INTRODUCTION TO OCCUPATIONAL HEALTH

INTRODUCTION

Definition

What is industrial hygiene?

Industrial hygiene has been defined as "that science or art devoted to the anticipation, recognition, evaluation, and control of those environmental factors or stresses, arising in or from the workplace, which may cause sickness, impaired health and well-being, or significant discomfort and inefficiency among workers or among the citizens of the community."

The industrial hygienist, although basically trained in engineering, physics, chemistry, or biology, has acquired by undergraduate and/or postgraduate study and experience a knowledge of the effects upon health of chemical and physical agents under various levels of exposure. The industrial hygienist is involved with the monitoring and analytical methods required to detect the extent of exposure, and the engineering and other methods used for hazard control.

Historical Perspective

As a means of introduction, it is important to have a historical perspective regarding the field of industrial hygiene. To gain this perspective, selected significant persons and events in the progress of industrial hygiene will be presented along a time line. The environment and its relation to worker health was recognized long ago. However, in antiquity, little was done to protect the workers because they were considered expendable.

We will begin our time line circa 400 BC. History records that as early as the fourth century BC, lead toxicity in the mining industry was recognized and recorded by Hippocrates. This recognition, however, did not lead to any subsequent protection of the miners.

Approximately 500 years later, in the first century AD, Pliny the Elder, a Roman scholar, referred to the hazards in handling zinc and sulfur. He also described a bladder-derived protective mask to be used by laborers subjected to large amounts of dust or lead fumes. For the most part, Romans were more concerned with engineering and military achievements than in making advances in the field of occupational medicine.

In the second century AD, Galen, a Greek physician who resided in Rome, wrote extensively on areas including anatomy and pathology. Galen accurately described the pathology of lead poisoning. Galen also recognized the hazardous exposures of copper miners to acid mists. However, no preventive measures were discussed.

The advent of feudalism in the Middle Ages did little to improve work standards. Possibly the sole advancement of that time was the establishment of feudal guilds which served to assist ill workers and their families.

The study of occupational disease was virtually ignored until 1473 when Ulrich Ellenbog published his pamphlet on occupational diseases and injuries among gold miners. He also wrote about the toxic action of carbon monoxide, mercury, lead, and nitric acid. The field of industrial hygiene was boosted by his instruction in hygiene and other preventive measures.

The field of industrial hygiene was advanced by a German Scholar, Agricola, in 1556. Agricola described the diseases of miners and prescribed preventive measures. His book entitled De Re Metallica included suggestions for mine

ventilation and personal protection for workers, discussions of mining accidents, and descriptions of diseases associated with mining occupations (e.g., silicosis).

In the sixteenth century, industrial hygiene was characterized by mysticism. It was believed that demons inhabited the mines and could be controlled by fasting and prayer.

In 1700, industrial hygiene regained respectability. The first comprehensive book on occupational medicine was published in 1700 in Italy by the "father of industrial medicine," Bernardino Ramazzini. His De Morbis Artificum Diatriba or The Diseases of Workmen, contained accurate descriptions of the occupational diseases of most of the workers of his time. The book described silicosis in pathological terms from observations of autopsies on miners' bodies. Unfortunately his ideas for preventive measures were to be largely ignored for several centuries. However, his book was to have an effect on the future of industrial hygiene. Ramazzini believed occupational diseases were most effectively studied in the work environment rather than in hospital wards. The question posed by Ramazzini, which he felt should be included in every physician's case history of a patient, was "of what trade are you?"

The area of industrial hygiene made further progressions in the eighteenth century due to the efforts of notable physicians. Percival Pott, in recognizing soot as one of the causes of scrotal cancer, was a major force in the passage of the "Chimney-Sweepers Act of 1788." In England, Charles Thackrah wrote a 200-page treatise dealing with occupational medicine. Thackrah's influence was felt in America, because in 1837, the first article on occupational disease appeared and it relied on Thackrah as an authority.

In the twentieth century, efforts in industrial hygiene matters were led by Dr. Alice Hamilton, a champion of the cause of social responsibility for workers' health and safety. She observed industrial conditions first-hand and startled

mine owners, factory managers, and state officials with evidence that there was a correlation between illness and exposure to toxins. She also presented definitive proposals for elimination of unhealthy work conditions.

