FEATURE ARTICLE
Continuing Education

Toxicology Primer

Understanding Workplace Hazards and Protecting Worker Health

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Occupational health nurses must understand the potential adverse health effects associated with chemical exposures in the workplace. Toxicology is defined as "the study of adverse effects of chemicals on biologic systems" (Droull, 1986). More than 20,000,000 chemicals are registered in the Chemical Abstracts Service (CAS) of the American Chemical Society (2002). Many of these chemicals are used in more than 1,000,000 worksites in the United States (U.S. Department of Labor, Occupational Safety and Health Administration [OSHA], 1999a). The American Association of Occupational Health Nurses (AAOHN) has identified the study of health effects resulting from chemical exposures in the workplace as a research priority (AAOHN, 1998).

Occupational health nurses, occupational physicians, industrial hygienists, safety personnel, laborers, and management share the responsibility of protecting and assessing the health and safety of workers who may be exposed to chemicals in the course of their work. The occupational health and safety team works together in assessing workplace exposures and worker health to identify and implement appropriate interventions to maintain a safe and healthy work environment. The OSHA reference document, "The Occupational Health Professional's Services and Qualifications: Questions and Answers" (U.S. Department of Labor, OSHA, 1999b) recognizes that personal observations, scientific knowledge, sampling data, and other health and safety information are necessary to achieve this objective. Occupational health nurses must be able to effectively communicate and collaborate with other highly trained professionals in health promotion and risk reduction efforts (White, 1999).

This article aids the occupational health nurse in applying toxicological principles in the assessment of workplace chemical exposures and provides an overview of toxicology with explanations of general principles including:

- Routes of exposure.
- Dose–response relationship.
- Disposition of toxins.
- Effects of exposure.
- Units of measure.
- Overview of the standard terms of exposure levels in industry.

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BASIC PRINCIPLES OF TOXICOLOGY

The Dose–Response Relationship

In the study of adverse chemical effects, it is important to note the words of Paracelsus (1493-1541), "soli dosis facit venenum," which has been translated, "all substances are poisons, it is the dose only that distinguishes a poison from a remedy" (Schaper, 1998). The dose–response relationship is a primary principle of toxicology.

Dose is the concentration of exposure of a toxic agent to an organism, or the amount of substance deliv-

ered to an organ (Schaper, 1998). Response is the outcome of that dose. Responses can range from no observable effect to death. The dose–response relationship can be illustrated graphically by plotting increases in dose versus changes in response.

Most nurses have seen the effects of alcohol intoxication in relation to blood alcohol levels and can relate to the concept clinically. If imbibed in small quantities over several hours, alcohol may have little measurable effect. It is biotransformed (i.e., metabolized) and eliminated before the dose crosses the response threshold. However, with larger doses over a shorter period of time there is a progression of signs and symptoms from euphoria, excitement, confusion, stupor, coma, to death. Like most chemicals, alcohol has a more toxic effect on the body with increasing doses.

Dose–response for workplace chemical exposures follows the same principle. A well-defined relationship exists between measured dose and expected response (Agnew, 2001).

Time

Time is an important factor in toxicology and occupational health exposure assessment. Two components of time are duration of exposure and response time. Duration of exposure refers to the amount of time a worker has contact with an environmental or chemical agent. An exposure time may be expressed as acute (seconds to hours) or chronic (months to years).

Response time is the time between exposure to the agent and onset of a measurable effect. It varies with the conditions of exposure and the nature of the substance. The response may be acute (i.e., occurring immediately) or latent (i.e., after a period of time). If sufficient time is permitted between repeated exposures, biological systems eliminate the chemical, preventing an accumulation in the body (i.e., body burden). If there is insufficient time between exposures, the body burden increases and may cross the threshold for causing harm (Timbrell, 2000).

Chemical carcinogenesis, or the induction of cancer by chemicals, is a more complex process that does not follow the typical dose–response relationship. The latency period between exposure and response in chemical carcinogenesis is generally quite long. There are at least three main stages in the development of cancer:

- Initiation.
- Promotion.
- Progression.

Initiation involves genetic changes in the cell so it has the potential to develop into pre-neoplastic cells. The promotion stage is characterized by an alteration in genetic expression of the pre-neoplastic cells, which may result in unregulated growth, cell membrane effects, and suppression of latent tumor cell growth. In the progression stage, the pre-neoplastic cells have become a malignant tumor, with changes in the chromosomes resulting in increased growth rate, invasion into healthy tissue, and formation of metastases (Timbrell, 2000).

