Mining Surveillance:

Potentially Toxic Occupational Exposures

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Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

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Executive Summary

The Federal Mine Safety and Health Act of 1977 requires that the Department of Health, Education, and Welfare prepare reports on toxic chemical and physical agents found in mines. The National Institute for Occupational Safety and Health (NIOSH) has conducted a review of the pertinent existing information on these agents. The sources of information utilized include government agencies, private industry, universities, associations, and labor unions.

Of the many agents identified during this review, thirty-five are identified in this report as being found in mines at potentially toxic levels. Twenty-one of the thirty-five agents exceed NIOSH Criteria values; four exceed the Mine Safety and Health Administration standards; ten exceed standards developed by consensus standards bodies. Summaries of environmental and toxicity data are included.

NIOSH intends to identify the agents found in mines and to establish their exposure levels, to describe the populations exposed to them and the patterns of concurrent exposure, and to conduct toxicity evaluations based on population exposures. NIOSH will report on these activities in future reports.

Introduction

This document has been prepared pursuant to Section 101(a)(6)(B) of the Federal Mine Safety and Health Act of 1977. That Section states that the Secretary of Health, Education, and Welfare ". . . shall for each toxic material or harmful physical agent which is used or found in a mine, determine whether such material or agent is potentially toxic at the concentrations in which it is used or found in a mine." The Act allows eighteen months after the date of enactment for the transmittal of the first determinations to the Secretary of Labor. Subsequent determinations will be developed and transmitted on a continuing basis after the initial report.

The Act designates the National Institute for Occupational Safety and Health (NIOSH) as the agency in the Department of Health, Education, and Welfare responsible for health research in mines. In this first transmittal under Section 101(a)(6)(B) of the Act, NIOSH reports thirty-five agents found to occur in mines at potentially toxic concentrations.

Outline of Approach

Section 101(a)(6)(B) directs NIOSH to identify all chemical and physical agents which are used or found in a mine, to determine the concentrations at which they are encountered and their potential toxicity at those concentrations, and to submit these determinations to the Secretary of Labor through the Secretary of Health, Education, and Welfare.

It was not possible, with the allotted time and resources, to initiate and complete field surveys to do workplace health hazard characterizations for a significant segment of the mining industry. Therefore, NIOSH conducted an extensive review of existing information.

The information which NIOSH reviewed is of three types: (1) research findings, (2) compliance data, and (3) inventory listings. This information was gathered from the following sources.

1. Governmental agencies: Eighty-one Federal and State agencies responded to requests for information on environmental levels and use of subtances in mines. One hundred-thirty-seven agencies were contacted, using Occupational Safety and Health Directory (1) as a guide. (The State agencies contacted have titles related to labor, mines, environment, and geology.) Most State agencies reported limited or no occupational environment monitoring programs for mines. Some State agencies reported dust sampling programs, but without qualitative

analysis of the dust. One State provided data on a variety of hazards, including some inventory information on substances used in mines. One State reported plans to implement an inventory program.

The Federal agencies which were contacted included the Bureau of Mines, Mine Safety and Health Administration (MSHA), Department of Labor, Environmental Protection Agency, U.S. Geological Survey, and NIOSH. The Mine Safety and Health Administration has amassed considerable exposure data collected at various mines by its mine inspectors. The Bureau of Mines has been active in mine health research through its inhouse and contracted research program. The Environmental Protection Agency has developed lists of reagents used in some ore refining processes. The U. S. Geological Survey has collected some information on naturally occurring substances. The Consumer Product Safety Commission and Department of Transportation were also contacted but no information was obtained from these agencies or this report. NIOSH research into various facets of the mining industry was also utilized.

2. Mining companies: Sixty mining companies were contacted, covering forty-five four-digit Standard Industrial Classifications. For the most part these sources provided no exposure data, but were helpful in identifying some chemicals currently used in ore extraction, milling, maintenance, and waste treatment.

3. Mining trade and professional associations: Twenty-seven professional and trade associations were contacted, using National Trade and Professional Associations (2) and Encylopedia of Associations (3) as guides. Typically, these organizations function as clearinghouses of information for the mining industry and are not active in mine health hazard research. Some provided information on the chemicals used in the mining operations of their member corporations. Others introduced NIOSH personnel to mining company representatives, thus allowing easier collection of information.

