ESTABLISHING OCCUPATIONAL EXPOSURE LIMITS IN YOUR WORKPLACE

Protecting All Workers

Funded By
Workers Compensation Board of Manitoba
Community Initiatives and Research Program

OHG Consulting

SAFE WORK
SAFE: SPOT THE HAZARD. ASSESS THE RISK. FIND A SAFER WAY. EVERYDAY™

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Published by	OHG Consulting Inc. 108 Turnbull Dr. Winnipeg MB R3V 1X2 ohgconsulting.com 204-261-1770
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Project Funding	Workers Compensation Board of Manitoba Community Initiatives and Research Program

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DEFINITIONS

ACGIH®	American Conference of Governmental Industrial Hygienists – The association that establishes the TLVs.
\BEIs®	Biological Exposure Indices – guidance values for assessing biological monitoring results.
Biological half-life	The time required for the body to eliminate one-half of an administered dose.
Biotransformation	Biotransformation is the process whereby a substance is changed from one chemical to another (transformed) by a chemical reaction within the body. Metabolism or metabolic transformations are terms frequently used for the biotransformation process.
Body Burden	The total amount of a substance in the body following exposure.
C/B	Chemical or biological substance.
Documentation	A publication by ACGIH that contains supporting data and rationale for the TLVs.
Dose	The amount of a substance to which a worker is exposed.
Metabolism	The transformation of energy and matter within the body.
Occupational Physician	A physician having the professional training, skills and competence to advise on the clinical management of people at work and upon the impact of environmental factors facing the general community.
Occupational Exposure Limit	The limit of exposure of a worker to an airborne chemical or biological substance established under Part 36 of the Manitoba Workplace Safety and Health Regulation.
OEL	Occupational Exposure Limit
Potentiating	One material, usually of low toxicity, enhances the expression of toxicity by another. The result is a more severe injury than is produced by exposure to the toxic species alone. An example would be the enhanced central nervous system depression of carbon tetrachloride in the presence of alcohol.
ppm	Parts per million. An expression of concentration as the number of parts of a contaminant in a million parts of air. Usually used for gases or vapours.
Skin Notation	If the TLV Booklet gives a skin notation for a chemical, it means that there can be a significant exposure due to skin, eye, or mucous membrane contact with the vapours, liquids or solids.
Synergistic effect	Two materials act together to produce toxicity greater than that produced by either material if administered separately
TLVs®	Threshold Limit Values – Workplace exposure guidelines.
TLV-STEL	Short term (15 min) exposure limit
TLV-TWA	Average exposure limit for an eight hour workday

TLV-C	A ceiling exposure limit that should not be exceeded even for a short time.
Toxicology	The science and study of chemicals and their adverse systemic effects, including source, chemical composition, action, tests, and antidotes.

Introduction to the guideline

What Are Our Responsibilities For Workers' Health?

General Duties

The general duty to protect workers is spelled out in the Workplace Safety and Health Act [1]. Under this act it is the responsibility of the employer to ensure the safety, health and welfare of all workers. This responsibility must be done to the extent that it is reasonably practicable. One of these responsibilities is the requirement to ensure that workers are not exposed to chemical substances that may cause adverse health effects.

Exposure To Chemical Substances

The steps that must be taken to ensure the safety, health and welfare of workers resulting from the use, production, storage, handling, and disposal of chemical substances are spelled out in Part 36 of the Workplace Safety and Health Regulation, 217/2006. Part 36, Chemical and Biological Substances. A decision diagram of this regulation is shown in Figure 1. The part requiring that the exposure limits be adjusted to take into account conditions in your workplace (Section 36.5(2)) is circled. This section states that when:

> (a) conditions in the workplace, (including, heat, ultraviolet and ionizing radiation, humidity, pressure, length of work shift, work-rest regime, or additive and synergistic effects of materials and workload); or
> (b) the health or physical condition of a worker in the workplace known to an employer;
>
> the employer must establish a lower occupational exposure limit for that substance than the limit established by the ACGIH. The occupational exposure limit established by the employer must ensure that the safety or health of workers who are exposed to the substance in that workplace at levels below that limit will not be placed at risk.

We are now going to explore how to establish lower occupational exposure limits to protect all workers.

