A Framework Document:

Factors to Consider in Characterizing Vulnerability to Environmental Contamination Across North America

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Abbreviations and Acronyms

As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
CBRA	Community-based risk assessment
Cd	Cadmium
CDC	Centers for Disease Control and Prevention
CEC	Commission for Environmental Cooperation
CO	Carbon monoxide
Dioxin	Polychlorinated dibenzo-*para*-dioxins
DPSEEA	Driving Force – Pressure – State – Exposure – Effect – Action
EAF	Environmentally attributable fraction
EBD	Environmental burden of disease
Hg	Mercury
NO	Nitric oxide
NO_x	Nitrogen oxides
PAHs	Polycyclic aromatic hydrocarbons
Pb	Lead
PBDEs	Polybrominated diphenyl ethers
PBTs	Persistent, bioaccumulative and toxic substances
PCBs	Polychlorinated biphenyls
POPs	Persistent organic pollutants
SO_2	Sulfur dioxide
SO_x	Sulfur oxides
UN	United Nations
US EPA	United States Environmental Protection Agency
US FDA	United States Food and Drug Administration
WHO	World Health Organization

Abstract

Assessing individual or community risk from environmental pollution is complex and requires consideration of chemical and non-chemical stressors, community priorities and values, and numerous other factors. This framework document is intended to serve as an information and awareness resource for the development of environmental health assessment tools. It draws from an exhaustive review of scholarly and grey literature from varied disciplines (e.g., environmental pollution, nutrition, social sciences, health and public health promotion), and from consultations with subject-matter experts and stakeholders from the three North American countries.

The factors that need to be considered in characterizing the vulnerability of an individual or community to the health consequences posed by environmental pollution are here grouped under four key properties of vulnerability: the degree of *exposure* to pollutants; the individual's *susceptibility* to the harmful effects of the pollution; and an individual's or community's level of *preparedness and responsiveness* (the capacity to cope with and mitigate the risks associated with these environmental contaminants).

The framework can provide the basis for developing integrated environmental health impact assessments, and assist in targeting and prioritizing communities needing urgent intervention. It also lists existing tools that can be used to assess vulnerability, or serve as models to develop new, targeted tools to do so. The framework will enable more informed decision making by individuals and communities throughout North America, helping them to confront the complexity in assessing and mitigating the risks posed by environmental pollution.

Executive Summary

A vast number of chemicals, either singly or as components of mixtures, are part of our environment and hence our daily lives. Only some of these chemicals have been thoroughly assessed for the risk that they may pose to human health. Some chemicals are known or suspected of contributing to harmful health conditions, including asthma, cancer, and respiratory, cardiovascular, and reproductive disorders. Exposure to chemicals can occur via such pathways as inhalation, ingestion, or contact with the skin. Fetuses can potentially be exposed to any chemical the mother was exposed to, through placental transfer of the chemical during pregnancy. In any case, a series of events must occur in order to develop health outcomes following exposure to one or more chemicals. Differential vulnerability to chemical exposures is characterized by the degree of exposure, an individual's susceptibility to the harmful effects caused by the chemical, and the capacity to cope with and mitigate chemical risks.

Informed by existing tools, this framework document aims to identify the factors that need to be considered in characterizing the vulnerability of an individual or community to the health consequences posed by environmental pollution throughout North America. The term "community," as used in this document, is not confined to a geographic location. It could refer to a town or a city, of course, but it could also represent a human subpopulation, such as infants, indigenous populations, or pregnant women, for example. The material in this document is intended to serve as an information and awareness resource for the development of environmental health assessment tools. The framework document is also intended to assist informed decision-making by individuals and communities about how to protect their health from environmental contaminants, by enabling identification of their vulnerabilities to potential health risks and the actions that can be taken to mitigate them.

Evidence-based knowledge, **transdisciplinarity**, **community participation**, and **environmental and gender justice** are the key foundational elements of the framework. Building on these foundations are four overarching properties that characterize vulnerability to environmental contamination: *exposure, susceptibility, preparedness and responsiveness*. These four properties each encompass a set of specific factors that can help to explain how environmental, social and cultural circumstances can influence exposure to environmental contaminants, and why some individuals or communities might be more (or less) vulnerable because of their capacities and resources, coping mechanisms, and institutional support.

Additionally, material gathered in the course of using this strategic document can support the creation of tools to characterize the vulnerability of targeted communities to environmental risks. Potentially, in use, the framework can:

- Form the basis for planning, organizing, and developing integrated environmental health impact assessments;
- Aid in targeting and prioritizing communities needing urgent intervention, by providing tools for screening and assessing sources of pollution;
- Promote multi-stakeholder dialogues to enhance community understanding and collaborative problem solving; and
- Promote more holistic thought and action, bridging the isolation that sometimes occurs between disciplines.

The implementation of this framework may face challenges on many fronts: community engagement, scientific knowledge, governmental involvement, knowledge transfer and communications, and the global production and use of chemicals. Strategic possibilities for addressing those challenges are also presented in this document.

Effective consideration of both chemical and non-chemical stressors and of community priorities and values in community risk assessment activities is a complex business. This framework document is a major step in accomplishing that task, providing a list of existing tools that can be used to assess vulnerability, or serve as models to develop new, targeted tools to do so.

1. Introduction

Over the last two centuries, the development and use of chemicals has significantly contributed to economic and social development worldwide. As a result, myriad chemical mixtures are part of our environment and hence our daily lives. A vast number of chemical products are now available in the global market, subject to regulatory and inventory systems. Tens of thousands of chemicals are listed on national inventories of chemicals in commerce around the world. In North America, more than 84,000 chemicals are currently listed in the Toxic Substances Control Act inventory of the United States,[1] about 23,000 substances can be commercialized or used in Canada according to the Canadian Environmental Protection Act,[2] and about 5,800 substances are included in the *Inventario Nacional de Sustancias Químicas* of Mexico.[3] Differences observed among national inventories reflect the different approaches used in creating them; each has a different history, original purpose and legislative basis, resulting in inventories that range from widely inclusive to purposely limited. Nonetheless, only some of the chemicals in use have been thoroughly assessed for the risk that they may pose to the environment or to human health. While some of these chemicals may not be harmful, others that are in use are known or suspected of contributing to certain harmful health conditions, including asthma, several types of cancers, birth defects, neurobehavioral disorders, disturbed cognitive development, damage to the respiratory, cardiovascular, reproductive or endocrine systems, and other chronic diseases (GEO-5 2012). Many variables can directly or indirectly influence these health outcomes. For example, air pollutants can trigger asthma among the very young and very old, as well as in individuals who have a family history of asthma, or aggravate existing respiratory and cardiac conditions (Neidell and Kinney 2010). Exposure to environmental pollution is one of the many environmental factors that can have an impact on human health.

Daily exposure to chemicals can occur via a single or complex matrix of exposure routes and pathways; and while not all exposures are harmful the vulnerability[4] and the negative health-related outcomes of chemical exposure can be much greater for certain individuals or communities. This vulnerability arises from different factors—including age, genetic makeup, lifestyle, geographic location and climate variability, heightened susceptibility to chemicals,

[1] The Toxic Substances Control Act (TSCA). US Environment Protection Agency (Available at <www.epa.gov/oppt/existingchemicals/pubs/tscainventory/>, accessed in January 2013).
[2] Canadian Environmental Protection Act (CEPA) Environmental Registry. Environment Canada (<www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=D44ED61E-1>, accessed in January 2013).
[3] *Inventario de Sustancias Químicas de México*, 2012. *Instituto Nacional de Ecología y Cambio Climático* (Available at: <www2.ine.gob.mx/publicaciones/consultaPublicacion.html?id_pub=684>, accessed in January 2013).
[4] The term "vulnerability" is used throughout this document as the intrinsic propensity of an exposed entity to experience adverse effects from external agents, events, perturbations, or stresses.

socioeconomic status and many others (e.g., differences in individual or population susceptibility, exposure, preparedness, and ability to recover).

The governments of Canada, Mexico and the United States acknowledge the significance of environmental factors to the health and well-being of the human population. They also recognize that protecting the health of ecosystems, people and communities from the effects of environmental contaminants is essential for the maintenance of the socio-economic and ecological systems that underpin North American society.

The Commission for Environmental Cooperation (CEC) has served as a forum and catalyst for environmental cooperation among the three countries. Various CEC reports and activities have been developed on the relationship between certain vulnerable groups and levels of exposure to environmental chemicals. In particular, two reports focused on children's health and the environment helped to identify environmental factors that may contribute to or exacerbate certain health outcomes in children [*Children's Health and the Environment in North America: A First Report on Available Indicators and Measures* (CEC 2006a) and *Toxic Chemicals and Children's Health in North America: A Call for Efforts to Determine the Sources, Levels of Exposure, and Risks that Industrial Chemicals Pose to Children's Health* (CEC 2006b)].

As a step forward in this direction, and recognizing that many North Americans are burdened by multiple sources of environmental pollution and that some people or communities are more vulnerable to the effects of pollution than others, the CEC commissioned the development of a framework to assist communities throughout North America in identifying the factors that need to be considered in characterizing an individual's or community's vulnerability to the health consequences posed by environmental pollution.

This framework is anticipated to further the CEC goals of cooperation among governments, facilitating and supporting information-sharing for tool developers who will create tools to help identify and characterize community vulnerability. Additionally, it can serve as the basis for planning and developing integrated environmental health risk assessments.

1.1 Functional Criteria of the Framework Document

A review of existing tools (e.g., official web sites, fact sheets, peer-reviewed articles) and strategies for protecting or improving human health in regard to environmental contamination revealed some important scientific and practical criteria which were used to guide the development of the framework presented in this document. A comprehensive framework for protecting and improving the environmental health of vulnerable communities should:

- Be applicable in diverse operational situations of different scales and in the different types of communities across North America;
- Be based on scientific and community knowledge;
- Be largely accessible;

- Provide information to tool developers about the characteristics that make communities vulnerable to chemical contamination; and
- Ensure that information on human and ecological health is up to date.

