Conducting Occupational and Environmental Exposure Assessments

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PURPOSE. The purpose of this technical information paper (TIP) is to educate what exposure science and exposure assessments are, why exposure assessments are necessary, and provide guidance for conducting exposure assessments for use in occupational and environmental exposure assessments.

REFERENCES.

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INTRODUCTION.

Overview

Exposure science is the study of human contact with chemical, physical, or biological hazards present in their environments, and advances knowledge of the mechanisms and dynamics of events either causing or preventing adverse health outcomes. Exposure science applies to all levels of biologic organization which includes ecologic, community, or individual. Detecting potential environmental hazards are essential for protecting soldiers and the general public.

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A receptor-based approach to exposure assessments is designed to determine if individuals are actually exposed to hazards, at what level, and from what sources. In risk assessment the source is the origin of a hazard and the medium is the material (air, water, soil, etc.) that surrounds or contains the hazard.

Hazards can be defined as any physical, biological, or chemical change in the natural environment that impacts the growth, development, reproduction or physiology of organisms in that environment. The relationship between source activities, environmental concentrations, exposure, dose, and health effects can be described as the environment-health chain shown in Figure 1.

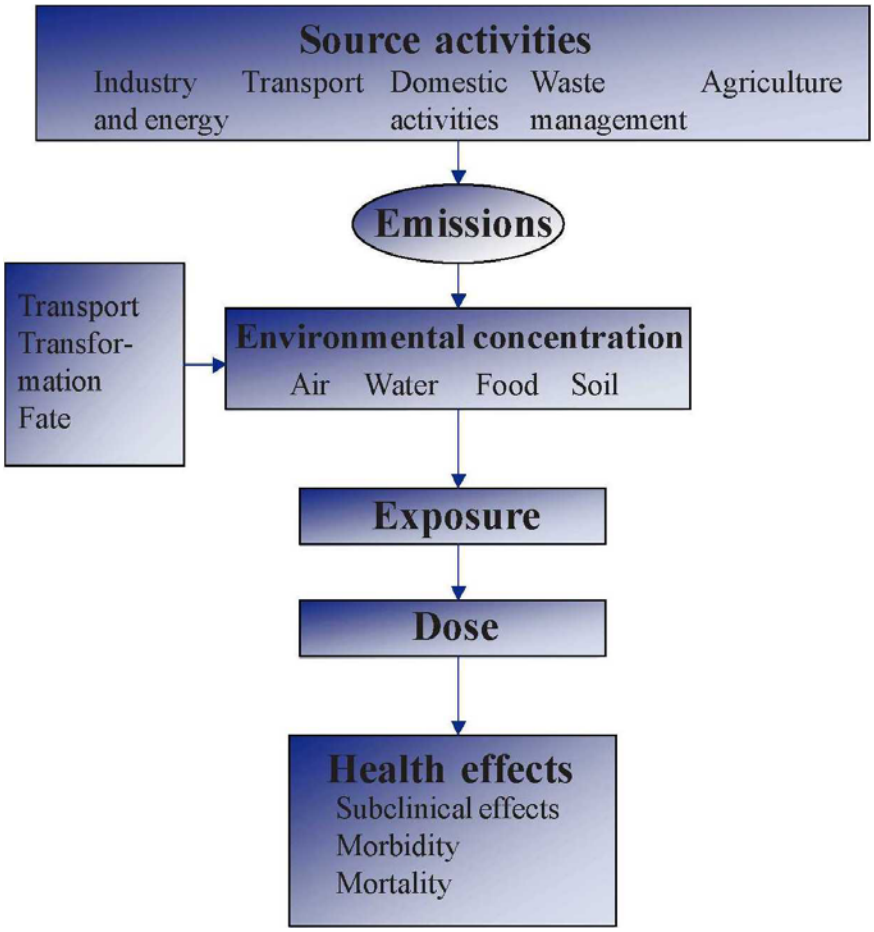

Figure 1. Environment-Health Chain

BACKGROUND.

What is exposure?

Exposure is the contact of a hazard (chemical, physical, or biological) with the outer boundary of a receptor organism over an interval of time. Exposure does not result only from the presence of a hazard in the environment; contact at the boundary of the receptor organism must occur.

To define exposure four primary characteristics must be determined.