[1] http://www.safemanitoba.com

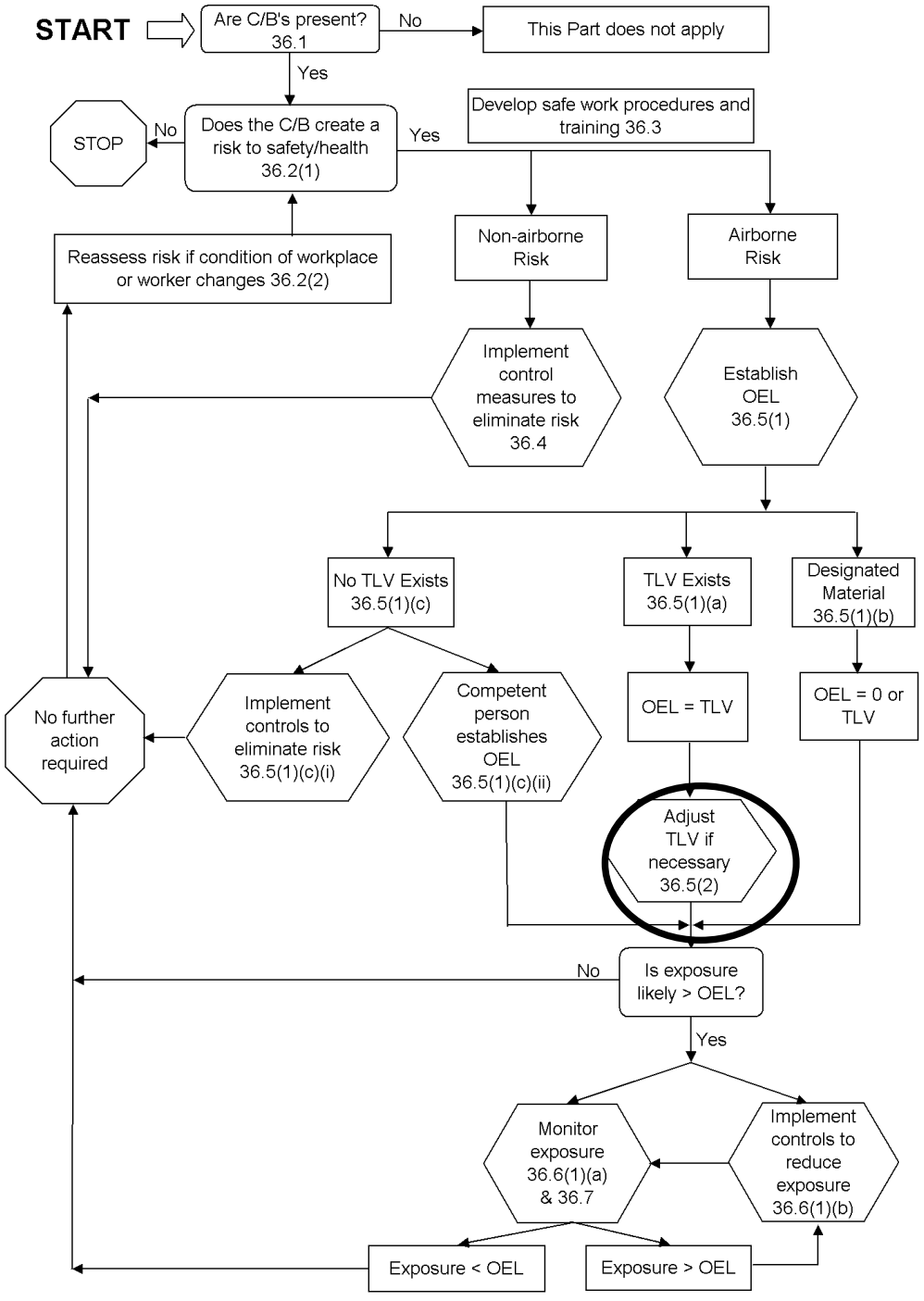

Figure 1: Decision diagram for Part 36 of the Workplace Safety and Health Regulation, Chemical and Biological Substances. The circle shows the area to be addressed here.

What Are Occupational Exposure Limits And Why Must They Be Adjusted?

Exposure limits are established concentrations which, if not exceeded, will not generally cause adverse effects to the exposed worker. Exposure levels were developed as guidelines or recommendations in the control of potential health hazards and are not fine lines between safe and unsafe exposures, nor are they a relative index of toxicity.

The most commonly used workplace exposure limits are the Threshold Limit Values (TLVs®), guidelines proposed by the American Conference of Governmental Industrial Hygienists (ACGIH®). The TLVs are used in Manitoba as exposure limits.

Part of the reason for the TLVs being guidelines is the variation in worker's reactions to the same exposures, and the differences in working conditions. Since a guideline that is to be applied to many workers and workplaces cannot take into account all possible combinations of workers and workplaces, a model workplace was used that will cover most workers and workplaces. Essentially this can be thought of as a young healthy male worker, working 8 hours/day at an even exposure at a moderate exertion of energy. If your workplace is different from this standard workplace, then you must review the exposure limits to determine if there is a possible problem.

It has been our experience that when problems arise in the application of TLVs or other exposure standards, it is the result of 1 of 2 possible lapses.

1. Overestimation of the tolerance of the worker/workforce by not recognizing the implications of an atypical worker/workforce in terms of age, reproductive status, pre-existing medical condition, etc.; or

2. Underestimation of exposure by not considering all routes of exposure, additive effects with multiple chemicals, increased dose via inhalation during physical exertion, non-occupational exposures etc..

What Is The Purpose of This Guideline?

This guideline is to assist workplaces to comply with the regulations, apply the TLVs as intended, and protect all workers from the ill effects of workplace chemicals. As described above, if the conditions of the workforce or workplace are not taken into account, there is an increased probability that you will underestimate the risk to workers.

This guideline is intended to be a screening method to help workplaces in the decision process to determine if:

- there is not likely to be a problem;

- there is a problem and action is needed; or
- expert help is needed.

The guideline cannot always provide absolute answers. Where you believe there is a problem, fix it or carry out a detailed assessment and document your findings or get expert help. Remember, failure to assess is a violation of your duty as well as the regulations.

What Are The Principles Used In This Guideline?

This guideline will take you through the main conditions that can affect the risk to workers. It will provide guidelines to assist you to determine:

- If there is a Class 1 condition where the probability that the conditions of the workforce or workplace are not likely to have an unexpected effect on workers, and good health and safety practice will protect workers.

- If there is a Class 2 condition where the conditions of the workforce or workplace can affect some or all workers and rules of thumb to adjust the TLVs are given.

- If there is a Class 3 condition where the need to adjust the exposure level or the amount of adjustment is not clear, is complex, or requires confidential medical information and therefore expert advice is recommended.

ADJUSTMENTS FOR CONDITIONS OF THE WORKER

- ✓ ADJUSTMENTS FOR AGE
- ✓ ADJUSTMENTS FOR HEALTH
- ✓ ADJUSTMENTS FOR SEXUAL DIFFERENCES
- ✓ ADJUSTMENTS FOR PREGNANT WORKERS
- ✓ ADJUSTMENTS FOR SENSITIZATION
- ✓ ADJUSTMENTS FOR NONOCCUPATIONAL EXPOSURES

INTRODUCTION - WORKER

There is a large variation in how different workers react to similar exposures in the workplace. These variations depend on many things such as genetics, age, health, reproductive status.

If everyone reacted the same to the same chemical exposure, fixed standards could be used. Since this is not the case, you must adjust the TLV to accommodate individual workers. Failure to do this frequently results in an overestimation of a worker's tolerance to workplace chemicals. This is the same as underestimating the risk to a worker. This could result in workplace related illness.

The following is a description of the Classes of adjustments possible for conditions of the worker. See the following sections for details.

- **Class #1 –** There is not likely to be a significant impact on workers under these conditions. And good workplace practice should protect all workers.

- **Class #2 –** Under these conditions additional precautions as described should be implemented. Because we are often dealing with an individual health condition, there is often little we can do without the assistance of a physician.

- **Class #3** – Under these conditions expert advice should be found. Since worker health condition is often the basis for the potential problem, the expert should be an occupational health physician or in some cases an occupational hygienist familiar with the toxicology of the materials used in your workplace.

It is believed that the advice offered here will usually be conservative and offer more protection than is actually needed. For a more precise risk assessment, the help of a professional such as an occupational hygienist is needed.

CAUTIONARY NOTES

Estimating Exposure Level

In some cases, such as with older workers or with workers with health related issues, it necessary to know what their exposure to toxic workplace materials is as part of the risk assessment and adjustment process. Usually, if the exposure level is <10% of the TLV, the probability of overexposure is low.

