Understanding Toxic Substances

An Introduction to Chemical Hazards in the Workplace

State of California
Department of Public Health
Department of Industrial Relations

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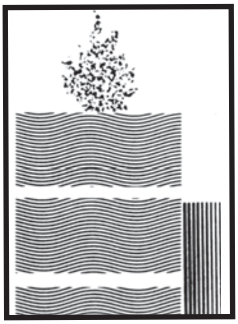
Introduction

Hazardous substances are used in many workplaces today. Working people are discovering that they need to know more about the health effects of chemicals they use or may be exposed to on the job. Textbooks, fact sheets, and Material Safety Data Sheets (MSDSs) provide important information, but they are often written in technical language.

To help you better understand technical information about hazardous workplace chemicals, this booklet explains:

- how chemicals can affect the body,
- what to look for when reading health information,
- the different types of exposure limits for chemicals in the workplace,
- how to know if you are exposed and what you can do to reduce exposure, and
- where to go for additional information.

What makes a chemical toxic?



“Toxic” and “hazardous” are not the same

Toxicity is the ability of a substance to cause harmful health effects. These effects can strike a single cell, a group of cells, an organ system, or the entire body. A toxic effect may be visible damage, or a decrease in performance or function measurable only by a test.

All chemicals can cause harm at a certain level. When a small amount can be harmful, the chemical is considered toxic. When only a very large amount of the chemical can cause damage, the chemical is considered to be relatively non-toxic.

The toxicity of a substance depends on three factors: its chemical structure, the extent to which the substance is absorbed by the body, and the body’s ability to detoxify the substance (change it into less toxic substances) and eliminate it from the body.

The toxicity of a substance is the potential of that substance to cause harm, and is only one factor in determining whether a hazard exists. The hazard of a chemical is the practical likelihood that the chemical will cause harm. A chemical is determined to be a hazard depending on the following factors:

toxicity: how much of the substance is required to cause harm,

route of exposure: how the substance enters your body,

dose: how much enters your body,

duration: the length of time you are exposed,

multiple exposures: other chemicals you are exposed to, and

individual susceptibility: how your body reacts to the substance, compared to other individuals.

Some chemicals are hazardous because of the risk of fire or explosion. These are important dangers, but are considered to be safety hazards. Toxic hazards are more fully explained in this booklet.

Toxicity

Why are some chemicals more harmful than others?

A product's toxicity is determined by its chemical composition – how the atoms and molecules it is made of interact with living tissues. Substances with similar chemical structures often cause similar health problems. For example, many organic (carbon-based) solvents can cause dizziness, affecting the brain in a similar way.

However, sometimes a slight difference in chemical structure can lead to important differences in the type of health effect produced. For example, certain organic solvents can cause cancer.

The way the atoms and molecules cause harm to living tissues is called the mechanism of toxicity. The mechanism of hydrocarbon toxicity to the brain is not fully understood. Some mechanisms, such as the action of carbon monoxide on hemoglobin in red blood cells, are well understood.

Route of exposure

How can chemicals enter the body?

Exposure normally occurs through inhalation, skin or eye contact, and ingestion. These are known as the routes of exposure.

Inhalation. A very important type of workplace exposure occurs when you breathe a substance into the lungs. The lungs consist of branching airways (called bronchi) with clusters of tiny air sacs (called alveoli) at the ends of the airways. The alveoli absorb oxygen and other chemicals into the bloodstream. The surface area of a person's alveoli is roughly equal to that of half of a tennis court.

Some chemicals are irritants and cause eye, nose, and throat irritation. They may also cause discomfort, coughing, or chest pain when they are inhaled and come into contact with the bronchi (chemical bronchitis). Other chemicals may be inhaled without causing such warning symptoms, but they still can be dangerous.

Sometimes a chemical is present in the air as small particles (dust or mist). Some of these particles, depending on their size, may be deposited in the bronchi and/or alveoli. Many of them may be coughed out, but others may stay in the lungs and may cause lung damage. Some particles may be absorbed into the bloodstream, and have effects elsewhere in the body.

Skin Contact. The skin is a protective barrier that helps keep foreign chemicals out of the body. However, some chemicals can easily pass through the skin and enter the bloodstream. If the skin is cut or cracked, chemicals can penetrate through the skin more easily. Also, corrosive substances, like strong acids and alkalis, can chemically burn the skin. Others can irritate the skin. Many chemicals, particularly organic solvents, dissolve the oils in the skin, leaving it dry, cracked, and susceptible to infection and absorption of chemicals.

Eye Contact. Some chemicals may burn or irritate the eye. The eyes are easily harmed by chemicals, so any eye contact with chemicals (particularly liquids) should be taken as a serious incident.

Ingestion (swallowing). Chemicals can be ingested if they are left on hands, clothing, or beard, or when they accidentally contaminate food, drinks, or cigarettes. Metal dusts, such as lead or cadmium, are often ingested this way. Also, particles trapped in nasal or lung mucus can be swallowed.

Dose

How much is too much?

In general, the greater the amount of a substance that enters your body, the greater is the effect on your body. This connection between amount and effect is called the *dose-response relationship*.

For example, solvents such as toluene, acetone, and trichloroethylene all affect the brain in the same way, but to different degrees at different doses. The effects of these solvents are similar to those which result from drinking alcoholic beverages. At a low dose, you may feel nothing or a mild, sometimes pleasant (“high”) sensation. A larger dose may cause dizziness or headache. With an even larger dose you may feel as if you are drunk, pass out, or even stop breathing.

When you inhale a toxic chemical, the dose you receive depends on four factors:

- the level (concentration) of chemical in the air,
- how hard (fast and deep) you are breathing, which depends on your degree of physical exertion,
- how much of the chemical that is inhaled stays in your lungs or is absorbed into your bloodstream, and
- how long the exposure lasts.

It is safest to keep exposure to any toxic substance as low as possible. Since some chemicals are much more toxic than others, it is necessary to keep exposure to some substances lower than others. Some toxic effects appear to have a “threshold” of exposure, below which effects are unlikely to occur. Others, such as increased risk of cancer, are believed to be without a threshold.

