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An Introduction to Toxicology

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Improving Safety in the Chemical Laboratory: A Practical Guide, Jay A. Young, editor,
Wiley-Interscience, 2nd Ed., New York, 1991.

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Toxicology is the study of chemicals that can cause harm to organisms by chemical action and of the ways in which the harm is caused. (Harm to organisms caused by chemical actions such as fires or explosions is not included in this definition.) In this introduction we shall discuss the general concept of toxic harm, the types of chemicals that cause such harm, how the harm is caused, and how to prevent or mitigate that harm.

The specific concepts to be discussed are (1) harm, (2) exposure, (3) responses, (4) signs and symptoms of exposure, (5) susceptibility and risk, (6) treatment of exposure, and (7) prevention. The purpose is to provide information to assist you in making decisions about whether a chemical can cause harm, and how to prevent injury to yourself and others.

HARM

Chemicals can cause toxic harm (injury) in various ways:

1. Injury by poisoning, such as eating a poisonous mushroom.
2. Injury by destruction of tissue, such as an acid burning the skin.
3. Injury by contaminating the air that is in the "breathing zone" – the volume of air surrounding the face, nose and mouth.
4. Injury by displacing the air to be inhaled, such as carbon

monoxide from an automobile exhaust building up in a closed garage.
5. Injury by penetrating through intact skin, and carried by the blood stream to a vulnerable organ within the body – or similarly, by penetration via a cut or blemish in the skin.
6. Injury by penetrating into the body via other body orifices, (ear, eye socket, etc.)

Saying it differently: When you use or handle a chemical, remember that all chemicals are toxic. Oxygen, for example, is poisonous when inhaled at concentrations only slightly greater than 19%, the (approximate) concentration of oxygen in the air. Even water is hazardous; toxic products from chemical reactions of other substances with water have killed more humans than toxic products from chemical reactions involving substances other than water.

It's a good idea to be alert to the toxic hazards that are present whenever you use or handle any chemical. Fortunately, the preponderance of toxic hazards does not cause fatalities. But it's still a good idea to be alert!

Phillipus Aureolus Paracelsus Theophrastus Bombastus von Hohenheim (1493 – 1541), known today as "Paracelsus", wrote many years ago:

> WHAT IS THERE THAT IS NOT POISON? ALL THINGS ARE POISON AND NOTHING [IS] WITHOUT POISON. SOLELY THE DOSE DETERMINES THAT A THING IS NOT A POISON.

That's enough introduction; let's get down to business.

EXPOSURE

The concept of exposure demonstrates that the same chemical can be both harmful and harmless. There are three aspects of exposure.

I. Dose (how much) -- a teaspoonful or a gallon.
2. Duration and frequency (how long and how often) -- a minute or an hour, once or every day for years.
3. Route (how the victim is exposed) -- ingesting (eating or drinking) it, or injecting it (residual potassium cyanide crystals on a shard of glass from a broken beaker penetrating through the skin, for example), or spilling it on the skin, or breathing its vapors, dust, or mist.

Changing any one of these aspects can change the effect. For example, snake venom is harmless if ingested but potentially fatal if injected (by snakebite). And acetaminophen (Tylenol) is effective as a painkiller if you weigh at least 150 pounds and for no longer than 10 days ingest no more than 650 mg every four hours for a total of 3.9 g per day, but severely toxic if you exceed these limits or weigh less than 150 pounds.

Dose

Paracelsus was correct: In general, the larger the dose, the shorter the time it takes for an injury to occur. Conversely, it usually takes longer for injury to result from smaller doses. Further, if the dose is increased, the severity of the harm is intensified. If increased further, the toxin will often eventually cause immediate systemic responses that can be fatal. On the other hand, the dose may be so small that immediate local and systemic injury is not noticed but longer-term problems are created (see the discussion on chronic toxicity, below).

Another term that applies here is *threshold.* The threshold is the dose at which a chemical begins to be harmful. A chemical may have a toxicity threshold of 0.5 g such that drinking less than 0.5 g is not harmful but more than 0.5 g causes nausea. Threshold and its relation to exposure limits are discussed in more detail below.

Duration and Frequency

How long (duration) a person is exposed to a chemical directly affects how severe the injury will be. A chemical that is capable of damaging the eye will do less damage the sooner it is washed out; conversely, the longer it remains in the eye, the more severe the injury. Any chemical that can be absorbed through intact skin and cause an illness will have a less severe effect if it is promptly washed off the skin. The shorter the time such a toxin is on the skin, the less that will be absorbed through the skin.