Federal Regulations

The impact of these advances was not truly felt by the workers until government legislation was passed to protect workers. The need for legislation was brought on by the Industrial Revolution which introduced new hazards into the workplace and intensified old ones. In addition, the number of industrial workers increased markedly in this period. With the passage of the English Factory Acts beginning in 1833, the government first showed its interest in the health of the individual worker. These are considered the first effective legislative acts in the field of industry. The emphases of these acts were directed at providing compensation for accidents rather than for controlling the causes of these accidents. Various European nations jumped on the bandwagon and developed Worker's Compensation Acts. These laws stimulated the adoption of increased factory safety precautions and the establishment of medical service within industrial plants.

In the United States, public awareness of occupation-related diseases brought on the passage of compensation acts for certain civil employees in 1908. In 1911, the first state compensation laws were passed. By 1948, all states had passed such legislation.

Worker's compensation laws were an important factor in the development of industrial hygiene in the United States. The original compensation laws only covered compensation for accidental injury. Occupational diseases were only included if they could be classified as accidents. Today, in most states, there is some coverage for occupational diseases. Worker's compensation laws made it more profitable to control the environment than to pay for the compensation.

Investigations into health conditions in industry were begun by state and federal agencies in the early 1900's. The US Public Health Service and the US Bureau of Mines were the first federal agencies to conduct exploratory studies in the mining and steel industries. The first state industrial hygiene programs were established in 1913 in the New York Department of Labor and by the Ohio Department of Health.

By 1933, federal employee health service was offered by the Tennessee Valley Authority. The Departments of the Army, Navy, and Air Force, and the Atomic Energy Commission all followed within ten years.

Concern for worker safety and health has become international. The establishment of the International Labor Organization (ILO) and the World Health Organization (WHO) has given the world common goals for which to strive.

Today, emphasis has shifted from correctional to preventive industrial hygiene. Social pressures have led to Congress' passing three major pieces of legislation:

- The Metal and Nonmetallic Mine Safety Act of 1966

- The Federal Coal Mine Safety and Health Act of 1969

- Occupational Safety and Health Act of 1970 (OSH Act)

The declared Congressional purpose of the OSH Act is to "assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources." The federal government is authorized to develop and set mandatory occupational safety and health standards applicable to any business affecting interstate commerce. The responsibility for promulgating and enforcing occupational safety and health

standards rests with the Department of Labor.

The OSH Act has brought a restructuring of programs and activities relating to safeguarding the health of the worker. Uniform occupational health regulations now apply to all businesses engaged in commerce, regardless of their locations within the jurisdiction. Nearly every employer is required to implement some element of an industrial hygiene or occupational health or hazard communication program, to be responsive to OSHA and the OSH Act and its health regulations.

ENVIRONMENTAL FACTORS OR STRESSES

Classification

The various environmental factors or stresses that can cause sickness, impaired health, or significant discomfort in workers can be classified as chemical, physical, ergonomic, or biological.

Chemical Hazards

Chemical hazards arise from excessive airborne concentrations of mists, vapors, gases, or solids that are in the form of dusts or fumes. In addition to the hazard of inhalation, many of these materials may act as skin irritants or may be toxic by absorption through the skin.

Physical Hazards

Physical hazards include excessive levels of electromagnetic and ionizing radiations, noise, vibration, and extremes of temperature and pressure.

Ergonomic Hazards

Ergonomic hazards include improperly designed tools or work areas. Improper lifting or reaching, poor visual conditions, or repeated motions in an awkward position can result in accidents or illnesses in the occupational environment. Designing the tools and the job to be done to fit the worker should be of prime importance. Intelligent application of engineering and biomechanical principles is required to eliminate hazards of this kind.

Biological Hazards

Biological hazards include insects, molds, fungi, and bacterial contaminants (sanitation and housekeeping items as potable water, removal of industrial waste and sewage, food handling, and personal cleanliness.) Biological and chemical hazards overlap.

Chemical Hazards

The majority of the occupational health hazards arise from inhaling chemical agents in the form of vapors, gases, dusts, fumes, and mists, or by skin contact with these materials. The degree of risk of handling a given substance depends on the magnitude and duration of exposure.

To recognize occupational factors or stresses, a health and safety professional must first know about the chemicals used as raw materials and the nature of the products and by-products manufactured.

