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Using TLVs for Common-Sense Risk Assessment for Solvents Workplace exposure to airborne chemicals is regulated in many countries based on governmental exposure limits established according to a concept

called the threshold limit value (TLV). The TLVs are intended as guidelines or recommendations in the control of potential health hazards. TLVs are not absolute guarantees of protection. Considering TLVs in combination with other important risk factors, however, can help conservators identify some of the more obviously hazardous solvent exposures or substitute safer chemicals for more toxic ones.

In the United States, the enforceable air quality limits are called permissible exposure limits (PELs); the regulatory agency is the Occupational Safety and Health Administration (OSHA). The Canadian limits are called occupational exposure limits (OELs). In addition, the U.S. National Institute for Occupational Safety and Health (NIOSH) sets standards called recommended exposure limits (RELs). All these limits are based on TLVs, which are set by the American Conference of Governmental Industrial Hygienists (ACGIH; see Resources).

For many substances, the PEL and OEL are identical to the TLV. When the two limits are not identical, there is usually a political reason, not a toxicological one. PELs and OELs must be established through slow and deliberate regulatory processes during which industry and other interest groups may lobby for consideration.

When the TLV and the PEL for a particular substance are different, the lower of the two should be used to evaluate safety of workplace exposure. This is true even though TLVs are not legally binding; the courts will consider the opinion of ACGIH as they would the opinion of an expert witness. Indeed, a panel of experts sets the TLVs. If someone claims to be injured from an exposure that was above the TLV, it is already a given that many experts consider the exposure excessive.

This article will discuss TLVs rather than governmental limits because they are recognized as standards in the United States, Canada, and many other countries and because 428 PELs have recently been set aside by the U.S. Court of Appeals for the Eleventh Circuit. This action may well eliminate many PELs and returns many others to unprotective levels set in the 1970s.

HOW PROTECTIVE ARE TLVs? The TLV is set to avoid the health effect that occurs at the lowest concentration. For example, most solvents are narcotic and can cause acute and chronic damage to the nervous system and other organs. However, the TLV for many solvents is set to avoid the health effects seen at the lowest concentration, commonly respiratory and eye irritation.

TLVs previously thought adequate have been revised repeatedly as better methods of assessing bodily damage are developed. For most but not all healthy workers, keeping airborne contaminants below the TLV provides protection from both irritant and narcotic effects. However TLVs do not apply to children, people with chronic illnesses, and other high-risk individuals. Workers who already have respiratory problems, for example,

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should not expect to be protected. Or workers who are already neurologically impaired (e.g., they are developmentally disabled, have a disease such as multiple sclerosis, or take certain medications) may be exquisitely at risk from a solvent's secondary effect on the brain.

TYPES OF TLVs

To accommodate different patterns of work exposures, there are three types of TLVs:

1. TLV-TWA, or threshold limit value–time weighted average, are airborne concentrations of substances averaged over eight hours. They are meant to protect from adverse effects those workers who are exposed to substances at this concentration over the normal 8-hour day and 40-hour work week.

2. TLV-STEL, or threshold limit value–short-term exposure limit, are 15-minute average concentrations that should not be exceeded at any time during a workday.

3. TLV-C, or threshold limit value–ceilings, are concentrations that should not be exceeded during any part of the workday exposure.

TLV-TWAs do not apply to people who work longer than eight hours a day. This group includes people who live and work in the same environment, such as conservators whose studios are at home. In these cases, very great exposures have been noted. Home studio workers are likely to be exposed 24 hours a day since contaminants linger in the environment. With no respite during which the body can detoxify, even small amounts become significant.

ODOR THRESHOLDS

Knowing when TLVs are exceeded is difficult to determine. One "seat-of-the-pants" method is to note the odor. Each chemical has a threshold concentration at which most people can smell it. This airborne level is called the odor threshold (OT).

OTs are not always reliable because not everyone detects odors at the same level. But if the OT is smaller than the TLV, then the chemical provides warning before health effects are expected. If the OT is larger than the TLV, a person is already at risk by the time the odor can be smelled. For example, carbon tetrachloride has an OT of 96 ppm and a TLV-TWA of 5 ppm. By the time the odor is detected, the TLV-TWA is greatly exceeded. OTs are required when known on Canadian material safety data sheets (MSDSs) but are not required on U.S. MSDSs. For those interested, the information for many substances is available on the New Jersey Department of Health Hazardous Substances Fact Sheets and some other databases (see Resources, p.5). U.S. conservators should consider this information when assessing risk.