How often (frequency) one is exposed to a chemical can directly affect the type, time of onset, extent, and severity of the toxic effect. Some chemicals cause immediate or almost immediate injury upon exposure (acute toxicity), while others cause injury only after lengthy, or repeated, exposures (chronic toxicity).

Chronic toxicity deserves further brief discussion: Because the body has the ability to get rid of almost all of certain chemicals that enter it, if the exposure dose is small, the body will eliminate almost all of such a dose. So it will be only after several small exposures that the total amount then remaining in the body will become sufficient to produce a toxic effect. For example, certain chemicals pass through the stomach and intestines with little or no absorption. Others may be absorbed into the blood, then be filtered out by the kidneys, and leave the body via the urine. The speed with which this elimination process occurs is different for different chemicals. A chemical may be cleared from the body faster than it is absorbed, or it may slowly accumulate in various organs over time. Thus, one exposure to a large amount of a chemical may not result in any toxicity, but repeated exposures to smaller amounts of the same chemical could cause injury because each time a tiny amount is absorbed and hence, over time, eventually accumulates to a harmful level.

Routes of exposure

Chemicals can take different routes, different pathways, to enter the body. Probably the most obvious is by mouth (ingestion).

> ***Exposure by ingestion*** is usually accidental, but not necessarily so. For example, a victim might have a chemical on his or her fingers and then put a finger in the mouth, or might eat a sandwich or smoke a cigarette without first washing their hands. For a different example: keeping sugar in a beaker in the lab can result in putting the wrong white crystalline solid, from a different beaker, into a cup of coffee.
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> ***Exposure by inhalation*** (breathing) is obvious; however, some gases such as carbon monoxide are odorless, and many others, such as chloropicrin, methanol, and phosgene, are harmful at concentration levels very much lower than their odor detection threshold. Dusts, mists, gases, vapors, and sprays can enter the lungs through the nose and mouth during normal breathing. Of all the different routes of exposure, exposure by inhalation provides the most rapid

means of entry into the body, usually causes harmful effects most rapidly, and is the predominant route by which users of chemicals are exposed to toxic substances.

Exposure by absorption through intact skin. Chemicals can be absorbed into the body through unbroken, intact skin. The victim is not always aware of the absorption. Usually skin absorption is a slow process. But when the skin is damaged by cuts, abrasions, and the like, chemicals can be absorbed much more rapidly. In either event, chemicals can be absorbed through the skin when clothing, shoes, or a lab coat has been contaminated with a toxic chemical. Some chemicals (phenol is an example) can penetrate the skin very rapidly, causing death within 30 minutes of the initial contact.

Exposure by injection is typically accidental. For example, when cleaning up the debris from a broken glass beaker or bottle that contained a toxin, and the sharp edge of a piece of broken glass cuts, say, a hand or arm, some of the residual toxin on that glass shard can be injected into the body of the victim.

Exposure via orifices in the body. A less obvious route of entry is through body orifices other than the nose or mouth. For example, consider the space between each of the eyeballs and the eye-socket. Chemicals are very quickly absorbed through these two spaces and enter the bloodstream. Also, there are open passages inside the skull joining the eyes, nose, and mouth, so that anything that gets into the eyes can be inhaled and/or swallowed. Chemicals can get into the eyes as liquids or powders by splashing or by being on the fingertips when the eyes are rubbed. Any gas, mist, fume, or dust can enter the body through the eyes.

There are many ways a chemical can enter the body, sometimes without the victim's knowing that it is happening.

TYPES OF RESPONSE

The body's response from exposure to a toxic chemical can take many forms. To begin with, the response may be immediate, within seconds or minutes of contacting a chemical. For example, a skin burn from spilled acid is immediate, the result of a one time contact (an acute exposure) with the chemical. Responses that occur only after several separate exposures over a long period of time (chronic exposures) are referred to as delayed responses. These types of response are usually (though not necessarily) more life threatening than acute responses, and can be insidious because the victim often is not aware of the hazard until it may be too late.

Instead of classifying a response as acute or chronic, the response to a chemical exposure can be described as either local or systemic, or both.

Local Responses

Local responses occur at the site of chemical contact. These sites typically, but not always, are the skin and eyes. (Taking a chemical by mouth, for example, would cause local effects inside the mouth, in the esophagus, in the stomach, and/or in the intestines.) Most local effects occur after a single exposure and range from minor irritation to severe tissue destruction.

However, local effects may require repeated exposures to show up for instance, a delayed response resulting in an allergic skin rash (technically, a local contact skin allergy is a systemic response with local effects). The following examples of specific types of local responses will illustrate.