TOXIC AGENTS

A toxic agent is a physical, biological, or chemical substance that causes harm. Certain chemicals, such as oxygen, nitrogen, sodium, and potassium are necessary for life. Under physiological conditions, life is supported. However, higher concentrations may lead to toxic consequences. Non-nutritive chemicals such as mercury, lead, and arsenic are ubiquitous in the environment and not necessary for life. They may be benign or deadly, depending on the dose. All chemicals have the capacity to be toxic and to produce harmful effects on biological and environmental systems (Hein, 1993). Conversely, every chemical has a set of conditions under which harm will not occur. Although exceptions to every rule exist, hypersensitive or hypersusceptible individuals may experience some effect with any exposure. Thus, toxicity is a relative term that refers to potential for causing harm. Physical properties, the dose of the chemical, and the manner in which a chemical exposure occurs are important determinants of toxicity.

Physical Characteristics of Toxic Agents

Physical characteristics of chemicals play a role in toxicity (Johnson, 1998). Size, surface area, and density are important factors. These factors determine whether particles reach the deep regions of the lung (alveoli), are caught in the upper respiratory tract and are eliminated or swallowed (Agnew, 2001), or settle on surfaces and are not respirable. Within the workplace, the manufacturing process is a significant determinant for these factors. Various forms of respiratory inhalants have specific definitions.

Aerosols are the dispersions of solid or liquid particles in air. They vary in size, shape, density, and other dimensions. Several types of aerosols include the following:

- Dusts are defined as solid particles that can be temporarily suspended in air. Dust may be composed of rock, metal, coal, grain, or wood. The size of dust particles ranges from .1 μm to 400 μm. The size determines if the particles remain airborne and are respirable (DiNardi, 1998) or settle on surfaces.
- Mists are liquid droplets suspended in air. Mists occur as a result of condensation of gasses or aerosolization of a liquid. Some examples of mists are paint sprays and airborne oils from cutting and grinding operations.
- Fumes are solid airborne particles formed when heated or melted metallic substances evaporate, condense, and undergo a chemical reaction such as oxidation. Welding, soldering, and smelting may produce respirable fumes.
- Fogs are liquid droplets of condensation, but are much smaller in size than mists. Therefore, they tend to stay suspended in air longer than mists.
- Fibers are elongated particles that have a length to width ratio (aspect ratio) of greater than three to one. Fibers may be natural or synthetic substances. Diameter, length, and composition of the fiber influence its toxicity (Lippmann, 2000). Certain forms of asbestos, if released into the environment, can result in a respirable exposure.
- Gasses and vapors are airborne substances of highly energized particles with no fixed shape and indefinite volume (Hein, 1993). The term vapors refers specifically

to airborne particles that have been released (evaporated) from a solid or liquid. Gasses and vapors have the ability to disperse quickly into the space provided. When a container of liquid ammonia is opened in a room, ammonia vapors disperse and can be detected throughout the room through the sense of smell. Other examples of substances that emit vapors are elemental mercury and methylene chloride. Examples of gasses are hydrogen and nitrous oxide. The chemical can be changed from a gaseous state to a liquid or solid state by increasing pressure and decreasing temperature (Hein, 1993).

- Particulates are particles of solid or liquid matter that vary in size and shape. In industrial hygiene sampling, particle size and shape is important when determining actual exposure and dose. When technologically possible, these parameters should be measured (American Conference of Governmental and Industrial Hygienists [ACGIH], 2003).

Effects of Toxic Agents

Harmful effects occur to biologic cells, tissues, and organs by metabolic poisoning, disruption of cell membranes, interference with biochemical reactions, and binding to nucleic acids. A chemical can cause more than one response (effect), or type of harm. The response is not unpredictable nor is it random (Ottoboni, 1991). For example, exposure to ethylene oxide can cause a variety of effects including irritation of the respiratory tract, nausea and vomiting, and reproductive changes. Ethylene oxide is both an irritant and a teratogen. However, response to similar ethylene oxide exposure will not differ substantially from one individual to another. Some differences may be found in degree of response because of individual variation, but the same organs and systems will be affected. This principle is critical to the science of toxicology, injury and illness assessment, and identification and prevention of hazards (Ottoboni, 1991).

Several common types of harm can occur from chemical exposures in the workplace. Many of the following terms are found in Material Safety Data Sheets (Hathaway, 1994).

