4

Exposure

EXPOSURE

Exposure is any direct contact between a substance and an individual, whether by touching, breathing, or swallowing material from a source. Contaminants must follow pathways from the point of release into the environment to the point of contact with humans in order for exposure to take place.

4.1 Exposure Pathways

An **exposure pathway** describes how a contaminant travels through the environment from its source to humans or other living organisms. An exposure pathway consists of the five following elements:

- source of contamination;
- environmental media;
- point of exposure;
- receptor person or population; and
- route of exposure.

Source of Contamination

Sources of environmental contaminants are numerous. They include exhaust from vehicles, emissions from smokestacks, waste water released by factories and mills, waste disposal sites, closed factories and storage sites, consumer products (e.g., paints, household cleaning products) and numerous other sources, both indoors and outdoors. A number of substances are also released into the environment from natural sources (volcanoes, forest fires).

Environmental Media

Once released from its source, a contaminant will travel through the air, water or soil (environmental media) to points where human exposure can occur. In humans, the major environmental media can include water, soil, air, and food products:

Water

Water is essential to sustain life. Groundwater and surface water, however, can be important in exposure to contaminants.

Groundwater (water below ground, such as from aquifers and wells)

- drinking water from wells (municipal or domestic), bathing, showering;
- industrial, agricultural or recreational use of groundwater(e.g., swimming pools); and
- recreational and other use of natural springs, sink holes.

Surface water (water from lakes, rivers, and ponds)

- drinking water (municipal or domestic), bathing, showering;
- recreation, such as windsurfing, canoeing, and swimming; and
- industrial or agricultural use.

Soil (including Dust and Sediment)

Soil and dust are important carriers of environmental contaminants, especially for small children who may inadvertently ingest soil or dust through normal activities. Examples of possible sources follow:

- bare ground (exposure of workers to soil, swallowing soil, or skin contact with soil);
- contaminated soil blown as dust in the air and particles deposited on other surfaces (such as food);
- soil below the surface (workers involved in digging and excavating);
- contaminated sediments, both chemical and microbial, in river and lake bottoms. Sediment is comprised of soil (or silt), plant, and animal matter which settles at the bottom of lakes, rivers and ponds; and
- sediments that have been resuspended in the water by activities such as shipping and dredging.

Soil may also act as a contaminant reserve, contaminating groundwater and air by slow leaching and volatilization, and may also contaminate agricultural produce through incorporation into foods during cultivation. Sediment can act as a sink for contaminants that chronically contaminate the overlying body of water.

Air

Air is capable of transporting contaminants widely and quickly. In many instances, some contaminants may be more concentrated indoors than outdoors. The following are examples of contaminants carried by air:

- contaminant gases and vapours from combustion processes (e.g., car exhaust, home heating, industrial processes);
- gases and vapours from contaminated soils or water bodies;
- contaminants adsorbed onto airborne dust and particles;

- bacteria and fungi (spores) dispersed indoors from humidifying, heating and ventilation systems; and
- gases from paints, glues, solvents, building materials and furniture in homes and offices, and radon gas seeping into homes from surrounding soils.

Food

Food provides an important medium for exposure to many persistent contaminants and to micro-organisms. Exposure may result from ingestion of:

- foods grown with contaminated water or grown in areas where the soil is contaminated, (in general, these foods would be for personal consumption, as foods produced under these conditions would not be permitted for sale in the marketplace);
- contaminated fish and wildlife;
- pesticide residues on food;
- packaging, e.g., lead-soldered cans used in some imported goods; and
- mother's milk (for nursing infants) where the mother has been exposed to chemicals, which are then mobilized to breast milk.

Point of Exposure

The point of exposure is the location where contact with a contaminant occurs. For example, people can be exposed to contaminants in the home, a business, a playground, a lake, river or other body of water.

Receptor Person or Population

The receptor person or population are those who are exposed to the contaminant at the point of exposure. For example, swimmers may be exposed while bathing in a contaminated river; anglers may be exposed by consuming contaminated fish that they have caught.