Duration

How long is too long?

The longer you are exposed to a chemical, the more likely you are to be affected by it. Chemical exposure which continues over a long period of time can be particularly hazardous because some chemicals can accumulate in the body or because the health damage does not have a chance to be repaired.

The body has several systems, most importantly the liver, kidneys, and lungs, which change some chemicals to a less toxic form (detoxify) or eliminate them. If your rate of exposure to a chemical exceeds the rate at which you can eliminate it, some of the chemical will accumulate in your body. Illness that affects the organs for detoxification and elimination, such as hepatitis (inflammation of the liver), can also decrease their ability to eliminate chemicals from the body.

Accumulation may not continue indefinitely. There may be a point where the amount in the body reaches a maximum and remains the same as long as your exposure remains the same. This point will be different for each chemical. Some chemicals, such as ammonia and formaldehyde, leave the body quickly and do not accumulate at all. Other chemicals are stored in the body for long periods. For instance, lead is stored in the bone, cadmium is stored in the liver and kidneys, and polychlorinated biphenyls (PCBs) are stored in the fat. There are a few substances, such as asbestos fibers, that can remain in the body forever.

How long does it take for a toxic effect to occur?

The effects of toxic substances may appear immediately or soon after exposure, or they may take many years to appear. An acute exposure is a single exposure or a few exposures. Acute effects are those which occur following acute exposures. Acute effects can occur immediately, or be delayed and occur hours or days after exposure. Chronic exposure is repeated exposure that occurs over months and years. Chronic effects are those which occur following chronic exposures, and so are always delayed.

A toxic chemical may cause acute effects, chronic effects, or both. For example, if you inhale high levels of solvents on the job, you may experience acute effects such as headaches and dizziness which go away at the end of the day. Over months, you may begin to develop chronic effects such as liver and kidney damage.

The delay between the beginning of exposure and the appearance of disease caused by that exposure is called the latency period. For example, the latency period of lung injury after exposure to nitrogen dioxide gas may be a few hours. Cancers due to chemical exposure have very long latency periods. Most types of cancer develop following a latency period of many years after a worker's first exposure.

The length of the latency period for chronic effects can make it difficult to establish the cause-and-effect relationship between the exposure and the illness. Since chronic diseases develop gradually, you may have the disease for some time before it is detected. It is, therefore, important for you and your physician to know what chronic effects might be caused by the substances with which you work.

What are the differences between acute and chronic effects?

Acute	*Chronic*
Occurs immediately or soon after exposure (short latency).	Occurs over time or long after exposure (long latency)
Often involves a high exposure (large dose over a short period).	Often involves low exposures (small and repetitive doses) over a long period.
Can be minor or severe. For example, a small amount of ammonia can cause throat or eye irritation; higher concentrations can cause serious or even fatal lung damage.	Often involve inflammation and scarring of organs, such as the lung or kidney. Chronic effects are still unknown for many chemicals. For example, most chemicals have not been tested in experimental animals for cancer or reproductive effects.
Relationship between chemical exposure and symptoms is generally, although not always, obvious.	It may be difficult to establish the relationship between chemical exposure and illness because of the long time delay or latency period.
Knowledge often based on human exposure.	Knowledge often based on animal studies.

Chemical combinations

What if you're exposed to more than one chemical?

Many jobs expose workers to several chemicals. There may be several ingredients in one mixture or product, or there may be several separate chemicals used for different parts of the job. There may also be non-occupational toxic exposures from polluted air, from contaminated food and water, or from alcohol, drugs, and tobacco use. Many toxic chemicals can be found in the body at the same time.

Normally we think of each chemical as having a separate toxic effect inside the body. When some chemical combinations are present, however, the reality is more complicated. For instance, one chemical may interfere with the body's defenses against another chemical, resulting in an increased toxic impact. Combination toxic effects may be additive, synergistic, or potentiating types.

Combination toxic effects

Additive effects. If several chemicals are similar in their toxic effects, the health effect is usually like being exposed to a larger dose of one chemical. A common example is exposure to several solvents, each of which affects brain function in a similar way, causing acute dizziness, drowsiness, and difficulty concentrating. When the results simply add up in this way, the combination is called "additive."

Synergistic effects. Sometimes a chemical combination produces a health effect that is greater than the sum of the individual effects. This kind of interaction is called synergism. An example of synergism is the increased risk of developing lung cancer caused by exposures to both cigarette smoking and asbestos. By either smoking one pack of cigarettes per day or being heavily exposed to asbestos, you may increase your risk of lung cancer to five to ten times higher than someone who does neither. But if you smoke a pack a day and are heavily exposed to asbestos, your risk may be 50 times higher than someone who does neither.

Potentiating effects. Another type of interaction occurs when an effect of one substance is increased by exposure to a second substance, even though the second substance does not cause that effect by itself. For example, although the solvent methyl ethyl ketone does not damage the nerves of the arms and legs by itself, it increases n-hexane's ability to cause this kind of nerve damage.

Unfortunately, few chemicals have been tested to determine if interactions occur with other chemicals.

Susceptibility

Are some people more affected than others?

Yes. People vary widely in their susceptibility to the effects of a chemical. Many things determine how an individual will react to a chemical. These include age, sex, inherited traits, diet, pregnancy, state of health, and use of medication, drugs, or alcohol. Depending on these characteristics, some people will experience the toxic effects of a chemical at a lower (or higher) dose than other people.

People may also become allergic to a chemical. These people have a different type of response than those who are not allergic. This response frequently occurs at a very low dose. Not all chemicals can cause allergic reactions. Substances that are known to cause allergies are called allergens, or sensitizers.

For example, formaldehyde gas has irritating effects, and is also a sensitizer. Everyone will experience irritation of the eyes, nose, and throat, with tears in the eyes and a sore throat, at some level of exposure. All people will experience irritation if exposed to high enough levels. A person may be more sensitive to formaldehyde and have irritation at low levels of exposure. Formaldehyde also occasionally causes allergic reactions, such as allergic dermatitis. People who are allergic to formaldehyde may develop these reactions at very low levels, although most people will not get allergic reactions no matter how much they are exposed to formaldehyde.