AIR SAMPLING

Air sampling and analysis are required to prove that TLVs are exceeded. "Area sampling" means a detection device is used to measure levels in a location, while "personal sampling" measures levels in the worker's breathing zone. Personal sampling is most effective in determining a particular worker's actual exposure. To be accurate, such sampling must be done every time there is a change in product, method, or procedure. For many conservators, this could happen hundreds of times a year resulting in expensive air sampling. Fortunately, TLVs are useful in other ways. They are used most commonly as an aid in identifying highly toxic chemicals and in choosing safer substitutes.

USING TLVs TO ASSESS TOXICITY

In general, the smaller the TLV, the more toxic the substance. TLV-TWAs for gases and vapors are usually measured in parts per million (ppm). Canadian MSDSs and Workplace Hazardous Materials Information System (WHMIS) training materials use milligrams per cubic meter for gases and vapors as well as for particulates. TLV-TWAs range from 5000 ppm for carbon dioxide to 0.0002 ppm for osmium tetroxide. By convention, gases or vapors with TLV-TWAs of 100 ppm and below are said to be "highly toxic." However, relying on TLV comparison alone is far too simplistic. In addition to considering the TLV of a chemical, conservators must asses a number of other factors, including the evaporation rate, which influences the amount that becomes airborne; the nature of the chemical's effects (local or systemic); and the seriousness of the effect for which the TLV was set.

EVAPORATION RATE

A chemical whose TLV indicates it is of low toxicity may actually be more dangerous if it evaporates so quickly

THRESHOLD LIMIT VALUE-TIME WEIGHTED AVERAGES[1] (TLV-TWA) OF COMMON SOLVENTS

GAS OR VAPOR	TLV-TWA/cancer[2]	ER[3]	HEALTH EFFECTS[4]
Ethanol	1000	Medium	*Eye/respiratory irritation,* narcosis
Acetone	750	Fast	*Respiratory/eye irritation,* narcosis, headaches, central nervous system depression
Isopropanol	400	Medium	*Eye/nose/throat irritation,* narcosis
VM and P Naphtha	300	Medium	*Eye/respiratory irritation,* narcosis
Turpentine	100	Slow	*Eye/respiratory irritation,* narcosis, rapid pulse, allergy
N-hexane	50	Fast	*Permanent nerve damage* to peripheral and central systems, narcosis
N-butyl alcohol (SKIN)	50	Fast	*Hearing damage in noise-exposed workers,* vertigo, narcosis, irritation
Carbon tetrachloride (SKIN)	5 IARC-2B NTP-2	Fast	*Liver damage, synergistic interaction with alcohol,* liver cancer, narcosis
2-ethoxyethanol (SKIN)	5	Fast	*Reproductive damage,* blood changes, irritation
Carbon disulfide (SKIN)	4 PEL[5]	Fast	*Heart damage,* nerve damage, reproductive effects, head ache, psychosis, fatigue
Chloropicrin	0.1 IARC-3	Medium	*Eye/respiratory irritation,* lung hemorrhage/edema, kidney and liver damage
Diglycidyl ether	0.1	Slow	*Eye/respiratory/skin irritation, blood and reproductive*

1. In parts per million (ppm). TLVs could be compared with any of the three types of TLVs, but more chemicals have been assigned TLV-TWAs than short-term or ceiling limits (TLV-STELs or TLV-Cs). For this reason, it is easiest to use TLV-TWAs.

2. Cancer classification; see text.

3. Evaporation rate

4. The italicized health effect is the one the TLV was set to avoid.

5. The TLV-TWA is 10 ppm. The PEL-TWA is lower and should be used.

that large amounts may be breathed. The easiest method of determining how fast a solvent evaporates is to look at its evaporation rate (ER).

The ER is the rate at which a material will vaporize from the liquid or solid state when compared to another material. The two common liquids used for comparison are butyl acetate and ethyl ether. When butyl acetate = 1.0, >3.0 = Fast; 0.8–3.0 = Medium; and <0.8 = Slow. When ethyl ether = 1.0, <3.0= Fast; 3.0–9.0 = Medium; and >9.0 = Slow.

ERs are only useful for determining the hazard during use. Whether they evaporate fast or slowly, all of the solvents in a paint or other applied product will evaporate eventually. This means that all of the solvents used in the home studio will eventually contaminate the environment. The ER is usually listed on the MSDS. If it is not, a rough estimate of the butyl acetate-derived evaporation rate (at 68°C) is easily calculated by dividing the vapor pressure (at 68°C) of the compound or mixture by 10.

Vapor Pressure (VP) is the pressure exerted by a saturated vapor above its own liquid in a closed container. VPs combined with evaporation rates are useful in determining how quickly a material becomes airborne and thus how quickly a worker is exposed to it. VPs are usually reported in millimeters of mercury (mm Hg) at 68°F (20°C) unless otherwise stated. Substances with VPs above 20 mm Hg (ER = 2.0) may present a hazard due to their volatility.