4. Universities: Twenty-six universities and colleges having mining or occupational health related programs were approached for information; Universities and Colleges Offering Degrees in Mining Engineering (4) was used as a guide. NIOSH found that few schools having these programs were active in mine health hazard research. The limited research underway was funded primarily by the Bureau of Mines or NIOSH. Two programs supplied mining environmental data.

5. Labor unions: Six separate unions representing the bulk of organized mining labor and the AFL-CIO were contacted. The unions did not provide any environmental data although they did comment on potential sources of information.

6. Computerized abstract listings: These information sources were used as a tool for identifying other sources. Nine computerized abstract

The method of contact and follow-up for each source varied, depending on which method appeared to be most effective. Letters, telephone calls, visits, and publication reviews were used in various combinations.

Description of Data in Table of Agents Found at Potentially Toxic Levels in Mines

The Table summarizes the environmental data ranges and toxicity information for thirty-five agents identified as occurring at potentially toxic levels. Twenty of those agents are based on MSHA data only, six are based on Bureau of Mines data only, four are based on NIOSH data only, and five are based on a combination of MSHA and Bureau of Mines data.

Several guidelines were established to assure a uniform review of data received. The guidelines are as follows:

1. Outlying data were checked for validity. If the data source did not verify the data, the data were eliminated.

2. MSHA welding fume data required editing because the MSHA procedure for analysis of welding fumes required reporting on all of sixteen specific metals for each sample. Many zero-values were reported under that procedure, since some of the sixteen metals would not be expected in all welding fumes. After consultation with MSHA, all zero-values were eliminated from MSHA welding fume data.

3. Grab samples and short-term samples were included in the data distributions if a ceiling limit exists for the agent or the agent is a carcinogen. A ceiling limit is a level which should not be exceeded for a specified time period. Where grab samples were included, a comment is found in the Table. Grab samples may indicate peak exposures which are not representative of full-shift average exposures. Data from sampling durations less than full shift but longer than a grab sample distributions. Grab sample area data were used only if they approximated personal exposures.

4. Data from different sources were included in the same distribution only if the sampling methods and strategies were similar.

5. After following the above guidelines, a substance was determined to occur at a potentially toxic concentration if (a) a carcinogen was reported at any detectable level, or (b) the maximum level exceeded the NIOSH Criteria Document value. If a NIOSH Criteria Document value was not available for comparison, other nationally recognized occupational health standards were used as noted in the Table.

The data in the Table are presented in the form of the 50th, 90th, and 100th (maximum) percentiles. These values represent the point in the

ordered data at which the stated percentage of the data are at or below the stated level. Thus, at the 90th percentile level, 10% of the data are above the stated level.

The exposure data in this document are the most reliable information obtained by NIOSH at the time of this report; however, certain limitations apply. First, the amount of information obtained for a given agent does not correlate with the number of persons exposed. Many workers may be exposed in cases where relatively little data were obtained. Second, the data include surveys of worst-case conditions. Thus, in some cases, extremely high levels are reported which, while accurate, may only occur infrequently. Third, the data do not reflect concurrent exposures to more than one agent. Some agents are believed to have synergistic effects. Finally, the data may not precisely reflect present-day conditions. The data referenced in the document are between nine months and six years old. NIOSH has attempted to identify completely outdated information; some data are considered valid, although several years old.

NIOSH has also identified many more agents found or used in mines for which no environmental data can be reported. Some of those agents may be determined to exist at toxic levels when environmental data are obtained. NIOSH intends to transmit future documents describing these agents encountered in the mining industry.

Continuing Efforts

NIOSH recognizes that there may exist other data on certain agents which were not obtained. In addition, data which have been included may, in certain instances, not be representative of workplace conditions. For those reasons, NIOSH invites submission of additional information which might improve the documentation of mining environmental exposures.

NIOSH believes this document establishes the need for additional information on occupational health in the mining industry. This need is indicated by the paucity of exposure data for certain agents, and the absence of comprehensive information on the many substances used or found in mines.

NIOSH intends to identify the agents found in mines, to establish their exposure levels, to describe the populations exposed to them, and the patterns of concurrent exposure, and to conduct toxicity evaluations based on population exposures. NIOSH will report on these activities in future reports.