- Asphyxiants cause harm by either displacing or preventing the essential use of oxygen. Carbon dioxide can act as a simple asphyxiant by displacing oxygen. Carbon monoxide is a chemical asphyxiant which prevents the use of oxygen.
- Corrosives are solids, liquids, or gasses capable of causing an irreversible effect of cell destruction from direct tissue contact. Strong acids (e.g., hydrochloric acid, nitric acid) or alkalis (e.g., potassium hydroxide) can cause visible destruction and irreversible alteration in tissues because of their corrosive effect (Loomis, 1996).
- Primary irritants are similar to corrosives but produce a reversible effect following direct tissue contact. By changing the parameters of exposure, a corrosive effect can be avoided and the primary irritation will resolve without sequelae.
- Carcinogens are chemicals associated with the development of cancer or the abnormal proliferation of cells. A substance is classified as a carcinogen based on evaluation by the International Agency for Research on Cancer (IARC) and the National Toxicology Program (NTP), or if OSHA has regulated the substance as a carcinogen (Rogers, 1994). Classifications are based on strength of evidence of risk derived from experimental animal and human epidemiological studies (McClellan, 1998).
- Mutagens cause damage to reproductive cells at the genetic level (Williams, 1985) resulting in chromosomal damage or interference with meiosis, mitosis, or cell division (Gochfeld, 1992). Harm occurs before embryonic formation or fetal development. Ionizing radiation, hyperthermia, and some chemotherapeutic drugs are examples of mutagens (McKinnon, 1998).
- Teratogens cause damage to replicating cells of the developing zygote, embryo, or fetus. Maternal chemical inhalation may expose the developing zygote, embryo, or fetus to substances resulting in early termination of pregnancy or malformation of the fetus. The stage of fetal development at the time of exposure largely determines the organ system affected. Exposures prior to embryonic implantation may result in spontaneous abortion, later exposures may result in various organ system effects, some of which may not be obvious at birth (Gochfeld, 1992). Ethylene oxide and some chemotherapeutic drugs are teratogens.
- Sensitizers produce an immunological response. Both exposure and response can be acute or chronic. However, after the immune system is primed, hypersensitivity develops and subsequent exposures, regardless of size, produce an immunological response. When hypersensitivity develops, the dose–response principle no longer applies. The effects on the body are determined more by the response of the immune system than by the dose of the substance. Clinical effects can include edema, inflammation, rash, and anaphylaxis. The most common target organs for immune responses are the respiratory tract, skin, and eyes (ACGIH, 2003). When a person becomes sensitized, exposure to the sensitizer should be avoided (Ottoboni, 1991). Some substances recognized as sensitizers include nickel used in plating (targets skin), and toluene diisocyanate used in polyurethane foam production (targets skin and respiratory tract).

TARGET ORGANS

The term target organ refers to the cells and tissues of an organ against which a chemical exerts its specific biologic toxicity. Chemicals can be classified and referred to according to their specific organ toxicity. Nephrotoxic chemicals damage the kidneys, neurotoxic chemicals damage the nervous system, and hepatotoxic chemicals damage the liver. A chemical's toxicity depends on physical properties, dose, duration of exposure, route of exposure, and reaching a target organ.

Although any organ may be damaged by a toxin, many factors determine the degree of susceptibility of a particular organ. These factors include (Timbrell, 2000):

- Blood supply.
- Metabolic activity.
- The particular enzymes associated with the organ.
- Physiologic activity of the organ.

- Anatomic location.
- The organ's ability to repair itself.
- The organ's binding capacity to certain molecules.

In relation to workplace exposure, the organs most frequently affected are the lungs and skin. Effects of toxicity may be local or systemic. Local effects are limited to those areas of the body directly exposed to the substance. For example, skin contact with methane sulfonic acid will cause a burn but has no known effect on other body organs or systems. Local effects may be eye irritation, skin irritation, burns, and contact dermatitis.

Systemic effects involve damage to major organs, tissues, and cells. The organs most often affected are the liver, kidneys, heart, nerves, brain, and gonads. Carbon monoxide (CO) produces no local effects because it is not irritating to the respiratory tract and dermal exposure does not occur. However, a sufficient inhalation of CO can cause systemic effects ranging from headache to death.

Some chemicals have the ability to cause local and systemic effects. For example, if liquid phenol contacts the skin, irritation is likely. With dermal absorption, damage to the liver and kidneys may occur.