This sometimes requires great effort. The required information can be obtained from the Material Safety Data Sheet (MSDS) that must be supplied by the chemical manufacturer or importer to the purchaser for all hazardous materials under the Hazard Communication Standard. The MSDS is a summary of the important health, safety, and toxicological information on the chemical or the mixture ingredients. Other stipulations of the Hazard Communication Standard require that all containers of hazardous substances in the workplace be labeled with appropriate warning and identification labels.

If the MSDS or the label does not give complete information but only trade names, it may be necessary to contact the manufacturer of the chemicals to obtain this information.

Many industrial materials such as resins and polymers are relatively inert and nontoxic under normal conditions of use, but when heated or machined, they may decompose to form highly toxic by-products. Information concerning these types of hazardous products and by-products must also be included in the company's Hazard Communication Program.

Breathing of some materials can irritate the upper respiratory tract or the

terminal passages of the lungs and the air sacs, depending upon the solubility of the material. Contact of irritants with the skin surface can produce various kinds of dermatitis.

The presence of excessive amounts of biologically inert gases can dilute the atmospheric oxygen below the level required to maintain the normal blood saturation value for oxygen and disturb cellular processes. Other gases and vapors can prevent the blood from carrying oxygen to the tissues or interfere with its transfer from the blood to the tissue, thus producing chemical asphyxia or suffocation. Carbon monoxide and hydrogen cyanide are examples of chemical asphyxiants.

Some substances may affect the central nervous system and brain to produce narcosis and/or anaesthesia. In varying degrees, many solvents have these effects. Substances are often classified according to the major reaction that they produce, as asphyxiants, systemic toxins, pneumoconiosis-producing agents, carcinogens, irritant gases, and so on.

ROUTES OF ENTRY

In order for a harmful agent to exert its toxic effect it must come into contact with a body cell, and must enter the body through inhalation, skin absorption, or ingestion. Chemical compounds in the form of liquids, gases, mists, dusts, fumes, and vapors can cause problems by inhalation (breathing), absorption (through direct contact with the skin), or ingestion (eating or drinking).

Inhalation

Inhalation involves those airborne contaminants that can be inhaled directly into the lungs and can be physically classified as gases, vapors, and particulate matter that includes dusts, fumes, smokes, and mists.

Inhalation, as a route of entry, is particularly important because of the rapidity with which a toxic material can be absorbed in the lungs, pass into the bloodstream, and reach the brain. Inhalation is the major route of entry for many hazardous chemicals in the work environment.

Absorption

Penetration through the skin can occur quite rapidly if the skin is cut or abraded. Intact skin, however, offers a reasonably good barrier to chemicals. Unfortunately, there are many compounds that can be absorbed through intact skin.

Some substances are absorbed by way of the openings for hair follicles and others dissolve in the fats and oils of the skin, such as organic lead compounds, many nitro compounds, and organic phosphate pesticides. Compounds that are good solvents for fats (such as toluene and xylene) also can cause problems by being absorbed through the skin.

Many organic compounds, such as cyanides, and most aromatic amines, amides, and phenols, can produce systemic poisoning by direct contact with the skin. Absorption of toxic chemicals through the skin and eyes is the next important route of entry after inhalation.

Ingestion

In the workplace, people can unknowingly eat or drink harmful chemicals if they do not wash before eating or store drinking containers in the workplace. Toxic compounds are capable of being absorbed from the gastrointestinal tract into the blood stream. Lead oxide can cause serious problems if people working with this material are allowed to eat or smoke in work areas. In this situation, careful and thorough washing is required both before eating and at the end of every shift.

Inhaled toxic dusts can also be ingested in amounts that may cause trouble. If the toxic dust swallowed with food or saliva is not soluble in digestive fluids, it is eliminated directly through the intestinal tract. Toxic materials that are readily soluble in digestive fluids can be absorbed into the blood from the digestive system.

It is important to study all routes of entry when evaluating the work environment - candy bars or lunches in work area, solvents being used to clean work clothing and hands, in addition to air contaminants in working areas.

TYPES OF AIR CONTAMINANTS

There are precise meanings of certain words commonly used in industrial hygiene. These must be used correctly in order to :

- Understand the requirements of OSHA's regulations;

- Effectively communicate with other workers in the field of industrial hygiene; and

- Intelligently prepare purchase orders to procure health services and personal protective equipment.