NATURE OF EFFECTS

Local effects are restricted to the chemical's potential for damaging the skin, eyes, or respiratory system on contact through properties such as corrosiveness, irritation, sensitization, or mechanical damage from sharp particles. Examples would be inhaling acid vapors (corrosive), skin contact with a solvent (irritation, drying effects), skin contact with poison ivy (sensitization), or inhalation of dust from grinding glass (mechanical irritation). Systematic effects are restricted to the effects on various organ systems such as blood, kidneys, lungs, and brain. These effects are seen if substances are absorbed into the body through the skin, respiratory system, or digestive tract. The substances then travel to target organs through the blood, lymph system, or some other route. Chemicals that cause serious sys-

temic effects, especially permanent organ damage or cancer, should be avoided.

SERIOUSNESS OF EFFECTS

1. SKIN ABSORPTION.

The ACGIH uses the word "skin" with the TLV to indicate that a particular chemical is capable of being absorbed into the body in significant amounts by skin contact. If skin contact is expected to occur during work, this additional exposure must be considered when evaluating the hazard.

2. CARCINOGENS.

Chemicals that cause cancer must be treated with special care because they change normal tissue cells in the body into cancer cells by altering genetic material (DNA). Theoretically, even one molecule of a carcinogen in the right cell and at the right instant can affect DNA. By analogy, buying one ticket gives you a chance of winning the lottery--not a good chance, but a chance. The more tickets you buy, the better are your odds. This means that there is essentially no safe level of exposure to a carcinogen. The same odds apply to chemicals that cause mutations or birth defects.

Ideally, carcinogens should be avoided or used in ways that preclude exposure. TLVs for chemicals that cause cancer are usually very low. NIOSH does not assign TLVs to known human carcinogens, but says exposure to them should be limited to the lowest feasible concentration that can be achieved by engineering controls (ventilation), protective equipment, and work practices. Conservators may want to adopt this policy.

CANCER CLASSIFICATIONS

ACGIH classifies chemicals in terms of their cancer data. However, ACGIH is not one of the three agencies whose classifications must be reported on U.S. MSDSs: the International Agency for Research on Cancer (IARC); the National Toxicology Program (NTP); and OSHA. The classifications these agencies use are as follows:

AGENCY	CATEGORY	RATIONALE
IARC	1	Carcinogenic to humans; sufficient evidence of carcinogenicity
	2A	Probably carcinogenic to humans; limited human evidence; sufficient evidence in experimental animals
	2B	Possibly carcinogenic to humans; limited human evidence in the absence of sufficient evidence in experimental animals
	3	Not classifiable as to carcinogenicity to humans
	4	Probably not carcinogenic to humans
NTP	1	Known to be carcinogenic, with evidence from human studies
	2	Reasonably anticipated to be carcinogenic, with limited evidence in humans or sufficient evidence in experimental animals
OSHA	X	Carcinogen defined with no further categorization

COMMON-SENSE STRATEGY FOR ASSESSING TOXICITY

Take the following steps when considering use of a toxic substance:

1. LOOK AT THE TLV.
- Remember that TLVs relate to exposure by inhalation of airborne concentrations only.
- When OSHA PELs are different than the TLV, use the most protective.
- Compare TLV-TWAs. The smaller the number, the lower the concentration at which workers will begin experiencing health effects. Vapors and gases with TLVs of 100 ppm and smaller are generally considered very toxic.

2. LOOK AT THE CHEMICAL'S CHARACTERISTICS.
- How fast does it evaporate?
- Is it a carcinogen?
- Is it a skin absorber?
- Is it a systemic toxin? It doesn't matter how the chemical enters the body if its effects are systemic. All routes of entry contribute to the total amount absorbed. For this reason, TLVs (which only consider the inhalation route) are not good predictors of risk from skin-absorbing or ingested chemicals (unless skin contact and ingestion can be completely avoided).
- Are there other hazards, such as reactivity or flammability?

3. LOOK AT THE WORKER.
- Keep in mind that TLVs are designed to protect most but not all healthy adult employees. Many experts agree that most TLVs are not set at levels that will protect children or the fetus.
- Consider the health effect for which the TLV was established in terms of the worker's health. For example, if the primary effect is lung irritation, those with lung problems may have to avoid exposure.
- Consider all health effects exhibited by the chemical for impaired workers, whether they are permanently disabled or temporarily impaired by illness, injury, or medication. For example, people with heart problems should avoid chemicals known to affect the heart.

4. LOOK AT THE JOB.
- How much of the hazardous substance is being used?
- How close is the conservator's nose to the point of application?
- Are there other dangers on the job that may be exacerbated by toxic substance exposure? For example, working on ladders with narcotic solvents increases risk of accident.
- What kind of ventilation or protective equipment is present?