1. Eyes. Local eye responses occur as a result of splashing a liquid or solid in the eve, or from contact with a gas, mist, or dust. Responses are usually (but not always) immediate, and result in pain and tearing. Some chemicals can produce an immediate loss of feeling (anesthesia) in the eye, so even though there is no pain, the eye is being damaged, sometimes severely. Also, delayed local responses can occur in the eye. Loss of sight may not necessarily be immediate; it may occur slowly over several days or even weeks.

2 Skin. Local skin responses occur as a result of splashing or spilling a liquid or solid on the skin. As is the case with the eyes, skin responses can be either immediate or delayed, and result in pain and tissue destruction. For example, solutions of sodium or potassium hydroxide on the skin usually cause no pain – until the underlying skin and interior tissues have been destroyed, even down to the bone, before any pain develops. Hydrofluoric acid has similar properties except that the eventual pain is extremely severe.

3. Digestive tract. Local responses can occur in the mouth, esophagus, stomach, and intestines. They occur as the result of swallowing a chemical. Local responses of this type include burns of the mouth and esophagus and ulcers of the stomach and intestines. These local responses can cause severe long-term illness and even death.

4. Nose and lungs. Breathing in certain gases, powders, mists, or fumes can cause burns inside the nose and lungs. Again, as in the case of the digestive system, this type of exposure can lead to death, for example, by destroying lung tissue.

5. *Phototoxicity.* A special type of local irritation, known as phototoxicity occurs when a chemical on the skin is exposed to sunlight. Although the chemical may not be an irritant by itself, it is activated by sunlight to cause the burning sensation characteristic of irritation. Thus, one may come in contact with a phototoxic chemical without knowing it because there is no discomfort until the exposed skin is in the sunlight. (See the discussion on photosensitivity, below.)

6. *Corrosivity.* The most severe local response is a corrosive response. Corrosivity results in direct tissue destruction. Some chemicals can "burn" a hole through the skin down to the bone (see above). Others can destroy the tissue of the eye or the lining of the stomach or lungs. Solids, liquids, and gases are capable of causing corrosive responses. Liquids probably are the most significant concern because they are the most readily spilled or splashed.

   Corrosive solids pose somewhat less of a hazard than liquid because their effects depend to some extent on how soluble they are in the tissue, how much moisture is present in the air, the tissue involved, and how long they are in contact.

   Whereas liquid corrosivity is almost always rapid, solid corrosivity is somewhat slower. Therefore, quick removal of the solid can limit the extent of the damage. An additional danger that solids often pose is the heat given off when they come in contact with moisture on or within the underlying tissue. The heat can be great enough to cause thermal destruction of tissues in addition to corrosive destruction.

Liquids and solids can be seen; one can be aware of their presence. But gases can be pervasive, they do not always warn by their odor, and they are usually invisible. Corrosive gases such as ammonia can destroy the lining of the lungs, resulting in death or in a pneumonia-like condition that leaves the victim sick for a long time. Fumes and mists from corrosive liquids are almost invisible but are equally destructive. Dusts from corrosive solids are also destructive.

Systemic Responses

In general, systemic (meaning inside the body) responses are usually much more serious than local responses. As described earlier, there are many routes available to a chemical for entry into the body, and there is not necessarily a local response at the site of entry to act as a warning. Some chemicals can pass through the eyes, skin, or lungs without causing any local effects, but they can cause severe systemic responses.

For a systemic response to occur, the chemical must get into the bloodstream. Once in the blood, the chemical can be transported to all organs and systems of the body, affecting some but not affecting others. An organ or system which is susceptible to damage by a chemical is referred to as a target organ or system for that chemical.

Systemic responses are classified by the organ or system affected, such as the heart, liver, bladder, respiratory system, and central nervous system. There are hundreds of different systemic responses. The following general principles and examples illustrate how organ systems can react to chemicals.

Like local responses, systemic responses can be immediate or delayed. Some allergic responses (called anaphylactic reactions) can occur within minutes of exposure. They are usually so severe that death will result in a short time if they are not treated. Other, not allergic, systemic responses develop slowly over many years. For example, after repeated exposures to a chemical, certain cancers can develop many years later even though the victim has never come in contact with that chemical again during the long interval between those exposures and the appearance of the cancer.

Chemicals that affect the reproductive system may prevent a victim from having children but otherwise have no recognizable effect on general health. Some other chemicals may change the genetic material in the reproductive cells (sperm or egg) such that the victim's general health appears normal and the apparent health of the victim's child also appears normal, but when the child nears physical maturity, at about age 20, he or she develops a serious illness.

