

CHAPTER 2
HEALTH INSPECTIONS

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Chapter 2

HEALTH INSPECTIONS

I. Establishing a Sampling Plan

Evaluating miners' exposures to contaminants is a required part of an inspector's health inspection. Since metal and nonmetal mines encompass a wide variety of mining techniques and environmental conditions, an inspector must utilize a strategy or sampling plan which addresses potential health hazards at each mine, especially targeting "high risk" occupations. When developing a sampling plan, the following must be considered:

- Type, nature, and source of contaminants at the mine;
- Miner's proximity to potential contaminant sources;
- Number of potentially exposed miners;
- Type of work being done, including routine and periodic tasks;
- Applicable exposure limits and other health-related standards; and
- Available sampling methods.

II. Health Inspection

A. Pre-Inspection Activities

Mines should be sampled in accordance with the current health inspection and sampling policy.

- 1. Review the mine file.** This should include but is not limited to: Part 50 forms (7000-1) for past health-related injuries and illnesses; health hazard complaints and investigations; health sampling history; existing "P" codes; process flow sheets and associated Material Safety Data Sheets (MSDS); and previous or outstanding health citations and orders. Carefully review the health field notes associated with each overexposure. Note the activities of the miner(s) during the shift on which the initial overexposure occurred.

2. **Review relevant mandatory standards and enforcement policy**, based on hazards identified. For reference, a synopsis of contaminant-specific health-related standards is provided at the end of this chapter. See Table 2-1.
3. **As a general rule, consult your immediate supervisor** before seeking additional guidance. For additional information, contact inspectors, supervisors, industrial hygienists, health specialists, MSHA Technical Support, or the Metal and Nonmetal Health Division.
4. **Draw on your own experience** with other mines of this type and commodity. If possible, discuss the details with the last inspector who visited the mine.

B. On-Site Activities

Walk-around observations, discussions with miners, and direct-read area sampling can be used to determine which occupations are “high risk” and need to be sampled. When overexposures occur, whether on a previous inspection or from sampling conducted during the current inspection, expand the group of miners sampled in that occupation or area until you are certain that all miners at risk of overexposure have been identified and evaluated. To determine which hazards are present and which miners are “high risk”:

1. **Observe:**
 - **Proximity of miner to contaminants and tasks performed.** Miners working near or in direct contact with a hazard (such as welding fumes, process chemicals, or parts cleaning) are more likely to be at risk of an overexposure. Noise exposure may be greater for a miner working in or around multiple pieces of machinery than one working near a single noise source.
 - **Nature of operation and work practices.** Certain mineral processes may create hazardous environmental conditions which can affect miners’ health when physical or chemical changes occur during ore processing (kilns, dryers, chemical reagents, etc.). Hazards may be present in on-site laboratories that use and store chemicals. A substance used around a heat source (where heat intensifies chemical reactivity) may have a more toxic effect than if used in a cool atmosphere. Miners working in confined areas with little or no ventilation are more likely to be overexposed.

Insufficient housekeeping or improper clean-up methods (such as broom and shovel instead of a vacuum) may lead to increased exposures.