- Nature of the hazard: whether it is chemical, biological, or physical
- Intensity of the exposure: the concentration or magnitude of a specific hazard at the boundary.
- Duration of the exposure: how long exposure lasted.
- Frequency of exposure: how often exposure occurred.

What is exposure assessment?

Exposure assessment is the process of identifying, defining, and measuring the magnitude, frequency, and duration of exposure to a hazard that occurs, or is anticipated to occur, in human populations in the environment.

Why is exposure assessment important?

Exposure assessment is important because exposure to hazards can potentially lead to adverse health effects. However, a highly toxic hazard that is released by a source into the environment may not pose a risk if there is no exposure. Conversely, a less toxic hazard that is released into the environment may pose a high risk because there is high exposure to the population. Conducting an exposure assessment accurately illustrates the relationship between source activities, exposure, and the subsequent health effects to the study population.

A clearly illustrated exposure assessment is critical for determining if a hazard poses a potential risk to the population. If there is no exposure, there is no risk. Additionally, understanding the exposure of a population will allow for the collection of more accurate sampling data and in turn more accurate risk estimates can be developed. Lastly, in instances where there is potential for risk from hazards, an accurate exposure assessment allows exposure scientists to make recommendations for reducing risk by reducing exposure to the study population.

EXPOSURE ASSESSMENT PROCESS.

Detailing the purpose and objectives

The first step in conducting an exposure assessment is to outline the purpose and the objectives of the study. Environmental studies are conducted for a variety of reasons and each exposure assessment should be tailored so that it answers the needs of the environmental study. Assessors detail the purpose, scope, level of detail, and approach that will be used in the study. The purpose should indicate why the study is being conducted and how results will be used. The scope details the study area that is being considered, the hazards and media that need to be measured, and the populations that need to be considered. The level of detail indicates how accurate the exposure and dose estimates need to be in order to achieve the purpose of the study. It also indicates whether the assessment is limited by resources and if so, it questions what the most effective use of the resources are. The approach details how environmental concentrations, exposure, and dose will be sampled and measured (Reference 5).

Addressing each of these points will help the exposure assessor develop clear and concise study objectives that will influence the subsequent portions of the exposure assessment process.

Identification of study population

After the purpose, scope, level of detail, and approach for the exposure assessment has been addressed, the study population must be identified. Identification should be based on high exposures, health status, geographical location, etc. Often it is not realistic to measure exposure for each individual person in a population. Therefore, characteristics that are representative of the larger population are necessary for the exposure assessment. Characteristics of these larger populations that affect exposure, such as activity patterns, location compared to the source, an estimate of the number of individuals within the exposed population, and the presence of subpopulations should be identified. If a subpopulation is expected to have a different exposure than another subpopulation, the exposure assessment should treat each as individual study populations. High-risk populations need to be identified as specific subpopulations. High-risk populations are groups that are more exposed than the average individual or individuals that are more susceptible to exposure and develop health effects at lower exposures than the average person. Individuals can be more susceptible to the health effects caused by a hazard due to genetics, age, gender, nutrition and stress, and pre-existing disease.

Identification of hazards

After the purpose, scope, level of detail, and approach for the exposure assessment has been addressed, the source of potentially harmful hazards must be identified. The source in an exposure assessment is the point of origin, stationary or mobile, from which hazards are discharged or emitted into the environment. Most often the source is a product of human activities; however sources can be natural in origin as well. For example, the source of ash released during industrial combustion procedure would have an anthropogenic source (the incinerator). However, the source of ash released during a volcanic eruption would have a natural source (the volcano). Sources of emissions vary between point sources (such as industrial stacks releasing agents into the air), mobile sources (such as construction equipment that generates loud noises), line-sources (such as power lines), and area sources (such as agricultural land that releases pesticides in run-off water during excess rainfall). In some instances physical hazards such as heat or cold may originate from the general environment as opposed to a specific point of origin. In these cases the environment would act as an area source for heat or cold stress.

Once a source has been identified, the hazards that are introduced into the environment from the source are identified. Hazards can be biological, chemical, or physical in nature.

- Biological hazards are living organisms or products created by living organisms: bacteria and viruses from wastewater and venom injected by animal bites or stings.

- Chemical hazards are derived from chemical compounds: pesticides and volatile organic compounds.

- Physical hazards have a direct, tangible impact on the receptors: nonionizing radiation from radio frequency devices, noise from an airport, or heat stress from the environment.