This can occur as a result of the mother or father having been exposed to a chemical before the child's conception, or the mother being exposed during pregnancy. Exposure of pregnant women to certain chemicals during certain specific times in the pregnancy can cause the unborn child to die or to be born with any of several birth detects, even though the mother was never sick. These examples of delayed systemic responses illustrate how serious the exposures to some chemicals can be, especially because there are no immediate signs or symptoms of exposure.

A special type of systemic response is the sensitization response. Sensitization is the process whereby the body reacts against a chemical by means of an allergic response. An allergic response consists of a series of events that take place as the body tries to get rid of the chemical. Sensitization develops over a long period of time because it takes a few exposures or several exposures before the body begins to recognize the chemical as foreign (sometimes it takes years for this to happen). However, once this happens, the body never forgets it. Usually there are no noticeable symptoms of exposure during the development period, so the victim is unaware of the developing sensitivity to the foreign substance until sensitivity is fully developed. Then it is too late.

Once sensitivity has developed, there are two possible types of sensitization response. The immediate type can occur within minutes of exposure. The severity of response ranges from anaphylaxis, mentioned previously, to hay fever, which is not life threatening. Sensitizing chemicals enter the body through the mouth, eyes nose, and skin. The delayed type of response takes several hours or even a day to develop. The area of skin that comes in contact with the chemical becomes red, swollen, and itchy. The response usually worsens over the next several hours, even though the sensitizing chemical is removed, and may last for days. Response to poison ivy is an example of delayed contact sensitization. The contact sensitization response can be distinguished from a local chemical irritation by its itching and persistence. The local irritation response usually stings or burns rather than itches, and once the irritating chemical is removed, the response does not get worse as time passes.

A special type of sensitization is photosensitization. This is a delayed allergic response that occurs when certain chemicals are exposed to sunlight. The chemical by itself does not cause an allergic response. It must be in the skin at the time of exposure to the sun. However, the victim does not have to get the chemical directly on the skin, as in contact allergy. It may be a photosensitizing chemical that entered the body through the mouth, eyes, or nose. After being absorbed into the blood, it is distributed to the skin, where the sunlight can reach it. Thus, victims can get photosensitizers in their skin and have no response as long as they are wearing long sleeves, or go between home and work in the dark. But upon going out into the sunlight, they get a strong allergic skin response. The symptoms of this type of response can be severe compared to ordinary allergic skin responses.

There is a special disease associated with photosensitization called persistent light reactivity. Although rare, this disease is becoming more frequent. Essentially, persons with this disease have been photosensitized to a certain chemical. Their entire body produces a severe allergic response, not just a local skin rash, every time they are exposed to sunlight -- for the rest of their lives. These unfortunate persons may also develop other complicating medical conditions and must spend the rest of their lives in the shadows.

RECOGNITION OF EXPOSURE

How can a person tell if he or she has been exposed to a harmful chemical? Quite often, the first sign or symptom is given by the senses.

The victim may feel it -- a liquid on the skin feels wet, warm, or cold, or it hurts.

The victim may smell or taste it (some gases or vapors in the air can be smelled or tasted).

The victim may see the chemical on the skin.

The victim's eyes or nose may begin to water or sting.

Or, the victim may have no sense stimulation; instead, the victim has a mild or severe headache, or feels dizzy, starts to cough, feels nauseated, or has slurred speech, stumbles or falls down when they try to walk or stand, or has difficulty breathing. Or the victim may fall down unconscious or dead.

Except for the fatal effect, all of these are signs that provide an early warning of exposure and of possible injury. Unfortunately, these signs are not foolproof; as mentioned earlier, some chemicals may induce a local anesthesia (loss of feeling). Other chemicals with strong odors, hydrogen sulfide is an example, can cause anosmia (loss of the sense of smell) very soon after exposure, so the victim thinks the exposure is over when it really is still present.

When you use or handle chemicals, be alert, be continuously aware of how you feel every day. Be sensitive to any changes in normal bodily functions. Some symptoms of exposure are tricky: they come, they go, and then come again later. One day the victim does not feel right, the next day he or she feels fine. Then a week or so later the victim again does not feel right, but this, too, passes. These warning signs should not be disregarded. They should be recognized as possible signs of toxic exposure, whether they are persistent, or seem to come and go, or are strong or mild. Persons who suspect that they may have been exposed to a harmful chemical should consult a physician promptly.

