Module Two

Routes of Exposure

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Time Allotted: 60 Minutes

Objectives:

Upon completion of this module, the learner will be able to

- Define and understand the types of environments
- Identify the protective barriers of the body
- Identify the routes of exposure
- Identify the pathways for exposure
- Identify the types of exposures
- Understand local and systemic exposures
- Identify the pathways for excretion of toxins

Presentation Outline

I. Introduction - Types of Environments

A. Inner versus Outer Environment
B. Personal versus Ambient Environment
C. Gaseous, Liquid, and Solid Environments
D. Chemical, Biological, Physical, and Socioeconomic Environments

II. Routes of Exposure
A. Dermal absorption
B. Inhalation
C. Ingestion
D. Other Routes of Exposure

III. Elements for a Pathway of Exposure
A. Source of contamination
B. Media for contaminant travel
C. Point of Exposure
D. Route of Exposure
E. Receptor Population

IV. Types of Exposure
A. Acute
B. Chronic
C. Sub-acute
D. Sub-chronic

V. Effects After Exposure
A. Local
B. Systemic

VI. Excretion of Toxins
A. Urine
B. Liver
C. Lungs

VII. Test Your Knowledge Quiz

VIII. Activity Lab

IX. Question and Answer Period

Lecture Notes

I. Types of Environments

Before one can understand the routes and pathways of exposure, it is important to have an understanding of the term "environment." Environment can be defined in a number of ways (7):

- Inner versus outer environment
- Personal versus ambient environment
- Gaseous, liquid, and solid environments
- Chemical, biological, physical, and socioeconomic environments

A. Inner Versus Outer Environment

This refers to the human body and consists of the environment within the body and the environment outside of the body. The human body has three protective barriers against outside environmental contaminants.

- The skin, which protects the body from contaminants outside the body;
- The gastrointestinal (GI) tract, which protects the inner body from contaminants (toxins) that have been ingested,
- The membranes within the lungs, which protect the inner body from contaminants that have been inhaled.

However, each of these barriers are liable to damage under certain conditions. Contaminants can penetrate to the inner body through the skin by dissolving the layer of wax that we have covering our oil (sebaceous) glands. The GI Tract is also very

vulnerable to compounds that are soluble and can be easily absorbed and taken into the body cells. However, the body has ways of protecting the GI tract. For example, unwanted material can be vomited through the mouth, or rapidly excreted through the bowels (as in the case of diarrhea).

The lungs are the most important route for toxic substances, and they are also the most fragile. Airborne materials that are inhaled can be deposited in the lungs, and, if they are soluble, they can be absorbed. A number of mechanisms protect the lungs, such as, simple coughing, or cleansing by "macrophages" that engulf and promote the removal of anything foreign.

Unless a toxicological agent or environmental contaminant penetrates one of the three barriers that protect the body, it will not get into the inner environment, and even if it does get in, there are other ways to remove it. For example, materials entering the circulatory system (arteries, veins, etc.) can be detoxified in the liver or excreted through the kidneys.

B. Personal Versus Ambient Environment

Your personal environment represents the environment that you can control. The ambient (working) environment represents the environment over which you have no control. It is thought that the working environment poses the greatest threat to health, but some health experts believe that the personal environment, influenced by a number of factors, is the

most important for our well being. Factors which are important for the personal environment include hygiene, diet, sexual practices, exercise, use of tobacco, drug and alcohol use, and frequency of medical checkups.

C. Gaseous, Liquid, and Solid Environments

Our environment exists in one of three forms: gas, liquid, or solid, each of which can be polluted. Particulate (large particles) and gases are released into the air (gaseous), sewage and liquid wastes are discharged into water (liquid); and solid wastes, such as plastics and toxic chemicals are disposed of on land (solid). People interact with all of these environments.

D. Chemical, Biological, Physical, and Socioeconomic Environments

These types of environments could affect people's health.

- Chemical factors and contaminants include toxic wastes and pesticides in the environment; chemicals used at home (cleaning products) and by industry; and preservatives for food.
- Biological factors include different forms of disease organisms in food and water, and those that can be transmitted by insects and animals, and person-to-person contact.
- Physical factors include elements that may influence health and well-being, such as injuries and deaths from accidents, loud and excessive noise, extreme temperatures (heat and cold), and the effects of radiation.

- Socioeconomic factors - are hard to measure, but significantly affect the lives and the health of people. Low socioeconomic status increases death and illness rates.