1.2 Framework Design

The word “community,” as used throughout this document is not confined to the people that live in a specific geographic location such as a village, town or city. Rather, the word community is broad in scope. That is, a “community” could be those individuals living in a town or a city, but it could also be a human subpopulation, such as pregnant women, a particular ethnic group, infants, or indigenous populations, to name a few. A community could be defined by factors such as age, financial status, literacy level, extent of education or religious beliefs, among others. How a discrete community is defined or composed is often related to its vulnerabilities to the hazards posed by chemicals. Typically, individuals simultaneously belong to several distinct but inextricably linked communities. For example, older housing found in low-income areas often contains lead-based paints. Infants and children are especially susceptible to lead exposure through natural mouthing habits and therefore more vulnerable than adults to the neurotoxicity of lead. While this is true of all infants and children, those living in such residences because of the limited financial means of their caregivers are generally more vulnerable to lead poisoning than are children and infants of more affluent households. The infants and children in this scenario are part of at least three distinct communities: one based on age; one based on family income; and the third, based on residence in a building containing lead-based paint.

Many environmental health risks are preventable or can be mitigated. Accordingly, as this framework is intended to demonstrate, the use of variables that influence the vulnerability of individuals, communities or populations in combination with other information (e.g., emission data) enables one to characterize vulnerability as it relates to a particular community, population, or subpopulation. This characterization will allow the identification of risk mitigation activities. This document is oriented and designed to provide information on factors to be considered when characterizing the potential health consequences of environmental contamination. Such information is to be used differently by different tool developers to deliver effective and accessible communication tools describing these factors, and facilitate mechanisms to assess vulnerability to the potential health effects of environmental pollution.

2. Background

Many emerging environmental health concepts have influenced the composition of the framework that will be discussed in section 3. This section reviews these concepts and provides background for the identification of factors that need to be considered in characterizing the vulnerability of an individual or community to the potential health consequences posed by environmental contamination.

2.1 Environmental Health

Environmental health comprises those aspects of human health that are determined by chemical, physical, biological, social and psychosocial factors in the environment. It also encompasses the assessment, prevention and mitigation of those environmental factors that can potentially affect the health of present and future generations.[5] The estimation of the environmental burden of disease (EBD)—which is characterized as the morbidity and mortality caused by exposure to preventable environmental hazards—requires the identification of outcomes associated with relevant environmental risk factors; statistics on morbidity and mortality; and the environmentally attributable fraction (EAF), which is the percentage of each health condition that can reasonably be attributed to exposure to environmental factors, including physical, chemical and biological hazards (Kay et al. 2000; Prüss-Üstün et al. 2003; Prüss-Üstün and Corvalán 2006). For example, the incidence of cardiovascular diseases is estimated to be 1.3, 15.5 and 81 million people in Canada, Mexico and the United States, respectively, with an EAF ranging from 7 to 23 percent (Prüss-Üstün and Corvalán 2006; Boyd and Genuis 2008; Sinais 2008; PHAC-ASPC 2011; NIH 2012). According to World Health Organization (WHO) estimates, environmental factors are responsible for 13, 16, and 13 percent of the overall disease burden of Canada, Mexico and the United States, respectively (WHO 2009).

2.1.1 Environmental Health Indicators

Indicators are commonly used to express things that cannot be directly seen or measured, but are at least suspected to exist. There is an increasing need and demand for environmental health indicators to track the population's health status with respect to environmental factors, such as pollution, and to support, monitor, and enforce policy on the environment and health at all levels—from local to global. The WHO estimates that some indicators are needed, for example (Briggs 2003):

- To monitor the state of the health of ecosystems and humans, in order to identify exposure to environmental risk factors and corresponding potential health risks;
- To provide information to the public and help create a better informed society;
- To help raise awareness about environmental health issues across different stakeholder groups (such as civil society, industry officials, advocates, practitioners, etc.);
- To help target action where it is most needed or to help allocate resources;
- To help investigate potential links between environment and health as a basis for informing interventions and facilitating policy development.

[5] World Health Organization. Environmental Health (http://www.who.int/topics/environmental_health/en/).

The use of the DPSEEA[6] framework is accepted as an aid for the development of environmental health indicators—which must certainly be adapted and modified according to such circumstances as (Corvalán et al. 1996):

- Socio-demographic context: Poverty, population density, age, educational attainment, minority status, immigrant status, access to clean water and safe food;
- Exposures: Ambient concentrations of air and water pollutants, biomarkers of exposure (e.g., blood-lead levels);
- Sensitive populations: Percent of children under five years, percent of elderly over 65 years, or percent of immuno-compromised populations; and
- Public health effects: Morbidity and mortality due to environmental and occupational health hazards, birth outcomes, and asthma rates.

Indigenous peoples observing traditional lifestyles across North America use signs and signals as environmental indicators that they can read and observe to assess the environment's health, which will influence their livelihoods (Downie and Fenge 2003; Cobb et al. 2005; Manseau et al. 2005a, 2005b; Berkes et al. 2007). These may be related to:

- Environmental changes (including changes in winds and temperature, changing seasons, sea-ice cover and thickness);
- Abundance of wildlife (e.g., monitoring harvest, animal migration, abundance of fruits);
- Condition and quality of animals (including abnormal body conditions such as abnormal liver size and color, body deformity, discolored bones, small eggs, low body fat content, abnormal taste and consistency);
- Unusual patterns in animal distribution (unusual occurrences of species); and
- Occurrence of unfamiliar human diseases.

2.2 Chemical Exposure

Throughout our daily lives, we are exposed to chemicals in foods, drinking water, personal care products, prescription drugs, household cleaners, lawn care products, and industrial waste, among others. Although some chemical exposures do not pose risks to human and ecological health, others do, either directly or through the presence of other particular chemicals. Some toxic chemicals may also persist in the environment, bioaccumulate throughout the food web, biomagnify up the food chain, or be transported great distances from their point of entry into the environment [mercury and dioxins are examples of such persistent, bioaccumulative and toxic (PBT) substances].

Chemical exposure can occur via various pathways, including inhalation (breathing), ingestion (eating, drinking), through the skin, through placental transfer (to the fetus) during pregnancy, or through breastfeeding. Selected exposure routes are presented in Table 1.

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[6] DPSEEA stands for Driving Force – Pressure – State – Exposure – Effect – Action

Exposure to toxic chemicals does not necessarily mean that an individual will develop negative health outcomes. A series of events needs to occur for adverse health consequences to develop after exposure to one or more chemicals in the environment. First, the contaminant(s) must be released from its source, reach human receptors and enter the human body. Secondly, the contaminant(s) must be present within the body at sufficient doses to potentially cause biological changes that may ultimately result in an observed health effect (US EPA 2008). Environmental contaminant exposure may be just one of several factors that can contribute to disease occurrence or to the severity of a pre-existing disease (Sexton et al. 1992). These include:

- The toxicity and dose of the chemical;
- The frequency, extent and pathway of exposure;
- The interactions amongst chemical mixtures (e.g., additive, synergistic, or antagonistic mechanisms);
- Non-chemical stressors that may affect the health outcome of exposure to environmental contaminants. For example, stress has been associated with exacerbated lead toxicity (Clougherty and Kubzansky 2009);
- Past exposures to certain chemicals that may predispose an individual or population to be more vulnerable to subsequent exposures;
- Timing (e.g., age) and family disease history;
- Genetic predisposition to increased susceptibility; and
- Lifestyle and health status.

In some cases, it is possible to reduce the exposure to certain chemicals by simply changing day-to-day behaviors (for example, avoiding the smoke from cooking fires and cigarettes, following fish advisories, or ensuring proper home ventilation, to suggest a few).

Currently, more attention is being devoted to cumulative exposures, which refers to past and/or present exposure to multiple environmental stressors occurring through all relevant routes, pathways, and sources. Consequently, conducting cumulative assessment provides an appraisal of simultaneous, overlapping and/or sequential exposure to multiple stressors that may contribute to potential adverse health outcomes (Sexton and Hattis 2007).

Recent investigations have identified a number of harmful chemicals (such as arsenic and dioxins) which can trigger modifications in gene expression that may predispose future generations to the health effects of such toxicants (Jirtle and Skinner 2007).

The multifaceted associations between chemical exposure and potential health effects have been studied and modeled via varied probabilistic tools, such as ASPEN (US EPA’s Assessment System for Population Exposure Nationwide), Carex (Carcinogen Exposure) Canada, and E-FAST (US EPA’s Exposure and Fate Assessment Screening Tool). A list of selected existing tools to track exposure to chemical mixtures is presented in Appendix A.

Table 1. Potential Sources and Pathways of Human Exposure to Selected Chemicals

Exposure media	Examples of exposure pathways	Examples of chemicals
Outdoor air	Inhalation of gases and particles from vehicle and industrial emissions, combustion of solid fuels and hazardous waste	SO_2, NO_x, ozone, suspended particulate matter, lead, benzene, dioxins and furans, and dioxin-like compounds
Indoor air	Inhalation of pollutants released during indoor combustion of solid fuels, tobacco smoking, or from construction materials and furnishings, contaminants in indoor air and dust	SO_x, NO, CO, suspended particulate matter, PAHs, Hg, Pb from Pb-based paints, benzene, formaldehyde, asbestos, phthalates, PBDEs, radon, solvents
Drinking water	Consumption of drinking water containing chemicals from industrial effluents, human dwellings, agricultural runoff, oil and mining wastes, or from natural sources	Pesticides, fertilizers, trace metals, fluoride, nitrate, cyanide, industrial solvents, petroleum products, disinfection byproducts
Food	Ingestion of food containing chemicals at toxic levels introduced through agricultural practices, industrial processes, environmental contamination, and natural toxins	Pesticides, methylmercury, Pb, As, Cd, dioxins, bisphenol A
Non-food consumer products	Exposure by ingestion, inhalation or dermal exposure to chemicals contained in toys, jewelry and decoration items, textiles, or food containers, consumer chemical products	Pb, Hg, Cd, phthalates, formaldehyde, dyes, triclosan, and pesticides
Soil	Ingestion (particularly for children) or inhalation of chemicals in soil introduced through industrial processes, agricultural processes or inadequate household and industrial waste management	Heavy metals, pesticides, and POPs
Occupational exposure	Chronic or acute exposure through inhalation, dermal absorption, or secondary ingestion of chemicals or byproducts of industrial processes such as agriculture, mining or manufacturing, cleaning industry, etc.	Pesticides, benzene, heavy metals, solvents
Human to human	Exposure during pregnancy and breastfeeding	Metals, dioxins, benzene
Others	Natural disasters, industrial incidents and conflicts, accidental chemical spills	

Source: Adapted from Prüss-Ustün et al. 2011.

2.3 Vulnerable Communities

To some extent, everyone is vulnerable to environmental threats of some kind. What differentiates individuals is the degree of exposure, the individual susceptibility to whatever outcomes can result from the threats, and the capacity to cope with and mitigate chemical risks.