SUSCEPTIBILITY AND RISK

Not all people are affected to the same degree by the same chemical. Each person has a different level of susceptibility. Many factors affect an individual's susceptibility, including the following.

I. Age. Very young and very old people are usually more likely to be affected. They are also typically susceptible to a lower dose than are those between the ages of 20 and 60.

2. Gender. Some chemicals specifically harm only the male or female reproductive organs. Also, a general harmful effect may be worse for one gender than the other because of differences in body chemistry (hormones) and metabolism (the chemical reactions that occur in the body).

3. General Health. People who are ill or run down or tired seem to be more susceptible to toxins than those who are healthier and well rested.

These are the three most common factors that affect susceptibility to injury. There are several other factors; some can be controlled, such as diet or the general state of one's health; other factors, such as inherited differences in toxic susceptibility, cannot be controlled.

Risk can be defined as the probability of being injured. The exposure aspects influence this probability: how much, how long, how often, and route of exposure. Risk is also influenced by personal susceptibility factors: age, weight, sex, inherited characteristics, general health, and many others. It is not a simple matter to predict the risk of harm because of the influence of personal susceptibilities. Not only do these differ from one person to another, they may vary for the same person from one day to the next, and they may vary without that person being aware of a change.

TREATMENT OF EXPOSURE

The discussion here describes recommended general first aid procedures only. It should not be understood or interpreted as giving general or specific medical advice.

The basic principle in all first aid procedures is to dilute the chemical as much as possible, as quickly as possible, and to get competent professional medical care immediately. The following suggested procedures apply not only when someone else is accidentally exposed, but also when you, the reader, are exposed. In many cases fellow workers may not know how to help when a victim is exposed to a chemical, or may panic at the sight of an accident. A person then may save their own life by telling someone else how to help.

Acute Exposure

For local reactions, first remove the chemical from the site of exposure. That is, wash the exposed area *immediately* with copious running water (e.g., a safety shower delivering at least 50 gal/min) for at least 15 minutes. While washing, remove any contaminated clothing, including shoes, socks, wristwatch, belt, and so on. Do not risk contaminating the eyes by pulling clothing (such as a sweater) off over the head of the victim; cut it off with scissors. *Never* wash off the chemical with a solvent other than water. In many cases, this would only drive the chemical into the skin more rapidly.

Eyes should be rinsed *immediately* in copious running water for at least 15 minutes (e.g., at an eyewash fountain). While the eyes are being washed, hold the upper and lower eyelids away from the eyeball and move the eyes up, down, left, right, continuously as the water washes the eye. The idea here is to rinse out any contaminant from the rear of the eyeball, to get it as far away from the optic nerve as possible, and quickly so.

While the washing procedure is going on, a fellow worker should call for emergency assistance -- doctor, hospital, or ambulance, stating the details and especially including the chemical or chemicals involved. Only when specifically directed by a physician (not by a nurse or paramedical person) should the 15 minute minimum washing be terminated prematurely and the victim removed for other treatment. Almost always, the most important immediate action is to wash the chemical away: only a 15-minute minimum washing with copious flowing water is known to be generally effective.

Under all circumstances, no matter how minor the exposure may appear to be, someone other than the victim should transport the victim to a hospital or other suitable location for further treatment.

First aid treatment for ingestion is not the same for all chemicals. Unless the label or material safety data sheet specifically recommends that vomiting be induced (by drinking two glasses of water and tickling the back of the throat with a finger) do not induce vomiting. Even if vomiting is reliably recommended, never give anything by mouth to an unconscious victim.

If so directed by a physician, take the victim to the hospital promptly. The hospital should be alerted in advance that the victim is coming and the chemical should be identified; if possible take a copy of the label and/or the Material Safety Data Sheet (MSDS) along with the victim.

Inhalation of a chemical should be treated similarly: dilute the chemical. In this case, the chemical is diluted with fresh air. Get the victim away from the contaminated area immediately and have him or her breathe fresh air. If there is difficulty in breathing, maintain artificial respiration until the ambulance arrives to transport the victim to the hospital. If a victim is overcome and is unconscious, remove him or her to fresh air immediately and, if not breathing, begin artificial respiration on the spot. Meanwhile, the emergency services should be alerted.

The most important thing is to remain calm and not panic (easier said than done). Do not shrug off an accidental exposure as not being serious enough to report or to seek medical attention. *Without exception*, all exposures should be reported and should receive medical attention. A victim should never assume that they are able to treat even a small exposure themselves.