Unfortunately, there is often only one sample to base this judgment on. Airborne concentrations can vary considerably due to work levels, work practices, daily changes in the operation of the ventilation system, and even outside weather conditions. Therefore a single sample should not be used to determine if the <10% of the TLV criteria has been met.

If there is only one sample, you should seek the opinion of an expert, or at least multiply the value of the single sample by 3 to take into account some of the variations in exposures.

ADJUSTMENTS FOR AGE

Could you have a problem?

What are the exposure levels in the workplace?

- ✓ What chemicals are you exposed to? Review Material Safety Data Sheets.
- ✓ What symptoms can the chemicals produce? Review the TLV Booklet for a summary of systems affected. Review the Documentation for details. Review other sources to determine what illnesses the chemical can produce.
- ✓ Estimate exposure levels by sampling to determine how much is in the air and how big a dose the worker is getting.
- ✓ If the exposure level is well below the TLV (<10% of TLV), there probably is not a significant risk due to exposure to that chemical.

What are the worker symptoms?

- ✓ Do you have an older worker showing symptoms of workplace illness similar to those caused by the chemicals in the workplace?
- ✓ Do you have an older worker showing symptoms of a workplace illness that may be caused by interactions between medications and workplace exposure?
- ✓ Remember, a person's health condition is a private matter, and they may not wish to discuss it with anyone other than their physician, and it may be **none of your business.**
- ✓ Remember most older workers will not have a problem. If they do have a problem, is it work related?

If you have significant exposure levels (>10% of the TLV), and older workers showing illnesses that could be related to the chemicals used in the workplace, you have a potential problem.

TLV Adjustments for Age

Class #	Condition	Adjustment
1	Exposure level is <10% of the TLV.	There is only a small probability that a worker would be affected. Use good industrial hygiene practice and general ventilation.
2		
3	Exposure is >10% of the TLV, and there are symptoms similar to those produced by the chemicals used in the workplace.	Since you are dealing with an individual worker's health, **you must work with a physician.**

NOTE #1

There is little information about the effects of age on the toxicity of chemicals in humans, although it has been demonstrated in laboratory animals. There is a lack of scientific evidence on the effects of age between the extreme ages (children and elderly) and those that make up the workforce. There is even less evidence within the age group that makes up the workforce. However, the potential effects of age cannot be ignored. Therefore one cannot assume that just because some workers are older, they will have problems in the workplace.

NOTE #2

Daily exposure levels vary from day to day. Therefore one sample may not accurately define long term workplace exposure. Where there is a single exposure sample >10% of the TLV, there could be still be overexposures on some days. If there is no information on long term exposure levels of if the sample was a random sample, multiply it by three to estimate a more likely long term exposure.

If there are several samples suggesting exposures are < or = 10% of the exposure limit it is unlikely (but not impossible) that the TLV will be exceeded.

NOTE #3

The following are some conditions that could make a worker more susceptible to workplace exposures and that should be considered by a physician.

- ✓ Is there an underlying illness that may make a worker more sensitive to exposure to the chemical?
- ✓ Are there any medications that the worker is taking that could make the worker more sensitive?

NOTE #4

The number of youths in the workforce is shrinking due to the aging baby boomers, and there is a growing pool of older workers emerging from retirement to return to work. This creates an aging workforce. Even today's workforce may not represent the "normal" workforce that the guidelines assume; thus, age should be taken into account in assessing "acceptable" exposures for groups and individuals in the current workforce, and workforces of the of the future.

EXAMPLE 1a

Air samples were just taken. The TLV for the contaminant was 100 ppm. The sample showed an exposure level of 7 ppm in the air. Could there be a problem?

A – One sample may not accurately define an exposure. Exposures vary from day to day. The average exposure could be 21ppm (3 times 7 ppm). A predisposed worker may be affected.

EXAMPLE 1b

The last sample collected (7 ppm) was part of a long term sampling program that showed the average exposure level was 9 ppm. Is there a problem?

A – Since the average long-term exposure level was <10% of the TLV it is unlikely that a worker would be affected.

ADJUSTMENTS FOR HEALTH

Could you have a problem?

What are the exposure levels in the workplace?

- ✓ What chemicals are you exposed to? Review Material Safety Data Sheets.
- ✓ What symptoms can the chemicals produce? Review the TLV Booklet for a summary of systems affected. Review the Documentation for details. Review other sources to determine what illnesses the chemical can produce.
- ✓ Estimate exposure levels by sampling to determine how much is in the air and how big a dose the worker is getting.
- ✓ If the exposure level is well below the TLV (<10% of TLV), there probably is not a significant risk due to exposure to that chemical.

What are the worker symptoms?

- ✓ Remember, a person's health condition is a private matter, and they may not wish to discuss it with anyone other than their physician, and it may be **none of your business.**
- ✓ Do you have a worker with a predisposing illness of an organ or system (heart, respiratory, kidney) that workplace chemicals also affect.
- ✓ Do you have a worker showing symptoms of workplace illness similar to those caused by the chemicals in the workplace?
- ✓ Do you have a worker showing symptoms of a workplace illness that may be caused by interactions between medications and workplace exposure?

If you have significant exposure levels (>10% of the TLV), and workers showing illnesses that could be related to the chemicals used in the workplace, you have a potential problem.

Since you are dealing with an individual worker's health, **you must work with a physician.**

- ✓ Is there an underlying illness that may make a worker more sensitive to exposure to the chemical.
- ✓ Are there any medications that the worker taking that could make the worker more sensitive.
- ✓ Determine what an acceptable exposure level is for the affected worker.

TLV Adjustments for Health

Class #	Condition	Adjustment
1	Exposure level is <10% of the TLV.	There is only a small probability that a worker would be affected. Use good industrial hygiene practice and general ventilation.
2		
3	Exposure >10% of the TLV and a worker has an affected organ or organ system that the workplace chemicals can affect; or Exposure is >10% of the TLV, and there are symptoms similar to those produced by the chemicals used in the workplace.	Since you are dealing with an individual worker's health, **you must work with a physician.**

NOTE #1

Any illness that could reduce blood flow through the liver of kidney could result in retained chemicals in the body. This could result in overexposures unrelated to the underlying illness.

NOTE #2

Not only could any predisposing illness be a problem, but the medications used to treat the illness could create problems of their own. The effect of drugs is similar to the effects of chemicals on the rates of metabolism and toxicity. The effects of drugs can be significant. Therefore, in assessing the total effect of illnesses, the effect of the drugs needed to treat it must also be considered.