EXPOSURE

The OSHA's Hazard Communication Standard, 29 CFR 1910.1200(c) (U.S. Department of Labor, OSHA, 1999c) states:

> "Exposure or exposed" means that an employee is subjected in the course of employment to a chemical that is a physical or health hazard, and includes potential (e.g. accidental or possible) exposure. "Subjected" in terms of health hazards includes any route of entry (e.g. inhalation, ingestion, skin contact or absorption).

An exposure does not necessarily mean harm has or will occur, but only that there is the potential for harm.

Routes of Exposure

There are four main routes of exposure or ways a chemical can enter the body. In industry, inhalation is the most common, followed by dermal, ingestion, and parenteral routes. The routes of exposure are not mutually exclusive. Exposure to a given chemical may involve more than one route.

- Inhalation is a significant route of exposure, both in terms of frequency and toxicity. In the workplace, it is the most common route of exposure and absorption. The large surface area of the lungs, highly perfused tissues, and thin alveolar barrier provide for efficient and fast delivery of a substance into the blood stream and to target organ(s).
- Dermal exposure is also common in industry. The skin forms a natural barrier to foreign substances. The outer layer, stratum corneum, contains an extremely tough protein (keratin) that limits absorption of many substances. If the stratum corneum becomes compromised in some way, the underlying dermis is more accessible. However, the dermis is several layers thick, so absorption may still be limited. Timbrell (2000) points out that the skin itself performs metabolic functions caused by the lipid layers, which may biotransform substances upon absorption.
- Ingestion can occur because of poor hygiene. Not washing hands before eating, smoking, chewing tobacco, swallowing inhaled particles, and consuming contaminated food or beverages are ways exposure can occur by ingestion. The gastrointestinal tract is proficient at absorption. The pH of the gastrointestinal tract may inhibit or promote absorption and alter the structure of ingested substances.
- Parenteral exposures in industry are rare, although direct introduction of chemicals into the bloodstream can occur. It is more common in health care settings and laboratories where accidental needlesticks may occur. In industry, parenteral exposures may occur with high pressure operating systems where liquid substances move at rapid speeds creating an injection potential.

DISPOSITION OF TOXINS

Disposition of toxins refers to what happens to a toxin after exposure. Exposure to a chemical (i.e., toxin) may not necessarily result in biological alteration. The biological system performs defensive responses that must be overcome for harm to occur. Harmful effects of potentially toxic substances may be eliminated or decreased by the defensive responses. These responses are described in a very basic and simplistic manner in the four interrelated phases below.

- Absorption is the process by which a toxic substance crosses cell membranes and enters the blood stream. Cell membranes are composed of a bi-layer of phospholipids, proteins, cholesterol, and carbohydrates. These components vary in size, shape, lipid solubility, structure, and polarity. All of these factors play a role in the absorption of chemical substances. Absorption may occur through the skin and mucous membrane, gastrointestinal tract, and lungs. The defensive response is to prevent absorption of the substance.
- Distribution occurs following absorption. If absorbed, the substance is distributed via the bloodstream. If a substance is absorbed in the lungs, the first site of distribution is the pulmonary circulation. The first site of distribution from the gastrointestinal tract is the portal vein supplying the liver. If absorption occurs through the skin, the chemical enters the peripheral circulation.

After absorption takes place, dilution of the substance and protein binding can occur. The concentration of a substance in the plasma is important. Concentration determines the dose of the substance delivered to the target organ(s) and, thus, the potential for harm. Plasma dilution of the substance reduces the concentration and subsequent biochemical reactions (Timbrell, 2000).

Chemicals in the plasma may bind to proteins. Protein binding helps reduce adverse effects by lowering the concentration of free compound in the plasma.

- Metabolism or biotransformation is the enzymatic process in the liver and other tissues. If a substance is changed to facilitate excretion, harmful effects are lessened by reduced exposure time in the body. Metabolism affects the activity of a substance in the body. However, in some cases this may lead to greater toxicity (Timbrell, 2000). The process of metabolism is dependent on the

chemical pathway and subsequent biochemical reactions (Timbrell, 2000).

The series of metabolic changes involving enzyme-catalyzed chemical reactions is referred to as pathways. Pathways play a major role in the process of detoxification by altering a substance into one that can be eliminated or inactivated.