Chronic Exposure

Although they may now feel fine, persons who think they have been overexposed to a chemical recently or even some time ago should see a physician, preferably a physician specializing in industrial medicine. They should be prepared to identify the chemical(s) to which they may have been exposed, and when and for how long they were exposed, and to bring copies of MSDSs for the chemical(s). Persons who are not sure they have been overexposed to a harmful chemical but "just do not feel right lately" should see a physician. As discussed above, some chemicals do not have any immediate or local effects, but cause harm after a period of repeated low dose exposures. Persons who work with chemicals should have annual examinations to establish baseline medical values that can be compared from year to year. In this way, the physician may be able to pick up a change in a person's medical condition before the victim feels ill. The earlier the exposure is recognized the better the chance of successful treatment.

PREVENTION OF HARM

The best way to prevent being harmed by a chemical is to avoid being overexposed to it. Workers who use or handle chemicals should learn all about the possible harmful effects of every chemical they use or handle. They should learn and then use the proper procedures for protecting themselves from excess exposures, and learn and be able to use the proper first aid procedures in case of an exposure. This information is found in brief form on the label of the chemical container and in detail in the MSDS for that chemical. For every chemical that you will use or handle, you should know all of these details before you start to do any work.

Knowing the Dangers

Federal OSHA and corresponding state regulations in the United States require that before employees begin work with any hazardous chemical, employers are required by those regulations to instruct their employees about the hazards of the chemicals they may be exposed to and the means they should take to protect themselves from harm. To fulfill this obligation, employers train employees and make available MSDSs for the hazardous chemicals used or handled by employees.

The following discussion deals with the health hazard data section of an MSDS. As briefly mentioned above, for most chemicals there is a safe dose, a “threshold”, the concentration or amount of the chemical to which a person can be exposed without harm. This concentration or amount is usually very small, and for approximately 700 commonly used chemicals, it is listed in the MSDSs as the threshold limit value (TLV®) and/or as the permissible exposure limit (PEL). TLVs are recommended by the American Conference of Governmental Industrial Hygienists, and PELs are promulgated by the Occupational Safety and Health Administration.

In the discussion that follows, keep in mind that PELs and TLVs are both threshold values. But in fact, since TLVs are up-dated annually and PELs are only very infrequently changed, it is wiser to rely on a TLV as the safer threshold value for a chemical rather than the PEL for that same chemical.

The average concentration of a chemical in the air to which nearly all persons can be repeatedly exposed for 8 hours a day, day after day without adverse effect is the TLV-time weighted average (TLV-TWA). In an MSDS, TLV is often used when the TLV-TWA is meant. But in any case, this value refers only to a person's exposure by breathing the chemical in the air; it has nothing to do with skin or eye contact or with ingestion. The one exception is for chemicals that can be absorbed through the skin. These are sometimes identified in an MSDS by a special skin notation.

Another term rarely seen in an MSDS is the TLV-STEL, which is the TLV-short term exposure limit. It is the concentration of a chemical in the air, greater than the TLV, to which a worker may be exposed for a short period (no more than 15 minutes) without harm, provided there are no more than 4 such exposures during an 8 hour working day, that each exposure after the first is at least I hour after the preceding exposure, and provided that the time-weighted average exposure for the whole 8 hours does not exceed the TLV-TWA.

Another term is the TLV-C, the TLV-ceiling limit. This is the maximum concentration of a chemical in the air that must not be exceeded during any part of the working day. This term is rarely stated in an MSDS for a chemical to which it applies.

The concept of a TLV should be used wisely. Not all TLVs have been established by scientific experimentation. Many are estimates based on experience with a chemical over many years or based on known information about other chemicals with similar properties. The TLVs are listed in a paperback book available from the American Conference of Governmental Industrial Hygienists (ACGIH) at www.acgih.org/store; for PELs refer to www.osha/gov and look for title 29 CFR part 1000, tables Z-1, Z-2, and Z-3.

The Health Hazard Data section of an MSDS also addresses the toxicity of the chemical, an indication of how much harm the chemical can cause. Often in an MSDS, the level of toxicity (harm) is indicated by a value referred to as the lethal dose 50 (LD-50) or the lethal concentration 50 (LC-50). The LD-50 is the amount of a chemical that kills 50% of the animals it is given to by any route other than breathing. The LC-50 is the concentration of a chemical in the air that kills 50% of the animals exposed to it. You may also see an LD-lo, or LC-lo; these are the lowest doses or concentrations of a chemical known to kill at least one animal by the appropriate route of exposure. The TD-lo (toxic dose low is the lowest dose of a chemical that causes any signs of toxicity (but not death) in animals or humans. The LD and TD values are usually expressed in terms of a dosage, the amount of a chemical per unit of body weight, that is, milligrams of chemical per kilogram of body weight of the test animal (mg/kg). In the case of chemical concentration in the air, the LC values are expressed in terms of the number of parts of a chemical per 1 million parts of air (ppm) or the amount of a chemical by weight per unit volume of air (mg/m3).