EXAMPLE 1

A welder is showing symptoms of overexposure to welding fume. The problem appears worse during the week and less on weekends. Exposure levels are less than the TLV. This is an older worker with heartburn and gastroesophageal reflux disease. Is there a workplace problem?

A – From ingredient lists of the drugs used to treat these conditions, it appears that antacids contain metals (aluminum, magnesium) that could have an additive effect with welding fumes.

EXAMPLE 2

A painter with cardiac problems has appears to have symptoms similar to solvent exposure. Is there a workplace problem?

A – Cardiac problems can reduce blood flow. This would reduce flow through the kidneys and thus reduce their ability to eliminate some solvents.

ADJUSTMENTS FOR SEXUAL DIFFERENCES

Could you have a problem?

Not likely for normal healthy workers, no changes have to be made for normal healthy workers.

NOTE #1

Some animal data are available. It should be noted, however, that sex-related effects often appear in a single species of test animal and often only in a single strain of that species. Also, often the effect can be demonstrated only when animals are fed a protein-deficient diet. Where there were some differences, it was shown that the differences related to the rate of metabolism by the liver and the relative toxicity of the parent chemical and the metabolite. The male sex hormone (testosterone) is associated with a more rapid rate of liver metabolism. As a result, males are more susceptible where the metabolite is more toxic than the parent chemical. Females, then, would be more susceptible where the parent chemical is more toxic. This form of metabolism, where an environmental chemical is changed to a more toxic form is called bioactivation.

Generally speaking, there appears to be no basis for the conclusion that non-pregnant women are more or less susceptible than men to the toxic effects of chemical exposures. However, where toxic effects of specific chemicals are known, appropriate protective actions must be taken.

ADJUSTMENTS FOR PREGNANT WORKERS

Could you have a problem?

Where there are pregnant workers, the TLVs should carefully reviewed and adjusted where necessary. This is not the condition where one waits for an obvious problem to occur. When the problem is obvious, it is too late. Only preventive action is effective.

Check to see if adjustments are necessary.

- ✓ Review the TLVs to determine if reproductive effects have been considered, if so, use the TLV as written.
- ✓ The Documentation is the preferred source for this information. A quick answer can be obtained from the TLV Booklet. The 6th Column, “TLV Basis” gives a one or two word statement on the basis for the TLV in question.

There is no information readily available

- ✓ Review the toxicological information to determine if there are specific problems related to pregnancies and if so are these concentrations higher or lower than the TLV. Expert advice may be required for this.

- ✓ If no information is available, reduce the TLV by 30% to take into account the increased respiratory rate of pregnant workers.

- ✓ If the material has no TLV, or if the simple reduction of the TLV by 30% appears inadequate (carcinogens, teratogens etc.) the help of an expert to help is advised.

TLV Adjustments for Pregnant Workers

Class #	Condition	Adjustment
1	Exposure level is <10% of the TLV. The TLVs have taken pregnancies into account	There is only a small probability that a worker would be affected. If TLVs were considered in setting the exposure limit, no change is required for normal healthy workers. Use good industrial hygiene practice and general ventilation.
2	When exposures are >10% and there is no specific information about the chemical	Adjust the TLV down by 30%
3	The concentration is >10% and there are technical issues related to reducing exposure levels.	Expert advice to review the toxic properties of the chemical to determine if the TLV does in fact protect pregnant workers. If there is no recommendation for pregnant workers, expert advice should be found to develop an exposure limit for pregnant workers.

NOTE #1

Examples of materials where the TLVs took into account reproductive effects and adjustments do not have to be made.

Acrylic Acid	Amitrole	Carbaryl
Carbon monoxide	Chloroform	2-Chloropropionic Acid
Dibutyl Phthalate	N,N-Dimethyl Acetamide	Dinitrotoluene
Epichlorhydrin	2-Ethoxyethanol	2-Ethoxyethyl Acetate
Ethyl Chloride	Ethylene Oxide	Halothane
Hexafluoroacetone	Indium & Compounds	Lead
Lead Arsenate	Lead Chromate	Manganese, Elemental & Inorganic Compounds
Mercury (Inorganic)	2-Methoxyethanol	2-Methoxyethyl Acetate
Methyl tert-Butyl Ether	Methyl Chloride	Nitrous Oxide
Phenyl Glycidyl Ether	Phenylphosphine	Tin, Organic Compounds
Toluene	4-Vinyl Cyclohexene	Vinyl Cyclohexene Dioxide

NOTE #2

Examples of TLVs where the exposure guideline was set on other effects but were believed to be low enough to take into account reproductive effects and adjustments do not have to be made.

Acrylonitrile	Benomyl	Carbofuran
Carbon Disulfide	*b*-Chloroprene	Endosulfan
Ethyl Benzene	Ethylene Dibromide	Ethylene Glycol
Glycerin Mist	Hexachlorobenzene	Hexamethyl Phosphoramide
Lithium Hydride	Mercury (Aryl Compounds)	Methyl n-Butyl Ketone
Nitromethane	Parathion	Sodium Fluoroacetate
Trichloroethylene	Warfarin	

NOTE #3

The Documentation ® contains much information about chemicals and how they affect the body. These should be reviewed to help determine if changes in the exposure limit is necessary. This would require the expert advice of a doctor or occupational hygienist.

NOTE #4

Although not a normal part of the workforce, there is a requirement to protect nursing infants. They should be protected either as part of the requirement to provide a safe workplace for mothers who breast feed or to ensure that persons who are not employed at the workplace are not exposed to risks arising out of that workplace.

EXAMPLE 1

A pregnant worker uses toluene, ethyl benzene and chlorobenzene. What adjustments should be made?

A Toluene – The TLV was set to protect pregnant workers (See Note #1)

Ethyl benzene – The Documentation® shows that the TLV was set for effects other than pregnancy but was low enough to protect pregnant workers (See Note #2)

Chlorobenzene – There was no readily available information so reduce the TLV by 30%. However, if an expert was called, they would have found, in the Documentation® Summary for chlorobenzene that the TLV is based on slight liver changes, including increased weight and congestion, reported

for rats exposed by inhalation to 50 or 75 ppm chlorobenzene. In the Reproductive/Developmental section it stated that rats exposed by inhalation at either, 0, 50, 150, or 450 ppm for two generations showed no adverse reproductive effects. This would suggest that reproductive effects occur at levels above the TLV and that adjustments are not required.