ACETONE: AN ILLUSTRATION

1. LOOK AT THE TLV.

The TLV-TWA for acetone is 750 ppm, indicating it is one of the least toxic of the solvents.

2. LOOK AT THE CHEMICAL'S CHARACTERISTICS.

The *odor threshold* for acetone is reported to be around 13 ppm, so it can be detected by smell long before the TLV is exceeded.

The *vapor pressure* of acetone is 266 mm Hg at 77°F (room temperature). Its *evaporation rate* is 1.9 when compared with ether. These characteristics make it highly volatile.

Acetone is not listed as a *skin-absorbing* chemical, so no additional significant exposure can be expected through skin contact. However, it dissolves skin oils, making the skin more penetrable to other chemicals.

Acetone's effects are both *systemic and local.* The TLV was set to the avoid

irritation of the respiratory tract and eyes, which is a local effect. Its secondary systemic effects are narcosis, headaches, and central nervous system depression.

Acetone is not a *carcinogen.* All narcotic solvents, however, are suspected of being toxic to the developing fetus.

Other effects. Acetone is extremely flammable. No sources of ignition can be present in the work area. If local ventilation is used it must be explosion-proof. Fire protection systems must be in place and operable.

3. LOOK AT THE WORKER.

Health impairment of any kind, no matter how small, must be considered. For example, imagine that the conservator has a cold. The irritation from the acetone can easily exacerbate the cold's symptoms. If the conservator is taking cold medication that contains alcohol, acetone will increase the alcohol's narcotic effect. If the medication is an antihistamine, it may interact adversely with the solvent.

4. LOOK AT THE JOB.

If workers are exposed to very small amounts of acetone during application of an acetone-containing coating over small labels, there should be no problem. The exposure is greater if acetone is used for Q-tip cleaning and the conservator's face is inches from the work. This job probably will require ventilation or protective equipment.

If workers are on ladders with open buckets of B-72 in acetone and are coating a large dinosaur skeleton with broad brushes in a room with no ventilation, then respiratory protection is obviously necessary. Clearly, the rapid evaporation rate, the secondary narcotic effects, and the additional hazard of the height from which a dizzy person might fall make the job unacceptable without precautions.

SUMMARY

Considering TLVs in combination with other important risk factors can help conservators identify some of the more obviously hazardous solvent exposures. When in doubt, conservators should err on the side of caution or consult an industrial hygienist for advice or air sampling. Conservators are also welcome to call or write ACTS for advice: Arts, Crafts, and Theater Safety, Inc., 181 Thompson St., # 23, New York, NY 10012-2586; [redacted]—Monona Rossol

RESOURCES

ACTS FACTS, Arts, Crafts and Theater Safety, New York. A monthly newsletter updating health and safety regulations and research affecting the arts. Available from ACTS, 181 Thompson St., #23, New York, NY 10012.

A.M. Best Company, *Best's Safety Directory.* 2 volumes. Annual directory of safety equipment and supplies. Available from: A. M. Best Company, Ambest Rd., Oldwick, NJ 08858. [redacted].

American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Bldg. D-7, Cincinnati, OH 45211-4438. (513) 661-7881. Publishes *Threshold Limit Values and Biological Exposure Indices* (updated annually);. *Industrial Ventilation: A Manual of Recommended Practice.*(updated annually);. and *The Documentation of TLVs and BEIs.*

Clark, N., T. Cutter, and J. McGrane. Ventilation: A Practical Guide. New York: Center for Safety in the Arts, 1980. *A guide to basic ventilation principles and step-by-step guidance for those who wish to evaluate, design and build an adequate ventilation system.* Available from: CSA, 5 Beekman St., New York, NY 10038.

Hazardous Substances Fact Sheets (HSFS) can be purchased very reasonably from the New Jersey Department of Health, Right-to-Know Program, CN 368, Trenton, NJ 08625-0368; [redacted]. There are HSFS on several hundred chemicals and odor thresholds are reported when known.

Rossol, M. The Artist's Complete Health and Safety Guide. New York: Allworth Press, 1990. *A guide to safety and OSHA compliance for those using paints, pigments, dyes, metals, solvents and other art and craft materials.* Available from: Allworth Press, 10 E. 23rd St., New York, NY 10010.

Sax, N. I., and R. J. Lewis Sr. *Dangerous Properties of Industrial Materials,* 7th ed. New York: Van Nostrand-Reinhold, 1988. (Available from the ACGIH; see address above.)

Monona Rossol is an industrial hygienist and president of Arts, Crafts, and Theater Safety, Inc. (ACTS), in New York City.