselves, it is important to discuss issues such as the scale of applicability (e.g., local, regional, national), the types of comparison that the indicators will illuminate (e.g., geographic comparisons, temporal comparisons, combinations of these). In some ways, these issues attend to goals. Thus, in conclusion, we recommend that the following issues be addressed in the order presented below to begin any identification and selection of indicators for monitoring and surveillance:

- Goals of the indicators;
- Conceptual model used for indicator identification and selection;
- Criteria (scientific and practical) to select indicators with the balance between the types fully discussed;
- Indicator selection – first, for each environment, select 7 ± 2 indicators, and then for the ecosystem as a whole, select 7 ± 2, in light of the choices made with respect to the most important criteria;
- Identification of sentinel events and stories – first for each environment, site or a sentinel indicator/event/story; then for the ecosystem as a whole, select 3 ± 2 sentinel indicators/events/stories.

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Putting Indicators to Work

A Summary of Roundtable Presentations on the Latin American and Caribbean Experience with Environmental Health Indicators

Chris Furgal, PhD

ABSTRACT

A roundtable was held at the conclusion of the formal conference presentations to present and discuss experiences in Latin America and the Caribbean with indicator selection, implementation and use. Four presentations were given covering the following topics: the Pan American Health Organization's (PAHO) implementation of a core indicators program in the Americas; Latin America's use and application of the WHO developed Driving forces, Pressure, State, Exposure, Effect, Action framework (DPSEEA) for indicators; the Chilean experience in identifying, selecting and implementing indicators for use throughout the country; and finally, the use and application of the WHO DPSEEA framework to the issue of water quality monitoring in Brazil. Each paper presented a summary of knowledge gained to date from their experience and some of the strengths and challenges identified from the various approaches taken. The summary presented here provides a brief overview of the presentations given at the workshop.

RÉSUMÉ

À la fin des présentations habituelles de la conférence, un groupe de discussion a présenté et analysé les résultats des expériences en Amérique latine et dans les Caraïbes en ce qui a trait au choix, à la mise en place et à l'utilisation des indicateurs. Quatre présentations ont abordé les sujets suivants : le rôle de l'Organisation panaméricaine de la santé (OPS) dans la mise en place de programmes d'indicateurs de base dans les Amériques; l'utilisation et l'application en Amérique latine du cadre Forces motrices-Pressions-État-Exposition-Effets sur la santé-Actions (DPSEEA) de l'OMS en ce qui a trait aux indicateurs; l'expérience chilienne de détermination, de choix et de mise en place d'indicateurs partout au pays; et finalement, l'utilisation et l'application du cadre DPSEEA au Brésil. Chaque article résume les connaissances acquises à ce jour dans le contexte de ces expériences et certains des points forts et des lacunes propres à chacune des approches. Ce résumé constitue un aperçu des présentations de l'atelier.

CHUQ – Pavillon CHUL, Public Health Research Unit, Beauport, Québec
Correspondence: Chris Furgal, Public Health Research Unit, CHUQ - Pavillon CHUL, 2400 rue d'Estimauville, Beauport, QC G1E 7G9, Tel: 418-666-7000 ext. 555, Fax: 418-666-2776, E-mail: christopher.furgal@crchul.ulaval.ca

PAHO Health Indicators Initiative: Selection, Analysis, Use and Dissemination of Health Indicators in an International Context

Presentation by: Dr. Carlos Castillo Salgado, Coordinator of Special Program for Health Analysis-PAHO

Created in 1902, PAHO is the oldest international public health agency. The organization has a strong technical and political presence with offices in most of its countries, a field office in El Paso, Texas specifically dealing with issues along the Mexican American border area, and several research centres covering the areas of nutrition, environmental research, and epidemiology. The PAHO core health indicators initiative was started in response to the tremendous inequalities in health that exist in the Americas. This gap had been growing consistently over the past decades with the exception of the 1980s, during which many of the countries in the Americas lost much of their economic capacity, thus reducing the gap in inequalities.