- Elimination is the excretion of a chemical from the body. The sooner a toxic substance is excreted, the less chance it will produce harmful effects. Elimination most often occurs by way of urinary excretion. However, some substances may be exhaled from the lungs or excreted in bile through the feces or in other fluids such as saliva, milk, sweat, tears, and semen (Timbrell, 2000).

The excreted toxin or its metabolites in urine or exhalation can be used as biomarkers in the evaluation of exposures. The biological materials for measuring biomarkers include urine, blood, expired air, nasal lavage, and sputum. Biomarkers may be classified in terms of exposure, effect, or susceptibility (Zhitkovich, 1998). Rogers (1994) lists several biological monitoring tests for chemical exposures and the media to be tested.

UNITS OF MEASURE

Occupational health nurses review workplace exposure data from industrial hygienists, occupational physicians, and other health and safety professionals. Exposure data are essential in the assessment and evaluation of occupational disease. Airborne exposures to liquids and gasses are usually quantified in terms of parts per million (ppm) or milligrams per cubic meter (mg/m^3).

Parts per million is a quantitative measure (i.e., volume concentration in ratio form) of how many parts of contaminant are in 1 million parts of air or other medium. One ppm is an extremely small concentration. In terms of volume, it represents 1 pint in a total volume of 125,000 gallons.

Milligrams per cubic meter (mg/m^3) is the term used to quantify the concentration of a solid (i.e., dust, fume) in a sample volume. The solid mass, often called weight, collected in a given volume of air or other medium is measured. To understand this, picture a single aspirin (325 mg) crushed into a dust and dispersed into a 38 foot by 38 foot room with an 8 foot ceiling. The measured mass of the aspirin in the room equates to 1 milligram of aspirin per cubic meter of air.

STANDARDS FOR OCCUPATIONAL EXPOSURES

Occupational exposure limits are established to protect the health of workers (Rose, 1998). Occupational exposure limits apply to the workplace and working population (Klonne, 1998). The ideal environment with no exposure to harmful substances is unrealistic at home or at work, although it is a goal health and safety professionals work toward. Compliance with exposure levels does not guarantee a "safe" exposure level for all workers. Individuals and conditions vary. Very old or very young individuals and individuals with compromised immune systems represent populations that may be more susceptible to chemical effects than the healthy working population. Safety factors or margins of safety are established to account for the individual variances and susceptibilities in individuals. Safety factors are determined by evaluating animal experiment data and human epidemiologic data to determine the level of exposure thought to be safe for humans. The workplace health professional should be aware of and assess for individuals with particular susceptibilities and respond appropriately.

Three main organizations are involved in occupational exposure limits in the United States: OSHA, the National Institute for Occupational Safety and Health (NIOSH), and the American Conference of Governmental and Industrial Hygienists (ACGIH). Differences exist in the recommendations or standards among these organizations. OSHA is required to perform feasibility testing for economic effect and technological capabilities prior to setting occupational exposure limits standards (U.S. Department of Labor, OSHA, 1992). Although science and technology for determining occupational exposure limits have improved, most of the promulgated standards set by OSHA in the 1970s are still in effect today (Levine, 2003). Legislative action is required to make changes in OSHA permissible exposure limits. Therefore, many occupational exposure limits have not kept pace with current technology. ACGIH and NIOSH conduct research in this area and make recommendations for observable effect levels (OELs). Employers may voluntarily comply with the recommendations of ACGIH and NIOSH or develop more stringent company standards. However, only OSHA's standards are legally enforceable.

Permissible Exposure Limit (PEL)

Permissible exposure limits are established by OSHA to identify the maximum allowable exposure to the typical worker during a 30 year working lifetime of 40 hours per week that does not result in an increased risk of harm. Individual variations and sensitivities should be recognized when determining the exposure risk to a specific worker.

Recommended Exposure Limit (REL)

The recommended exposure limit is the term used by NIOSH when making recommendations for exposure limits to protect the health of workers. Recommended exposure limits as time weighted averages (TWAs), according to NIOSH, are appropriate for a 10 hour day, 40 hour work week (Rose, 1998).