REFERENCES

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Table of Agents Found at Potentially Toxic Levels in Mines

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
Ammonia	140	40	1	50 (ppm) (5 minute period)	The data consist of 75 area grab samples from non-coal mines. The NIOSH Criteria Document value is based on airway irritation. The present MSHA exposure limit is 100 ppm (30 minute ceiling).
Arsenic (other than welding)	143.3	13.0	1.6	2.0 (ug/m3) (15 minute period)	The data consist of 130 full-shift personal samples obtained primarily in lead, salt, and zinc mines. The highest exposures are due to dust in underground mines. The Criteria Document value is based on lung cancer risks. The present MSHA exposure limit is 500 ug/m3 (full-shift).
Asbestos	27.6	4.4	0.8	0.1 (fiber/cc)	The data consist of 509 full-shift personal samples obtained in non-coal mines and mills. The highest exposures are associated with asbestos mining and milling operations; asbestos has also been found in a variety of other mine and mill dusts. All samples were analyzed by phase-contrast microscopy only. The Criteria Document value is based on risks of lung cancer and asbestosis. The Criteria Document

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)	Comment
					value applies only to fibers greater than 5 micrometers in length. The present MSHA exposure limit is 2 fibers/ cc (full-shift).
Asbestos	9.7	0.14	0.05	0.5 (fiber/cc) (15 minute period)	The data consist of five short-term breathing zone and personal samples taken in surface coal mine shop brake relining operations. The present MSHA exposure limit is 10 fibers/cc (15 minute excursion).
Benzo(a) anthracene	0.055	0.049	0.015	200 (ug/m3) (Source: 1978 ACGIH)	The data consist of 15 full-shift area samples taken in underground coal and non-coal mines which utilize diesel equipment. These data and the values listed for other polynuclear aromatics indicate the presence of agents which have been implicated as carcinogens. Sampling and analytical techniques for aerosolized polynuclear aromatics are not fully developed; the levels reported may be low.
Benzo(a)pyrene	0.079	0.018	0.011	200 (ug/m3) (Source: 1978 ACGIH)	The data consist of 15 full-shift area samples from underground coal and non-coal mines which utilize diesel equipment. These data and the values listed for other polynuclear aromatics indicate the presence of agents which have been implicated as carcinogens. Sampling and analytical techniques for aerosolized polynuclear aromatics are

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					not fully developed; the levels reported may be low.
Beryllium	0.60	0.03	0.01	0.5 (ug/m3) (130 minute period)	The data consist of 9 full-shift personal samples taken at a beryl mine and a lead/zinc mine. The exposures were found in crushing and chemical treatment operations. The NIOSH Criteria Document value is based on lung cancer risk. The current MSHA exposure limit is 2.0 ug/m3 (full-shift).
Carbon monoxide	250	17	0	200 (ppm) (maximum ceiling)	The data consist of 11,500 area grab samples taken at coal and non-coal mines. The NIOSH Criteria Document advise a full-shift limit of 35 ppm. The NIOSH Criteria Document ceiling value is based on heart effects. The present MSHA exposure limit is 400 ppm (15 minute excursion).
Carbon tetra-chloride	20	-	1	2 (ppm) (60 minute period)	The data consist of two breathing zone grab samples taken at coal mine float sink operations. The NIOSH Criteria Document value is based on risk of liver cancer. The present MSHA exposure limit is 20 ppm (15 minute excursion).

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
Chrysene	0.341	0.172	0.045	200 (ug/m3) (Source: 1978 ACGIH)	The data consist of 15 full shift area samples taken in underground coal and non-coal mines which utilize diesel equipment. Comments on benzo(a)pyrene apply here, as well. A NIOSH Special Hazard Review dated June 2, 1978 recommended that chrysene be controlled as an occupational carcinogen.
Coal mine dust	4.0	2.3	1.7	2.0 (mg/m3 MRE) (Source: MSHA)	The data consist of full-shift respirable samples for "high risk" occupations in coal mines. The term "MRE" refers to an adjustment factor based on equipment developed by the British Mining Research Establishment. The present MSHA exposure limit is 2.0 mg/m3 MRE.
Ethylene glycol dinitrate	3.41	0.06	0.03	0.1 (mg/m3) (20 minute period)	The data consist of seven short term area samples in closed explosives magazines at coal mines. The NIOSH Criteria Document value is based on circulatory system effects. The present MSHA exposure limit is 0.12 mg/m3 (ceiling).
Gamma radiation	2.2	2.0	2.0	2.5 (mR/hr) (Source: MSHA)	The data consist of four mine averages based on instantaneous area measurements in four non-coal underground mines. The fourth value is 0.9 mR/hr (milli-Roentgen per hour).