The purpose of the PAHO core health indicators initiative was to provide input for strategic planning activities of PAHO and its participating countries and support the identification, evaluation and monitoring of specific issues. These core data are considered to be the minimum data needed to describe the health situation in a given country, area, or population group. In developing core indicators, we used specific requests from the countries for the inclusion of critical aspects relating to health, such as the inclusion of indicators on smallpox eradication, life expectancy, etc. Many of these elements were needed in all countries, but we also realized that different countries had unique needs and therefore the core data set needed to expand. As a result, it expanded to accommodate several local and regional needs. The process to get to this point took several months. Initially, an inter-thematic group was created made up of the thematic and technical advisors. This group interacted with country representatives who had technical teams supporting them for the selection of their indicators. Initially, more than 6,000 indicators were reviewed. At first, participants wanted all the indicators included, however, as this was impossible, a more practical core of indicators was developed and retained; 117 indicators are now included in the core list, with approximately 8-10 in each thematic category.

Since the implementation of this program, we have seen the countries in the region maintaining or showing no change in the status of these indicators, with the exception of the rich countries that have been growing. For almost all indicators, the great differences that were originally expected between some countries can be observed. The core health indicators process attempted to develop common definitions, standard validation procedures, and common communication networks among the participating countries. Currently, 21 countries have adopted the core indicators disaggregated to the subnational level. This has allowed PAHO, and the individual countries, to address far more than previously possible as national estimates would never have reflected what is happening in various regions inside these countries. To date, all countries, with the exception of Canada and the United States, have developed core data following this format. Through the use of GIS technologies, we have also used the data to show inequalities between groups and geographical areas. A great deal of disaggregated health data are now available for the first time in these regions and PAHO is using these data in the identification of issues and areas needing attention within the countries of the Americas (for examples of applications, see http://165.158.1.110/english/sha/shasitio.htm and follow links for "Country Health Data"). Through its use by various groups (communities, health professionals, politicians) and in various applications, these data have evolved into a source of information now used for the most important health analyses and reports in the Americas.

Regional Meeting on Environmental Health Indicators in the Latin American Region

Presentation by: Mr. Alexandrino Maciel, Coordinator of Environmental Surveillance, Ministry of Health of Brazil

Representatives from several countries of the Americas (Brazil, Chile, Costa Rica, and Peru) came together in Washington, DC in November, 1999 to discuss issues related to indicators for environmental health. Some consensus was reached at this meeting regarding a variety of indicator-related issues (comparability, applicability, identification of at-risk areas to facilitate political action, etc.) as well as the value of the World Health Organization (WHO) DPSEEA framework for indicator selection and organization. Further, a number of priority environmental health issues were identified to which monitoring through indicators could be applied. Priority areas and issues identified included:

- Sanitation – water supply system, sanitation sewer system, excreta and solid waste disposal system
- Workers' health and health of the work environment
- Zoonoses – the control of vectors
- Protection of foods
- Environmental protection – water, air, soil and the biota
- Hazardous waste – chemical substances and radiation
- Natural and technological disasters
- Housing and urbanization.

Further, participants identified a number of actions necessary for the implementation and use of indicators in the Americas:

- Incorporate indicators of environmental health into country health plans;
- Disseminate information generated by the use of indicators of environmental health to production sectors, general population and service providers;
- Orient technical cooperation among countries;
- Orient capacity for the implementation and use of indicators.

The goals of these efforts were to:

- Guide health policies and other sectors involved in education for environmental health;
- Evaluate the projects and programs using the indicators of environmental health;
- Mobilize resources for the implementation of indicators for environmental health.