II. Routes of Exposure

It has been estimated that about 70,000 chemicals are used worldwide, and the chemical industry introduces about 200 to 1,000 new chemicals each year (8). Because of this, we are exposed to a number of chemicals in our home, at work, and in the general environment. Trace amounts of toxic chemicals are present in the food, the air, and the drinking water. Exposure to toxic substances occurs through the three major routes listed below. ☛ **Refer to Handout 2.1. Routes of Exposure**

- The skin (dermal absorption)
- The respiratory tract (inhalation)
- The digestive tract (ingestion)

A. Dermal Absorption

Contact with the skin is the most common path of toxic substance exposure (1). The skin is composed of three layers:

- Epidermis (outer layer). The outermost layer is the *stratum corneum (carnified layer).* This is the structure that determines the rate of absorption of substances through the epidermis. For example, a pesticide such as Malathion, which easily penetrates the stratum corneum, moves

quickly through the other layers of the skin and is rapidly absorbed into the bloodstream. DDT, another type of pesticide, does not easily penetrate the stratum corneum, so the rate of absorption is much slower.

- Dermis (inner layer). The inner layer of the skin is sometimes referred to as the true skin. In animal hides, this is the layer that turns to leather when chemically processed. The dermis is the source of oxygen and of nutrients for the epidermis. The hair follicles, sweat glands, and sebaceous (oil) glands are found in this layer. These structures play a limited role in the absorption of substances across the skin.
- Subcutaneous fatty tissue. This layer provides a cushion for the underlying structures and allows the skin to move to some extent.

Factors affecting dermal absorption of toxic substances include

- The condition of the skin. An intact stratum corneum (epidermis) is an effective barrier to absorption of **some** toxic chemicals. However, physical damage to the protective barrier, such as a cut or abrasion, allows toxic substances to penetrate the epidermis and enter the dermis where they more readily enter the bloodstream and are carried to other parts of the body.
- The chemical make up of the substance. Inorganic chemicals and substances are not easily absorbed through intact, healthy skin (such as cadmium, lead, mercury, and chromium. Organic chemicals dissolved in

water do not easily penetrate the skin because the skin is impermeable to water. However, organic solvents, such as paint thinner or gasoline, are easily absorbed through the epidermis.

- Increasing the concentration of the toxic substance or the exposure time can increase the rate or amount of material absorbed.

B. Inhalation

Inhalation is the easiest and fastest means of exposure to toxic substances because toxic substances are readily absorbed in the respiratory tract. The lining of the respiratory tract is NOT effective in preventing absorption of toxic substances into the body. The respiratory tract consists of the nasal passages, trachea (windpipe), larynx (voice box) and the lungs. The following factors affect inhalation of toxic substances:

- Concentration of toxic substance in the air,
- Solubility of substance in the blood and tissue,
- Respiration rate,
- Length of exposure,
- Condition of respiratory tract , and
- Size of toxic particle.

C. Ingestion

Ingestion of toxic substances usually occurs accidentally or unknowingly. The digestive tract consists of the mouth, the esophagus (food canal), stomach, and intestine (large and small). The major function of the digestive tract is to digest and absorb the foods we eat.

Physical and chemical factors affect the absorption of toxic substances. Absorption is affected because of the structure of the body and the length of time food containing the substance remains in the body. Once a chemical is absorbed, its effects depend on its concentration in the target organs, its chemical and physical form, what happens to it after it is absorbed, and how long it remains in the tissue or organ of choice. After being taken up in the blood, a chemical is be quickly distributed throughout the body; it may be moved from one organ or tissue to another (translocation), or changed into a new compound (biotransformation).

D. Other Routes of Exposure

The eye is a common point of contact for toxic substances. The primary point of contact for toxic substances is the cornea. Acidic and basic compounds are the most common types of exposures that do damage. Depending on the amount of damage, the cornea may be able to repair itself. The outer layer of the eye is made up of connective tissue called the *sclera*. In the front of the eye, this forms into the *cornea*, which is transparent. The middle layer of the eye is called the *choroid*, which forms the *iris*, in the front of the eye. The innermost layer is the *retina*, which produces images. Two compartments within the eye contain a fluid-like substance called the *aqueous humor*, and a transparent jelly-like substance called the *vitreous humor*. All nutrients and oxygen must diffuse through the aqueous humor in the back to the cornea to repair the damaged tissue.

Injections are another common route for exposure. Injections are mainly used in

laboratory studies on experimental animals. Following are the different types of injections:

- Intravenous injections (into a vein).
- Intramuscular injections (into the muscle).
- Intra peritoneal injections (into the abdominal cavity).
- Intradermal injections (into the skin).
- Subcutaneous injections (under the skin).

III. Elements for a Pathway of Exposure

ATSDR defines an exposure pathway as the process by which an individual is exposed to contaminants that originate from some source of contamination (9). For exposure to occur, a completed exposure pathway must exist. A completed exposure pathway exists when all of the following five elements are present:

- A source of contamination, for example a smoke stack on a factory;
- Media for the contaminant to travel, such as groundwater, surface soil, surface water, air, subsurface soil, sediment, and biota (animal and plant life);
- A point of exposure, or a place where people actually come into contact with the contaminated material;
- A route of exposure, or how contaminants enter or contact the body (i.e. ingestion, inhalation, dermal contact, and dermal absorption); and
- A receptor population, or those persons who are exposed or potentially exposed to the contaminants.