Identification of exposure pathways and routes of exposure

After the source has been identified, the next step in an exposure assessment is to understand the process by which hazards move through the environment from the source to the receptor organism. Hazards that are emitted from a source are transported through one or more environmental media to the receptor organism via an exposure pathway. An exposure pathway is the physical course by which a hazard travels from the source of the hazard to the receptor organism. The exposure pathway can be further broken down into the environmental media, the exposure media, and the exposure route. Environmental media is the media into

which the source emits the hazard—typically air, soil, or water. The specific type of environmental media that the receptor comes in contact with is called the exposure media. Examples of exposure media include breathing zone air, tap water, and household dust. Some physical hazards such as cold, radiation, noise, or vibrations are not associated with a specific type of environmental media and are simply present in the environment itself.

The way that a hazard enters the receptor organism, from an exposure media is called the route of exposure. The major routes of exposure for human receptors are:

- Inhalation: breathing the hazard
- Ingestion: eating or drinking (consciously or incidentally) the hazard
- Dermal absorption: absorbing the hazard through the skin barrier
- Injection: injecting the hazard through the skin barrier
- Direct: being in the presence of a hazard (typically a physical hazard—radiation, noise, heat, vibrations, etc.)

Determination of duration and frequency of exposure

At this point of the exposure assessment the bridge between the source and the receptor has been identified as a complete exposure pathway. The completed exposure pathway indicates that the receptor population has potentially been exposed to the potential hazard. The next step in the exposure assessment is to characterize the behavior patterns of the receptor population that determine how much of the potential hazard the receptor population comes in contact with. The daily activities of the receptors—what they do during the day, when do they do it, where do they do it, and how long do they do it will indicate how a receptor's daily activities bring them into contact with the hazards.

The behavior patterns of primary interest are the duration and frequency of exposure. Exposure duration is the length of time over which the receptor population is in contact with the potential hazard. Exposure frequency is how often receptors are exposed throughout an exposure duration. For example, if Soldiers on guard duty near a burn pit come in contact with burn pit smoke for 8-hours per day for 260 days over a 1-year deployment, the exposure duration is 1 year and the exposure frequency is 260 days. Typically the longer and more frequently that a receptor population is exposed to a hazard, the more likely adverse health effects from exposure to that hazard will occur; especially if the health effects from the hazard are cumulative, such as in carcinogens.

Determination of intensity of hazards in the environment

In order to estimate potential health effects to receptors, the intensity of the hazard in the environment must be measured. The intensity of the hazard is determined most often by measuring the concentration or magnitude in a given medium. Hazard concentrations or magnitudes are measured in the food people eat, water they drink, air they breathe, or soil they touch. The intensity of hazards that have a direct route of exposure is measured directly since they are not contained in a medium.

There are two types of concentrations of the hazard in the transport medium that can be identified.

- The first is the environmental concentration. The environmental concentration indicates the concentration of a hazard in a medium. For example: micrograms per cubic meter of lead in the ambient air.

- Alternately the concentration of the hazard can be measured by quantifying the concentrations at the point of contact where the receptor will come in contact with the hazard. This concentration is called the exposure concentration. This is the most desirable option because it demonstrates the actual concentrations to which the receptors are exposed.

Concentrations quantified from the source can be used as a surrogate, either directly or through fate and transport modeling. These methods are less desirable due to the introduction of uncertainty into the exposure assessment. Using concentrations quantified at the source location is the least desirable because it does not consider how concentrations of the hazard change when transported from the source to the receptor location. This method most often overestimates the concentration of the hazard because transport of a hazard tends to decrease its concentration. When only concentrations quantified at the source are available, fate and transport models can be applied in order to determine a more accurate concentration at the receptor location. Such models consider the changes in concentrations as the hazard is transported from the source to the receptor location but these models use assumptions that introduce uncertainty. The best way to determine the concentration of hazards in media is by quantifying at the point of exposure.

THE NEXT STEPS

The completed exposure assessment has delineated the entire environmental-health chain, showing how hazards move throughout the environment from the source of hazards to the receptors. The next step in the risk assessment process is the creation of a sampling plan in order to collect sample data for analysis. The completed exposure assessment is essential for determining where, when, and how to collect samples that will accurately reflect the exposures of populations to hazards in the environment.

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