Participants agreed on the need to proceed with indicator use and the development of a system for environmental surveillance. They agreed on the need to work with basic or essential groups of indicators for environmental health for a specific purpose and finally, recommended that PAHO should promote an intense mobilization of resources for this purpose. (For further information on this workshop, see http://165.158.1.110/english/hep/heqare02.htm)

Chile's Experience in Choosing, Using, Promoting and Disseminating Environmental Health Indicators

Presentation by: Dr. Mauricio Ilabaca, Director, Environmental Health Division of the Ministry of Health of Chile

The national system of public health in Chile is made up of 23 health services, each containing an environmental health team. Regularly, the national health department requests environmental health status information from each region. However, we have realized the challenge in this because of an inequality in data availability among regions and have therefore adjusted the number of indicators for which we request data accordingly. The simplification of this process, through requesting fewer samples, variables and indicators from each region, has improved our response rate and data quality. In order to establish this core group of indicators for which we collect data from each region, we started with 9 main indicators. As the environments are vast and diverse in the country, the regions are invited to propose new indicators according to their own local needs and issues and resources for collection. Ideally, we would like to slowly increase the number of indicators used throughout all regions as regional capacities for collection, organization and management develop. At the national level we are reviewing this information and establishing goals on a quarterly basis, providing training to regions, and taking action on environmental health issues. We are challenged by the fact that a great deal of variability exists between the regions and departments dealing with environmental health in the country. Some teams are comprised of only veterinarians, and have neither engineers nor physicians on staff. This challenges their ability to provide quality data. In closing, the now established national surveillance system is directly concerned with problem-solving and long-term planning. Indicators for management, control, and environmental

health status are an integral part of this work. Indicators currently included in these activities cover aspects of: occupational health, fatal accidents, zoonoses, air pollution, food safety, basic sanitation, urban population health, domestic waste deposition, water quality, chemical safety, and chemical production.
(For more information on this topic, see http://www.minsal.cl/).

Brazil's Water Quality Surveillance System

Presentation by: Mrs. M. Lucia Oliviera, Environmental Surveillance, National Health Foundation, Brazil

In Brazil, two workshops have been held to discuss the WHO model for indicator organization. In August 1992, a meeting was held during the Brazilian Presidential Congress to discuss theoretical and conceptual issues with regard to environmental and public health indicators. Recommendations made by participants at this meeting included the need for various aspects of health and the environment to be covered by any potential indicator selection process, the need for public participation in this process, as well as the inclusion of various existing environment and health indicators related to environmental quality, human exposure and health effects. The following May, the Brazilian Association of Sanitary and Environmental Engineers Congress took place. At this meeting, a workshop on surveillance systems for water supplies was convened, and the DPSEEA framework for indicators was used to discuss and organize indicators on various topics. The model helped the participants identify many inadequacies in the water systems and related policies. For example, currently Brazil's sewer sanitation system reaches 60% of the country but only 20% of the population have access to treatment systems. Nearly 80% of individuals are reached by the water supply but many only get water once or twice a week. By using the DPSEEA framework, the workshop identified many of the indicators required to identify and monitor these situations and it was realized that much of the information required by many of the indicators already existed. A basis for the national health information system now exists and is being augmented with the national hospital information system, disease information system, mortality data, etc. Eventually, these data will all be included with the drinking water information system that is now under construction. The issue of drinking water surveillance was also discussed at this meeting and an initiative to document the different types of water supplies used by people (e.g., public system, private system, rivers, lakes, etc.) has begun. Many of these information systems are being developed with the hope of making them web-based in the future, ultimately searchable on various geographic scales. Expected completion of the initial data systems in Brazil is 2003.

List of Conference Attendees

Ms. Catherine Allen
Director, International Activities
U.S. EPA
allen.catherine@epamail.epa.gov

Mr. Doug Alley
IJC, Great Lakes Regional Office
alleyd@windsor.ijc.org

Dr. Joan Aron
President, Science Communication Studies
jaron@mmscenet.org

Dr. Luiz Augusto Galvao
Environmental Quality Program Coordinator
Pan American Health Organization
galvaolu@paho.org

Mr. Albertino Alexandre Maciel Filho
Coordenador de Vigilancia Ambiental em Saúde Fundação Nacional de Saúde - FUNASA CENEPI/CGVAM
maciel.filho@saude.gov.br