- **Warning signs, tags, and labels.** Areas, boxes, drums, bottles, etc., marked with warnings can be used as a guide in determining toxicity, proper handling procedures, required engineering controls, and necessary personal protective equipment (PPE). Review available MSDS for similar information. Miners working in or around these items should follow all precautions outlined and should be sampled accordingly. Review handling procedures and storage for compliance with applicable MSHA standards (refer to Chapter 19).
2. **Use your senses** - sight, smell, and hearing. *To protect your own health and safety, do not place yourself at risk of contaminant exposure. Call your supervisor or the District Office for guidance on proper handling, storage, use, and appropriate PPE for unfamiliar chemical substances.* Smoke or dust clouds may indicate sites where miners are at risk of particulate overexposures. Odd odors or bitter/sweet taste sensations may indicate the presence of fumes, gases, or vapors that may be toxic. When miners are unaware of these odors, it may be that long-term exposure to chemicals (e.g., hydrogen sulfide) has “numbed” their senses. A prickly sensation of the skin and nose linings may indicate the presence of acid mists or caustic dust. When sound levels consistently require miners to shout to be heard from only a few feet away, noise sampling should be considered.
 3. **Screen with direct reading instruments.** A sound level meter can pinpoint noise sources and help identify miners for full-shift noise surveys. Direct-reading instantaneous dust or particle monitors, such as real-time aerosol monitors (RAM), can measure excessive dust concentrations, pinpoint leaks and problems with engineering controls, and indicate the best location for conducting personal monitoring. Multi-gas instruments or direct reading stain tubes can detect gases and vapors (such as gases from diesel exhaust or vapors from processing chemicals) which may create problems.

4. **Interview miners.** Since they work in the environment on a day-to-day basis, the miners' insights into problems are invaluable.
 - **Listen to miners' comments and complaints.** A miner's symptoms (headaches, nausea, skin rash, pains, etc.) can indicate the presence of potential contaminants.
 - **Ask miners on all shifts** to discuss specific work tasks and required personal protective equipment. If these tasks pose a high risk, the miners should be sampled accordingly.
 - **Talk to maintenance personnel** about precautions taken and PPE used when working in or around machinery which may pose significant health risks (baghouses, ball mills, kilns, etc.).
5. **Assess control measures.**
 - Are engineering controls in place and are they being maintained to minimize exposures? Are there additional controls that can be implemented?
 - Have administrative controls been established and are they being followed? Are miners knowledgeable regarding any administrative controls?
 - Is personal protective equipment (PPE) required? Is it being provided, worn, and maintained, and is training given on its use?
 - Where engineering controls are used, look for evidence that the mine operator is assessing the effectiveness of the controls during workplace examinations required by 30 CFR §§ 56/57.18002 and whether records are being kept.
 - Determine if the mine operator is conducting exposure monitoring and surveys to determine the adequacy of the control measures in accordance with 30 CFR §§ 56/57.5002 for air quality and with §62.110 for noise.
 - At mine sites where abrasive blasting or drilling is being conducted, check for compliance with 30 CFR §§ 58.610 and 58.620, respectively.

III. Sampling Protocol

If the pre-inspection review and the on-site assessment indicate that sampling is warranted, it becomes an integral part of the health inspection. Conditions within the work environment on the day of sampling must be similar to those experienced by the miner when sampling is not being done. Sample a sufficient number of miners to characterize the typical exposure levels of all affected occupations and areas during “normal” workshifts. In certain situations, such as when independent contractors are performing specialized tasks, samples should be collected.

A. Duration of Sampling

The duration of sample collection must be sufficient to compare a miner's exposure to the appropriate permissible exposure level (PEL). Permissible exposure levels are established by time-weighted average concentrations, short-term exposures, excursion limits, and ceiling values.

1. **Full-Shift Sampling.** Full-shift samples must be collected during the miner's entire workshift regardless of the number of hours worked. This is best accomplished by full-period, single-sample measurements (one full-shift sample) or full-period, consecutive sample measurements (multiple samples collected back-to-back throughout the shift).

For some contaminants, **partial-period sampling** may be used to represent the full shift. For example, sampling can be done for 10 minutes every hour with a midjet impinger (graphite, talc, mica, etc.) for an entire workshift or with one stain tube for a 15-minute interval each hour (carbon monoxide, sulfur dioxide, etc.) during the entire workshift.