Routes of Exposure

People can be exposed to contaminants in water, air, food, and soil in several different ways. The exposure route is the final link in the chain from the contaminant source through the exposure pathway to people. The exposure route describes how the contaminant enters the body. The three main routes are:

- **Ingestion:** Swallowing food, water, small amounts of soil and accidental ingestion of objects or other liquids containing the contaminant. The mouth, throat, stomach, and intestines can absorb ingested materials rapidly and at different rates, depending on the material.

- **Inhalation:** Breathing in a contaminant, such as a gas, vapour, or airborne particles. This includes small amounts of soil and dust that can be inhaled into the lungs. The lungs often absorb gases and vapours quickly and efficiently.
- **Dermal (skin) contact:** Some contaminants in water, soil or air can be absorbed through the skin. The skin can act as an efficient barrier to many contaminants. In the case of radioactivity, exposure can occur through penetration of the skin by radioactivity in the atmosphere, or released from radionuclides that are in the air or on the ground. The radionuclide does not actually need to be in contact with the skin.

The major pathways of human exposure to environmental contaminants are shown in Figure 4.1.

Food ingestion is the major exposure pathway for many persistent chemicals such as DDT, polychlorinated biphenyls and some metals such as mercury, with air, water, and soil products contributing only small amounts to the total human exposure. Based strictly on environmental contaminants, ingestion of untreated drinking water is the most important exposure pathway for micro-organisms. However, due to improper storage and handling, food is an important pathway for exposure to micro-organisms causing illness.

Exposure to ionizing radiation from radionuclides in environmental media may also occur by direct external irradiation.

4.2 Absorption

It is important to remember that exposure to chemicals does not always result in their absorption into the body. The lungs, digestive system and especially the skin can present very effective barriers to many substances. For instance, inhaled substances can be cleared from the lungs through normal processes, such as mucociliary action. Absorption of chemicals may vary depending on the route of exposure. For example, a substance that is readily absorbed through the respiratory tract may not be as readily absorbed through the gastro-intestinal tract or skin, and vice versa. The absorption of a chemical is affected by its chemical and physical properties.

Substances that are absorbed can be transported throughout the body by the bloodstream. Once in the body, these substances can be either metabolized, excreted, or stored. When the intake exceeds excretion, these substances are said to accumulate.

Micro-organisms behave differently from chemical contaminants. Drinking water contaminated with micro-organisms can cause diarrhea, nausea, cramps and other intestinal upsets. Irritant substances such as detergent ingredients, sawdust and ore from mining can cause dermatitis on the contacted areas of the skin without absorption into the body. Radionuclides can exert effects through indirect and direct contact.

4.3 Estimated Daily Intake

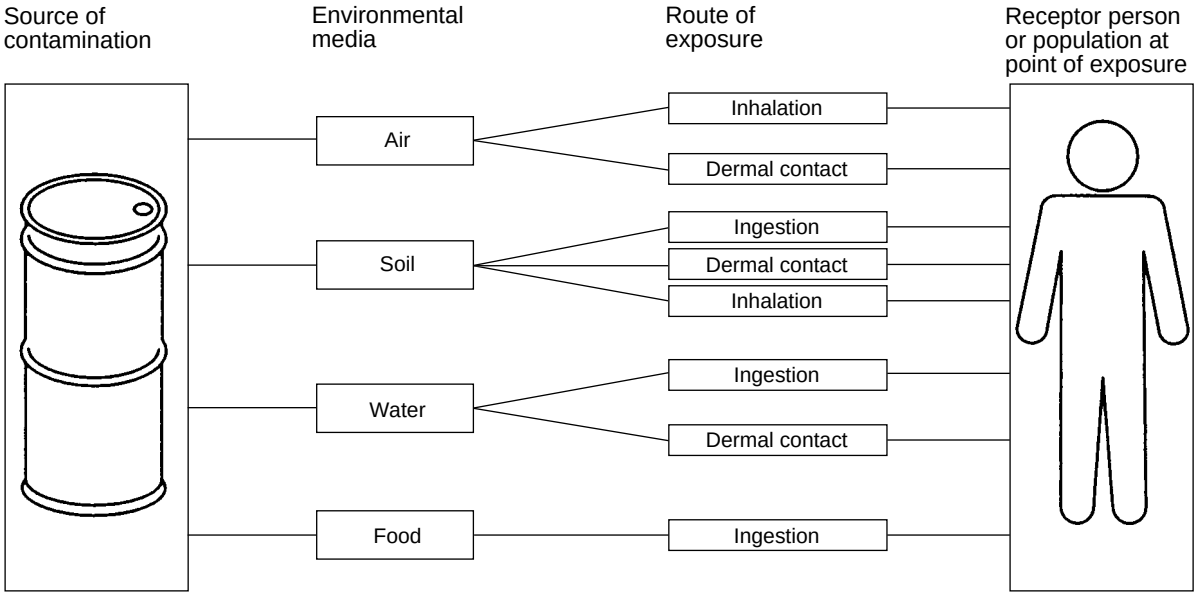
People are exposed to low levels of contamination in the air they breathe, in the food they eat, and in the water they drink. In detailed exposure assessments, this exposure is quantified and called the estimated daily intake (EDI). A separate EDI is calculated for each contaminant of concern. The EDI is the sum of exposures from all known or suspected exposure pathways for an average person. Numerous other factors must be considered and assumptions made, making these types of estimates complex. The information in the box below gives a basic overview of the type of calculations involved.