ADJUSTMENTS FOR SENSITIZATION

Could you have a problem?

What are the exposure levels in the workplace?

- ✓ What chemicals are you exposed to? Review Material Safety data Sheets.
- ✓ What symptoms can the chemicals produce? Review the TLV Booklet for a summary of systems affected. Review the Documentation for details. Review other sources to determine what illnesses the chemical can produce. Can the materials in question produce sensitization. Most chemicals do not produce sensitization.
- ✓ Estimate exposure levels by sampling to determine how much is in the air and how big a dose the worker is getting.
- ✓ Are there opportunities for exposures above the TLV since peak levels are more important to developing sensitization than are long term low level exposures?
- ✓ Even if the exposures are low (<10% of TLV), there could be a reaction in a sensitized worker.

What is the worker's exposure experience?

- ✓ Is the worker likely to become sensitized, not all persons are.
- ✓ Has the worker been exposed to the material over a long period of time?
- ✓ Has there been exposures to high levels above the TLV?

What are the worker symptoms?

- ✓ Remember, a person's health condition is a private matter, and they may not wish to discuss it with anyone other than their physician, and it may be **none of your business.**
- ✓ Do you have a worker showing symptoms of workplace illness similar to those caused by the chemicals in the workplace?
- ✓ Since you are dealing with an individual worker's health, **you must work with a physician.** Is there any clinical evidence that the worker is sensitized to the chemical in question?

Investigate to see if there is something that can be done.

- ✓ Once a worker has become sensitized, they can react to very low levels of the sensitizing material, and control may be difficult.

TLV Adjustments for Sensitization

Class #	Condition	Adjustment
1	The chemical is not a sensitizer.	No adjustment necessary. Use good industrial hygiene practice and general ventilation.
2		
3	The chemical is a sensitizer, the worker has a history of allergies, and there is a potential for peak exposure levels.	Expert device to determine if the worker has actually sensitized to the chemicals in question. This is not always determined. If the person is sensitized to the chemicals in the workplace, they may have to be relocated to an area without any of the suspect materials.

NOTE #1

TLVs are usually set to prevent sensitization form occurring. However, if sensitization occurs, the TLV may not prevent an allergic reaction.

NOTE #2

Not all workers will become sensitized. If a worker has a history of allergies, or a family history of allergic reactions, they may be a candidate for becoming sensitized to workplace chemicals.

EXAMPLE 1

A painter is using a paint with toluene diisocyanates and toluene and shows symptoms of sensitization. Are adjustments necessary?

A – Before a decision can be made, you must find out if the person has a history of allergic reactions, and what are the controls and exposure histories. If they are favourable for sensitization, then:

- ✓ Toluene diisocyanates – the TLV Booklet shows that this is a respiratory sensitizer, and if the worker has become sensitized to it, he may have to be relocated to keep exposures very low.

- ✓ Toluene – is not a sensitizer and changes do not have to be made.

ADJUSTMENTS FOR NONOCCUPATIONAL EXPOSURES

Could you have a problem?

Non-occupational exposures are beyond the scope of the workplace, and adjustments cannot be made. Actions, where such exposures may be known will likely be limited to counseling the individual about limiting such exposures.

Exposures from moonlighting and hobbies will be difficult to assess. Not only may you not be aware that the extra exposure exists, but it is unlikely that the level of exposure will be known.

The method for accounting for exposures due to moonlighting is the same as for overtime described in the section on “Adjustment for Unusual Work Hours.” Estimates of these exposures may have to be based on professional judgment.

Exposures arising out of hobbies may be even more difficult to assess. Exposure levels will frequently be unknown; length of exposure will be variable or even seasonal, such as the smelter worker who made his own lead fishing weights, resulting in high lead-in-blood levels. In these situations, your role may be limited to counseling the worker or providing some limited advice.

ADJUSTMENTS FOR CONDITIONS OF THE WORKPLACE

- ✓ ADJUSTMENTS FOR UNUSUAL WORK SCHEDULES
- ✓ ADJUSTMENTS FOR MULTIPLE ROUTES OF EXPOSURE
- ✓ ADJUSTMENTS FOR EXPOSURE TO MULTIPLE CHEMICALS
- ✓ ADJUSTMENTS FOR LEVEL OF EXERTION
- ✓ ADJUSTMENTS FOR UNUSUAL TEMPERATURES

INTRODUCTION - WORKPLACE

Just as there are large differences between individual workers, there are differences between workplaces. In establishing the TLVs, the Committee must make some assumptions such as how long the workday is, how hard the work is, and how many chemicals are present.

When determining what is safe in any one workplace, these and other factors must be taken into account. If these factors are not taken into account, worker exposures can be underestimated.

This section provides useful planning information that can be used to prevent workplace illness. For example, if you are planning an extra shift, longer workdays, or more chemicals, this section will help you to anticipate potential problems and to make adjustment when still in the planning stage where costs are minimal.

Action for each condition of the worker is outlined in a table giving the condition and action for each condition class. The following is a description of the classes of adjustments possible for conditions of the worker. See the following sections for details.

- **Class #1 –** There is not likely to be a significant impact on workers under these conditions. And good workplace practice should protect all workers.

- **Class #2 –** Under these conditions additional precautions as described in the action column should be implemented. Because we are often dealing with an individual health condition, there is often little we can do without the assistance of a physician.

- **Class #3** – Under these conditions expert advice should be found. Since worker health condition is often the basis for the potential problem, the expert should be an occupational health physician or in some cases an occupational hygienist familiar with the toxicology of the materials used in your workplace.

It should be noted that a significant exposure in this section is usually defined as an exposure level of 50% or more of the TLV. Most adjustments for conditions of the workplace are less than 50% unlike some conditions of the worker. An exception is for physical exertion. It should also be noted that an exposure level of 50% of the TLV is a true exposure level determined by repeated sampling over a period of time, and not a single sample of 50% of the TLV.

It is believed that the advice offered here will usually be conservative and offer more protection than is actually needed. For a more precise risk assessment, the help of a professional such as an occupational hygienist is needed.

ADJUSTMENTS FOR UNUSUAL WORK SCHEDULES

Could you have a problem?

The TLVs assume an eight hour day and a 40 hour week. If you work extra hours (a 10 hour shift, or overtime) or if you work extra days, adjustments may have to be made.

Check to see if adjustments are necessary.