2. **Short-Term Sampling.** Short-term samples may be collected during the miner's workshift. The representative sampling period should be at least as long as the time specified in the **short-term exposure limit (STEL)**. Many exposures are not continuous 8-hour daily exposures, but are short-term or intermittent exposures that may be addressed better by STELs. STELs for 5, 15, or 30 minutes for 142 substances are found in the regulations of the Pennsylvania Department of Health, Chapter 4, Article 432, revised January 25, 1968 (PA Rule). These PA Rule STELs are referenced in the *TLVs[®] Threshold Limit Values for Chemical Substances in Workroom Air Adopted by the ACGIH for 1973*, which is incorporated by reference into MSHA health standards (30 CFR §§ 56/57.5001).

The sampling times for these STELs vary from 5 to 30 minutes depending upon the contaminant. In general, when sampling a mixture of similar contaminants and toxicities, the sampling duration should correspond to the contaminant with the longest STEL time period. When sampling for specific contaminants, the duration should correspond to the listed time for the respective STEL. However, you need to ensure that the sample will provide enough contaminant for the Laboratory to analyze. Refer to Chapter 3, or contact the MSHA Laboratory.

Example I: A miner must not be exposed to greater than 400 ppm (parts per million) of Carbon Monoxide (CO) for any 15 minute period. It is not necessary to sample continuously during the period, but the sample must be representative of the time. CO detector tube readings taken every 5 minutes for the 15 minute period would be adequate.

Example II: A miner is performing routine arc welding on steel machinery for one hour. He or she must not be simultaneously exposed to an average concentration greater than 20 mg/m³ of Iron Oxide for any 15-minute period, 0.1 mg/m³ of Copper fume for 30 minutes, or 10 mg/m³ Zinc Oxide for 30 minutes. It is not necessary to sample continuously for the maximum STEL time period (30 min.), but the sample must be representative of the welder's actual work time. Therefore, taking two 15-minute samples in succession or multiple 5-minute samples would encompass all the listed times for the contaminant mixture and ensure that a large enough sample is obtained for analytical purposes.

- 3. Sampling for Ceiling and Excursion Concentrations.** Samples to evaluate exposure to contaminants having **ceiling limits** or **excursion limits** must be taken only just long enough to determine the contaminant concentration and during periods of maximum contaminant concentrations. Ceiling limit concentrations are identified by a "C" in *TLVs[®] Threshold Limit Values for Chemical Substances in Workroom Air Adopted by the ACGIH for 1973*. Ceiling limits cannot be exceeded at any time during the workshift. Ceiling exposure limits have been established by the ACGIH for substances that are fast-acting. That is, for these contaminants, 15 minute exposures may result in intolerable irritation, chronic or irreversible tissue change, or narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency. This does not mean that a sample must be taken for at least 15 minutes to determine whether a ceiling limit has been exceeded. For ceiling limit concentrations, use direct-reading instruments or detector tubes so that immediate action can be taken to remove miners if a ceiling

limit has been exceeded. Excursion limits are maximum exposure concentrations established by the application of the ACGIH's Excursion Factors listed in Appendix D of the 1973 TLV Booklet which must not be exceeded at any time for those substances not bearing a "C" designation.

B. Types of Samples (Personal vs. Area Samples)

- 1. Personal samples** are taken on or near the miner to determine exposure to the contaminant(s) present. These samples are taken with the sampling device or media attached to the miner or held in the **breathing zone** or **hearing zone** of the miner.

Breathing zone - 12-inch (30-centimeter) radius sphere of air space surrounding the miner's head. Air taken from this region represents the air the miner is breathing while working.

Hearing zone - the areas within 12 inches (30 centimeters) of the miner's ears. Noise samples taken in this region will be representative of the noise the miner actually experiences while working. Refer to Chapter 15 for the sampling protocol for noise.

- 2. Area samples** are collected to determine the presence of potential contaminants in an area where miners work. These samples may be taken with or without miners being present.

C. Determination of a "Normal" Workshift

Observe and document the sampled miner's activities during the shift. Interview the miner and mine management to determine whether the observed activities and exposures are characteristic of a **"normal" workshift**.