It is well established that many factors directly or indirectly influence an individual's susceptibility to environmental hazards. That is, some individuals may be more susceptible to a given environmental stressor, making such individuals more vulnerable to the potential risks posed by the stressor. The same is true for populations or groups of people. Factors that influence an individual's vulnerability include, but are not limited to: genetic makeup, race, ethnicity, age, behavior, geographic location, and the extent to which the individual has control over the environment (which may be related to socio-economic status, among other factors).

Understanding differential community vulnerabilities may also allow communities to identify effective options for reducing chemical exposure. For example, if an individual or a group of individuals within the community has a language barrier that impairs the ability to read and understand the potential health effects of lead paint or fishing advisories, then supplying information materials in a different, more appropriately targeted manner may be key to reducing risk.

The material in this document targets the identification of factors that affect how an individual, group of individuals or community might be more (or less) vulnerable because of their capacities and resources, coping mechanisms, and institutional support. To accomplish such a goal and to capture more integrative factors, the approach is characterized by the four main properties that characterize vulnerability:

***Exposure*:** refers to the magnitude, duration, frequency, or timing of contact with a chemical or chemicals. Individuals can be more vulnerable to exposure for a variety of reasons. A common reason is they are living or working near a source of contamination and are therefore exposed to a higher level of pollutant than the general population (US EPA 2003).

***Susceptibility*:** refers to individuals facing an increased likelihood of sustaining an adverse effect due to a life stage, genetic predisposition, an impaired immune system, or pre-existing health condition, such as asthma. Lead, cadmium, dioxins and mercury are well-known examples of chemicals that cause toxic effects to which fetuses, the newborn, and younger children are more susceptible than adults because their biological systems are not fully developed (Faustman et al. 2000; CEC 2006a, 2006b).

***Preparedness*:** refers to the coping systems that an individual or community displays in advance of the stress condition. Although preparedness is often a matter of concern for entities larger than the individual person—preparations put in place at the national, state/provincial, or community level—there are many things that individuals can do. The more prepared they are, the less vulnerable they will be (US EPA 2003). Poverty and poor nutrition may affect the strength of an individual's ability to be prepared. Closely allied with preparedness is responsiveness, because both are linked to the kind of coping systems and resources of an individual, a population, or a community.

Responsiveness **(*ability to recover*):** reflects traits that allow an individual or community to heal from or compensate for the effects of exposure to environmental stressors (US EPA 2003). Some individuals are more able to recover from an environmental stressor because they have more information about environmental risks, health and disease; ready access to health care; or better nutrition. Poverty and poor nutrition negatively affect the strength and ability of the individual to cope with environmental stressors.

2.4 Resilient Communities

Resilience can be considered as the ability of a community to proactively respond to and recover from adversity (Turner 2010). Community resilience depends on the ability of the community to prepare, coordinate and mobilize its social, economic, political, and cultural resources toward its common objectives of mitigating environmental hazards, withstanding or adapting to negative changes, and promoting positive behaviors. In order to leverage existing resources and behavior to build a resilient community, key elements are needed, such as community participation and inclusive engagement, strong alliances and partnerships among stakeholders, sustained local leadership, relevant education about risks, self-sufficiency, increased capacity (including capacity to anticipate risks, to respond and to recover), and individual and community preparedness.

To promote a more resilient community, efforts and resources need to be focused on understanding individual and/or community factors that increase vulnerability to environmental pollution or other stressors and addressing them.

2.5 Community-based Risk Assessment

The purpose of community-based risk assessment (CBRA) is to guide practical steps in preparedness and mitigation to reduce both the likelihood of unwanted occurrences (e.g., emergencies such as industrial catastrophes, workplace injuries, natural catastrophes, etc.) and the consequences when they cannot be avoided (Sanchez et al. 2009).[7] Additionally, this approach can provide a sound foundation, integrating existing scientific data and local community knowledge of various environmental health factors to monitor and characterize vulnerability (of individuals, groups of individuals, or communities) under current conditions, or predict future scenarios to assist them to increase their resilience. The overarching goals of participatory community risk assessment include:

- Protecting human health and the environment by providing decision makers with *in situ* information that can be used to minimize risks posed by environmental agents;

[7] In the context of a community-based risk assessment the term "community" means a geographic location, such as a village or town.

- Raising awareness and gathering information through risk screening;
- Identifying areas of concern and capacity needs (e.g., to anticipate risk, to respond);
- Allocating and using resources according to prioritized community needs;
- Supporting the design of programs and activities (with the communities themselves and for national-level priorities);
- Anticipating future pollution problems;
- Building capacity to alter the community's situation; and
- Empowering communities and integrating risk reduction into day-to-day livelihood strategies.

A typical CBRA gathers information of many different types, including data about local risks and hazards, health facilities, livelihoods, and the community's collective resilience. Through the application of this multidimensional approach, the programs and activities that emerge will certainly have the community's ownership and participation and thus be more easily accomplished.

However, the application of CBRAs faces challenges and limitations. One fundamental challenge involves limitations in what can be dealt with at the community level, as some hazards require activities that community organizations, particularly underfunded ones, cannot easily address through their own actions. As a result, they will lack information necessary to prioritize and minimize the effects of certain risks factors (e.g., industrial and traffic emissions, watershed management, asbestos-containing buildings, lead-based paint, etc.). As a multidisciplinary and collaborative approach (including governments, scientists, nongovernmental organizations, citizens and other local interested parties), another important challenge faced when applying CBRA is communicating, understanding and addressing concern among participants. Often, serious chemical hazards identified by the scientific community are not among a community's key concerns (because they are not at the top of the community's list, or simply because the community is not even aware of them). Frequently, priority in a community is given to everyday problems—which may or may not include environmental chemicals—and sometimes, reluctance to change arises because the community has adapted to living with chemical hazards, or because of a lack of knowledge.

While CBRA is not a panacea for all aspects of exposure to environmental contaminants, it can contribute to better strategies of resilience and adaptation and could play a larger role if employed more systematically.

3. The Framework

3.1 Purpose

This framework document presents the factors that need to be considered for assessing an individual's or community's vulnerability to the risks posed by environmental contaminants.[8] It is intended to support informed decision-making by individuals or communities to protect their health from environmental contaminants, by enabling identification of their vulnerabilities to potential health risks and the actions that can be taken to mitigate them.

It also provides assistance in characterizing vulnerability to environmental contamination, based on concepts discussed in the previous sections and on publicly available materials. The information gathered needs to be adapted to the context and language of targeted communities by strategic and knowledgeable tool developers.[9] A diverse set of products and tools specifically designed for these communities can then be generated to reduce vulnerability to environmental contamination. The framework recognizes the importance of the social determinants of health, such as access to health care, quality of schooling, resources available in homes and neighborhoods, workplace safety, and access to social and economic opportunities.

3.2 Scope

This document is intended to serve as a foundation for tool developers wishing to develop products tailored to selected audiences. It recognizes the social, cultural and socioeconomic links to human health and defines health in terms of an individual's physical, mental, emotional, spiritual and social well-being.

Figure 1 depicts a conceptual model of the interrelationship between vulnerability and the tools that can be derived to address it: the key foundational elements for assessing the vulnerability of targeted audiences and building sustainable capacity outcomes, and the four properties that characterize vulnerability—exposure, susceptibility, preparedness, and responsiveness—and that lead to the development of tools for assessing it.

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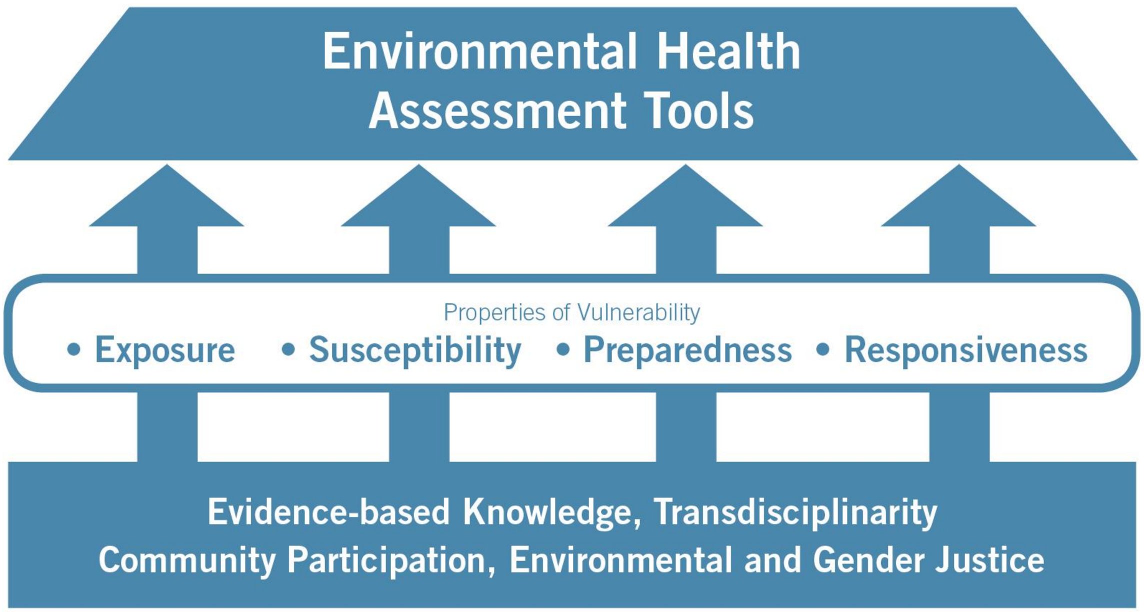
[8] Here the term "community" is not limited to a geographic location. Rather, a "community" could be a town, a city, or a human subpopulation (e.g., pregnant women, specific ethnic groups, infants and children).
[9] "Tool" is a broadly defined umbrella term that may include information, strategies, printed materials, web portals, databases, geographic information systems, videos, radio messages, drawings, story-telling, sacred fires, prayers and other spiritual ceremonies, as well as other methods (Barzyk et al. 2010).

Figure 1. The Vulnerability Assessment Schema



3.3 Foundational Elements

There are four key foundational elements for assessing the vulnerability of targeted audiences and building sustainable capacity outcomes. They form the base of the conceptual model.

3.3.1 Evidence-based Knowledge

The integration of knowledge and the adoption of a common language among stakeholders is an important step in increasing capacity to reduce vulnerability and improving the environmental health of communities. Equivalent weight is assigned to traditional and scientific knowledge.