How can toxic substances harm the body?

When a toxic substance causes damage at the point where it first contacts the body, that damage is called a local effect. The most common points at which substances first contact the body are the skin, eyes, nose, throat, and lungs. Many toxic substances can also enter the body and travel in the bloodstream to internal organs. Effects that are produced this way are called systemic. The internal organs most commonly affected are the liver, kidneys, heart, nervous system (including the brain), and reproductive system.

A toxic chemical may cause local effects, systemic effects, or both. For example, if ammonia gas is inhaled, it quickly irritates the lining of the respiratory tract (nose, throat, and lungs). Almost no ammonia passes from the lungs into the blood. Since damage is caused only at the point of initial contact, ammonia is said to exert a local effect. An epoxy resin is an example of a substance with local effects on the skin. On the other hand, if liquid phenol contacts the skin, it irritates the skin at the point of contact (a local effect) and can also be absorbed through the skin, and may damage the liver and kidneys (systemic effects).

Sometimes, as with phenols, the local effects caused by a chemical provide a warning that exposure is occurring. You are then warned that the chemical may be entering your body and producing systemic effects which you can't yet see or feel. Some chemicals, however, do not provide much warning, so they are particularly hazardous. For example, some toxic solvents can pass through the skin and cause serious internal damage without producing any observable effect on the skin.

Do all toxic chemicals cause cancer?

No. Cancer, the uncontrolled growth and spread of abnormal cells in the body, can be caused by some chemicals but not by others. It is not true that "everything causes cancer" when taken in large enough doses. In fact, most substances do not cause cancer, no matter how high the dose. Only a relatively small number of the many thousands of chemicals in commercial use today cause cancer.

Chemicals that can cause cancer are called carcinogens, and the ability to cause cancer is called carcinogenicity. Evidence for carcinogenicity comes from either human or animal studies. As of 2008, there is enough evidence for about 500 chemicals to be considered carcinogenic in humans by the California Environmental Protection Agency. Determining the causes of cancer in humans is difficult. There is a long latency period (12 to 25 years or more for most tumors) between the start of exposure to a carcinogen and the diagnosis of cancer. Thus, a substance must be used for many years before enough people will be exposed to it long enough for researchers to see a pattern of increased cancer cases. It is often difficult to determine if an increase in cancer in humans is due to exposure to a particular substance, since exposure may have occurred many years before, and people are exposed to many different substances.

Since the study of cancer in humans is difficult and requires that people be exposed to carcinogenic chemicals and possibly get cancer, chemicals are sometimes tested for carcinogenicity using laboratory animals. If animals were exposed to the low levels typical of most human exposure, many hundreds of animals would be required for only a few to get cancer. To avoid this expense, animal cancer tests use large doses of chemicals in order to be able to detect an increase in cancer in a reasonable number of animals, such as 25-50. However, animal tests are still expensive, take about three years to perform, and are often inconclusive. When an animal cancer test is positive, the risk to a small number of animals at high doses must be used to try to predict the risk to humans at much lower doses. Chemicals that cause cancer in animals are considered likely to cause cancer in humans, even if the degree of risk is uncertain.

The issue of whether there is a safe dose for a carcinogen is complex. Some scientists believe that any exposure to a carcinogen, no matter how small, carries some risk. However, at very low exposures, the risk may be so small that it cannot be distinguished from "background" (naturally occurring) risk. Most carcinogens appear to require either exposure over a number of years or very high doses before the risk of developing cancer from exposure to them becomes of serious concern.

Mutagens

Toxic chemicals can also cause genetic damage. The genetic material of a cell consists of DNA, which is organized into genes and chromosomes. DNA contains the information that tells the cell how to function and how to reproduce (form new cells).

Some chemicals may change or damage the genes or chromosomes. This kind of change, or damage in a cell, is called a mutation. Anything that causes a mutation is called a mutagen. Mutations may affect the way the cell functions or reproduces. The mutations can also be passed on to new cells that are formed from the damaged cell. This can lead to groups of cells that do not function or reproduce the same way the original cell did before the mutation occurred.

Some kinds of mutation result in cancer. Most chemicals that cause cancer also cause mutations. However, not all chemicals that cause mutations cause cancer.

Tests for the ability of a chemical to cause a mutation take little time and are relatively easy to perform. These tests are often performed on microorganisms or cell cultures. If testing shows a chemical to be a mutagen, additional testing must be done to determine whether or not the chemical also causes cancer.

Can future generations be affected?

Exposure to chemical substances may affect your children or your ability to have children. Effects of chemicals on reproduction include a decreased ability to conceive children (infertility, sterility, abnormal sperm, or a longer wait for conception), lowered sex drive, menstrual disturbances, spontaneous abortions (miscarriages), low birth weight, stillbirths, and defects in children that are apparent at birth or later in the child's development. Developmental problems detected after infancy may involve the brain or reproductive system.

Teratogens are chemicals which cause malformations or birth defects by altering the development of tissues in the fetus in the mother's womb. Other chemicals that harm the fetus are called fetotoxins. If a chemical causes health problems in the pregnant woman herself, the fetus may also be affected.

Endocrine disruptors are chemicals that can upset the balance of hormones in workers, possibly affecting reproductive function. It is believed that some endocrine disruptors may affect development of the reproductive organs of the fetus.

For purposes of regulating exposures, there is insufficient information available on the reproductive toxicity of most chemicals. In fact, most chemicals have not been tested for reproductive effects in animals. Even for those chemicals that have been tested in animals, it is difficult to predict risk in humans using animal data. Despite these data gaps, as of 2008, approximately 275 drugs and industrial chemicals are considered to be reproductive risks by the California Environmental Protection Agency.

For more information, see the HESIS booklet, *Workplace Chemical Hazards to Reproductive Health*.

What are the different forms of toxic materials?

Toxic materials can take the form of solids, liquids, gases and vapors, as well as particles of various sizes, including very small, or nanoparticles. Particles, in turn, occur as dusts, fumes, fibers, and mists. How a substance gets into the body and what damage it causes depends on the form or the physical properties of the substance.