For example, a fume respirator is worthless as protection against gases or vapors. Too frequently, terms (such as gases, vapors, fumes, and mists) are used interchangeably. Each term has a definite meaning and describes a certain state of matter.

States of Matter

Air contaminants are commonly classified as either particulate contaminants or gas and vapor contaminants.

Particulate Contaminants
The most common particulate contaminants include dusts, fumes, mists, and fibers.

Dusts. These are solid particles generated by handling, crushing, grinding, rapid impact, detonation, and decrepitation (breaking apart by heating) of organic or inorganic materials, such as rock, ore, metal, coal, wood, and grain.

Dust is a term used in industry to describe airborne solid particles that range in size from 0.1 to 25 micrometers (µm). One micrometer is a unit of length equal to one millionth of a meter. A micrometer is also referred to as a "micron" and is equal to 1/25,400 of an inch.

Dust can enter the air from various sources, such as the handling of dusty materials, or during such processes such as grinding, crushing, blasting, and shaking.

Most industrial dusts consist of particles that vary widely in size, with the small particles greatly outnumbering the large ones. Consequently (with few exceptions), when dust is noticeable in the air near a dusty operation, probably more invisible dust particles than visible ones are present. A process that produces dust fine enough to remain in the air long enough to be breathed should be regarded as hazardous until proven otherwise.

An airborne dust of a potentially toxic material will not cause pulmonary illness if its particle size is too large to gain access to the lungs. Particles 10 µm in diameter and larger are known as *non-respirable*. These particles will be deposited in the respiratory system long before they reach the alveolar sacs - the most important area in the lungs.

Particles less than 10 µm in diameter are known as *respirable*. Since these particles are likely to reach the alveoli in great quantities, they are potentially more harmful than larger particles.

By using a size-selective device (such as a cyclone) ahead of a filter at a specific airflow sampling rate, it is possible to collect respirable-sized particles on the filter. This allows one to determine the dust concentration of respirable particles.

Fumes. These are formed when the material from a volatilized solid condenses in cool air. The solid particles that are formed make up a fume that is extremely fine - usually less than 1.0 μm in diameter. In most cases, the hot vapor reacts with the air to form an oxide. Gases and vapors are not fumes, although the terms are often mistakenly used interchangeably.

Welding, metalizing, and other operations involving vapors from molten metals may produce fumes; these may be harmful under certain conditions. Arc welding volatilizes metal vapor that condenses - as the metal or its oxide - in the air around the arc. In addition, the rod coating is partially volatilized. These fumes, because they are extremely small, are readily inhaled.

Other toxic fumes - such as those formed when welding structures that have been painted with lead-based paints, or when welding galvanized metal - can produce severe symptoms of toxicity rather rapidly in the absence of good ventilation or proper respiratory protection.

Mists. These are suspended liquid droplets generated by condensation of liquids from the vapor back to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing or atomizing. The term mist is applied to a finely divided liquid suspended in the atmosphere. Examples include oil mist produced during cutting and grinding operations, acid mists from electroplating, acid or alkali mists from pickling operations, and spray mist from spray finishing operations.

Fibers. These are solid particles having a slender, elongated structure with length several times as great as their diameter. Examples include asbestos, fibrous talc, and fiberglass. Airborne fibers may be found in construction activities, mining, friction product manufacturing and fabrication, and demolition operations.

Gas and Vapor Contaminants

Gases. These are formless fluids that expand to occupy the space or enclosure in which they are confined. Gases are a state of matter in which the molecules are unrestricted by cohesive forces. Examples are arc-welding gases, internal combustion engine exhaust gases, and air.

Vapors. These are the volatile form of substances that are normally in the solid or liquid state at room temperature and pressure. Evaporation is the process by which a liquid is changed into the vapor state and mixed with the surrounding atmosphere.

Some of the most common exposures to vapors in industry occur from organic solvents. Solvents with low boiling points form vapors readily at room temperature. Solvent vapors enter the body mainly by inhalation, although some skin absorption can occur.

Units of Concentration

In addition to the definitions concerning states of matter that find daily usage in the vocabulary of the industrial hygienist, other terms used to describe degree of exposure include the following:

ppm: This means parts per million parts of contaminated air on a volumetric basis. It is used for expressing the concentration of a gas or vapor.

mg/m³: This means milligrams of a substance per cubic meter of air. The term is most commonly used for expressing concentrations of dusts, metal fumes, or other particles in the air.

mppcf: This means millions of particles of a particulate per cubic foot of

air. This term is not widely used today.

f/cc: This means the number of fibers per cubic centimeter of air. This term is used for expressing the concentration of airborne asbestos fibers.