Threshold Limit Values (TLV)

ACGIH introduced the term threshold limit value. Threshold limit value is the concentration of airborne substances to which most workers may be exposed without increased risk of an adverse health effect (ACGIH, 2003). Threshold limit values are not measures of relative toxicity between substances (Rekus, 1996). They are guidelines for the control of workplace health hazards and are made strictly with regard to protection of health. The economic and technical feasibility of achieving the threshold limit values are not considered when determining these recommendations (ACGIH, 2003). The categories of threshold limit values (e.g., TWA, short term

Additional Resources for Information on Toxic Substances

Agency:	Source:	Contact:
AAPCC	American Association of Poison Control Centers	www.aapcc.org/ Telephone: 1-800-222-1222
ACGIH	American Conference of Governmental and Industrial Hygienists	www.acgih.org/home.htm
ATSDR	Agency for Toxic Substances and Disease Registry	www.atsdr.cdc.gov Telephone: (888) 42-ATSDR
	Medical Management Guidelines for Acute Chemical Exposure	www.atsdr.cdc.gov/mmg.html
EPA	Environmental Protection Agency	www.epa.gov
Haz-Map	National Library of Medicine	http://www.nlm.nih.gov/pubs/factsheets/hazmap.html
IARC	International Agency for Research on Cancer	www.iarc.fr/
MSDS	Material Safety Data Sheets	www.ilpi.com/msds/
NIEHS	National Institute of Environmental Health Sciences	www.niehs.nih.gov/
NIOSH	National Institute for Occupational Safety and Health	www.cdc.gov/niosh/homepage.html Telephone: (800) 35-NIOSH or (800) 356-4674
NIOSH	NIOSH Pocket Guide to Chemical Hazards (NPG)	www.cdc.gov/niosh/npg/npg.html
NTP	National Toxicology Program	http://ntp-server.niehs.nih.gov/
OSHA	Occupational Safety and Health Administration	www.osha.gov Telephone: (800) 321-OSHS or (800) 321-6742
Poison Control Centers	Each state has a certified poison control center	www.medicinenet.com/Script/Main/Art.asp?li=USA&d
TOXNET	National Library of Medicine	www.toxnet.nlm.nih.gov/

exposure limit [STEL], threshold limit value—ceiling [TLV-C]) are described.

Time Weighted Average. In the real world, exposure levels fluctuate throughout the day. Therefore, a constant exposure is not maintained. To better characterize the exposure, the term TWA was introduced. TWA is the average concentration or exposure during an 8 hour work day and 40 hour work week.

Short Term Exposure Limit. A special limit is set on exposures to substances known to be acutely toxic at a very short duration of exposure. STELs are exposures limited to a 15 minute TWA. The TWA–STEL must never be exceeded even if the overall exposure for the 8 hour day is well within the threshold limit value (Klonne, 1998).

Ceiling Limits. The ceiling limit identifies the level of the maximum allowable exposure that should not be exceeded for any amount of time. Ceiling limits are set for highly toxic chemicals. Because of their quick action, harm may occur before biological safeguards have a chance to compensate.

Lowest Observable Adverse Effect Level (LOAEL). The LOAEL is the level of exposure at which increases in either frequency or severity of harm occur in exposed groups (when compared to non-exposed groups). The increase in adverse effects may be determined either statistically or through biological monitoring.

No Observable Effect Level (NOEL). This is the level of exposure at which a substance produces no recognizable effect on animals. Many consumable products for humans contain contaminants at levels where there is not an observable effect from the exposure. Allowable levels of toxins in drinking water are set many times lower than the NOEL to allow for a wide margin of safety (Ottoboni, 1991).

Lethal dose/Lethal concentration (LD50/LC50). The single oral dose of a substance at which 50% of the exposed test subjects die is noted as the lethal dose. Inhaled substances and aqueous solutions are given in terms of concentration. The concentration of a substance at which 50% of the test subjects die is noted as lethal concentration (Ottoboni, 1991). Units are usually expressed in milligrams of a chemical per kilogram of body weight (mg/kg). These measures are useful in determining relative acute toxicity of substances, allowing for

IN SUMMARY

Toxicology Primer

Understanding Workplace Hazards and Protecting Worker Health

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1. Occupational health nurses must be aware of potential hazards to employees in the work environment and apply scientific principles to their practice of promoting worker safety and health.
2. All chemicals have the capacity to produce harm. Toxicity is a relative term that refers to the potential for causing harm. Physical characteristics, potential effects, target organs, and conditions of exposure are factors that determine the toxicity of a chemical. Susceptibility of populations and individuals are also determining factors in toxicity.
3. The dose–response relationship between chemical exposure and the effects of that exposure is central to understanding toxic exposures in the environment. Environmental cancers are an exception to the typical dose–response relationship pattern both in time and response.
4. Professional, regulating, and research organizations set or recommend certain occupational exposure limits on chemicals in the workplace. These limits, or standards, are established to protect worker safety and health. There are differences in the published limits.

comparison of how toxic one substance is in relation to another. It is important to remember that lethal dose and lethal concentration refer to lethal effects and do not quantify levels of non-lethal effects. A chemical may produce various degrees of adverse effects below the lethal dose or concentration level.