3.3.2 Transdisciplinarity

Transdisciplinarity implies the participation not only of scientists but also of community representatives and others (including government officials), who, in addition to possessing particular knowledge of the problem at hand, have a role in addressing it. The complexity of the interaction between the various social, economic, and environmental links and health requires integrated strategies that go beyond interdisciplinary or multidisciplinary frameworks.[10] A transdisciplinary approach enables scientists from different disciplines and key contributors to develop a common vision, while preserving the richness and strength of their respective areas of knowledge (Lebel 2003). It also ensures that various perspectives of the problem will be taken into account.

3.3.3 Community Participation

Engagement is essential in enhancing a community's ability to address and prioritize its own health and environmental needs and, thus, develop a shared understanding of the problem. Community members or its representatives actively participate in pooling knowledge and developing solutions.

Strengthening partnerships and coalitions, and establishing long-term collaboration among stakeholders will assist the community to increase its self-reliance and capability to address specific environmental health issues.

3.3.4 Environmental and Gender Justice

This is a broad application of the term "justice," not only implying social and gender equity but also environmental justice (including ecological legacy and debt for future generations), the right to know, and respect for community priorities and interests. Equity for individuals across North America means that all must enjoy a healthy environment in which to live, learn, play and work. There is also a gender dimension of health that must be acknowledged. Beyond physiological differences, this dimension includes cultural characteristics of the social behavior of men and women and the relationships between them (Lebel 2003).

3.4 Identifying Factors that Characterize Vulnerability to Environmental Contamination

The factors listed in Table 2 under each of the four properties that characterize vulnerability were selected on the premise of understanding how social issues may interact with environmental contaminants and why some individuals, groups or communities experience greater vulnerability to the health effects of toxicants than other groups. They are intrinsically correlated and serve to describe different attributes of vulnerability. An illustrative case is the inherent vulnerability of children, which can be dramatically influenced by social factors. For example, a low

[10] The terms "multidisciplinary," "interdisciplinary" and "transdisciplinary" are increasingly being used in environmental health research, but are ambiguously defined and even interchangeably used. Choi and Pak (2006, 2007) comprehensively reviewed the definitions and uses of these terms, which can be summarized as follows: multidisciplinarity draws on knowledge from different disciplines but remains within their boundaries; interdisciplinarity analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole; and transdisciplinarity integrates the natural, social and health sciences and transcends their traditional boundaries and adopts a more holistic approach, frequently based on trust and mutual confidence.

socioeconomic status often means poor nutrition, low-quality housing in segregated neighborhoods (frequently associated with the proximity of industrial facilities or traffic emissions), with restricted access to various resources (including affordable, healthy food, schools, medical care system, etc.). This in turn may lead to future underemployment or even unemployment, which has the potential to propagate various psychosocial and economic problems (e.g., depression, increased chronic diseases, violence, smoking and alcohol use, substance abuse, and many other health outcomes) (Sexton and Hattis 2006; Menzie et al. 2007). This example illustrates the complex relationships among factors influencing vulnerability.

Table 2. Selected factors influencing vulnerability to environmental exposure to chemicals

Exposure	Susceptibility	Preparedness	Responsiveness
Chemical Release Factors (at the source): • Type of chemical (e.g., physicochemical properties, association with other chemicals in mixtures) • Release media (e.g., air, water, soil) • Site of release (e.g., proximity to populated areas) • Multiple routes of exposure (to one or multiple pollutants) *Environmental Factors (both natural and built):* • Housing quality and density • Land use patterns • Sanitation infrastructure • Traffic density • Noise • Geographic/climatic region • Proximity to chemical releases (e.g., industrial and recycling sites) • Climate variability • Natural disasters	*Biological Factors*: • Age • Sex • Genetic susceptibility • Biological stressors (e.g., acute and chronic disease status) • Compromised immune system • Preexisting health conditions • Repeated exposures (to one or multiple stressors) *Psychosocial Factors:* • Race/ethnicity • Socioeconomic status (including educational attainment) • Emotional state (e.g., depression, anxiety) • Social capital • Self-efficacy and empowerment (e.g., ability to participate in decision-making process) • Chronic and acute social stressors (e.g., conflict, crime)	*Structural Factors:* • Health and education infrastructure (e.g., access to affordable health care and schooling) • Local economy • Housing • Neighborhood physical conditions • Land use patterns • Employment (unemployment or underemployment) • Access to information and resources • Income • Health status (e.g., compromised health) • Self-efficacy and empowerment (e.g., ability to participate in decision-making process) • Language barriers • Access to communication channels *Psychosocial Factors:* • Socioeconomic status (including educational attainment) • Emotional state (e.g., depression, anxiety, stress) • Social capital	

Psychosocial Factors: • Gender roles • Race/ethnicity • Socioeconomic status • Segregation • Stress *Behavioral Factors:* • Occupational exposures • Past exposures • Time-activity patterns • Product use (and manner of use) • Diet • Subsistence practices	*Behavioral Factors:* • Hygiene • Diet • Smoking and substance abuse	• Self-efficacy and empowerment (e.g., ability to participate in decision-making process) • Chronic and acute social stressors (e.g., conflict, crime, violence) • Discrimination *Behavioral Factors*: • Nutrition • Hygiene • Diet • Product use • Smoking and substance abuse • Subsistence practices • Religious, spiritual and cultural practices

3.4.1 Exposure

3.4.1.1 Environmental Factors

Geographic Location

Where an individual lives can drastically affect his or her exposure to chemical contaminants. Certain populations are exposed to contaminants, such as POPs and mercury, even if they are located in regions that are remote from emitting sources because such chemicals are globally transported via atmospheric and oceanic currents (EC 2003; GEO-5 2012). Additionally, numerous studies have found that poor communities and racial or ethnic minorities tend to live in economically deprived neighborhoods. Real estate in such areas tends to be inexpensive, which attracts manufacturers to set up facilities. In other situations the opposite happens, where real estate value drops because facilities have moved in and set up operations. In either case, these facilities may emit toxic chemicals, and people who live or work near the facilities are potentially exposed to these chemicals (Morello-Frosch et al. 2011). This risk factor also applies to people living or working near roadways with high levels of vehicle traffic.

Residential segregation has been linked to an amplified association with numerous health outcomes (including asthma, neurological and respiratory disorders, stillbirth) caused by exposure to environmental contaminants, economic deprivation and reduced access to resources.

Climate Variability

Climate alterations—affecting temperature, precipitation, risk of floods and droughts, sea-ice retreat, ozone levels, and air quality—are expected to have an influence on the fate, distribution, toxicity and behavior of chemical contaminants (Noyes et al. 2009; Ma et al. 2011; Pascal et al. 2012). The nature of health outcomes associated with climate variability and the ability of individuals or communities to adapt and cope will depend on many factors (WHO, 2012; Health Canada, 2011). Some of them include age distribution, pre-existing health conditions, the physical, biological and social environment, and social and economic variables (e.g., education, access to health care system, employment, and local economy).

3.4.1.2 Psychosocial Factors

Gender Roles[11]

Gender differences in exposure are well documented for many substances. Every society tends to assign gender roles that influence activities and behaviors of women and men, girls and boys.

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[11] It is important to clarify the differences between sex and gender, which are often erroneously used interchangeably. Sex refers to the biologically recognized differences between men and women (e.g., hormonal makeup, internal and external sex organs). In contrast, gender refers to women's and men's roles and responsibilities that are socially determined or acquired. Gender is related to how women and men are perceived and expected to act, not because of biological differences but as a consequence of the way society is organized (WHO 1998). Exposure is influenced by various factors including chemical distribution, social, occupational, and behavioral differences.

Traditionally, women have been involved in caretaking roles and domestic duties, which can lead to higher risk from domestic exposure to chemicals in cleaning agents, household pesticides and indoor air pollution. For example, with respect to gender roles inside the home in specific communities, household use of solid fuels (e.g., for cooking and home heating) results in higher levels of certain pollutants (such as carbon monoxide, particulate matter, hydrocarbons, and nitrogen dioxide) associated with numerous respiratory problems in women than in men (Butter, 2006; Romieu et al. 2009).

Stress

Stress may influence the internal dose of a contaminant and, then, shift toxicity thresholds by weakening the immune system, and increasing the rate of absorption of toxicants through increased respiration, perspiration and consumption (Gordon, 2003; deFur et al. 2007).

3.4.1.3 Behavioral Factors

Unique Exposure Pathways

Some communities sustain unique environmental exposures because of practices linked to their cultural, spiritual, ceremonial and religious background, or socioeconomic status. Depending on its origin and the species consumed, diets high in fish or marine mammals can pose health risks from exposure to contaminants such as mercury, pesticides, and other persistent organic pollutants (Dallaire et al. 2004; van Oostdam et al. 2004; Hightower et al. 2006). Additionally, some communities may be affected by the combined effects of geographic exposure and behavioral patterns (e.g., people who exercise heavily along highly traveled roadways, and people who consume food from contaminated sources).

Occupational Exposure

Occupational exposure may be either direct (occurring in the workplace) or indirect (occurring at home). It constitutes a source of environmental inequalities. An example of direct occupational exposure would be farm workers, gardeners, and rural residents who experience heightened exposure to pesticides (Eskenazi et al. 1999; Baldi et al. 2003; Pearce et al. 2006). WHO estimates indicate that about 3 per cent of exposed agricultural workers world-wide suffer from an episode of acute pesticide poisoning every year (Thundiyil et al. 2008). These inequalities are amplified when associated with the gender and age of workers.

Indirect occupational exposures include those experienced by family members who may be exposed to occupational chemicals brought into the house by the worker (e.g., on clothing). Thus, workers and working class families may be subject to greater exposures than others in the population who do not have this additional burden.

3.4.2 Susceptibility

Individual response to chemical exposure varies from person to person. In a situation in which two people are exposed to an equal concentration of chemicals for an equal duration, a susceptible individual may experience adverse health effects, while another experiences less severe effects or none at all.

Everything else being equal, minority and low-income individuals or communities are generally at greater risk of suffering health outcomes related to environmental contamination than the general population, even at the same exposure levels. Studies have shown factors such as poverty, poor nutrition, tobacco and alcohol consumption, pre-existing health conditions (such as obesity, diabetes, and respiratory and cardiovascular diseases), psychosocial stress, and lack of access to affordable, healthy food, affordable health care, information, and high-quality green spaces and recreational programs, contribute to greater susceptibility of minority and low-income individuals to health risks, including those from exposure to environmental contaminants (Rios et al. 1993; Gee and Payne-Sturges, 2004; Morello-Frosch et al. 2011; Henning et al. 2012).