A toxic material may take different forms under varying conditions, and each form may present a different type of hazard. For example, lead solder as wire (solid) is not hazardous because it is not likely to enter the body. If the solid solder is rubbed with a file or an abrasive, this forms small particles (dust) that may be inhaled or ingested and absorbed. If lead is heated to a very high temperature (for example, in brazing), a fume may be created; a fume consists of very small particles which are extremely hazardous as they are easily inhaled and absorbed. It is thus important to know what form or forms a given substance takes in the workplace. A description of each of the forms follows.

Solid. A solid is a material that retains its form, like stone. Solids are generally not hazardous since they are not likely to be absorbed into the body, unless present as small particles such as dust, fumes, fibers, and nanoparticles.

Liquid. A liquid is a material that flows freely, like water. Many hazardous substances are in liquid form at normal temperatures. Some liquids can damage the skin. Some pass through the skin and enter the body, and may or may not cause skin damage. Liquids may also evaporate, producing vapors or gases which can be inhaled.

Gas. A gas is a substance composed of unconnected molecules, such that it has low density and no shape of its own, like air. Gases mix easily with air (air itself is a mixture of nitrogen, oxygen, and other substances). Some gases, like carbon monoxide, are highly toxic. Others, like nitrogen, are not toxic but can displace the air in a confined space, causing suffocation due to lack of oxygen; these are called asphyxiant gases.

Vapor. A vapor is the gas form of a substance that can also exist as a liquid at normal pressure and temperature. Most organic solvents evaporate and produce vapors. Vapors can be inhaled into the lungs, and in some cases may irritate the eyes, skin, or respiratory tract. Some are flammable, explosive, and/or toxic. The terms vapor pressure and evaporation rate are used to indicate the tendency for different liquids to evaporate.

Dust. A dust consists of small solid particles in the air or on surfaces. Dusts may be created when solids are pulverized or ground. Dusts may be hazardous because they can be inhaled into the respiratory tract. Larger particles of dust are usually trapped in the nose where they can be expelled, but smaller particles (respirable dust) can reach and may damage the lungs. Some, like lead dust, may then enter the bloodstream through the lungs. Some dusts, such as grain dust, may explode when they reach high concentrations in the air.

Fume. A fume consists of very small, fine solid particles in the air which form when solid chemicals (often metals or plastics) are heated to very high temperatures, evaporate to vapor, and combine with oxygen. The welding or brazing of metal, for example, produces metal fumes. Fumes are hazardous because they are easily inhaled, and have a large surface area in contact with body tissues. Some metal fumes can cause an illness called metal fume fever, consisting of fever, chills, and aches like the "flu." Inhalation of other metal fumes, such as lead, can cause poisoning without causing metal fume fever.

Fiber. A fiber is a solid particle whose length is at least three times its width. The degree of hazard is affected by the size of the fiber. Smaller fibers, such as asbestos, can reach the lungs and cause serious harm. Larger fibers may be trapped in the upper respiratory tract, and are expelled without reaching the lung.

Mist. A mist consists of liquid particles of various sizes which are produced by agitation or spraying of liquids. Mists can be hazardous when they are inhaled or sprayed on the skin. The spraying of pesticides and the machining of metals using metal working fluids are two situations where mists are commonly produced.

Nanoparticles. These extremely small particles, measuring 1 - 100 nanometers in diameter (a nanometer is 1 billionth of a meter), are engineered for useful properties that differ from ordinary materials. They include highly structured forms such as carbon nanotubes (hollow fibers), and unstructured nano-sized versions of familiar materials, such as metals. Airborne nanoparticles are easily inhaled and absorbed into the bloodstream, nervous system, and other organs. Absorption through the skin is also possible. Because of their relatively large surface area, nanoparticles have a high hazard potential relative to their weight.

What are exposure limits?

Exposure limits are established by health and safety authorities to control exposure to hazardous substances. In California the most important exposure limits are the Permissible Exposure Limits (PELs). These are set forth in California regulations. By law, California employers who use regulated substances must control exposures to be below the PELs for these substances. An employer can be cited and fined if employees are exposed over the PEL.

Exposure limits usually represent the maximum amount (concentration) of a chemical which can be present in the air without presenting a health hazard. However, exposure limits may not always be completely protective, for the following reasons:

1. Although exposure limits are usually based on the best available information, this information, particularly for chronic (long-term) health effects, may be incomplete. Often we learn about chronic health effects only after workers have been exposed to a chemical for many years, and then as new information is learned, the exposure limits are changed.

2. Exposure limits are set to protect most workers. However, there may be some workers who will be affected by a chemical at levels below these limits. For instance, employees performing heavy physical exertion breathe in more air and more airborne chemicals, and so may absorb an excessive amount.

3. Exposure limits do not take into account chemical interactions. When two or more chemicals in the workplace have the same health effects, industrial hygienists use a mathematical formula to adjust the exposure limits for those substances in that workplace. This formula applies to chemicals that have additive effects.

4. Limiting the chemical concentration in air may not prevent excessive exposure through skin contact or ingestion. Chemicals that may produce health effects as a result of absorption through the skin have an “S”

designation next to their numerical value in the Cal/OSHA PEL table. Workers exposed to these chemicals must be provided with protective clothing to wear when overexposure through the skin is possible.

In California, Permissible Exposure Limits (PELs) are set by the Occupational Safety and Health Standards Board, and enforced by the Division of Occupational Safety and Health (known as DOSH or Cal/OSHA). PELs have been set for about 850 chemicals. They are periodically revised when new information on toxicity becomes available. California PELs can be the same as federal OSHA PELs, or may be more protective.

These are three types of Cal/OSHA PELs:

1. The 8-Hour Time Weighted Average (TWA) is the average employee exposure over an 8-hour period, based on chemical measurements close to the worker. The measured level may sometimes go above the TWA value, as long as the 8-hour average stays below it. Most chemicals with PELs have a TWA value. Some chemicals have Ceiling or Short Term Exposure Limits in addition to – or instead of – TWA values.

2. The Ceiling Limit (C) is the maximum allowable level. It must never be exceeded, even for an instant.

3. The Short Term Exposure Limit (STEL) is a level that must not be exceeded when averaged over a specified short period of time (usually 15 minutes).