- 1.** The following are examples of the types of information that can be used to determine if activities are characteristic of a "normal" workshift: the number of truckloads of material processed by a crusher operator; the number of holes or vertical feet drilled by a driller; the number of trucks loaded by a shovel operator; the type of product and number of bags produced by a bagging machine operator; the number of pieces of equipment running during a production day; and indications operations have been modified.
- 2.** A "normal" workshift at many operations may exhibit wide variations in working conditions and activities. Ask the miner if these are "usual" or

“unusual” work conditions. Sample results are valid when collected on days that lie within the range of normal variations.

3. Sampling should be conducted among miners engaged in their “usual” activities under “normal” working conditions. However, it is quite common for a miner to engage in a variety of activities during a production cycle, day, week, or season. It is also common to experience variable production levels, equipment breakdowns, engineering control failures, poor maintenance or work practices, adverse weather conditions, and breakage and spills. These situations will not normally invalidate the sample.
4. Special effort should be made to sample non-routine maintenance operations when specific intermittent tasks involve health risks.

D. Refusal of the Miner to be Sampled

If a miner objects to wearing the sampling device, determine the reasons for the objection. Explain the need for the sampling. If you cannot obtain the cooperation of the miner and another miner performing the same job at the same location is available and cooperative, sample the cooperative miner. If the refusal is an attempt to impede or prevent an inspection, the inspector should attempt to complete any parts of the inspection that do not involve sampling, then contact his/her supervisor. In such cases, the supervisor is responsible for collecting all the facts, reducing them to writing, and contacting the district or assistant district manager. Consult the Program Policy Manual, Volume I, I.103-1, Assaulting, Intimidating or Impeding Inspectors, for current policy on actions to be taken in such circumstances.

E. Resampling

In most instances, you must resample to determine if the citation or order should be terminated. When resampling to terminate a citation or order, sample the job(s) being performed when the overexposure occurred. Where applicable, ensure that the same piece of equipment is being operated (e.g., front-end loader, packing machine, highwall drill) during a normal workshift.

If the citation or order resulted from an area sample, ensure that subsequent samples are taken in the same general area where the overexposure occurred and under similar conditions. However, if a sample was taken at a working face and the working face advanced considerably since the time of the initial sampling, resample at the new face area.

IV. Evaluation of Exposure

Once the sampling (personal or area) has been completed and results obtained, use the results to evaluate exposure. Determine compliance for the following contaminants by:

Dusts, fumes, mists, gases, and vapors -

- Calculating exposure concentration;
- Shift-weighted averaging;
- Applying error factors; and
- Calculating additive effects (if applicable).

Noise -

- Reading the personal noise dosimeter; or
- Reading the sound level meter; and
- Applying appropriate error factor.

Radiation -

- Reading the instrument;
- Applying time factor; and
- Applying the error factor.

A. Full-Shift Sampling

1. **Full-Shift Sampling.** Full-shift sampling is collecting one or more samples over an entire workshift. The total sampling time equals the full length of the shift.
 - a. **Single sample.** Calculate sampling results on the basis of **480 minutes**, regardless of the actual sampling time. This “shift-weighting” for work schedules less than or greater than eight hours provides direct comparison with the 8-hour based exposure limits (TLVs).

The general equation for calculating a shift-weighted average (SWA) or 8-hour equivalent time-weighted average (TWA₈) for dusts, fumes, and mists is:

$$\text{SWA in mg/m}^3 = \frac{\text{Total weight of contaminant in milligrams (mg)}}{\text{Flow rate in Liters per minute (Lpm) x 480 min x 0.001 m}^3/\text{L}}$$

where: mg/m^3 = milligrams per cubic meter
 m^3/L = cubic meters per Liter

The following formula can be used for converting mg/m^3 to parts per million (ppm) for gases and vapors. Do not use this conversion formula for dusts, mists or fumes.

$$\text{ppm} = \frac{\text{mg/m}^3 \times 24.45}{\text{MW}}$$

where: MW = molecular weight of compound (gas or vapor)