A potential exposure pathway exists when one or more of the elements is missing, but available

information indicates that exposure is likely. An incomplete exposure pathway exists when one or more of the elements is missing and available information indicates that exposure is not expected to occur.

IV. Types of Exposure

Toxic chemicals generally produce the greatest effect and the most rapid response when inserted directly into the bloodstream (2). Occupational exposure generally occurs from breathing contaminated air (inhalation) and/or direct or extended contact of the skin with the substance (dermal exposure). In contrast, accidental and suicidal poisoning occurs most frequently by oral ingestion. The types of exposures are

- Acute, which is exposure to a chemical for 24 hours or less.
- Chronic, which is exposure to a chemical for more than 3 months.
- Sub-acute, which is exposure to a chemical for 1 month or less.
- Sub-chronic, which is exposure to a chemical between 1 to 3 months.

V. Effects After Exposure

Local effects are seen at or near the body part or parts where exposure occurred. For example, inhaling particles can result in irritation of the respiratory tract, resulting in effects ranging from sneezing to chest pains and difficulty in breathing. An ant bite leads to redness and swelling at the bite location.

Some substances are absorbed into the bloodstream and are then carried to other parts of the

body, where they cause their effect. These types of substances usually cause their effect in one or two target body organs. Whether or not these effects occur depends on the concentration of the chemical in the target organ. The concentration in the organ is dependent on the absorption, distribution, biotransformation, and excretion of the substance. Biotransformation occurs when a substance is changed from one form to another, which may also change the toxic properties of the substance. It usually occurs in several steps, primarily in the liver, but it may also occur in other tissue like the kidneys, lungs, and digestive tract.

Some substances are absorbed from the bloodstream and stored in tissues where they may not cause an adverse effect. For example, lead can be stored primarily in the long bones of the body, but when released, has a toxic effect on the nervous system.

VI. Excretion of Toxins

The rate (speed) at which a toxic substance is removed from the body determines whether it will have a toxic effect. The longer a chemical is in the body, the greater the likelihood of damage. The main way a chemical is excreted from the human body is through the urine, but the kidneys, the lungs and the liver are also important in removing certain chemicals from the body. The kidney eliminates the greatest number of toxins than any other tissue/organ. The lungs eliminate substances that are in the gaseous phase, like carbon dioxide. The liver removes substances like lead or DDT (pesticide) by excreting them into bile, which is made by the liver and travels to the small intestine. From there the substance can be absorbed in the feces and then eliminated through excretion. Neither the sweat glands nor the GI tract are important routes for excreting of

toxic substances (2). Skin, hair and breast milk are pathways, although minor, for excretion.

VII. Test Your Knowledge Quiz

1. Name the four types of environments discussed in this module.
    a.
    b.
    c.
    d.

2. Which of the following is **NOT** a factor affecting inhalation of toxic substances?
    a. Concentration of toxic substance in the air
    b. Speed of the wind
    c. Length of exposure
    d. Size of toxic particle

3. Chronic exposure is classified as an exposure to a chemical or other substance for a period of one year or more.

    a. True b. False

4. Biotransformation occurs when a substance enters the body in one area and moves to another.

    a. True b. False

5. Which of the following is not a type of exposure?
    a. Long-Term Exposure
    b. Chronic Exposure
    c. Short-Term Exposure
    d. Small Exposure

6. The protective barriers for the inner environment are the _____, _____, and the _____.

VIII. Activity Lab

WORD SCRAMBLE

(1) **ikns** _____

(2) **nnttiesei** _____

(3) **osen** _____

(4) **yee** _____

(5) **thmuo** _____

(6) **tanbmei** _____

(7) **psegocamrha** _____

(8) **etnomvrnien** _____

(9) **bgcioaloil** _____

(10) **saeguos** _____

(11) **lsio** _____

(12) **ira** _____

(13) **eawrt** _____

(14) **odfo** _____

(15) **rdmeis** _____

(16) **haaitnoiln** _____

(17) **treuo** _____

(18) **damie** _____

(19) **wgorruentda** _____

(20) **Cfnooidah** _____

QUICK MATCHING

Match the routes of exposure with the correct way for the hazard to enter the body.

A. Absorption
B. Ingestion
C. Inhalation

___ Skin
___ Mouth
___ Eye
___ Intestine
___ Nose

GROUP ACTIVITY

☛Have participants break into small groups. Using information about their community, identify contaminants, possible route(s) of exposure, and define the exposure pathway, identifying the five needed for a completed exposure pathway.

IX. Question and Answer Period

HANDOUTS and VISUAL AIDS

MODULE II