Immediately Dangerous to Life and Health (IDLH). Another notation found on product labeling and the Material Safety Data Sheets is IDLH. OSHA defines an immediately dangerous to life or health concentration as:

> an atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere (U.S. Department of Labor, OSHA, 1999d).

CASE STUDY

A 38 year old woman visited the occupational health department of a chemical manufacturing company where she has been employed for almost 20 years as a chemical operator. The employee expressed concern that she and her husband had not been able to conceive a child during the past 4 years. The employee's husband has a child from a previous marriage. However, the employee has never conceived. The employee knows that ethylene oxide, a chemical to which she claims to have had a significant exposure, is a reproductive toxin. She asks the occupational health nurse whether the exposure could be the reason she has been unable to conceive.

The occupational health nurse examined the employee's health record and discovered that 10 years earlier, the employee had an exposure to ethylene oxide resulting in nausea, vomiting, and dizziness. The duration of exposure was approximately 3 hours, based on onset of first symptoms until termination of exposure. The employee stated in her report that while working near the ethylene oxide station she developed a headache, but continued working in the same location. A while later, she developed nausea, which she attributed to the headache. As time went on and she continued working, the headache became worse, she developed dizziness and began vomiting. The employee reported to the occupational health department when she began vomiting. She was sent to a local hospital and given palliative treatment for her symptoms, which resolved within 24 hours. No other employees were in the immediate area at the time of this event.

The exact exposure level was undetermined because the release of ethylene oxide was stopped before the industrial hygienist could obtain air samples. There were no stationary monitors in the area at the time of the incident. The ACGIH TWA for ethylene oxide is 1 ppm. OSHA's PEL is also 1 ppm and NIOSH recommends .1 ppm exposure limit.

The occupational health nurse examined the Material Safety Data Sheet, which indicated that ethylene oxide overexposure by inhalation has been shown to result in headache, nausea, dizziness, and vomiting. A NIOSH study reported that reproductive and carcinogenic concerns are associated with ethylene oxide exposures in test animals when they were exposed to 50 or 100 ppm of the chemical 7 hours a day, 5 days per week for 24 months. The occupational health nurse also referred to the Centers for Disease Control and Prevention, Agency for Toxic Substances and Disease Registry (ATSDR) to learn more about the health hazards of ethylene oxide (see Sidebar on p. 259). The ATSDR research states there is some evidence that exposure to ethylene oxide can cause a pregnant woman to miscarry as well as cause infertility in men. No mention is made of a correlation between ethylene oxide exposure and infertility in women.

The occupational health nurse sent the employee to an occupational physician for evaluation related to the reproductive effects of ethylene oxide exposure, the exposure incident, and this employee's apparent infertility. The occupational physician evaluated the employee, reviewed records from her personal infertility specialist and determined that, although ethylene oxide is known to be a teratogen and overexposure may produce symptoms such as nausea, dizziness, and vomiting,

there was no evidence that the exposure event 10 years prior contributed to her inability to conceive at the present time.

Ethylene oxide is known to effect replicating cells such as those of sperm, a zygote, or a fetus resulting in decreased sperm count and motility in men, malformations in a fetus, and spontaneous abortion. However, ova are not replicating cells in adult women and, as such, are not affected by ethylene oxide exposure. This employee's infertility etiology is not likely caused by her prior occupational exposure to ethylene oxide.

The occupational health nurse scheduled the employee for a follow up visit to the occupational health department. During this visit, the occupational physician's report is explained to the employee and she is encouraged to ask any other questions she may have in relation to this issue. Ultimately, the employee is referred to her personal physician to address her inability to conceive.

SUMMARY

Hazardous substances are ubiquitous in the environment and common in industrialized societies. Serious harm can occur with sufficient exposures under certain conditions. However, much harm can be avoided if hazardous substances are handled with respect and appreciation for their use and potential. Occupational health nurses must be aware of potential hazards to employees in the work environment and apply scientific principles to their practice of promoting worker safety and health.

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