3.4.2.1 Biological Factors

Age

The elderly (i.e., individuals at or above 65 years of age) and children (including fetuses, newborns, infants, and adolescents) are often more susceptible to hazards once exposed to environmental pollutants. Heightened susceptibility of children is due to physiological differences, such as rates and extent of absorption, distribution, metabolism, and excretion of chemicals, and psychological differences, such as disparities in attitudes and behaviors when compared to adults (Faustman et al. 2000). More insight into children's susceptibility to environmental contaminants is provided in Box I, including effective ways to reduce their exposure to chemicals.

The elderly are more susceptible because of their weakened cardiovascular and respiratory systems, their altered immune response, higher prevalence of certain diseases and disorders, medical conditions, social isolation, and functional limitations and mobility impairments (Sandström et al. 2003).

Box I – Children’s Susceptibility to Environmental Chemicals

Paracelsus once pronounced “All things are poison, and nothing is without poison: the dose alone makes a thing not poison.” But, this proclamation only addresses the magnitude of exposure, and does not encompass the well-established relationships between exposure and toxicity. The timing of the exposure is also a critical factor that determines whether a chemical will cause toxicity in an exposed individual. Chemical exposure during prenatal and early postnatal life (to substances such as air pollutants, lead, mercury, pesticides, endocrine-disrupting chemicals) can bring about important effects on the baby’s development and growth, which may predispose him or her to disease during adolescence and adult life (Tulve et al. 2002; CEC 2006a, 2006b; Xue et al. 2007). Some substances are passed on to the baby through breast milk (e.g., trace metals, dioxins).

Children’s unique behavioral and physiological characteristics increase their exposure and susceptibility to environmental contaminants. Newborns and children are generally more exposed to environmental contaminants than adults because of their relatively larger absorptive surface areas, more rapid breathing, higher rate of ingestion, and hand to mouth exploratory behavior. Children are also more vulnerable to these environmental contaminants once exposed due to rapidly-developing, still immature organs and body systems, including the immune system (Nwachuku and Gerba 2004; Xue et al. 2010).

There are effective ways pregnant women can reduce their exposure to chemicals, including:

- Limiting consumption of marine mammals and fish high in mercury. For certain populations, this may conflict with cultural and spiritual considerations (Mozaffarian and Rimm 2006);
- Washing fruits and vegetables before consumption;
- Avoiding contact with pesticides, fertilizers and other household chemicals;
- Being aware of chemicals in household cleaning and personal care products; and
- Avoiding areas where the soil, water, or air is known to be contaminated.
  (Government of Canada 2012)

Genetic Makeup

Studies have found that certain genetic variations trigger physiological alterations and can eventually increase the health effects of certain pollutants (e.g., the effect of air pollution on chronic obstructive pulmonary diseases) (Morello-Frosch et al. 2011). A brief discussion about the potential effects of chemical exposure on future generational predisposition and susceptibility to health outcomes is presented in Box II.

Box II – Genetic Susceptibility

Epigenetics: During the last two decades, increased research has been devoted to the potential effects of environmental chemical exposure on heritable changes in gene expression—also known as epigenetics—and the likelihood of future generational predisposition to health and disease outcomes.

An increasing body of literature indicates that certain substances – including some trace metals, benzene, vinclozolin, methoxychlor, PAHs, particulate matter, PCBs, dioxins, Bisphenol A and others – may trigger epigenetic changes, leading to long-lasting changes in gene expression (Anway et al. 2005; Jirtle and Skinner 2007; Baccarelli and Bollati 2009; Bollati and Baccarelli 2010; Skinner et al. 2010; Kundakovic and Champagne 2011; Guillette and Iguchi 2012; Herbstman et al. 2012). Studies have demonstrated that given the bioaccumulation of dioxin and its half-life in humans (up to a decade), any woman becoming pregnant even 20 years after dioxin exposure may face the risk of transmitting dioxin effects to her fetus and later generations (Boekelheide et al. 2012; Manikkam et al. 2012a, 2012b). For example, a study of the population of Seveso, Italy, which in 1976 experienced exposure to high dioxin doses following an industrial accident, documented health effects in children of women who conceived as long as 25 years after the initial dioxin exposure (Baccarelli et al. 2008). Epigenetics has emerged as a potential tool for developing biomarkers to predict which exposures would put exposed individuals at risk and which individuals will be more susceptible to developing a disease.

Metabolomics: It has also become apparent that genetics have a major role in determining how an individual will metabolize a given chemical substance. The study of the unique metabolite profile of individuals is known as metabolomics. Since the toxicity of many chemicals is due to their metabolic conversion (bioactivation) to another chemical, an individual's genetic makeup is an important determinant of vulnerability to the hazard posed by chemicals whose toxicity requires metabolism to toxic metabolites. Similarly, genetic makeup is also an important determinant of the degree to which a person will respond clinically to a drug, and whether the person will tolerate the drug. The implications of genetics on individual variations in drug response (pharmacogenomics) are beginning to affect drug development, and an increasing number of drug labels approved by the US FDA now contain pharmacogenomic information (Ginsburg et al. 2005; Frueh et al. 2008). Integration and use of genetic biomarkers in drug development, regulation and clinical practice will undoubtedly continue to increase (Marrer and Dieterle 2007).

3.4.3 Preparedness and Responsiveness

3.4.3.1 Psychosocial Factors

Social Capital

Social capital, such as interpersonal trust, aid, social networks, and solidarity, can play an important role in determining the ability to prevent, withstand, or recover from environmental risks. Institutional, social and neighborhood resources may act as buffers against environmental risks. For example, supportive social relationships and work camaraderie may help promote health and well-being and, then, reduce the effects of environmental risks (Gee and Payne-Sturges 2004).

Self-efficacy

The capacity of individuals to feel empowered and meaningfully participate in the environmental and health decision-making process is critical in the characterization of vulnerability to environmental hazards. Factors contributing to lessened participation include language barriers (leading to fewer connections, and lower access to information or influence), socio-cultural issues, lack of trust, lack of information, low participation in the political process, limited access to technical and legal resources, and inability to access traditional communication channels (Hamilton 1993; Pastor et al. 2001).

3.5 Existing Tools for Assessing Individual or Community Vulnerability

There are a variety of web-based tools, peer-reviewed scientific articles, fact sheets, programs, and guidelines describing individual or community vulnerability to chemical contaminants, including C-FERST (Community-Focused Exposure and Risk Screening Tool), CEVA (Cumulative Environmental Vulnerabilities Assessment) and US EPA's Framework for Cumulative Risk Assessment. With a geospatial mapping component, most of these tools can be used to view and overlay publicly available data including chemical releases, pollution sources, environmental chemical concentrations, socioeconomic and demographic information, and ecosystem services. This information is restricted to a specific locality—usually determined by a postal address.

Currently, most available tools are web-based, which makes them broadly accessible, except to individuals without Internet access, such as low-income, rural, or remote communities across North America (Medina-Vera et al. 2010). Acknowledged limitations of these screening tools include environmental indicators being relatively crude; imperfect methodologies to compare and weight different factors, in-home exposure not being characterized, and the fact that postal address-based groupings (such as ZIP codes) do not break down the disparities within the grouping (Huang and London 2012). A list of selected available tools, websites, and databases can be found in Appendix B.

3.6 Application

This framework document has been developed to have broad application across North America. It can serve as a platform to foster collaboration and knowledge transfer among stakeholders, allowing them to communicate more effectively in an equal and open manner, as it enhances the community perspective in public decision-making processes that address environmental concerns. In addition, the framework can be a strategic step in tackling the creation of a multidisciplinary directory or network of individuals or organizations interested in environmental health across North America, and hence promote the establishment of strong, broad and sustainable partnerships amongst stakeholders.

Moreover, with the aid of this material, tailored tools can be created to characterize the vulnerability of specific communities to environmental contamination. Such tools should be developed in a clear and plain format and be user-friendly (i.e., use easy-to-understand vocabulary and are available in several languages). These tools need to consider alternatives to online resources, such as printed documents, radio programs, maps, cartoons (printed and video), holistic multimedia approaches (taking advantage of cultural practices), telephone messages, and stand-alone software (not requiring internet access).

The framework will also promote the exchange of information among governments and the use of CEC resources, including community-based projects such as the North American Partnership for Environmental Community Action (NAPECA), the *Taking Stock Online* database of reported North American industrial pollutant releases and transfers, and other databases.

Potential sustainable benefits from the framework document arise from its uses in:

- planning and organizing risk assessments and developing integrated environmental health impact assessments;
- developing tools for targeting and prioritizing communities needing urgent intervention, such as methods for screening and assessing sources of pollution;
- motivating and promoting multi stakeholder dialogues in ways that enhance community understanding and collaborative problem solving; and
- promoting more holistic thought and action, bridging the typical disciplinary silos (e.g., scientific, religious, spiritual, institutional, jurisdictional, geographic).

4. Challenges

The implementation of this framework is not without challenges and will require appreciable changes at various levels. There is a wide diversity of cultures, knowledge and education, ways of thinking and beliefs, languages and dialects, and territorial rights and governance across North America. Therefore, newly operational and widely accessible tools will be required to implement and use the document to its full potential. This section briefly describes some of the more significant challenges and offers a few strategies for addressing them.

4.1 Community Engagement

The focus of community engagement must shift from consultations to collaborative partnerships (e.g., coalitions in decision making). A sense of ownership and responsibility toward environmental health concerns must be created within the community. Strong participatory processes are not simple to articulate, and have to cope with the difficulties inherent to stakeholder involvement (including time, resources, defining stakeholders, participation requiring trust and mutual understanding, involvement being hindered by suspicion of some participants, etc.).

Strategy for Action: All community members have a role to play in preventing pollution and implementing practices that reduce chemical exposures. For example:

- Governments, nongovernmental organizations and private industries should work together to support the development of policies to provide protection from known and suspected environmental chemical hazards;
- Industry representatives should act to reduce their chemical releases and to find greener alternatives;
- Governments should help to ensure access to health care professionals, safe foods, and an environment with reduced chemical hazards;
- The scientific community and health care practitioners provide knowledge, expertise and advice on how chemicals and chemical mixtures in the environment can affect vulnerable communities and how to avoid or at least reduce exposure, and treat disease;
- Labor unions advocate workers' interests (including seasonal and migrant workers);
- Individuals, parents, and families provide a safe environment at home for children, the elderly, and other family members; and
- Citizens can reduce pollution through individual actions, changes in their consumption pattern (e.g., vehicle use, pesticides, personal care products, cosmetics, household cleaning products, etc.) and by engaging in public hearings to encourage industrial and commercial developers and local authorities to act according to the precautionary principle (e.g., through pollution prevention).