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
Graphite	27.0	24.0	22.0	15 (mppcf) (Source: 1978 ACGIH)	The data consist of five full-shift personal samples at a graphite mine and mill. Clean-up, concentrating, and bagging operations yielded the highest concentrations. The present MSHA exposure limit is 15 million particles per cubic feet (full-shift).
Heat	92	86	85	variable (F WBGT)	The data consist of 20 mine-averages for underground metal mines. Each "mine-average" is the average of several work and rest-site area temperatures in each of twenty hot mines. The heat is of terrestrial origin. The conditions documented by these data are not representative of conditions in most mines, but hot mines do exist. Reports of excessive heat exposures among heavy-equipment operators at surface mines have been investigated but no over-exposures have been documented. The Criteria Document value for hot environments is dependent on the work rate and proportion of work vs rest during a shift. The Criteria Document value is expressed in degrees Wet Bulb Globe Temperature (WBGT). The WBGT index represents a weighted combination of the wet and dry bulb and globe temperature. The data indicate that, for the mines surveyed, 77 percent of the underground work sites exceed the NIOSH Criteria Document value for 50 percent moderate work-rate and 50 percent rest.

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
Hydrogen sulfide	400.	0.05	0	10 (ppm) (10 minute period)	The data consist of 990 area grab samples taken at non-coal mines. The highest levels were obtained in confined areas which employees should not enter if proper work practices are followed. No personal exposure data was obtained for hydrogen sulfide. The present MSHA exposure limit is 20 ppm (5 minute excursion
Lead, inorganic (other than welding)	1.11	0.16	0.01	0.100 (mg/m3)	The data consist of 250 full-shift personal samples, primarily from lead mills. The highest exposures were associated with crushing, filtering, and clean-up operations. The NIOSH Criteria Document value is based on kidney, blood, and nervous system effects. NIOSH has also supported the OSHA standard of 0.05 mg/m3. The present MSHA exposure limit is 0.15 mg/m3 (full-shift).
Mercury vapor	0.37	0.33	0.15	0.050 (mg/m3)	The data consist of 30 full-shift personal samples obtained at three mills processing gold and mercury. The Criteria Document value is based on central nervous system effects. The present MSHA exposure limit is 0.05 mg/m3 (full-shift).
Nitrogen dioxide	6.70	1.20	0.19	1.0 (ppm) (15 minute period)	The data consist of 1300 full-shift personal samples from underground coal and non-coal mines some of which utilize diesel equipment. The data are

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					based on dosimeter measurements. The NIOSH Criteria Document value for nitrogen dioxide is based on respiratory system effects. The present MSHA exposure limit is 5 ppm (ceiling).
Nitrogen dioxide	20	2	1	1.0 (ppm) (15 minute period)	The data consist of 402 grab samples obtained in non-coal mines, some of which utilize diesel equipment. The NIOSH Criteria Document value is based on respiratory system effects. The present MSHA exposure limit is 5 ppm (ceiling).
Nitroglycerin	2.97	.009	.006	0.1 (mg/m3) (20 minute period)	The data consist of seven short term area samples in a closed explosives magazine at coal mines. The NIOSH Criteria Document value is based on circulatory system effects. The present MSHA exposure limit is 4.0 mg/m3 (15 minute excursion)
Noise	39.6	2.0	0.7	0.5 (C/T)	The data consist of 40,000 readings taken in coal and non-coal mines. The coal mine data are based on sound level meter readings; the non-coal mine data are based on personal noise dosimeter measurements. Most of the data were taken with noise dosimeters in non-coal mines. The highest exposures are associated with operations such as drilling, load/haul/dump, and jet piercing. The data are presented