Although the absolute LD or LC number for a test animal may not be the same as for a human, the relative toxicity usually will not change between animals and humans. That is, if a chemical is highly toxic to an animal, it will most likely be highly toxic to humans. This tabulation serves as an approximate translation of LD-50 values into everyday language:

Animal LD-50	Amount ingested by a 150 pound adult	Toxicity classification
Up to 50 mg/kg	1 teaspoon or less	Extremely toxic
50 – 500 mg/kg	1 teaspoon to 1 ounce	Very toxic
500 to 5000 mg/kg	1 ounce to 1 pint	Moderately toxic
5 to 15 g/kg	1 pint to 1 quart	Slightly toxic
More than 15 g/kg	More than 1 quart	Practically nontoxic

Adapted from R. E. Gosselin et *al., Clinical Toxicology of Commercial Products. 5th* ed., Williams & Wilkins, Baltimore, 1984.
This table indicates the approximate amount of a chemical ingested by humans that corresponds to an animal lethal dose 50

Another important piece of information in an MSDS is the contact hazard. This is an indication of the local harmful effects of a chemical and describes how irritating or corrosive a chemical is to eyes, skin, and the respiratory tract. Unlike the health hazard, the contact hazard is not usually expressed in terms of numbers, but in descriptive words, such as “highly irritating to eyes”. Sensitization may be listed as either a health hazard or a contact hazard.

The Signs and Symptoms information in an MSDS will often be listed as effects of overexposure. Compare the description in the MSDS with those listed in the above tabulation to understand the possible consequences of being overexposed. Also, you may wish to consult a medical dictionary or your supervisor to find out what is meant by an unfamiliar description in an MSDS. It is important to know for sure; a guess about the meaning could have serious adverse consequences.

Preventing Overexposure

Most MSDSs contain a personal protective equipment section. When properly prepared, this section provides specific information on how to prevent or reduce exposure to the specific chemical. The information includes equipment to prevent eye and skin contact and respiratory exposure. Depending on the chemical, the recommended equipment will range from safety goggles and a lab apron to full body enclosure with a self-contained breathing apparatus.

Pay close attention to the details in this section. If specific eye protection is described, ordinary corrective eyeglasses will not do; use only the type described. Despite what you may have heard so-called authorities recommend, do not wear contact lenses when working with chemicals. If a chemical is splashed on the eye, it can be trapped between the contact lens and the surface of the eye, and make an injury more severe.

When skin protection, such as a certain type of glove, is listed, use only that type; only the specified type will prevent the chemical from penetrating through the covering to the skin. Even then, keep in mind that no such barrier can prevent penetration for more than a few hours. Remember to test gloves for pinholes before using them.

If the information in an MSDS is vague, such as "use eye protection," "wear gloves”, or "use local ventilation," employees should ask their supervisor for specific information. If the supervisor does not know, contact the industrial hygienist. If no one who is competent knows, the risk of handling that chemical is likely to be very large. Beware of an MSDS that does not give specific protective information! This kind of problem with MSDSs is discussed in more detail, below.

Because appropriate protective equipment is specific for each chemical, it is beyond our scope here to give such information for all chemicals. In a competently prepared MSDS, the section on personal protective equipment is probably the most important section. By applying that information, the harmful toxic effects of chemical exposures may be prevented. By ignoring that information, life may be jeopardized.

How To Tell If an MSDS is Reliable

As you may know, there is no enforcement by OSHA, or any other agency, which requires that an MSDS be complete and accurate, without omissions or errors. Consequently, in this author's experience more than a few MSDSs are unreliable.

One way to test an MSDS for reliability is to look for inconsistencies, unqualified general statements, and technical errors. The greater the number of such faults, the less reliable that MSDS. Here are a few examples of what to look for:

> *Looking for inconsistencies* - - -
> Some MSDSs describe a chemical as flammable or combustible, but do not describe likely sources of ignition.

Some MSDSs state that a chemical will not burn in one section, and then in another section tell the user what to do in case that chemical catches on fire.

Some MSDSs state that a chemical is not volatile, and then in another place state that the vapor pressure is, say, 20 mm.