4.2 Scientific Knowledge

Scientists must respond to immediate intervention and decision-making needs, and through their research efforts increase knowledge and understanding of human exposure to chemical mixtures in the environment. For researchers, a major challenge can be to effectively communicate (in a common language) with community partners and to successfully compile, include, and understand traditional knowledge as a complement to scientific work. A serious difficulty can be anticipated in translating traditional knowledge and science into forms that are mutually intelligible and accessible to decision makers (Berkes et al. 2007). The knowledge, relationship, and connection that indigenous peoples have with nature make their traditional knowledge essential to a better understanding of the links between the environment and population health.

Strategy for Action: Strategic coalitions with citizens respected by their communities for their knowledge (e.g., elders, hunters, chief, shaman, teachers, physicians) will allow the integration of historical narratives and other local knowledge such as seasonal calendars, harvesting areas and other dialect-specific information.

Another major challenge is scientific uncertainty. Given the myriad chemicals now available, the many chemical combinations that are possible, and the byproducts that can result from their interactions in the environment, it is extremely complicated—if not impossible—to predict the toxicity of each of these compounds and their possible chemical combinations. Furthermore, it would be impossible to measure all chemicals and possible mixtures in all media to which humans and ecosystems are exposed. Additional uncertainty is created by several factors, for example:

- Many chemicals are transformed in the body, and the resulting products can also have biological activity that may or may not be similar to that of the parent chemical, hence even a single chemical may become a functional mixture once in the human body;
- A single chemical may lead to different health effects when exposure occurs at different ages, or is of different durations or magnitudes.
- Gather input from experts representing a wide range of scientific disciplines;
- Adopt an iterative approach to address and characterize uncertainty using the best available knowledge.

4.3 Government Involvement

Governmental authorities play an important role in protecting and improving the health and well-being of their citizens, while reducing the ecological debt for future generations. Therefore, governments need to play a key role in identifying and supporting communities in their efforts to protect the environment and safeguard their health. One of the most important challenges governmental institutions may face in the application of this framework is the allocation of resources to support environmental health programs that can develop tools to assist communities to characterize their vulnerability and also to support programs in pollution prevention (e.g., funding green chemistry research). Nonetheless, long-term funding of such programs may actually reduce costs to governments (e.g., establishing strategic alliances with nongovernmental organizations, industry, and community groups).

Strategy for Action: As a transdisciplinary approach, this framework will promote the interaction of official institutions, such as those involved in environmental protection, health, geographical information, demographics, socioeconomic data and legislation, which often work independently. Bridging the typical institutional silos can result in a wider and more comprehensive perspective of environmental health concerns, notably with vulnerable communities.

4.4 Knowledge Transfer and Communication

The exchange of knowledge, experiences, stories, and narratives amongst stakeholders is vital for a successful implementation of the framework. This requires the creation of a common language amongst stakeholders (such as official authorities, advocates, scientists, citizens, industrial officers). Gaps in communication, as well as differences among various stakeholder groups or jurisdictions in the capacity to develop tools, may pose important challenges to the use of the document.

Strategy for Action: Establishing a context for the framework document and developing communication tools targeted for the selected community will be crucial. Additionally, respect and understanding of the community's priorities is a key element in the effective implementation of the framework document.

Mechanisms for mentorship and training for communities should be fostered in order to demonstrate the effectiveness of implemented tools in other communities across North America with similar concerns. Trinational networks, partnerships, and resources—notably financial—are key components in the strategic implementation of this document.

With the help of community leaders, nongovernmental organizations, government officials, environmental justice advocates and industry representatives, communities can adapt the information provided in this document and develop not only the most effective ways to communicate this information but also the tools needed to reduce human vulnerability to chemical pollution. The document's widest possible distribution is key.

4.5 Global Production and Use of Chemicals

Another important consideration in the characterization of vulnerability of individuals and communities to the risks posed by chemicals in the environment is that new chemicals are constantly being produced and commercialized, with the annual production of existing chemicals generally fluctuating with consumer demand. This fact affects not only the specific chemicals to which one may be exposed, but also the extent of the exposures.

It has been estimated that global chemical production will grow at a rate of 3 percent per year, rapidly outpacing the rate of global population growth, estimated at 0.77 percent per year (UN 2004; GCO 2013). On this trajectory, chemical production will double by the year 2024, relative to the chemical production level of the year 2000 (OECD 2001; ACC 2003; UN 2004). If this forecast is true, while knowledge on risks and mitigation strategies will increase, so will environmental loading and the potential for exposure to these chemicals among humans and ecological receptors.

Consideration of the above for risk assessment purposes will undoubtedly be difficult for several reasons. First, the general public seldom knows when a new chemical enters the market place, whether as a component of a consumer product or for industrial use, as such information is generally not readily available to the general public. Also, since most pollutant release and transfer registries (e.g., the US EPA's Toxics Release Inventory) do not regularly add new chemical substances to their chemical lists, it is difficult to research whether a facility in one's community is manufacturing, processing or otherwise using a new chemical and, if so, to find the quantities of the chemical being released annually into the environment or otherwise managed as waste.

Also unknown are the potential risks to human health and the environment that may be posed by the individual chemicals that comprise (or will comprise) the expected increase in chemical production worldwide. Nor are the potential cumulative risks that may be posed from multiple exposures to these and other chemicals known. A confounding factor in assessing the risks posed by these chemicals is the extent to which hazard- and exposure-related information is available on these chemicals. While most countries have federal environmental authorities that impose regulatory controls on chemicals, these authorities have vastly different testing requirements for introducing new chemicals into commerce (Wilson and Schwarzman 2009). Therefore, the country in which a chemical is produced or used often determines the existence and availability of information on toxicity and other chemical-related matters.

Strategy for Action:

- Engage representatives from industry to share production data on new and existing chemicals;
- Adopt an iterative approach to address and characterize uncertainty using the best available production data.

5. Conclusions

There is an extensive yet incomplete body of knowledge on the impacts of chemicals on the health of both humans and ecosystems. Given the many factors that can affect health (chemical pollution, infectious and chronic diseases, gender, socioeconomic status, and marginality) and the complex interactions that can occur among them, it remains difficult to accurately estimate the health outcomes caused by environmental pollution.

This framework document emphasizes and addresses such entwined interactions and presents a list of factors—including chemical and non-chemical stressors—that need to be considered in characterizing the vulnerability of an individual or community to the health consequences posed by environmental contamination. *It has been developed to have broad application across North America and to support the creation of tools to characterize the vulnerability of targeted communities to environmental risks.*

The framework can serve as a *basis for planning and developing integrated environmental health impact assessments,* and as an *aid in prioritizing communities needing urgent intervention, by providing tools for screening and assessing sources of pollution. It can also be used to promote multi-stakeholder dialogues to enhance community understanding and collaborative problem solving*.

Implementing this framework presents opportunities and challenges and *will require appreciable changes at various levels. Newly operational and widely accessible tools will be required to implement and use the document to its full potential.* However, these tools will allow stakeholders to take more informed, effective, and accountable decisions toward reducing the vulnerability of individuals and communities to the health consequences of environmental contamination.

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Appendix A: Selected Existing Tools to Track Exposure to Chemical Mixtures

- AQHI (Air Quality Health Index). Environment Canada and Health Canada (http://www.ec.gc.ca/cas-aqhi/default.asp?Lang=En);
- CALENDEX™: Calendar-based dietary and non-dietary aggregate and cumulative exposure software system – USEPA (http://www.epa.gov/scipoly/sap/meetings/2000/september/calendex_sap_document_draft8_aug_2900.pdf);
- CalTox: (A total exposure model for Hazardous Waste Sites) (http://www.dtsc.ca.gov/AssessingRisk/caltox.cfm);
- CARES®: is a software program designed to conduct complex exposure and risk assessments for pesticides (http://www.ilsi.org/ResearchFoundation/Pages/CARES.aspx);
- CAREX (Carcinogen Exposure) Canada (http://www.carexcanada.ca);
- DEEM Dietary Exposure Evaluation Model: (http://www.epa.gov/oppfead1/cb/csb_page/updates/2011/dietary-exposure.html);
- OECD Quantitative Structure-Activity Relationship (QSAR) toolbox (http://www.oecd.org/env/ehs/risk-assessment/theoecdqsartoolbox.htm);
- ERICA Environmental Risk index for Chemical Assessment (Boriani et al. 2010);
- SHEDS Stochastic Human Exposure and Dose Model for Multimedia, Multipathway Chemicals (http://www.epa.gov/heasd/products/shesd_multimedia/sheds_mm.html);
- SUPERB (Study of Use of Products and Exposure-Related Behaviors) (Hertz-Picciotto et al. 2010);
- ToxTown: Environmental Health concerns and toxic chemicals where you live, play, and work (http://toxtown.nlm.nih.gov/flash/border/flash.php);
- US EPA's ASPEN Assessment System for Population Exposure Nationwide Model (http://www.epa.gov/ttnatw01/nata/aspen.html);
- US EPA's CoBRA (Co-benefits risk assessment screening model) (http://epa.gov/statelocalclimate/resources/cobra.html);
- US EPA's E-FAST (Exposure and Fate Assessment Screening Tool) (http://www.epa.gov/oppt/exposure/pubs/efast.htm);
- US EPA's Human Exposure and Atmospheric Sciences Program (http://www.epa.gov/heasd);
- US EPA's LifeLine™ (http://cfpub.epa.gov/crem/knowledge_base/crem_report.cfm?deid=152263)
- US EPA's Risk-Screening Environmental Indicators (RSEI) (http://www.epa.gov/oppt/rsei/);
- US EPA's ToxCast™ Screening Chemicals to Predict Toxicity Faster and Better (http://www.epa.gov/ncct/toxcast/);
- US EPA's TRIM.FaTE, TRIM.Expo and TRIm.Risk (Total Risk Integrated Methodology) (http://www.epa.gov/ttn/fera/trim_fate.html).