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					in C/T units as computed by adding the total time of exposure at each specified level (C) divided by the total time of exposure permitted at that level (T). An exposure of 90 dBA for eight hours yields one (1) C/T. The NIOSH Criteria Document value of 85 dBA is equivalent to one-half the daily noise dose allowed by MSHA.
Oxygen, deficiency	16.0	20.6	20.86	19.5 (percent) (Source: MSHA)	The data consist of 5910 area grab samples obtained in active areas of underground non-coal mines. The MSHA exposure limit applies only to underground active mine workings.
Perchloroethylene	24	20	10	100 (ppm) (15 minute period)	The data consist of 12 samples taken at coal mine float-sink testing operations. The samples are breathing zone grab samples which probably indicate peak exposure. Full-shift personal samples were not obtained. Perchloroethylene is not necessarily used every shift. The full-shift NIOSH value is 50 ppm. The NIOSH Criteria Document values are based on nervous system, heart, respiratory and liver effects. NIOSH Current Intelligence Bulletin 20 of January 20, 1978 reports that it is prudent to handle perchloroethylene as if it were a human carcinogen. The recommendation is based on findings

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					of liver cancer in mice. The present MSHA exposure limit is 150 ppm (15 minute excursion).
Perlite	38.8	28.6	7.7	30.0 (mppcf) (Source: 1978 ACGIH)	The data consist of eleven full-shift personal samples taken at a perlite mine. Only clean-up and load-haul-dump operations were sampled. The present MSHA exposure limit is 30 mppcf (million particles per cubic foot).
Radon daughters (Po-214, Po-218, other alpha-emitting elements)	20.9	1.5	0.3	0.3 (WL) (Source: MSHA)	The data consist of 4600 area grab samples taken at underground metal mines. Uranium mines yielded the highest levels; the average level in uranium mines is approximately four times the average level reported for non-uranium mines. A NIOSH Current Intelligence Bulletin dated May 11, 1976 supports the levels enforced by MSHA. The 0.3 working level (WL) limit is used by MSHA as a criteria for initiating exposure record-keeping procedures. Personal exposures are required to be below 4.0 working level-months per year. Excessive radon daughter exposures are associated with lung cancer. Current MSHA excursion limit is 1.0 WL.
Silica	11.7	0.175	0.026	0.050 (mg/m3)	The data consist of 21,000 full-shift personal samples from coal and non-

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					coal mines. The data indicate widespread exposure among any operations involving high dust concentrations; drilling, crushing, and bagging operations are most strongly associated with high silica exposures. The NIOSH Criteria Document value is based on risk of chronic lung disease. The present MSHA exposure limit is 0.1 mg/m3 in non-coal mines. The MSHA exposure limit for coal mines is controlled by the allowable respirable dust level, computed by dividing the percent of quartz into the number 10; the formula applies only when the percent quartz is greater than 5.
Talc	5.8	2.78	1.20	3.0 (mg/m3) (Source: 1978 ACGIH)	The data consist of 362 personal full-shift respirable samples taken at talc mines and mills. Bagging operations yielded the highest exposures. The present MSHA exposure limit is 20 million particles per cubic foot (full shift).
Trichloroethylene	200	150	80	25 (ppm)	The data consist of 7 breathing zone and area grab samples taken near degreasing tanks in coal mine surface shops. Trichloroethylene has been observed in use in non-coal mine shops, although no environmental data were obtained. The data represent peak exposures

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					which may occur infrequently. No full-shift personal data were obtained. The duration of exposure per shift will vary significantly. The NIOSH Criteria Document value is based on central nervous system effects. A NIOSH Special Hazard Review dated February 28, 1978 reports that animal data implicate trichloroethylene as a suspect carcinogen. The Special Hazard Review advised that exposure be limited to 25 ppm for a full-shift time-weighted average. The present MSHA exposure limit is 150 ppm (15 minute excursion).
Welding: Aluminum Oxide Arsenic Cadmium Chromium Cobalt Lead, inorganic Manganese Nickel Ozone Vanadium					Welding operations in mines are similar to welding operations in general industry. Welding fumes entail simultaneous exposure to several agents; the combined effects may be greater than the additive effects of individual exposures. MSHA welding samples which indicated zero exposures were eliminated because there was no evidence that specific metals should have been present at the sampling sites.
Aluminum oxide (welding)	15.0	0.62	0.05	10.0 (mg/m3) (Source: 1978 ACGIH)	The data consist of 197 full shift personal samples from non-coal mines. Only the maximum value exceeds 10.0 mg/m3. The