When there is an STEL for a substance, exposure still must never exceed the Ceiling Limit, and the 8-hour average still must remain at or below the TWA.

Recommended exposure limits

An independent professional organization, the American Conference of Governmental Industrial Hygienists (ACGIH), recommends exposure limits. These are called Threshold Limit Values (TLVs). TLVs are reviewed and updated each year as new information becomes available, and published each year in a booklet. Suggested changes are first published as proposals and are given two years for review before being adopted by ACGIH. TLVs are not enforceable standards; however, applying them is considered by many occupational health professionals as good work practice. The Documentation of the Threshold Limit Values summarizes the information on which each TLV is based.

NIOSH, the National Institute for Occupational Safety and Health, publishes recommended exposure limits (RELs) for some chemicals. RELs are usually highly protective to health. Neither RELs nor TLVs are enforceable by Cal/OSHA.

How can exposure be measured and monitored?

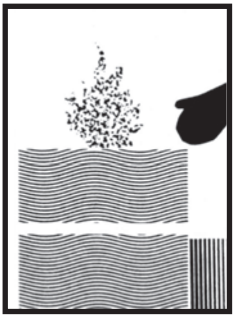
Air sampling

When toxic chemicals are present in the workplace, your exposure can be estimated by measuring the concentration of a given chemical in the air and the duration of exposure. This measurement is called air or environmental monitoring or sampling and is usually done by industrial hygienists, using various types of instruments. Laboratory analysis may be required. The air is collected from your breathing zone (the air around your nose and mouth) so that the concentrations measured will accurately reflect the concentration you are inhaling. The exposure levels calculated from this monitoring can then be compared to exposure limits for that chemical.

Biological monitoring

Environmental monitoring is the most accurate way to determine your exposure to most chemicals. However, for chemicals that are absorbed by routes other than inhalation, such as through the skin and by ingestion, air monitoring may underestimate the amount of chemical you absorb. The levels of the chemical (or its breakdown products) in the body can sometimes be measured in the blood, urine, or exhaled air. Such testing is called biological monitoring, and the results provide an estimate of the actual dose absorbed into the body. For several substances, biological monitoring is required by law when air monitoring results are above a certain level. The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended test methods, and the acceptable range of test results, for biological monitoring for some chemicals. There are approximately 50 of these Biological Exposure Indices (BEIs); they are published together with TLVs. For most workplace chemicals, however, biological monitoring is neither practical nor informative.

Practical clues to exposure



Odor. If you smell a chemical, you are inhaling it. However, some chemicals can be smelled at levels well below those that are harmful, so that detecting an odor does not mean that you are inhaling harmful amounts. On the other hand, some chemicals cannot be smelled even at levels that are harmful.

The *odor threshold* is the lowest level of a chemical that can be smelled by most people. If a chemical's odor threshold is lower than the amount that is hazardous, the chemical is said to have good warning properties. One example is ammonia. Most people can smell it at 5 ppm, below the PEL of 25 ppm. It is important to remember that for most chemicals, the odor thresholds vary widely from person to person. In addition, some chemicals, like hydrogen sulfide, cause you to rapidly lose your ability to smell them; this is called olfactory fatigue. With these cautions in mind, knowing a chemical's odor threshold may serve as a rough guide to your exposure level.

Don't depend on odor to warn you. Remember that your sense of smell may be better or worse than average, that some very hazardous chemicals have no odor (carbon monoxide), some chemicals of low toxicity have very strong odors (for example, mercaptans added to natural gas), and other chemicals produce olfactory fatigue.

Taste. If you inhale or ingest a chemical, it may leave a taste in your mouth. Of course, you should not taste toxic or unknown chemicals on purpose to identify them.

Particles in Nose or Mucous. If you cough up mucous (sputum or phlegm) with particles in it, or blow your nose and see particles or discoloration, then you have inhaled some chemical in particle form. Unfortunately, most particles which are inhaled into the lungs are too small to see.

Settled Dust or Mist. If chemical dust or mist is in the air, it will eventually settle on work surfaces or on your skin, hair, and clothing. It is likely that you inhaled some of this chemical while it was in the air.

Immediate Symptoms. If you or your co-workers experience symptoms known to be caused by a chemical during or shortly after its use, you may have been overexposed. Symptoms might include irritation and tearing of the eyes, a burning sensation of skin, nose, or throat, and cough, dizziness, or headache.

Can you be tested for health effects of exposure?

Sometimes. Medical surveillance is a program of medical examinations and tests designed to detect early warning signs of disease. A medical surveillance program may discover small changes in health before severe damage occurs. Testing for health effects is called medical monitoring. The type of testing needed in a surveillance program depends upon the particular chemical involved. Unfortunately, medical monitoring tests that accurately measure early health effects are available only for a small number of chemicals. A complete occupational surveillance program should consist of industrial hygiene monitoring, medical monitoring, and biological monitoring when appropriate. Tests for health effects when you are already sick are not part of medical surveillance, and must be selected by your physician on a case-by-case basis.

When there is employee exposure to certain chemicals, such as asbestos, arsenic, cadmium, formaldehyde, hexavalent chromium, and lead, employers are required by Cal/OSHA regulations to establish medical surveillance programs. You have the right under Cal/OSHA regulations (CCR, Title 8, Section 3204) to see and copy your own medical records and records of exposure to toxic substances. Your employer must keep these records for at least 30 years after the end of your employment.

How can exposure be reduced?

The surest way to prevent toxic chemicals from causing harm is to minimize or prevent exposure. Below are some methods of controlling exposure.

Training

Everyone who works with toxic substances should know the names, toxicity, and other hazards of the substances they use. Employers are required by law to provide this information, along with training in how to use toxic substances safely. A worker may obtain information about a chemical's composition, physical characteristics, and toxicity from the Material Safety Data Sheet (MSDS). Under California law manufacturers are required to supply an MSDS for products that contain toxic substances. Employers obtain the MSDS when they purchase the product and must make the MSDS available to employees. Unfortunately, the precise chemical composition may be proprietary (trade secret) information, and the toxicity information on an MSDS may be incomplete and unreliable. HESIS can help you interpret the information on an MSDS.