4.4 Assumptions and Inferences

Estimates of exposure are performed on a case by case basis and take into account a variety of factors, such as the age, sex, diet, lifestyle and number of people at risk. Other factors include body weight and surface area, breathing rates, water and food consumption rates, duration of exposure and length of life. Based on the data available for each case, it is often necessary to make assumptions around these factors when estimating exposure. Consequently, the more comprehensive the data available, the fewer the number of assumptions made.

Figure 4.1

Major Pathways of Human Exposure to Environmental Contaminants



CALCULATING THE ESTIMATED DAILY INTAKE

Estimated daily intake (EDI) of a chemical can be calculated by adding up all the exposures from various pathways. The EDI of one contaminant can be represented by the following equation:

$$\mathbf{EDI = ED_a + ED_w + ED_s + ED_f + ED_{ws} + ED_{ss}}$$

Each ED (Estimated Dose) is the amount of the contaminant taken in through a different combination of exposure pathway and exposure route. Specifically:

ED_a is the amount inhaled through the air

ED_w is the amount taken in by drinking water

ED_s is the amount taken in by eating soil

ED_f is the amount taken in with food

ED_{ws} is the amount absorbed through skin contact with contaminated water

ED_{ss} is the amount absorbed through skin contact with contaminated soil

To calculate the estimated amount of the contaminant taken in through each exposure pathway requires a different equation for each. However, all the equations are somewhat similar. The general equation for each estimated dose is:

$$\mathbf{ED = \frac{C \times CR \times EF}{BW}}$$

where,

ED = Estimated dose, which is generally the number of milligrams of the contaminant that enter the body each day for each kilogram of body weight (mg/kg/day).

C = Concentration of the contaminant in the exposure pathway being considered.

CR = Contact rate is the amount of water, food, air, etc. that is swallowed, inhaled or comes into contact with the skin in one day. Typical units for food eaten are grams per day (g/day).

EF = Exposure factor indicates how often the individual is exposed during a year and the number of years that this pattern has been repeating itself. This factor is needed especially when exposure does not occur daily, such as exposures at work (only five days a week) or exposures related to seasonal activities (swimming in the summer in contaminated water).

BW = Body Weight is average body weight of an individual in kilograms (kg).

Source: Health Canada. *Investigating Human Exposure to Contaminants in the Environment: A Handbook for Exposure Calculations*. Ottawa, 1995.

Exposure Handbooks Available

- The Great Lakes Health Effects Program of Health Canada has prepared two handbooks to assist communities in understanding the relationship between their health and the environment. The handbooks, entitled *Investigating Human Exposure to Contaminants in the Environment* are designed as tools to help individuals or groups to carry out studies in their communities. They also allow the interested public to understand how such studies are done.
- The first, *A Community Handbook*, gives an overview, describes the steps in carrying out community exposure and health studies, and provides background information and sources of further information. The second volume, *A Handbook for Exposure Calculations*, provides detailed instructions and examples for calculating human exposure to environmental contaminants.
- For further information about the Great Lakes Health Effects Program or to obtain these handbooks contact:

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