Identifying unqualified general statements - - -

Does the MSDS require the use of "protective equipment"? Or does it specify in some detail exactly what kind of protective equipment is recommended?

In particular, does the MSDS say "Use protective gloves"? Or does it say "Use protective gloves made of Neoprene" (or other named material)?

Does the MSDS describe symptoms of overexposure in terms that you can understand? Or does it use terms that require the knowledge of a doctor or nurse to figure out what the symptoms really are?

Does the MSDS describe in some detail what to do in order to clean up a spill?

Does the MSDS describe disposal procedures in detail? Or does it simply say "Dispose of in accordance with local regulations"?

Most MSDSs state correctly that you ***should never*** give an unconscious person anything by mouth. Does the

MSDS state what you ***should do*** for an unconscious person?

Ascertaining technical errors - - -

Some MSDSs tend to understate the degree of hazard of a chemical. For example, some relatively less harmful chemicals decompose when heated forming products that are quite toxic. An MSDS for such a chemical should caution that in a fire, the chemical decomposes, forming products that ***are*** toxic. Does the MSDS that you are evaluating state for such a chemical that the products ***might*** be toxic or that they ***are*** toxic?

As stated above, after a few hours or more of use all protective gloves become permeable to the chemical they are designed to protect from. Does the MSDS state correctly that the recommended protective gloves are not permanently impervious to the chemical and therefore should be replaced after they have been worn for a certain number of hours?

Ipecac should never be used to induce vomiting; it is too often ineffective and further, it is toxic. For different but equally compelling reasons, neither should solutions of salt be used to induce vomiting. The only proper way to induce vomiting is to drink two glasses of water, preferably warm water, and then tickle the throat with a finger. Does the MSDS recommend the correct, or incorrect, method of inducing vomiting?

On the other hand, vomiting should never be induced for victims who have swallowed any water–immiscible liquid or corrosive solution or liquid whether or not it is water-immiscible (e.g., liquid hydrocarbons, sodium hydroxide solutions). If a water-immiscible liquid is vomited, “chemical pneumonia” is likely to result. If a corrosive solution were vomited, the esophagus, already damaged when the solution was swallowed, would now be further damaged by a second exposure to the corrosive agent. Does the MSDS provide proper information regarding inducing vomiting?

When you find defects in an MSDS for a chemical, it is advisable to rely on a different MSDS for that same chemical; one that has been prepared by a different source before using the chemical (of course, evaluate that MSDS). If you cannot find a suitable MSDS for that chemical, treat the chemical as if it were the most toxic chemical known. This means taking every precaution to prevent any contact with that chemical. Such a decision should not create problems between employee and supervisor. Failure to take full precautions with a chemical of unknown properties could place the employee's life in jeopardy. Once exposed, a victim cannot be unexposed.

CLOSING REMARKS

Overexposure to a harmful chemical is the result of improper handling. Improper handling occurs because of a lack of knowledge, because of carelessness in applying that knowledge, or because of a combination of the two. The consequences of overexposure to harmful chemicals can be severe. The ounce of prevention described herein is certainly more valuable to the wise than a pound of cure to an unfortunate victim.

Use chemicals wisely. Never say to yourself, “I know it is not as safe as it could be if I do it this way, but I’ll do it anyway, just this one time.”

FOR FURTHER INFORMATION

R. E. Gosselin *et al., Clinical Toxicology of Commercial Products. 5th* ed., Williams & Wilkins, Baltimore, 1984. Although out of date to some extent, this reference is outstanding in its discussions of the toxicity and remedies for each of hundreds of different chemicals that a victim might have swallowed.

Curtis D. Klassen, editor, *Casarett and Doull’s Toxicology: The Basic Science of Poisons*. 6th ed., McGraw-Hill, New York, 2001. An excellent resource for anyone who really wants to learn more than the mere essentials of toxicology. This book is a classic in its field.

Curtis D. Klassen and John B. Watkins, III, *Casarett and Doull’s Essentials of Toxicology,* McGraw-Hill, New York, 2003. Similar in content to the discussion presented here in a few dozen pages, but requiring 533 pages instead. Obviously then, a more detailed discussion than the excellent(?) discussion you have enjoyed(?) here.

Eula Bingham *et al.*, *Patty’s Toxicology*, 5th ed., Wiley-Interscience, New York, 2001. Patty’s has been the single standard reference in toxicology for more than 50 years. This 2001 edition is much expanded, compared to previous editions, and now is in 8 volumes plus a cumulative index as the 9th volume. It is recognized as the reference used by professional toxicologists as well as other interested persons.