The “shift weighting” of sampling results serves two functions:

- Contaminant concentrations during unsampled periods of an 8 hour shift are assumed to equal zero.
 - Exposures for work schedules greater than 8 hours are proportionately adjusted to allow direct comparison with the 8-hour TLV.
- b. **Consecutive samples.** If the MSHA Laboratory notifies an inspector that a single full-shift sample (such as a filter cassette, charcoal tube, or passive badge) contains too much contaminant

and cannot be analyzed for enforcement purposes, the inspector will have to resample the occupation using consecutive samples (two or more samples collected back-to-back). The laboratory may be able to analyze the original “overweight” sample for screening purposes only, but the sample is void and the results should not be entered into the MSHA Standardized Information System (MSIS).

Further, if sampling experience or observation causes the inspector to believe that a sample could be overloaded due to excessive concentrations of contaminant in the work environment, use consecutive sampling to cover the full shift.

By collecting consecutive samples, the total amount of contaminant is spread out over several samples. In calculating the SWA exposure concentration, add together the individual consecutive sample weights and use the total in the formula found in subparagraph 1.a. above. When consecutive sampling for asbestos, and results are reported as individual TWAs, use the formula given in the example below in 2. b., Method 2.

2. **Partial-Period Sampling.** Partial-period sampling is the collecting of one or more samples taken intermittently during a full shift to represent the entire full-shift exposure. The total actual sampling time will be less than the time of the full-shift. Partial-period sampling must be time-weighted **and** shift-weighted to evaluate exposure to contaminants with 8-hour TLVs. For example, MSHA uses partial-period sampling when collecting impinger or detector tube samples. When taking a series of grab samples periodically throughout a shift, each sample can serve the dual purpose of being part of the full-shift sampling process as well as a stand alone short-term sample. See Chapter 11, V., Sampling Strategy for Detector/Diffusion Tube Sampling, and Chapter 13, VI, Sampling Procedures for Electronic Direct-Read Instruments (DRIs).
 - a. **Time-Weighting.** Each sample must be individually time-weighted. (TWA = time-weighted average). This is done by the following equation:

$$\text{TWA in mg/m}^3 = \frac{\text{Weight of contaminant in milligrams (mg)}}{\text{Flow rate (Lpm) x actual sampling time x 0.001 m}^3/\text{L}}$$

Note: mg/m^3 TWA for gases and vapors can be converted to ppm using the formula in A.1.a above. Do not use this conversion formula for dusts, mists or fumes.

- b. Shift-Weighting.** Once the time-weighted average of each sample has been calculated, determine the time represented by that sample. This can be accomplished by either of the following two methods:

Method 1: If the miner's location and activities were relatively uniform during the shift (for example, a crusher operator or truck driver), then the one sample can represent the hour in which it was taken, regardless of the exact time it was taken. For example, if the sample were to be taken from 8:25 a.m. to 8:35 a.m., it could represent the hour covering 8:00 a.m. to 9:00 a.m. The next sample could be taken at 9:35 a.m. to represent the hour from 9:00 a.m. to 10:00 a.m., and so on.

Method 2: If the miner's shift was divided into work periods of two or more separate activities or locations (e.g., cleanup, bagging, reagent mixing, leach pad, mill), the time period represented by the sample can be time spent performing that task or in that location. If multiple samples were taken during a task or in specific locations, their weighted average can be used to represent that time. The total time represented by the samples must equal the entire shift.

The calculation of the shift-weighted average (SWA) is determined by the following formula:

$$\text{SWA} = (\text{TWA}_1 t_1 + \text{TWA}_2 t_2 + \dots + \text{TWA}_n t_n) / 480 \text{ min.}$$

where: TWA = Contaminant concentration measured;
t = Time period represented by sample in minutes; and
 $t_1 + t_2 + \dots + t_n$ equals the total time of the full workshift.

Note: Do not mix TWA or time units of measure. The SWA and the multiple TWAs are in mg/m^3 or ppm; the units cannot be mixed.