Engineering controls

Limiting exposure at the source is the preferred way to protect workers. The types of engineering controls, in order of effectiveness, are listed below.

Substitution is using a less hazardous substance. But before choosing a substitute, thoroughly consider its physical and health hazards. For example, mineral spirits (Stoddard solvent) is less of a health hazard than perchloroethylene for dry cleaning, but is more of a fire hazard. Also consider environmental aspects such as air pollution and waste disposal.

Process or equipment enclosure is the isolation of the source of exposure, often through automation. This completely eliminates the routine exposure of workers. For example, handling of radioactive materials is often done by mechanical arms or robots.

Local exhaust ventilation is a hood or intake close to the source of exposure to capture or draw contaminated air from its source before it spreads into the room and into your breathing zone. All ventilation systems require careful engineering design and regular maintenance.

General or dilution ventilation is continual replacement and circulation of fresh air sufficient to keep concentrations of toxic substances diluted below hazardous levels. However, concentrations will be highest near the source, and overexposure may occur in this area. If the dilution air is not well mixed with the room air, pockets of high concentrations may exist.

Work practices

Work practices are behaviors performed by workers in order to reduce exposures. Controlling dust dispersion by spraying water (or dust suppressant products), closing containers of volatile chemicals when not in use, and labeling containers of hazardous substances, are common and effective chemical control work practices.

Personal protective equipment

The following devices should be used only when engineering controls are not possible or are not sufficient to reduce exposure.

Respiratory protective equipment consists of devices that cover the mouth and nose to prevent substances in the air from being inhaled. A respirator is effective only when used as part of a comprehensive program established by the employer, which includes measurement of concentrations of hazardous substances, selection of the proper respirator, training the worker in its proper use, fitting of the respirator to the worker, maintenance, and replacement of parts when necessary. A health care professional must first determine whether the individual worker can wear a respirator safely.

Protective clothing includes gloves, aprons, goggles, boots, face shields, and any other materials worn as protection. It should be made of material designed to resist penetration by the particular chemical being used. Such material may be called impervious to that chemical. However, most materials do not remain impervious for very long. The manufacturer of the protective clothing usually can provide some information regarding the substances that are effectively blocked and how often replacement is necessary.

Checklist for researching toxic substances used on the job

In order to determine the health risks of substances, and to find out how to work with them safely, you need to obtain information from many sources including Material Safety Data Sheets (MSDSs), medical and monitoring records, and reference materials. The law requires your employer to make much of this information available to you. The following checklist will help you gather facts which you can use along with the information in this pamphlet to get the answers you need.

1. What is the substance? What's in it? How toxic is it? Are potential health effects acute, chronic, or both?
2. Is there evidence based on studies of animals or humans that the substance is a carcinogen? A mutagen? A teratogen or reproductive toxin?
3. How does this substance enter the body (routes of entry): inhalation, skin absorption, ingestion?
4. What is the legal exposure limit (PEL) or recommended TLV?
5. How much of the substance are you being exposed to? Has the concentration of the substance in the workplace air been tested? How long are you exposed?
6. Are you exposed to other chemicals at the same time? Can they have a combined effect?
7. What symptoms, if any, are you or your co-workers experiencing?
8. Do you have any medical conditions or take any drugs that might interact with chemicals?
9. What controls are recommended to prevent overexposure?
10. Is any type of medical testing recommended?

The glossary in this booklet explains the terms that you are likely to see when you use various reference materials to answer these questions.

Resources

Cal/OSHA (California Division of Occupational Safety and Health)

Cal/OSHA is California's workplace health and safety agency. Cal/OSHA enforces rules to protect workers. You can make a complaint or ask questions about unsafe working conditions, including toxic substances. Your name will remain confidential.

There are Cal/OSHA offices throughout the state. To find a local office, call headquarters at (510) 286-7000, link to **www.dir.ca.gov/DOSH/DistrictOffices.htm**, or see the blue Government Pages of your phone book under: State Government Offices, Industrial Relations Dept., Occupational Safety and Health – Cal/OSHA Enforcement. See **www.dir.ca.gov** for workplace health and safety rules and publications. For chemical exposure limits in general industry, see **www.dir.ca.gov/title8/ac1.pdf**

The Cal/OSHA Consultation Service helps employers who want free, non-enforcement help to evaluate the workplace and improve the health and safety conditions. Employers can call (800) 963-9424.
www.dir.ca.gov/dosh/consultation.html

HESIS (Hazard Evaluation System and Information Service)

HESIS provides information to California workers, employers, and health professionals about the health effects of toxic substances, and ways to prevent work-related injuries and illnesses.
www.cdph.ca.gov/programs/hesis

NIOSH (National Institute for Occupational Safety and Health)

NIOSH is the federal agency for education and research on occupational safety and health. Use their Topics indexes to look up chemicals, safety hazards, diseases, or occupations. (800) 356-4674
www.cdc.gov/niosh/topics

Federal OSHA (Occupational Safety and Health Administration)

Use the OSHA indexes to find information on chemicals, other hazards, or industries.
www.osha.gov/SLTC/index.html

LOHP (Labor Occupational Health Program)

LOHP provides training and technical assistance to employees and labor groups on occupational safety and health in Northern California. (510) 642-5507
www.lohp.org

LOSH (Labor Occupational Safety and Health Program)

LOSH provides training and technical assistance to employees and labor groups on occupational safety and health in Southern California. (310) 794-5964
www.losh.ucla.edu

Internet Resources

The California Department of Public Health has up-to-date links to helpful, reliable information on:

- Workplace hazards
- Worker rights
- Workers' compensation
- Spanish-language resources
- Resources for employers
- Information for health care providers
- Finding workplace health and safety specialists
- Cal/OSHA regulations

www.cdph.ca.gov/healthinfo/workplace

Find HESIS and Occupational Health Branch publications, news, and project reports:

www.cdph.ca.gov/programs/ohb

Glossary

This glossary defines terms used on Material Safety Data Sheets (MSDSs) and other reference materials about toxic chemicals.