NOTE

The concentration of a gas or vapor in air is usually expressed in parts per million (ppm), but may be converted to mg/m³ at a temperature of 25°C and a pressure of 760 mm Hg through use of the following relationship:

$$mg/m^3 = ppm \ x \ (Molecular \ Weight \ / \ 24.45)$$

For example:
A 50 ppm concentration of carbon monoxide (molecular weight = 28) is equivalent to a concentration of 57.26 mg/m³ at 25°C and 760 mm Hg.

Note also that:

$$Concentration \ (ppm) = Concentration \ (\%) \ x \ 10,000$$

For example:
A concentration of a gas or vapor equal to 0.01% is equivalent to a concentration of 100 ppm.

The health and safety professional recognizes that air contaminants exist as a gas, dust, fume, mist or vapor in the workroom air. In evaluating the degree of exposure, the measured concentration of the air contaminant is compared to limits or exposure guidelines.

THRESHOLD LIMIT VALUES

Threshold limit values (TLVs) have been established for airborne concentrations of many chemical compounds. It is important to understand something about TLVs and the terminology in which their concentrations are expressed.

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes annually a list of "Threshold Limit Values and Biological Exposure Indices." The lists are reviewed annually and values are updated as relative data becomes available. The ACGIH is not an official government agency. Membership is limited to professional personnel in government agencies or educational institutions engaged in occupational safety and health programs.

The data for establishing TLVs come from animal studies, human studies and industrial experience, and the limit may be selected for several reasons. It may be based on the fact that a substance is very irritating to the majority of people exposed, or, other substances may be asphyxiants. Still other reasons for establishing a TLV include the fact that certain chemical compounds are anesthetic, or fibrogenic, or can cause allergic reactions or malignancies. Some additional TLVs have been established because exposure above a certain airborne concentration is a nuisance.

The basic idea of TLVs is fairly simple. They refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Because individual susceptibility varies widely, an occasional exposure of an individual at (or even below) the threshold limit may not prevent discomfort, aggravation of a preexisting condition, or occupational illness. In addition to the TLVs set for chemical compounds, there are limits for physical agents, such as noise, microwaves, and heat stress.

Several important points should be noted concerning TLVs. First the term "TLV" is a copyrighted trademark of the ACGIH. It should not be used to refer to the values published in OSHA or other standards. OSHA's limits are known as "Permissible Exposure Limits (PELs)" and will be discussed later. The ACGIH TLVs are not mandatory federal or state employee exposure standards. These limits are <u>not</u> fine lines between safe and dangerous concentrations nor are they a relative index of toxicity.

Three categories of TLVs are specified as follows:

Time-Weighted Average (TLV-TWA) is the time-weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. As shown in the accompanying figure, time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday.
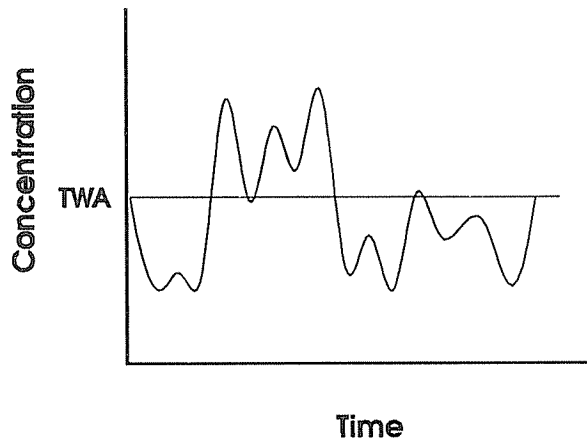
Short-Term Exposure Limit (TLV-STEL) is the maximal concentration to which workers can be exposed continuously for a short period of time without suffering from any of the following:

1. Irritation,

2. Chronic or irreversible tissue change, or

3. Narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency.

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The STEL is a 15-minute time-weighted average (TWA) exposure which should not be exceeded at any time during a work day, even if the 8-hour time-weighted average is within the TLV-TWA. Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range.