B. Short-Term Exposure Limits (STEL)

1. **Full-Period Sampling.** When sample duration equals or exceeds time specified for the STEL (5, 15, or 30 minutes), use the actual sampling time to determine the exposure by using the following formula:
Short-term exposure concentration for STELs in mg/m³ =

$$\frac{\text{Weight of contaminant in milligrams (mg)}}{\text{Flow rate (Lpm) x actual sampling time x 0.001 m}^3/\text{L}}$$

Note: mg/m³ STEL results for gases and vapors can be converted to ppm using the formula given in A.1.a above. Do not use this conversion formula for dusts, mists or fumes.

2. **Partial-Period Sampling.** When the partial-period sampling method is used (one or more samples taken intermittently) to represent the time specified for the STEL (5, 15, or 30 minutes), use the formula below to determine the exposure concentrations. Partial-period sampling would be conducted with detector tubes or direct read instruments.

$$\text{SWA} = (\text{TWA}_1\text{t}_1 + \text{TWA}_2\text{t}_2 + \dots + \text{TWA}_n\text{t}_n) / \text{STEL time}$$

where: TWA = Contaminant concentration measured by actual sampling;

t = Time period represented by sample; and

t₁ + t₂ + . . . t_n must equal the total of the STEL time.

Note: SWA and multiple TWAs are in mg/m³ or ppm units. The units cannot be mixed.

C. Ceiling Limits and Excursion Limits

Ceiling limits and excursion limits must not be exceeded at any time. If the instantaneous sampling method is used, base compliance determinations on that reading. If a method is used that requires submitting the sample for expedited lab analysis, sample for at least as long a time as required to collect an amount of contaminant greater than the lab's detection limits. Determine the concentration by using the following formula:

Ceiling or Excursion Limit concentration in mg/m³ =

$$\frac{\text{Weight of contaminant in milligrams (mg)}}{\text{Flow rate (Lpm) x actual sampling time (min) x 0.001 m}^3/\text{L}}$$

Note: Ceiling or Excursion Limit concentrations in mg/m³ for gases and vapors can be converted to ppm using the formula given in A.1.a above. Do not use this conversion formula for dusts, mists or fumes.

D. Error Factors

Error factors are used to compensate for sampling and analytical errors associated with a specific method, as well as to ensure that the sample is over the exposure limit with a 95% confidence level. An up-to-date index of error factors for sampling methods listed in Chapter 3 will be maintained by the MSHA laboratory, applied in analytical computations, and shown on the laboratory report.

To calculate the error factor of a particular sampling instrument or method not listed in Chapter 3, use the manufacturer's specified **coefficient of variation (CV)** or **relative standard deviation (RSD)** number. Multiply the highest value listed by 1.65; then add one. The permissible exposure limit is then multiplied by the error factor. This result determines the limit concentration above which a miner's exposure would be considered citable.

Example:

The Dräger Detector Tube Handbook (11th edition) states that the hydrogen sulfide detector tube #6728821 has a relative standard deviation of ± 5 to 10 %. To determine the appropriate error factor, multiply the highest value by 1.65, which is then added to one.

$$\begin{aligned} \text{Error Factor} &= (10\% \times 1.65) + 1 \\ \text{Error Factor} &= 1.17 \end{aligned}$$

E. Additive Effects

Inspectors must consider the effect on miners of exposure to multiple contaminants. When a miner is exposed to more than one airborne contaminant that produces the same effect on the body or on the same body site (target organ), they produce a combined effect. These exposures are said to be “additive.” There are many sources for finding the target organs and toxic effects of

chemicals. The **NIOSH Pocket Guide to Chemical Hazards** and MSDSs are good sources of information. An extensive discussion of additive threshold limit values for mixtures is found on pages 42-51 of the *TLVs[®] Threshold Limit Values for Chemical Substances in Workroom Air Adopted by the ACGIH for 1973*.