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
					present MSHA exposure limit is 10.00 mg/m3 (full-shift).
Arsenic (welding)	40.0	13.0	1.8	2.0 (ug/m3) (15 minute period)	The data consist of 65 full-shift personal samples taken on welders at non-coal mines. Iron, lead/zinc, silver, and limestone mines yielded the most samples. The Criteria Document value is based on lung cancer risks. The present MSHA exposure limit is 500 ug/m3 (full-shift).
Cadmium (welding)	0.13	0.12	0.04	0.040 (mg/m3) (15 minute period)	The data consist of 7 full-shift personal samples taken at non-coal mine facilities. The NIOSH Criteria Document value is based on lung and kidney effects. The present MSHA exposure limit is 0.1 mg/m3 (ceiling).
Chromium (welding)	0.20	0.05	0.011	0.001 or 0.025 (mg/m3)	The data consist of 67 full-shift samples taken on welders in non-coal mine shops. The NIOSH Criteria Document lists two levels, depending on whether the chromium is carcinogenic. The NIOSH Criteria Document value is based on risks of lung cancer, skin ulcers, and lung irritation. The present MSHA exposure limit is 0.1 or 1.0 mg/m3 (full-shift).

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
Chromium (welding)	4.6	0.20	0.02	0.050 (mg/m3) (15 minute period)	The data consist of 54 less than full-shift personal samples taken in surface coal mine facilities. The present MSHA exposure limit is 0.3 or 3.0 mg/m3 (15 minute excursion).
Cobalt (welding)	0.62	.07	.01	0.1 (mg/m3) (Source: 1978 ACGIH)	The data consist of sixty-three full-shift personal samples obtained at non-coal mines. The present MSHA exposure limit is 0.1 mg/m3 (full-shift).
Lead, inorganic (welding)	1.71	0.26	0.02	0.100 (mg/m3)	The data consist of 72 full-shift personal samples taken at non-coal mines. The Criteria Document value is based on kidney, blood, and nervous system effects. NIOSH has also supported the OSHA standard of 0.05 mg/m3. The present MSHA exposure limit is 0.15 mg/m3 (full-shift).
Manganese (welding)	57	1.4	0.07	5.0 (mg/m3) (ceiling) (Source: 1978 ACGIH)	The data consist of 59 personal samples covering less than a full-shift in coal mine. The second highest value is 5.7 mg/m3. The present MSHA exposure limit is 5.0 mg/m3 (ceiling).
Nickel (welding)	1.00	0.21	0.02	0.015 (mg/m3)	The data consist of 93 full-shift personal samples taken at non-coal mines. The Criteria Document value is based on risks of lung and nasal cancer and skin effects. The present MSHA exposure limit is 1.0 mg/m3 (full-shift).

Agent	Maximum of Exposure Data	90th Percentile of Exposure Data	50th Percentile of Exposure Data	NIOSH Criteria Document (units)* #	Comment
Nickel (welding)	0.9	0.4	0.01	0.015 (mg/m3)	The data consist of 38 personal samples covering less than a full-shift at surface coal mine facilities. The NIOSH Criteria Dcoument value is based on risks of lung and nasal cancer and skin effects. The present MSHA exposure limit is 3.0 mg/m3 (15 minute excursion).
Ozone (welding)	0.80	0.35	0.01	0.10 (ppm) (Source: 1978 ACGIH)	The data consist of 19 breathing zone grab samples from welding operations at surface coal mine shops. The present MSHA exposure limit is 0.3 ppm (15 minute excursion).
Vanadium (welding)	0.110	.037	.001	0.050 (mg/m3) (15 minute	The data consist of 117 full-shift personal samples taken at non-coal mine facilities. The NIOSH Criteria Document Value is based on eye, skin, and lung effects. The present MSHA exposure limit is 0.05 mg/m3 (ceiling).

* Key to abbreviations:

ACGIH = American Conference of Government Industrial Hygienists
ppm = parts per million
mg/m3 = milligrams per cubic meter
ug/m3 = micrograms per cubic meter
mppcf = million particles per cubic foot
WL = working level
C/T = see comment on Noise
F WBGT = degrees Fahrenheit, wet bulb globe temperature
dBA = decibels, A-weighted

NIOSH Criteria Document values are based on up to a 10-hour exposure unless otherwise noted.