- ✓ Find out what symptoms the chemicals produce? Review the TLV Booklet for a summary of systems affected. Review the Documentation for details. Review other sources such as MSDSs to determine what illnesses the chemical can produce.
- ✓ If the TLV based on short term effects such as irritation or odour. If so, adjustments may not be required.
- ✓ Estimate exposure levels by sampling to determine how much is in the air and how big a dose the worker is getting.
- ✓ If the exposure level is well below the TLV (<50% of TLV), there probably is not a significant risk due to exposure to that chemical.

What are the conditions in the workplace?

- ✓ If you have an unusual workshift, and a significant exposure to chemicals with long-term effects, adjustments to the TLVs should be made.

TLV Adjustments for Unusual Work Schedules

Class #	Condition	Adjustment
1	The work day is 8 hours or less, and the work week is 40 hours or less. OR Only chemicals with short-term effects are used.	No adjustment necessary. Use good industrial hygiene practice and general ventilation.
2	The work day is 8 hours or more, and the work week is 40 hours or more. AND Chemicals with long term effects are used.	Reduce the exposure level using the Brief and Scala method described below.
3	Same as #2, but there are other circumstances such as toxic properties of the material, costs, or non-standard work hours.	Expert device to determine if the Brief and Scala method is the best, and to explore other adjustment models.

NOTE 1

Brief and Scala Model

The Brief and Scala model was the first formal approach to the adjustment of unusual work schedules and is by far the simplest. This model offsets its simplicity by being very conservative and therefore requires greater adjustments (reductions) to occupational standards than the other models.

The Brief and Scala model recognizes that during work periods greater than 8 hours per day, 40 hours per week, the period of exposure (absorption) is increased while the period of no exposure (elimination) is decreased. For example, for a work schedule of 12 hours per day, the exposure period is 50 percent greater than in an 8-hour workday. In addition, the period of recovery (away from work) is shortened by 25 percent from 16 hours to 12 hours. It is expected that these factors would result in a higher peak body burden than a typical work schedule. Depending on the number of 12-hour workdays per week, the average body burden may also be higher.

The Brief and Scala model attempts to correct for unusual work schedules by reducing the permissible concentrations in proportion to both the increase in exposure time and the decrease in recovery time. Both daily exposures and weekly exposures should be considered using the following two formulae:

Daily Adjustment

Adjusted TLV = TLV x Daily Reduction Factor

$$\text{Adjusted TLV} = TLV \times \left\{\frac{8}{h_d}\right\} \times \left\{\frac{24 - h_d}{16}\right\}$$

Where h_d = hours worked per day

Weekly Adjustment

Adjusted TLV = TLV x Weekly Reduction Factor

$$\text{Adjusted TLV} = TLV \times \left\{\frac{40}{h_w}\right\} \times \left\{\frac{168 - h_w}{128}\right\}$$

Where h_W = hours worked per week

The adjusted TLV should be calculated for both the daily and the weekly formulae. The lesser of the two Adjusted TLVs should be substituted for the existing TLV.

NOTE 2

There are three main models used in adjusting occupational exposure limits for unusual work hours. Each of the models approach the situation with somewhat different assumptions, and each model has its own advantages and disadvantages. The three most common approaches to adjustment of occupational exposure limits for unusual work schedules are:

- Brief and Scala Model – the most conservative model, easy to apply
- OSHA Model – similar to Brief and Scala but is less conservative and requires some knowledge of the chemicals toxicological properties.
- Pharmacokinetic Models - requires some elaborate formulae and knowledge of the biological half-life of the chemical in question.

Because of its simplicity and conservative nature, we recommend the use of the Brief and Scala method here. If a more refined assessment is required, the help of a professional is recommended.

EXAMPLE

A worker is exposed to xylene with a TLV of 100 ppm (ACGIH 2007) over a work schedule of 10 hours per day, 4 days per week. What reduction in permissible TLV exposure is recommended by the Brief and Scala model?

Applying the daily and weekly adjustment formulae given above, the daily and weekly adjustment factors would be as follows:

Daily Adjustment

Adjusted TLV = $TLV \times \left\{\frac{8}{h_d}\right\} \times \left\{\frac{24-h_d}{16}\right\}$

Adjusted TLV = $100_{ppm} \times \left\{\frac{8}{10}\right\} \times \left\{\frac{24-10}{16}\right\}$

= 100 ppm x 0.8 x 0.875

= 70 ppm

Weekly Adjustment

Adjusted TLV = $TLV \times \left\{\frac{40}{h_w}\right\} \times \left\{\frac{168-h_w}{128}\right\}$

Adjusted TLV = $TLV \times \left\{\frac{40}{40}\right\} \times \left\{\frac{168-40}{128}\right\}$

= 100 ppm x 1.0 x 1.0

= 100 ppm

The lower of the two adjusted exposure limits proposed by the daily and weekly adjustment formulae should be used. Because the workweek in this example still consists of 40 hours, it is not surprising that the weekly adjusted TLV is the same as the unadjusted TLV. However, the presence of 10 hour workdays indicates a reduction factor of 0.7, reducing the standard TLV of 100 ppm to an adjusted TLV of 70 ppm. A TLV exposure of 70 ppm, 10 hours per day, 4 days per week, should provide the same level of protection as a 100 ppm TLV exposure, 8 hours per day, 5 days per week.

The table below shows examples of different work shifts and the daily and weekly adjustments required to give the same body burden. The recommended adjustment to the TLV is shown in bold.

Hours/day	Hours/week	Daily Adjustment	Weekly Adjustment
8	40	**1.0**	**1.0**
9	45	0.8	**0.9**
10	50	**0.7**	**0.7**
10	40	**0.7**	1.0
12	36	**0.5**	1.0

ADJUSTMENTS FOR MULTIPLE ROUTES OF EXPOSURE

Could you have a problem?

The TLVs are for airborne exposures. However, there are other routes of exposure such as absorption through the skin or ingestion. The dose received through these other routes are additive with the airborne levels and could present a problem when airborne levels alone are not a problem.

Check to see if adjustments are necessary.

- ✓ Is there significant skin contact with the workplace materials?
- ✓ What chemicals are you exposed to? Review Material Safety Data Sheets, the TLV Booklet and the Documentation to determine the chemicals properties.
- ✓ How can the chemical enter the body? Review the TLV Booklet to determine if there is a skin notation. Review the Documentation for details.

What are the conditions in the workplace?