Mrs. Susan Bayh
Commissioner, International Joint Commission
bayhs@washington.ijc.org

Dr. Yvan Bédard
Université Laval
Yvan.bedard@scg.ulaval.ca

Ms. Carolyn Cahill
Policy Advisor
National Roundtable for the Environment and the Economy
cahillc@nrtee-trnee.ca

Dr. Sabit Cakmak
Health Canada
Sabit_Cakmak@hc-sc.gc.ca

Ms. Sharon Campolucci
Deputy Director, Division of Health Studies
ATSDR
sscl@cdc.gov

Dr. Carlos Castillo-Salgado
Coordinator, Special Program for Health Analysis
Pan American Health Organization
castillo@paho.org

Dr. Murray Clamen
Secretary, International Joint Commission
clamenm@ottawa.ijc.org

Ms. Carmen Connolly
Director, Canadian Population Health Initiative
Canadian Institute for Health Information
cconnolly@cihi.ca

Dr. Eric Dewailly
CHUQ – Pavillon CHUL
Eric.Dewailly@crchul.ulaval.ca

Dr. Chris DeRosa
ATSDR
cyd0@cdc.gov

Dr. John Eyles
McMaster University
eyles@mcmail.cis.McMaster.ca

Dr. Chris Furgal
CHUQ - Pavillon CHUL
Christopher.Furgal@crchul.ulaval.ca

Ms. Connie Gaudet
Environment Canada
Connie.Gaudet@ec.gc.ca

Dr. Pierre Gosselin
CHUQ - Pavillon CHUL
Pierre-L.Gosselin@crchul.ulaval.ca

Mr. Jacques Grondin
CHUQ - Pavillon CHUL
Jacques.Grondin@crchul.ulaval.ca

Ms. Soo Han
U.S. Section Liaison HPTF
International Joint Commission
hans@washington.ijc.org

Dr. Trevor Hancock
Faculty of Environmental Studies
York University
thancock@on.aibn.com

Dr. Heraline Hicks
ATSDR
heh2@cdc.gov

Mr. Tony Hodge
Anthony Hodge Consultants Inc.
thodge@anthonyhodge.ca

Mr. Don Houston
Director, Environmental Programs
Canadian Institute of Child Health
dhouston@cich.ca

Dr. Mauricio Ilabaca
Jefe División de Salud Ambiental
Ministerio de Salud de Chile

Dr. Wendy Kaye
Division of Health Studies
ATSDR
wek1@cdc.gov

Mr. Germain Lebel
CHUQ - Pavillon CHUL
germain.lebel@ssss.gouv.qc.ca

Mr. David McGuinty
Director and CEO, National Roundtable for the Environment and the Economy
mcguintyd@nrtee-trnee.ca

Dr. Robert Morris
Tufts University School of Medicine
Robert.morris@tufts.edu

Ms. Mara Lúcia Barbosa Carneiro Oliveira
Fundação Nacional de Saúde
Assessora da Coordenação de Vigilancia Ambiental em Saúde
mara.carneiro@funasa.gov.br

Ms. Sandra Owens
Health Canada
Sandra_Owens@hc-sc.gc.ca

Ms. Joanne Papineau
Health Canada
Joanne_Papineau@hc-sc.gc.ca

Dr. Ray Pong
Laurentian University
rpong@nickel.laurentian.ca

Dr. Dieter Riedel
Health Canada
Dieter_Riedel@hc-sc.gc.ca

Ms. Sandra Schwartz
Director, Environmental Programs
Pollution Probe
sschwartz@pollutionprobe.org

Mr. Alan Sobel
Intersolv (Conference Facilitator)
asobel@sympatico.ca

Dr. Robert Spengler
Associate Administrator of Science
ATSDRrys2@cdc.gov

Dr. Yasmin von Schirnding
World Health Organization
vonschirnding@who.ch

Dr. Don Wigle
Senior Medical Advisor
Environmental Health Program
Health Canada
Don_T_Wigle@hc-sc.gc.ca