ACGIH American Conference of Governmental Industrial Hygienists, a professional organization which recommends exposure limits (*TLV, BEI*) for toxic substances.

acid A substance which dissolves in water and releases hydrogen ions (H+). Acids cause irritation, burns, or other tissue damage, depending on the strength of the acid, which is measured by *pH*.

alkali A substance which dissolves in water and releases a hydroxyl ion (OH-); it has the ability to neutralize an acid and form a salt. Alkalis can be *irritants* or even *caustic* to body tissues. A solution of alkali is often described as alkaline.

allergen A substance that can cause an allergy. Many plant materials, and some industrial chemicals, are allergens.

allergy A reaction to a specific substance, developed by an individual's immune system. Allergies are usually experienced by a minority of people exposed to an *allergen*. Allergic reactions in the workplace tend to affect the skin (see *dermatitis*) and lung (see *asthma*).

ANSI American National Standards Institute, a private organization that recommends safe work practices and engineering designs.

asphyxiant A vapor or gas that can cause loss of consciousness and death due to lack of oxygen, or a chemical that can interfere with the body's use or transport of oxygen.

asthma A lung disease characterized by increased reactivity of the airways to various stimuli. Symptoms include wheezing, coughing, and shortness of breath. It is a chronic inflammatory condition with acute exacerbations (periods when it is more severe). Exacerbations can be due to *irritant* chemicals, *allergens*, and other factors.

base See *alkali*.

BEI Biological Exposure Index, recommended by the *ACGIH* as the maximum recommended value of a substance in blood, urine, or exhaled air, at which most workers would not experience an adverse health effect.

boiling point The temperature at which a liquid boils and changes rapidly to a vapor (gas) state at a given pressure. Expressed in degrees Fahrenheit (F) or Centigrade (C) at sea level pressure.

Cal/OSHA A State of California agency which enforces worker health and safety regulations and provides consultative assistance to employers. Also known as the Division of Occupational Safety and Health (DOSH).

carcinogen A chemical or physical agent capable of causing cancer. Such an agent is often described as carcinogenic. The ability to cause cancer is termed carcinogenicity. Words having similar meaning include oncogenic and tumorigenic.

CAS number The Chemical Abstracts Service Registry Number is a numeric designation which is given to identify a specific chemical compound.

caustic Something alkaline that strongly irritates, corrodes, or destroys living tissue.

ceiling limit The maximum concentration of a material in air that must never be exceeded, even for an instant.

cell The structured unit of which the body's tissues are made. There are many types of cells, such as nerve cells, muscle cells, blood cells. Each type of cell performs a special function.

chromosome The part of a cell that contains genetic material (see *gene*).

combustible Able to catch on fire and burn. The National Fire Protection Association and the U.S. Department of Transportation generally define a "combustible liquid" as having a *flash point* of 100 F° (37.8 C°) or higher (see also, *flammable*).

concentration The amount of a specific substance mixed into a given volume of air or liquid. For workplace exposures, concentration usually refers to the amount of a toxic substance mixed into air.

corrosive — A chemical that causes visible destruction or irreversible alterations in human skin tissue, or other material, at the place of contact.

cubic meter (m^3) — A metric unit of volume, commonly used when expressing concentrations of a chemical in a volume of air. One cubic meter equals 35.3 cubic feet or 1.3 cubic yards. One cubic meter also equals 1000 liters or one million cubic centimeters (cc).

decomposition — Breakdown of a chemical into simpler parts, compounds, or elements.

dermal — Refers to the skin.

dermatitis — Inflammation of the skin; redness (rash) and often swelling, pain, itching, cracking. Dermatitis may be caused by an *irritant* or *allergen*, or by other factors.

dose — The amount of a chemical that enters, or is absorbed by, the body. Dose is usually expressed in milligrams of chemical per kilogram of body weight (mg/kg).

edema — A swelling of body tissues due to water or fluid accumulation.

endocrine disruptors — Substances that change the way natural hormones are produced or work in our bodies to maintain a balanced internal environment, including growth and development, reproduction, behavior, and other functions. When normal hormonal balance is changed, birth defects, reduced fertility, behavioral problems, cancer, and other adverse health effects are possible.

epidemiology — The scientific study of the pattern of disease in a population of people.

evaporation — The process by which a liquid is changed into a vapor and mixed into the surrounding air.

evaporation rate — The rate at which a liquid is changed to a vapor; usually compared to the rate of another substance that evaporates very quickly, such as ether.

explosive limits — The range of concentrations (% by volume in air) of a flammable gas or vapor that can result in an explosion from ignition. Usually given as Upper and Lower Explosive Limits (*UEL* and *LEL*).

exposed, exposure Being in a position of risk from a chemical or other hazard. The noun *exposure* often refers to a chemical to which a person is exposed.

flammable Catches on fire easily and burns rapidly. The National Fire Protection Agency and the U.S. Department of Transportation define a flammable liquid as having a flash point below l00 F° (37.8 C°).

flash point The lowest temperature at which a liquid gives off enough flammable vapor to ignite and produce a flame when an ignition source is present.

gene The part of the chromosome that carries a particular inherited characteristic.

g Gram, a metric unit of mass. One U.S. ounce equals 28.4 grams; one U.S. pound equals 454 grams. There are 1000 milligrams (mg) in one gram.

IDLH Immediately Dangerous to Life or Health. Describes an environment which is very hazardous due to a high concentration of toxic chemicals or insufficient oxygen.

ignition temperature The lowest temperature at which a substance will catch on fire and continue to burn.

incompatible Materials which could cause dangerous reactions, such as fire or explosion, from direct contact with one another.

industrial hygienist An occupational health professional who can recognize, assess, and control workplace health hazards.

inflammation When tissues are injured by chemicals or other causes, they usually respond by swelling, reddening, and leaking fluids. This is called the inflammatory response. Although inflammation can help defend the body and promote healing, excessive or chronic inflammation can cause additional health problems.

ingestion Taking in and swallowing a substance through the mouth.

inhalation Breathing in a substance.

irritant A substance which can cause an inflammatory response or reaction of the eye, skin, or respiratory system.

kg Kilogram, a metric unit of mass, equal to 1000 grams. Also equal to approximately 2.2 pounds.

latency The time between exposure and the first appearance of an effect.