1. The general equation for calculating an additive exposure, where the contaminants have similar toxicological properties, is the sum of the individual contaminant to exposure limit ratios as follows:

$$\text{Additive Exposure} = \frac{C_1}{(\text{TLV}_1 \times \text{EF}_1)} + \frac{C_2}{(\text{TLV}_2 \times \text{EF}_2)} + \dots + \frac{C_n}{(\text{TLV}_n \times \text{EF}_n)}$$

where: **C** = individual contaminant exposure concentration (in ppm or mg/m³);

TLV = individual contaminant exposure limit (in ppm or mg/m³); and

EF = error factor for contaminant sampling and analysis.

Express the individual contaminant concentration (C₁, C₂, etc.) and the corresponding exposure limit (TLV) in the same measurement units (e.g., ppm or mg/m³). They must relate to the same exposure period (e.g., full-shift, short-term).

When the additive exposure is greater than (1.0), an overexposure is indicated.

Example:

A mineral processing facility uses a variety of chemicals in the plant and stores them in large open tanks throughout the facility. There are several tanks in one room. A miner's exposure was measured using an air sampling method with an error factor of 1.25. Although none of the exposures to the individual contaminants exceeded the associated TLVs, the concentrations of the four contaminants listed below were considered for additive effects¹:

¹The example of additive effects calculation and the discussion and examples of TLVs for liquid mixtures and airborne contaminants were excerpted (in part) from Jack Caravanos, DrPH, *Quantitative Industrial Hygiene*, 1991, pgs. 46-48.

- muriatic acid (hydrogen chloride), 2.8 mg/m³ (TLV = 7.5 mg/m³);
- nitric acid, 2.7 mg/m³ (TLV = 5.2 mg/m³);
- sulfuric acid, 0.2 mg/m³ (TLV = 1.0 mg/m³); and
- tributyl phosphate*, 1.7 mg/m³ (TLV = 5.0 mg/m³).

* In this case, tributyl phosphate is not an acid gas, as are the other three contaminants, and does not have the same toxicological effects. Therefore, it is not included in the additive effects calculation which follows:

$$\begin{aligned}
 \text{Additive Exposure} &= \frac{C_1}{(TLV_1 \times EF_1)} + \frac{C_2}{(TLV_2 \times EF_2)} + \dots + \frac{C_n}{(TLV_n \times EF_n)} \\
 &= \frac{2.8}{(7.5 \times 1.25)} + \frac{2.7}{(5.2 \times 1.25)} + \frac{0.2}{(1.0 \times 1.25)} \\
 &= 0.2987 + 0.4154 + 0.1600 \\
 &= 0.8741
 \end{aligned}$$

The additive exposure of 0.8741 is less than 1.0, therefore, the TLV for the three similar contaminants (acid gases) has not been exceeded. This example illustrates that the miner's exposure to the contaminants, both individual and additive, would be in compliance.

2. Calculating TLVs for Liquid Mixtures.

For mixtures of liquid contaminants where the contaminants present have similar toxicological properties, it is an accepted practice to calculate a TLV for the mixture as a whole. The assumption is that the toxicological properties are additive in nature. The TLV of the liquid mixture is based on the percentage of each contaminant present and its respective TLV. The following formula can be used to calculate the combined TLV of the mix.

$$TLV_{\text{mix}} = \frac{1}{\frac{F_1}{TLV_1 \times EF_1} + \frac{F_2}{TLV_2 \times EF_2} + \frac{F_3}{TLV_3 \times EF_3} + \dots + \frac{F_n}{TLV_n \times EF_n}}$$

where: **F** = the weight fraction of the contaminant in decimal percentage;
TLV = respective TLV of the contaminant in mg/m³; and
EF = the associated error factor of the sampling method used.

Note: There are no air sampling concentration results involved in the calculation of the TLV for a liquid mixture.