Appendix B: Selected Existing Tools Applicable to Community Vulnerability Assessment

Computerized Models and Databases

- California Communities Environmental Health Screening Tool (CalEnviroScreen) (http://oehha.ca.gov/ej/cipa073012.html);
- CALPUFF Modeling System (http://www.src.com/calpuff/calpuff1.htm);
- CEC's North American Pollutant Release and Transfer Registers (NAPRTR), *Taking Stock* report and *Taking Stock Online* (http://www.cec.org/Page.asp?PageID=751&ContentID=&SiteNodeID=1097&BL_ExpandID=&AA_SiteLanguageID=1);
- Chemicals in Toronto: Reduction and Awareness in our Community (ChemTRAC) (http://www.toronto.ca/health/chemtrac/index.htm);
- Community Cumulative Assessment Tool (CCAT) (http://www.epa.gov/research/healthscience/health-ccat.htm);
- Community-Focused Environmental Risk and Screening Tool (C-FERST) (http://www.epa.gov/heasd/c-ferst/);
- Community Health and Site Inventory Tools (ATSDR site tool and ATSDR dose calculator) (http://www.atsdr.cdc.gov/sites/brownfields/tools.html);
- Cumulative Environmental Vulnerabilities Assessment (CEVA) (http://regionalchange.ucdavis.edu/projects/current/ceva-sjv);
- Environmental Health Capa-City (US CDC) (http://www.cdc.gov/nceh/ehs/CapacityBuilding/Capa-City.htm);
- Environmental Justice Screening Method (http://www.arb.ca.gov/cc/ejac/meetings/060910/presentation.pdf);
- Integrated Assessment of Health Risks of Environmental Stressors in Europe - INTARESE (http://www.intarese.org);
- Integrated Health Impact Assessment System (IEHIAS) (http://www.integrated-assessment.eu);
- Novel Methods for Integrated Risk Assessment of Cumulative Stressors in Europe (NOMIRACLE) (http://nomiracle.jrc.ec.europa.eu/default.aspx);
- SCORECARD. Environmental Scorecard (http://scorecard.goodguide.com);
- The Tiered Protocol for Endocrine Disruption (TiPED™) (http://www.tipedinfo.com);
- Tribal-Focused Environmental Risk and Sustainability Tool (T-FERST) (http://www.epa.gov/research/healthscience/health-tferst.htm);
- US CDC's National Center for Environmental Health and National Association for Country and City Health Officials Protocol for Assessing Community Excellence in Environmental Health (PACE EH) (http://www.cdc.gov/nceh/ehs/CEHA/);
- US CDC's National Environmental Public Health Tracking Network (http://ephtracking.cdc.gov/showHome.action);
- US EPA's Consolidated Human Activities Database (CHAD)

(http://www.epa.gov/chadnet1/);

- US EPA's Decision Analysis for a Sustainable Environment, Economy and Society (DASEES) (http://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=238232);
- US EPA's EnviroAtlas (http://www.epa.gov/research/healthscience/health-nationalatlas.htm);
- US EPA's Envirofacts (http://www.epa.gov/enviro/);
- US EPA's Enviromental Justice Strategic Enforcement Assessment Tool (EJSEAT) (http://www.epa.gov/compliance/ej/resources/policy/ej-seat.html);
- US EPA's National Scale Air Toxic Assessment (NATA) (http://www.epa.gov/nata/);
- US EPA's Risk-Screening Environmental Indicators (RSEI) Model (http://www.epa.gov/oppt/rsei/);
- US National Institutes of Health—Toxicology Data Network (TOXNET) (http://toxnet.nlm.nih.gov);
- US National Institutes of Health—ToxTown (http://toxtown.nlm.nih.gov);
- US EPA's Toxics Release Inventory Program—Chemical Hazard Information Profiles (TRI-CHIP) (http://www.epa.gov/tri/tri-chip/).

National and International Programs

- Environmental Initiatives' (ICLEI) Climate Resilient Communities™ (CRC) Program (http://www.icleiusa.org/climate_and_energy/Climate_Adaptation_Guidance/climate-resilient-communities-program);
- Health and Environment Integrated Methodology and Toolbox for Scenario Assessment (HEIMTSA) (http://www.heimtsa.eu);
- Health Impact Assessment (HIA) in Mining Projects Canada; International Council for Local (http://www.fmed.ulaval.ca/eis/index.php?id=80&L=1);
- National First Nations Environmental Contaminants Program (NFNECP) (http://www.environmentalcontaminants.ca/Home/tabid/63/language/en/Default.aspx);
- Promoting Environmental Health in Communities (PEHC) ATSDR's Environmental Health and Medicine Education Program (http://www.atsdr.cdc.gov/emes/public/);
- The Early Life Exposure in Mexico to Environmental Toxicants (ELEMENT) Project (http://sitemaker.umich.edu/merg/element);
- UN Health and Environment Linkages Initiative (HELI) (http://www.who.int/heli/en/);
- US CDC's Climate and Health Program (http://www.cdc.gov/climateandhealth/default.htm);
- US CDC's Community Environmental Health Assessment (CEHA) (http://www.cdc.gov/nceh/ehs/CEHA/);
- US CDC's Designing and Building Healthy Places (http://www.cdc.gov/healthyplaces/);
- US CDC's Environmental Health Capacity Building (http://www.cdc.gov/nceh/ehs/CapacityBuilding/);
- US CDC's Health Impact Assessment (http://www.cdc.gov/healthyplaces/hia.htm);
- US EPA's Bioaccumulative and Toxic (PBT) Chemical Program

(http://www.epa.gov/pbt/pubs/pbtsandyou.htm);

- US EPA's Community Action for a Renewed Environment (CARE). (http://www.epa.gov/care/basic.htm);
- US EPA's Extramural Research (http://www.epa.gov/ncer/);
- US EPA's Endocrine Disruptor Screening Program (EDSP) (http://www.epa.gov/endo/);
- US EPA's Integrated Risk Information System (IRIS) Program (http://www.epa.gov/IRIS/);
- US EPA's Regional Vulnerability Assessment (ReVA) Program (http://www.epa.gov/reva/);
- US EPA's Sustainable and Healthy Communities Research Program (http://www.epa.gov/ord/research-programs.htm).

Factsheets and Reports

- ATSDR Promoting Environmental Health in Communities Factsheets: Chemicals, Cancer, and You; Health Effects of Chemical Exposure; How Chemicals Exposures Happen; How to Reduce your Exposure to Chemicals at Home, Work, and Play; and Sensitive Populations (http://www.atsdr.cdc.gov/emes/public/promoting_environmental_health.html);
- Canada's National Strategic Framework on Children's Environmental Health (http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/Framework_children-cadre_enfants/index-eng.php);
- CEC's Children's Health and the Environment in North America: A First Report on Available Indicators and Measures (CEC 2006a);
- CEC's Toxic Chemicals and Children's Health: A Call for Efforts to Determine the Sources, Levels of Exposure, and Risks that Industrial Chemicals Pose to Children's Health (CEC 2006b);
- Community Action for a Renewed Environment—Publications (e.g., The Road Map) (http://www.epa.gov/care/publications.htm);
- Community Environmental Health Assessment (CEHA) Toolbox for New Mexico (http://nmhealth.org/eheb/documents/CommunityEnv.HealthAss.pdf);
- Community Health Map: A Geospatial and Multivariate Data Visualization Tool for Public Health Datasets (Sopan et al. 2012);
- Cumulative Environmental Vulnerability Assessment and Environmental Justice in California's San Joaquin Valley (Huang and London 2012);
- Environmental Justice Screening Method (Sadd et al. 2011);
- Environmental Risk Index for Chemical Assessment (ERICA) (Boriani et al. 2010);
- US CDC's Environmental Public Health Performance Standards (EnvPHPS) and EnvPHPS Assessment Toolkit (http://www.cdc.gov/nceh/ehs/envphps/);
- *Secretaría de Salud—Programa de Acción. Salud Ambiental* (http://www.cofepris.gob.mx);
- US CDC's National Environmental Public Health Tracking Network

(http://ephtracking.cdc.gov/showHome.action);

- US EPA's Exposure factors Handbook 2011 (http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252);
- US EPA's Framework for Cumulative Risk Assessment (http://www.epa.gov/raf/publications/framework-cra.htm);
- US EPA's Report on the Environment (http://www.epa.gov/roe/);
- US EPA's Toolkit for Assessing Potential Allegations of Environmental Injustice (http://www.epa.gov/compliance/ej/resources/policy/ej-toolkit.pdf).

Selected Institutional Websites

- Canada's Environmental and Workplace Health—Health Canada (http://www.hc-sc.gc.ca/ewh-semt/hazards-risques/index-eng.php);
- Canada's Northern Contaminants Program Aboriginal Affairs and Northern Development (http://www.aadnc-aandc.gc.ca/eng/1100100035611/1100100035612?utm_source=ncp&utm_medium=url);
- Canada's National Collaborating Centre for Aboriginal Health (http://www.nccah-ccnsa.ca/en/);
- Canada's National Collaborating Centre for Methods and Tools (http://www.nccmt.ca);
- Canada's National Inuit Organization—Inuit Tapiriit Kanatami (http://www.itk.ca);
- Canada's National Pollutant Release Inventory—Environment Canada (http://www.ec.gc.ca/inrp-npri/Default.asp?lang=En&n=4A577BB9-1);
- CEC's Pollutant Release and Transfer of Registers (PRTR) (http://www.cec.org/Page.asp?PageID=751&ContentID=&SiteNodeID=1097&BL_ExpandID=&AA_SiteLanguageID=1);
- Center for Environmental Research and Children's Health—The CHAMACOS exposure study (http://cerch.org/research-programs/chamacos/);
- Centre for Inuit Health and Changing Environments (http://www.nasivvik.ca);
- Chemical Right to Know (http://www.chemicalright2know.org);
- Creating Healthy Environments for Kids (http://www.healthyenvironmentforkids.ca);
- Environment and Health—Public Health Agency of Canada (http://www.phac-aspc.gc.ca/hp-ps/eph-esp/index-eng.php?rd=environ_eng);
- Environmental Indicators—Environment Canada (http://www.ec.gc.ca/indicateurs-indicators/);
- Environmental and Workplace Health Canada (http://www.hc-sc.gc.ca/ewh-semt/index-eng.php);
- Environmental Health for First Nations and Inuit Health Canada (http://www.hc-sc.gc.ca/fniah-spnia/promotion/public-publique/index-eng.php);
- First Nations Food, Nutrition and Environment Study (http://www.fnfnes.ca);
- Healthy Canadians Government of Canada (http://www.healthycanadians.gc.ca/index-eng.php);
- Healthy Canadians: A Healthier World—Public Health Agency of Canada