The STEL is not a separate independent exposure limit, rather it supplements the time-weighted average limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

Ceiling (TLV-C) is the concentration that should not be exceeded even instantaneously. Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are _predominantly fast acting_ and whose threshold limit is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling "C" limit that should not be exceeded.

For some substances, for example, irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, either two or three categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these three TLVs is exceeded, a potential hazard from that substance is presumed to exist.

Skin Notation
Nearly one-fourth of the substances in the TLV list are followed by the designation "Skin." This refers to potential significant contribution to the overall

exposure by the cutaneous route, including mucous membranes and the eyes, usually by direct contact with the substance. This designation is intended to suggest appropriate measures for the prevention of cutaneous absorption.

FEDERAL OCCUPATIONAL SAFETY AND HEALTH STANDARDS

The first compilation of health and safety standards promulgated by the Department of Labor's OSHA in 1970 was derived from the then-existing federal standards and national consensus standards. Thus, many of the 1968 TLVs established by the ACGIH became federal standards or permissible exposure limits (PELs). Also, certain workplace quality standards known as maximal acceptable concentrations of the American National Standards Institute (ANSI) were incorporated as federal health standards in 29 CFR 1910.1000 as national consensus standards. These PEL values for general industry were subsequently updated in 1989.

Unlike the TLVs, OSHA's PELs are enforceable by law. Employers must keep employee exposure levels below the PELs of regulated substances. As with TLVs, there are three types of PELs: The most common is the 8-hour Time-Weighted Average (TWA). The others are the Short-Term Exposure Limit (STEL) and the Ceiling Limit (C).

Time-Weighted Average
In adopting the TLVs of the ACGIH, OSHA also adopted the concept of the time-weighted average concentration for a workday. The 8-hour Time-Weighted Average (TWA) is the average concentration of a chemical in air over an eight-hour exposure period.

In general:

$$TWA = \frac{C_a T_a + C_b T_b + \ldots C_n T_n}{8}$$

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Where:

T_a is the time of the first exposure period.

C_a is the concentration of contaminant in period "a."

T_b is another time period during the shift.

C_b is the concentration during period "b."

C_n is the concentration during the "n^{th}" time period.

T_n is the "n^{th}" time period.

To illustrate the formula prescribed above, assume that a substance has an 8-hour time-weighted average PEL of 100 ppm. Assume that an employee is subject to the following exposure:

Two hours exposure at 150 ppm
Two hours exposure at 75 ppm
Four hours exposure at 50 ppm

Substituting this information in the formula, we have:

$$TWA = \frac{(150)(2) + (75)(2) + (50)(4)}{8} = 81.25 \text{ ppm}$$

Since 81.25 ppm is less than 100 ppm, the 8-hour time-weighted average limit, the exposure is acceptable.

Amendments to OSHA's Air Contaminant Standard

On January 19, 1989 (54 FR 2332), OSHA amended its Air Contaminant standard, §1910.1000. New limits were established for many substances and many new PELs were set for substances previously not regulated by OSHA.

The U.S. Court of Appeals, Eleventh Circuit, issued a decision vacating the "Final Rules" of the Air Contaminants Standard (29 CFR 1910.1000) on July 7, 1992. The Court's decision struck down the entire standard.

Effective March 22, 1993, OSHA is enforcing only the following Permissible Exposure Limits (PELs) in 29 CFR 1910.1000:

Table Z-1-A: Those limits specified in the "Transitional Limits" column only
Table Z-2:   All limits
Table Z-3:   All limits

PELs specified in 29 CFR 1910.1001 through the end of Subpart Z of Part 1910 are unaffected by the Court's decision.

Expanded Health - Work Practice Standards

OSHA also has promulgated expanded health standards at §1910.1001 through §1910.1101 for substances including asbestos, vinyl chloride, arsenic, lead, benzene, coke oven emissions, cotton dust, 1,2 - dibromo - 3 - chloropropane, acrylonitrile, ethylene oxide, and formaldehyde. Additionally, thirteen identified carcinogens are regulated.

These standards contain work practice requirements such as exposure monitoring, protective equipment, housekeeping, hygiene facilities, medical surveillance, and employee training in addition to permissible limits.

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Related Publication

Additional information regarding industrial hygiene, including sampling instrumentation and methods, can be found in OSHA Technical Manual, CPL 2-2.20B.