LEL Lower Explosive Limit (see *Explosive Limits*).

LC50 , LC_{50} (Lethal Concentration-50%) A concentration of chemical in air that will kill 50% of the test animals inhaling it. It is a rough measure of acute toxicity by inhalation.

LD50, LD_{50} (Lethal Dose-50%) The dose of a chemical that will kill 50% of the test animals receiving it. The chemical may be given by mouth (oral), applied to the skin (dermal), or injected (parenteral). It is a rough measure of acute toxicity.

liter A metric unit of volume. One U.S. quart is about 0.9 liter. One liter equals 1000 cubic centimeters.

melting point The temperature at which a solid substance changes to the liquid state.

mg/kg A way of expressing *dose*: milligrams (mg) of a substance per kilogram (kg) of body weight.

mg/m^3 A measure of concentration: weight of substance (mg) in a volume of air (m^3), often used to express PELs and TLVs, or to report air sampling results.

mg Milligram, a metric unit of mass. One gram equals 1000 mg. One U.S. ounce equals 28,375 mg.

mmHg A unit of measurement for pressure, expressed in millimeters (mm) of liquid mercury (Hg) in a tube apparatus. At sea level, the earth's atmosphere exerts 760 mmHg of pressure.

monomer See *polymerization*.

MSDS Material Safety Data Sheet, a form which lists the properties and hazards of a product or a substance.

MSHA Mine Safety and Health Administration, an agency in the U.S. Department of Labor which regulates safety and health in the mining industry.

mutagen A chemical or physical agent able to change or damage the genetic material in cells.

NFPA National Fire Protection Association. NFPA has developed a scale of 0 (no hazard) to 4 (severe hazard) for rating the severity of fire, reactivity, and health hazards of substances. The ratings are often displayed in a divided diamond shape.

NIOSH National Institute for Occupational Safety and Health, a federal agency which conducts research on occupational safety and health questions. NIOSH tests and certifies respirators.

odor threshold The lowest concentration of a substance in air that can be smelled. For a given chemical, different people usually have very different odor thresholds.

organic chemicals A large, important class of chemical compounds. The molecules of organic compounds contain carbon atoms. (Not related to organic agriculture.)

OSHA Federal Occupational Safety and Health Administration, an agency in the U.S. Department of Labor which establishes workplace safety and health regulations. Many states, including California, have their own OSHA programs. State OSHA programs are monitored by federal OSHA to ensure they are "at least as effective" as the federal OSHA program.

PEL Permissible Exposure Limit, a maximum allowable exposure level under OSHA or Cal/OSHA regulations.

pH Expresses how acidic or how alkaline a solution or chemical is, using a scale of 0 to 14. For example, a pH of 1 indicates a strongly acidic solution, a pH of 7 indicates a neutral solution, and a pH of 14 indicates a strongly alkaline solution.

polymerization A chemical reaction in which small molecules (monomers) combine to form much larger molecules (polymers) such as plastics. A hazardous polymerization is a reaction that occurs at a fast rate, and releases large amounts of energy. Many monomers are toxic in the liquid and vapor states, but form much less toxic polymers.

ppb Parts per billion, a measure of concentration, such as parts of a chemical per billion parts of air or water (one thousandth of one ppm).

ppm Parts per million, a measure of concentration, such as parts of a chemical vapor or gas substance per million parts of air. PELs and TLVs are often expressed in ppm.

psi	Pounds per square inch, a unit of pressure. At sea level, the earth's atmosphere exerts 14.7 psi.
pulmonary edema	Filling of the lungs with fluid, which produces coughing and difficulty breathing.
reaction	A chemical transformation or change.
reactivity	The ability of a substance to undergo a chemical reaction, such as combining with another substance. Substances with high reactivity are often hazardous, due to the generation of pressure, heat, or toxic products.
reproductive	Refers to the ability of males and females to produce healthy offspring.
respirator	A device that a person wears to reduce inhalation of hazardous substances.
respiratory	Refers to breathing.
solubility	The degree to which a chemical can dissolve in a *solvent*, forming a *solution*.
solution	A mixture in which the components are uniformly dispersed. All solutions consist of some kind of a *solvent* (such as water or other liquid) which dissolves another substance, usually a solid.
solvent	A substance, usually a liquid, into which another substance is dissolved. Often refers to organic solvents, not to water.
STEL	Short-Term Exposure Limit, the maximum average concentration allowed for a continuous 15 minute exposure period.
teratogen	Something that can increase the risk of birth defects in humans or animals. The ability to cause birth defects is called teratogenicity.
TLV	Threshold Limit Value, an exposure limit recommended by the ACGIH.
trade name	The trademark name or commercial name given to a product by its manufacturer or supplier. The trade name on the product label should be on the *MSDS*.
TWA	Time Weighted Average, the average concentration of a chemical in air over the total exposure time, usually an 8-hour work day.

UEL Upper Explosive Limit. See *Explosive Limits*.

vapor pressure A measure of the tendency of a liquid to evaporate and become a gas; usually expressed in *mmHg*. The higher the vapor pressure, the greater the tendency of the substance to evaporate.

volatility A measure of how quickly a substance forms vapors at ordinary temperatures. The more volatile the substance is, the faster it evaporates, and the higher the concentrations of vapor in the air.

On the Web…

Do you want to learn more about workplace health and safety?

The California Department of Public Health has up-to-date links to helpful, reliable information on:

- Workplace hazards
- Worker rights
- Workers' compensation
- Spanish-language resources
- Resources for employers
- Information for health care providers
- Finding workplace health and safety specialists
- Cal/OSHA regulations

www.cdph.ca.gov/healthinfo/workplace

Find HESIS and Occupational Health Branch publications, news, and project reports:

www.cdph.ca.gov/programs/ohb

Hazard Evaluation System and Information Service, HESIS
Occupational Health Branch
California Department of Public Health
(510) 620-5757
CA Relay Service: (800) 735-2929 or 711
www.cdph.ca.gov/programs/hesis