- ✓ If there is significant skin contact, and the material is absorbed through the skin additional protective measures may have to be taken.

TLV Adjustments for Multiple Routes of Exposure

Class #	Condition	Adjustment
1	Inhalation is the only route, and there is no skin notation.	No adjustment necessary. Use good industrial hygiene practice and general ventilation.
2	There is skin contact, and there is a skin notation.	Review PPE and work procedures. Reduce or eliminate exposures. Improve personal hygiene. Change chemical.
3	There is skin contact, and there is a skin notation, plus PPE and work procedures have been implemented, but problems remain. Or There is skin contact but no skin notation and there are exposure issues.	Expert advice should be found to determine what the routes of exposure are, and to estimate how much is by each route. Or Determine if the chemical in question can be absorbed through the skin but does not have a skin notation.

NOTE 1

When applying this section, there is an assumption that airborne exposures are acceptable (<50% of the TLV). If not, they should be controlled as a matter of course.

NOTE 2

Not all chemicals that can be absorbed through the skin have a skin notation. If this is suspected, expert help should be obtained to help determine if this is a potential problem.

NOTE 3

When routes of exposure other than through the respiratory tract are suspected, personal hygiene can be important. Washing the hand before eating or smoking can be important. As a rule, anything that gets on your hands will eventually get into your mouth.

Clean clothes are important. Contaminated clothing can act as a reservoir for the chemical prolonging any exposure beyond normal working hours.

EXAMPLE

A worker on the assembly line has been diagnosed as having methemoglobinemia. He is using an adhesive that contains dimethylanaline. Air sampling shows the exposures to be acceptable. What do you do now?

1 Is there a problem?
- A look at the TLV booklet shows that this material has a skin notation.
- The MSDS says that the material may be absorbed through the skin in harmful amounts.
- The TLV Documentation states that there is rapid and significant dermal absorption of dimethylaniline and contribution to systemic toxicity warrant the Skin notation.

Conclusion: air sampling and the TLV alone may not define the worker exposure.

✓ What are the work methods?
- Is there skin contact?
- What PPE is used?
- Is there a wash-up area? Time to use it?

Implement work practice controls and appropriate PPE.

ADJUSTMENTS FOR EXPOSURE TO MULTIPLE CHEMICALS

Could you have a problem?

Most workplaces have more than one chemical in them. There may be only one material present, such as paint, but it is often made up of many different chemicals. If these chemicals affect the same organ or organ system, their effects can be additive. Hus although individual exposure levels may be low, their cumulative effect may not.

Check to see if adjustments are necessary.

- ✓ Are workers exposed to more than one chemical?
- ✓ Check your MSDSs and look at the ingredient list to see what is in the workplace material.
- ✓ Review the TLV booklet and the Documentation to find out what the exposure limit is based on. If two or more materials affect the same organ or system, the effects are additive.

What are the conditions in the workplace?

- ✓ If there are additive chemicals present add their effects using the formula below.

TLV Adjustments for Exposure to Multiple Chemicals

Class #	Condition	Adjustment
1	If there is only one chemical present, or if they affect different organs or systems.	No adjustment necessary. Use good industrial hygiene practice and general ventilation.
2	Multiple chemicals are found in the workplace, and some or all of them affect the same organ or organ system.	Add their effects according to the formula in Note 2.
3	Multiple chemicals are found in the workplace, and there may be synergistic effects, potentiation, or partially additive effects. Or There are chemical/physical interactions.	Expert advice should be found to determine what the combined effects are, if any.

NOTE 1

Most workplaces use many chemicals. Sometimes these are present as separate materials, such as perchloroethylene used to clean metals and carbon monoxide from the forklift. In other times they are present in the same material, such as the solvents in paint or the metals in welding fume.

NOTE 2

If the separate chemicals affect different organs or systems, such as one affects the lung, the other the liver, they can be treated as independent, and their effects are not combined.

NOTE 3

With additive effects, the TLVs are not adjusted. Instead the toxic effects are added and essentially a new exposure limit is created for the mixture based on the TLVs of the individual chemicals.

NOTE 4

Most chemicals will affect different organs or systems depending on the dose. Usually, the TLV is based on one effect, the most sensitive one, then the worker is protected for the other effects which occur at higher exposure limits. Therefore only the effects that the TLV is based on are used here, not the other secondary effects.

NOTE 5

Standardized exposures are used in the familiar formula to evaluate the total exposure to chemicals with additive effects:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} \ldots\ldots \frac{C_n}{Tn} \leq 1$$

where C_1 is the observed atmospheric concentration of chemical 1 and T_1 is the TLV for that same chemical.

If the sum of the standardized exposures exceeds unity, then the threshold limit of the mixture should be considered as being exceeded.

EXAMPLE

A worker is exposed to 12 ppm toluene (TLV 20 ppm), 50 ppm xylene (TLV 100 ppm) and 0.08 mg/m^3 tetramethyl lead (0.15 mg/m^3). Is there an exposure problem here?

1 The TLVs for the materials are based on:
   - Toluene – pregnancy effects
   - Xylene - CNS effects
   - Tetramethyl lead – CNS effects

2 Only xylene and tetramethyl lead are additive.

3 Add the effects of xylene and tetramethyl

$$\frac{50_{Concentration\ xylene}}{100_{TLV\ xylene}} + \frac{0.08_{Concentration\ tetramethyl\ lead}}{0.15_{TLV\ tetramethyl\ lead}} = 1.03$$

The total is greater than 1 therefore there is an exposure problem even when all materials are below their TLV.

ADJUSTMENTS FOR PHYSICAL EXERTION

Could you have a problem?

A worker's exposure depends on how much air they inhale. Most TLVs assume that workers are not working too hard and thus m not breathing hard. The more air a worker inhales, the more material is drawn into the lungs. How much a worker inhales depends on how hard they work. Therefore working hard can result in a greater dose, and the TLVs must then be adjusted.

Check to see if adjustments are necessary.

- ✓ Determine the work activity. Study the work being done. Use the table below to determine what the respiratory rate is in L/min.
- ✓ Determine the respiratory rate that the TLV was based on. From the Documentation, estimate the respiratory rate. If it is unknown assume worst case, 21 L/min. If the TLV is based on work experience, no adjustment is necessary. Note: if the TLV is based on non-respiratory effects, such as skin or eye irritation, no adjustment is necessary.
- ✓ Calculate the adjusted TLV for the work being done. An adjustment to an existing exposure limit would be in proportion to the difference in the ventilation rates upon which the limit is based and the specific conditions under investigation.