Example:

What is the TLV in mg/m³ of a solution containing 25% naphtha (TLV = 1370 mg/m³), 15% toluene (TLV = 377 mg/m³), and the remainder (60%) Stoddard solvent (TLV = 525 mg/m³) when planning to sample using a charcoal tube. (Note: assume that for using a charcoal tube, the EF for naphtha = 1.15; the EF for toluene = 1.13; and the EF for Stoddard solvent = 1.11).

$$\begin{aligned} TLV_{\text{mix}} &= \frac{1}{\frac{0.25}{1370 \times 1.15} + \frac{0.15}{377 \times 1.13} + \frac{0.60}{525 \times 1.11}} \\ &= \frac{1}{0.0001586 + 0.0003521 + 0.001029} \\ &= \frac{1}{0.001540} \\ &= 649 \text{ mg/m}^3 \end{aligned}$$

The three-component solvent mixture will have an enforcement airborne TLV of 649 mg/m³.

Table 2-1. Contaminants and Commonly Related Standards²	
Contaminant	Commonly Related Standard(s)
1. Respirable Dust (Silica)	56/57.5001, 56/57.5002, 56/57.5005, 58.610, 58.620
2. Other Inhalation Hazards:	
Asbestos	56/57.5001(b), 56/57.5002, 56/57.5005, 56/57.15004, 56/57.15006, 56/57.16003, 56/57.16004, 56/57.20011, 56/57.20012, 56/57.20014
Other Mineral Fibers & Silicates	56/57.5001, 56/57.5002, 56/57.5005
Nuisance Particulates	56/57.5001, 56/57.5002, 56/57.5005
Mercury Vapor	56/57.5001, 56/57.5002, 56/57.5005, 56/57.20014
Welding Fumes	56/57.5001, 56/57.5002, 56/57.5005, 56/57.15007, 56/57.14213
Metal Dusts	56/57.5001, 56/57.5002, 56/57.5005, 56/57.20014
Caustic Dusts	56/57.5001, 56/57.5002, 56/57.5005, 56/57.20014
Chemical Vapors & Gases	56/57.5001, 56/57.5002, 56/57.5005, 56/57.5006, 56/57.15004, 56/57.15006, 56/57.20005, 56/57.20014
Radon Gas (underground)	57.5037 through 57.5047
3. Mixed Sound Levels	62.100 through 62.190
4. Diesel Exhaust: Gases Particulates	56/57.5001, 56/57.5002, 56/57.5005 57.5060, 57.5061, 57.5062, 57.5065, 57.5066, 57.5067, 57.5070, 57.5071, 57.5075

² This table is not intended to be an all-inclusive list of possible related standards. It is presented here only as a general reference.

Table 2-1. Contaminants and Commonly Related Standards	
5. Hazardous Chemical Waste (Storage or Used As Fuel)	56/57.5001, 56/57.5002, 56/57.5005, 56/57.5006, 56/57.15001, 56/57.15004, 56/57.15006, 56/57.20011, 56/57.20012, 56/57.20014
6. Confined Spaces:	56/57.5001, 56/57.5002, 56/57.5005, 56/57.16002
Chemicals	56/57.5001, 56/57.5002, 56/57.5005
Oxygen Deficiency	57.5015, 57.8527, 57.8528
7. Radiation Hazards:	56/57.15006, 56/57.16003, 56/57.16004, 56/57.20011, 56/57.20012
Ionizing (Nuclear)	57.5037 through 57.5047
Non-ionizing (Electromagnetic)	none
8. Biological Hazards	56/57.20002, 56/57.20003, 56/57.20008, 56/57.20013, 56/57.20014
9. Heat Stress	56/57.15006, 56/57.20002
10. Corrosive & Toxic Chemicals (Eye & Skin Hazards)	56/57.15001, 56/57.15004, 56/57.15006, 56/57.20005
11. Ergonomic Hazards	none
12. General	56/57.18002, 56/57.18006, 56/57.20011