(http://www.phac-aspc.gc.ca/about_apropos/);

- Health Impact Assessment Institut national de santé publique du Québec (http://www.ncchpp.ca/54/Health_Impact_Assessment.ccnpps);
- Indigenous People's Health Research Centre (http://www.iphrc.ca);
- Mexico's Instituto Nacional de Salud Pública—Secretaría de Salud (http://www.insp.mx);
- Mexico's Registro de Emisiones y Transferencia de Contaminantes (RETC) (http://www.semarnat.gob.mx/temas/gestionambiental/calidaddelaire/Paginas/retc.aspx);
- Mexico's Subscretaría de Prevención y Promoción de la Salud Secretaría de Salud (http://www.spps.gob.mx);
- Mexico's Secretaría de Medio Ambiente y Recursos Ambientals (Semarnat) (http://www.semarnat.gob.mx/Pages/Inicio.aspx);
- Mexico's Instituto Nacional de Ecología (http://www.ine.gob.mx);
- Mexico's Sistema Nacional de Información en Salud (Sinais) (http://www.sinais.salud.gob.mx);
- Mexico's Comisión Nacional para el Desarrollo de Pueblos Indígenas (http://www.cdi.gob.mx);
- The Centre for Environmental Health Equity (http://www.cehe.ca);
- The State of New Jersey Department of Environmental Protection (NJDEP) (http://www.state.nj.us/dep/);
- The California Wildlife Biology, Exposure Factor, and Toxicity Database (Cal/Ecotox) (http://oehha.ca.gov/cal_ecotox/);
- UN's United Nations Environment Programme—The Global Chemicals Outlook (http://www.unep.org/hazardoussubstances/UNEPsWork/Mainstreaming/GlobalChemicalsOutlook/tabid/56356/Default.aspx);
- US CDC's National Center for Environmental Health (NCEH) (http://www.cdc.gov/nceh/);
- US Department of Health and Human Services—Climate Change and Human Health (http://www.niehs.nih.gov/research/programs/geh/climatechange/);
- US Department of Health and Human Services—Office of Minority Health and Health Disparities (OMHD) (http://www.cdc.gov/omhd/);
- US Department of Health and Human Services—Environmental Health National Institutes of Health (http://www.niehs.nih.gov);
- US Department of Health and Human Services—Environmental Health and Toxicology (http://sis.nlm.nih.gov/enviro.html);
- US Department of Health and Human Services—Health People 2020 (http://www.healthypeople.gov/2020/default.aspx);
- US Department of Health and Human Services—National Institute on Aging (http://www.nia.nih.gov);
- US Department of Health and Human Services—Indian Health Service. The Federal Program for American Indians and Alaska Natives (http://www.ihs.gov);
- US EPA's Community Action for Environmental Public Health (http://www.epa.gov/communityhealth/);

- US EPA's America's Children and the Environment (http://www.epa.gov/ace/);
- US EPA's Children's Environmental Health and Disease Prevention Research Centers (CEHCs) (http://epa.gov/ncer/childrenscenters/);
- US EPA's Extramural Research—Environment, Health and Society (EHS) (http://www.epa.gov/ncer/ehs/);
- US EPA's Human Exposure and Atmospheric Sciences (http://www.epa.gov/heasd/);
- US Partnership for Sustainable Communities (US Department of Housing and Urban Development—US Department of Transportation and US EPA) (http://www.sustainablecommunities.gov).

National and International Environmental Health Networks:

- Alaska Native Tribal Health Consortium (ANTHC) (http://www.anthc.org/chs/ces/);
- Canada's Community of Practice in Ecosystem Approaches to Health—CoPEH (http://www.copeh-canada.org);
- Canadian Women's Health Network (http://www.cwhn.ca/en);
- Community of Practice in Ecosystem Approaches to Health—CoPEH Latin America and the Caribbean (http://www.una.ac.cr/copehlac/);
- First Nations Environmental Health Innovation Network—FNEHIN (http://www.fnehin.ca);
- Health and Environment Networking Portal—HENVINET (http://www.henvinet.eu);
- US CDC's Environmental Health Specialists Network (EHS-NET): (http://www.cdc.gov/nceh/ehs/EHSNet);
- US CDC's National Environmental Public Health Tracking Network (http://ephtracking.cdc.gov/showHome.action).

Appendix C: Glossary

This section lists a collection of terms used in the framework and other terms that may be of interest and can be found in related literature.

Adaptation

Adjustments to enable compatibility with surrounding conditions or environment.

Capacity

Refers to the combination of all strengths, attributes, and resources available to an individual, community, society, or organization that can be used.

Chemical Carcinogen

Chemical agent that is known, or believed, to cause cancer in humans.

Chemical Exposure

The amount of a chemical contaminant at the outer boundary of the body available for exchange or intake via inhalation, ingestion, skin or eye contact, and maternal transmission.

Chemical Sensitivities

The degree to which one will experience an adverse effect following a low level of exposure to a chemical. Some people (sensitive populations) cannot tolerate chemical exposure as well as others. Some chemical sensitivities are idiosyncratic. That is, only a few people are sensitive to a given chemical, whereas most others are not.

Chronic stress

The cumulative load of major or minor day-to-day stressors that can have long-term consequences and potentially lead to immune dysfunction.

Community

Given that this framework is to have trilateral application, “community” will be viewed in a continental context, that is, a community could be: a given location such as a town or a village, or a postal code locality; a particular category of people living in the same or different geographical location; or a particular human subpopulation, such as children, pregnant women, an indigenous population, or an ethnic group, to name a few.

Cumulative Exposure

The total amount of a chemical or chemicals with which an individual has come into contact over a given time interval following continuous, intermittent, or simultaneous exposure to the chemical(s). In the context of this framework these chemicals generally do not include nutrient chemicals or chemicals that are otherwise essential to life.

Cumulative Exposure Assessment

The appraisal of simultaneous, overlapping, and/or sequential exposure.

Cumulative Risk

The combined risks to health from cumulative exposure to multiple agents or stressors, including biological (e.g., *Mycobacterium tuberculosis*), chemical (e.g., toluene), physical (e.g., noise) and psychosocial (e.g., job- or family-related) entities.

Cumulative Risk Assessment

The process used to determine cumulative risk.

Differential exposure

Refers to differences in the magnitude, duration, frequency, or timing of exposure as well as dissimilarities in historical and background exposure levels and related body burden that can affect the likelihood, nature, and severity of adverse effects.

Environment

The term environment encompasses the natural, built and social worlds.

Environmental chemical

A natural or anthropogenically produced chemical present in air, water, food, soil, dust, or other media.

Environmental justice

The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Environmentally attributable fraction (EAF)

The percentage of a particular disease category that would be eliminated if environmental risk factors were reduced to their lowest feasible levels (Boyd and Genuis 2008).

Epigenetic

The regulation of gene expression by the chemical modification of DNA or of proteins in which DNA is usually wrapped.

Physical Environment

The universal set of all things external to the individual, excluding the social environment with which there is, of course, perpetual interaction. It comprises the full spectrum of biological, physical and chemical entities, whether natural or man-made.

Precautionary principle/approach

A principle or approach that highlights a duty to prevent harm.

Preparedness

A state usually linked to the kind of coping systems and resources an individual, population, or community has: the more prepared, the less vulnerable (US EPA 2003).

Psychosocial stress

It refers to everyday chronic stressful experiences related to social environments in families, the household, the workplace, neighborhoods, schools, etc.

Resilience

The capacity of individuals, groups of individuals and communities to cope successfully in the face of adversity or risk. Ability to recover (similar to resilience): to reflect traits that allow the organism, individual, or group to heal from, or compensate for, the effects of exposure to environmental agents or stressors.

Risk

The chance or likelihood that harmful effects to human health or to ecological systems will occur as a result of exposure to an environmental stressor.

Risk Assessment

The identification and characterization of the potential for a chemical or other environmental stressor to cause harm. The term can be used to predict the likelihood of many unwanted occurrences, including unintended exposures, industrial accidents, occupational exposure, workplace injuries, failure of machine parts, natural catastrophes and disasters, and the presence of infectious or vector borne agents, among others. Its ultimate goal is to protect human health and the environment by providing decision makers with information that can be used to minimize risks posed by environmental agents.

Social Environment

Encompasses the immediate physical surroundings, social relationships, and cultural milieu within which defined groups of people function and interact. It can be experienced at multiple scales, often simultaneously (such as household, neighborhoods, town, cities and regions). Components of the social environment include built infrastructure; industrial and occupational structure; labor markets; social and economic processes; wealth; social, human, and health services; power relations; government; race relations; social inequality; cultural and spiritual practices; the arts; religious institutions and practices; and beliefs about place and community.

Stakeholder

An individual, group of people, community, organization (public or private), business, or other party that has an interest in a specific activity.

Stressor

Any physical, chemical, or biological entity that can induce an adverse response.

Susceptibility

Refers to an increased likelihood of sustaining an adverse effect. For example, susceptible persons or populations may be those who are significantly more liable than the general population to be affected by a stressor due to life stage (e.g., children, the elderly, or pregnant women), genetic polymorphisms, prior immune reactions (e.g., individuals who have been "sensitized" to a particular chemical), or health state (e.g., asthmatics). Confronted with equal concentrations of a chemical for equal durations, for example, a susceptible individual may show effects, whereas the typical individual within the population would have no or less severe effects (US EPA 2003).

Traditional Knowledge

Indigenous knowledge is referred to in a number of ways, including but not limited to "local knowledge," "traditional knowledge," "indigenous technical knowledge," "peasants knowledge" "traditional environmental knowledge (TEK)" and "folk knowledge" (Sillitoe 1998). To summarize relevant literature, indigenous knowledge is considered to be a body of knowledge existing within or acquired by local people over a period of time through accumulation of experiences, society-nature relationships, community practices and institutions, and by passing it down through generations. TEK is based on diachronic observations accumulated over generations of detailed observation and interactions with local ecosystems.

Vulnerability

The propensity of individuals, specific subpopulations, or other groups (communities) of people or ecological systems to suffer harm from external stress and perturbations (Kasperson et al. 1995). The term “vulnerability” is specifically used in this document to mean the intrinsic propensity of an exposed entity to experience adverse effects from external agents, events, perturbations, or stresses.