TLV Adjustments for Multiple Routes of Exposure

Class #	Condition	Adjustment
1	The TLV is based on non-respiratory effects, such as skin or eye irritation?	No adjustment necessary. Use good industrial hygiene practice and general ventilation.
2	The respiratory rate is more that what the TLV bas based on.	Add the effects of the chemicals as described in Note 2.
3	The basis for the TLV is unclear, or the source of the data is unclear.	Expert advice should be found.

NOTE 1

The harder one works, the more air one breaths. The more air one breaths, the more contaminant is taken into the lungs. Once in the lungs the contaminant is absorbed into the body. The more contaminant that is brought into the body, the greater the dose.

The Table below shows breathing rates in L/min for different tasks. As can be seen, some tasks such as climbing stairs require up to 10 times the normal volume of air. This means, under some work conditions up to 10 times the amount of contaminants can be inhaled.

Ventilation Rates for Different Tasks.

Activity	Conditions of work	L/min
Sleeping		21.17
Sitting quietly		31.9
Sitting	moderate arm and trunk movements (desk work)	32.7 - 40.2
Sitting	Moderate arm and leg movements (e.g., playing organ, driving car in traffic)	40.2- 46.5
Sitting	heavy arm and leg movement	48.1-55.8
Standing	light work at machine or bench, mostly arms	40.2 - 46.5
Standing	light work at machine or bench, some walking about	48.1 -54.3
Standing	moderate work at machine or bench, some walking about	54.3 - 69.7
Walking	empty handed 4 km/hr, level smooth road	37.3
Walking	load on back, smooth level road, 4 km/hr: 10 kg load 30 kg load	 60.4 86.6
Walking	with moderate lifting or pushing	69.7 - 94.3
Climbing Stairs	30 degree gradient, 17.2 m/min without load with 20 kg load	 215 288
Pulling a handcart	3.6 km/hr, level hard surface	135
Working with an axe	two handed strokes, 35 strokes/min	166

Activity	Conditions of work	L/min
Working with a hammer	4.4kg hammer, 15 vertical strokes/min	117
Shoveling	10 shovels/min, throwing 2 m horizontally, 1 m vertically	125
Sawing wood	two handed saw, 60 double strokes/m	143
Brick laying	normal rate 0.0041m2/m	51.2
Digging	garden spade garden soil	132

NOTE 2

The TLV can be adjusted with the following formula.

$$TLV_{adj} = TLV \times \frac{Ventilation\ Rate_{TLV}}{Ventilation\ Rate_{actual}}$$

Where:

Ventilation Rate$_{TLV}$ = The rate the TLV was based on or 21 L/min if unknown.

Ventilation Rate$_{actual}$ = Value from Table.

EXAMPLE

A worker sharpens axes on a pedestal grinder. He gets an axe from a bin, sharpens it, and then places the sharpened axe on a shelf. If the TLV for iron is 5 mg/m^3, and 10 mg/m^3 for magnesium, what are the adjusted TLVs (Occupational Exposure Limits).

1. The TLV for iron is based on many workplace exposures as well as experimental studies on animals and humans. Because the TLV for iron used workplace exposure data, a change in the TLV is not necessary. Much of the data used to set the TLV for magnesium was based on exposure studies with humans, and were likely carried out with the volunteers at rest, therefore the TLV should be adjusted for magnesium.

2. The work involves standing at a grinder, with some walking about. The respiratory rate, from the table would be between 54.3 and 69.7 L/min.

3. The adjusted TLV for magnesium would be:

$$TLV_{adj} = 10\ (TLV\ for\ Magnesium) \times \frac{21\ (Ventilation\ rate\ for\ TLV)}{63(Ventilation\ rate\ for\ task)}$$

$$TLV_{adj} = 10 \times \frac{21}{63} = 10 \times 0.33 = 3.3\ mg/m^3$$

ADJUSTMENTS FOR UNUSUAL TEMPERATURES

Could you have a problem?

What are the conditions in the workplace?

- ✓ What is your work temperature? Normal temperature is about 25°C.
- ✓ If the air temperature is about 30°C, reduce the TLV by about 15%.

TLV Adjustments for the effects of temperature

Class #	Condition	Adjustment
1	The temperature of the workplace is normal (about 25°C).	No adjustment necessary. Use good industrial hygiene practice and general ventilation.
2	The temperature is about 30°C.	Reduce the TLV by 15%.

NOTE 1

Most molecular, cellular, and physiological processes have a positive temperature coefficient. Bodily functions depend on blood circulation including many chemical reactions occur best at about 98.6 degrees. Thermoregulation is the body's way of gaining or losing heat to maintain that temperature. Hot weather and high humidity increase risks of slowing the transfer of heat to the surrounding air.

When the core body temperature increases, the heart rate increases and the blood vessels expand to bring more blood toward skin, where the heat can be released. The heat produced by exertion cause blood vessels in the skin to dilate, which also increases the blood flow to the skin. This elevated blood flow to the skin and the large surface area of the skin allows the excess heat to be lost to the surrounding air.

At the same time blood flow to the liver and kidneys is reduced, this reduces the body's ability to eliminate contaminants.

NOTE 2

Respiratory rates accelerate in high temperatures and are slowed in cold temperatures. The increase in respiration due to heat results in an increase in the uptake of airborne chemicals.

NOTE 3

The absorption of chemicals on the skin is increased during heat stress because of the combined elevation in skin blood flow, increased permeability of the skin, and the moist skin from sweat.

NOTE 4

An experiment exposing humans to 2-Butoxyethanol at 22.6°C, 29% relative humidity and 32.9°C, 71% relative humidity. In the hot and humid conditions, the subjects were found to have:

- 15.2% increase in inhalation uptake rate
- 37.5% increase in dermal uptake rate
- 12.6% increase in pulmonary ventilation rate
- 17% decrease in blood clearance rate

EXAMPLE

Workers will be spreading asphalt on the roof of a building. The temperature is predicted to reach 32^{o}C later in the day. Should the TLV for asphalt be adjusted?

A review of the Documentation shows that the TLV is based on actual workplace exposures. This meant that exposures and reactions to them were measured for roofers and pavers in the real world. Asphalt handling had average temperatures ranging from 126°–150°C at paving sites to 180°– 304°C during asphalt roofing applications. It can be assumed that the TLVs, based on industrial experience, took temperature variations into account.