REGIONAL COPPER-NICKEL STUDY

SUMMARY

STANDARDS AND EFFECTS ON HUMAN HEALTH OF ENVIRONMENTAL POLLUTANTS

June, 1978

REGIONAL COPPER-NICKEL STUDY

SUMMARY

STANDARDS AND EFFECTS ON HUMAN HEALTH OF ENVIRONMENTAL POLLUTANTS

Minnesota Environmental Quality Board

Author: Peter Ashbrook

June, 1978

Purpose: This summary is intended for internal use by the Copper-Nickel Study. An attempt has been made to identify all possibly revelant standards ar ballpark figures considered important to human health. Also presented is a brief summary of adverse effects on human health which have been observed or might be expected to occur based upon appropriate animal studies. Additional information is available in literature reviews on each agent.

Definitions:

ACGIH: American Conference of Governmental Industrial Hygienists, the organization which develops TLVs.

Dust: A particulate $\geq$ 1μm in diameter, usually formed by physical processes such as crushing or grinding.

EPA: Environmental Protection Agency.

Fume: A particulate $\leq$ 1 μm in diameter, usually formed by volatilization of a solid.

MCL: Maximum contaminant level.

mg/m^3: Milligrams per cubic meter.

Mist: A particulate $\leq$ 10 μm in diameter, which contains a liquid (unlike fumes and dusts).

mppcf: Million oarts oer cubic foot.

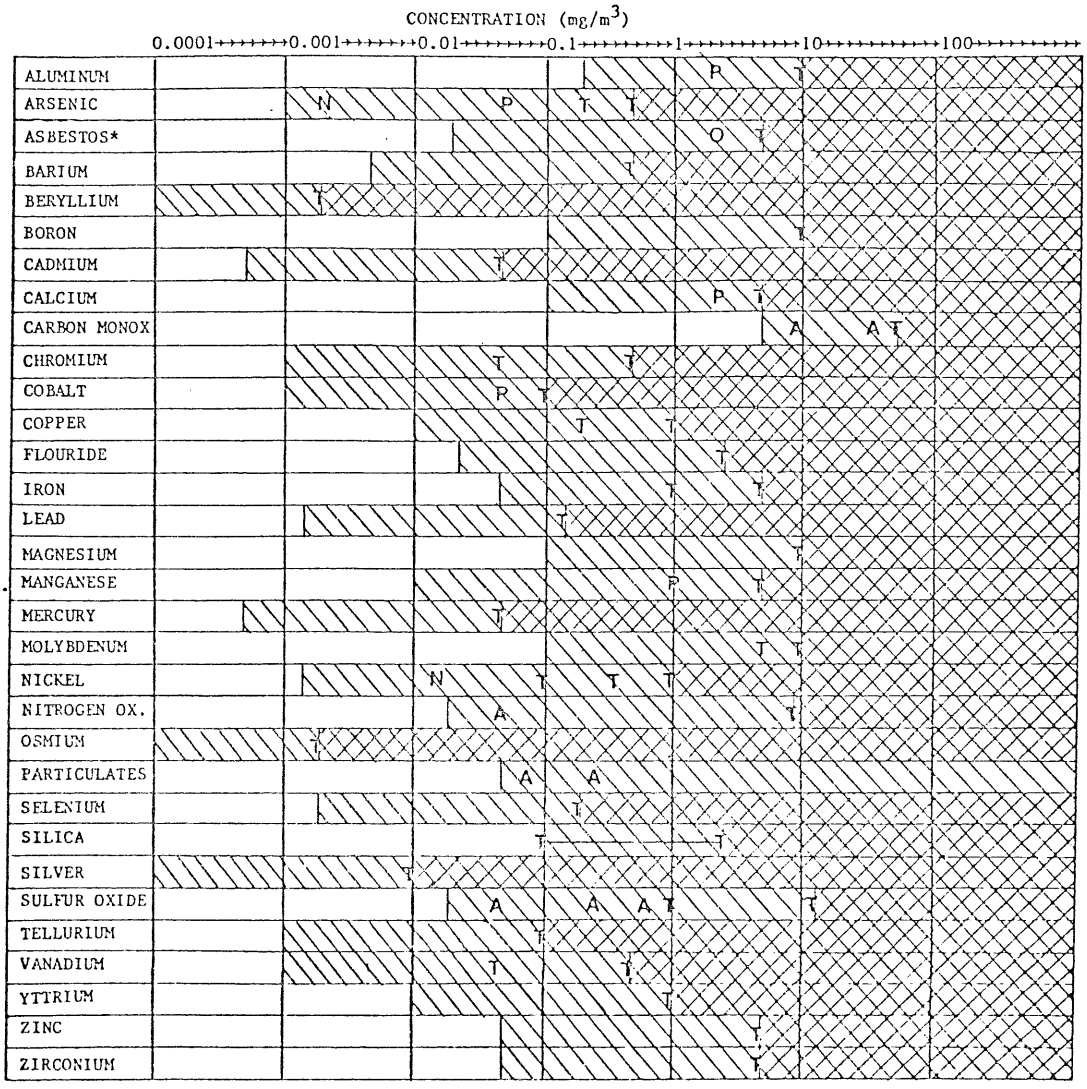
NIOSH: National Institute of Occupational Safety and Health-the research arm of OSHA (Occupational Safety and Health Adminstration).

TLV: Threshold limit value--a time weighted concentration for a 7-or 8-hour workday and 40-hour workweek under which it is currently believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

TLV: Short term exposure limit---the maximal concentration to which workers can be exposed for a period of up to 15 minutes continuously without suffering

from 1) irritation, 2) chronic or irreversible tissue change, or 3) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, providing that no more than four excursions per day are permitted with at least 60 minutes between exposure periods, and provided that the daily TLV-time weighted average also is not exceeded. These are absolute ceilings, not to be exceeded.

AIR QUALITY GUIDELINES FOR HUMAN HEALTH



T - THRESHOLD LIMIT VALUE (TLV)
A - AMBIENT AIR QUALITY STANDARD
P - PROPOSED REVISION OF TLV
N - NIOSH RECOMMENDATION
O - OSHA STANDARD
* - FIBERS PER CUBIC CENTIMETER

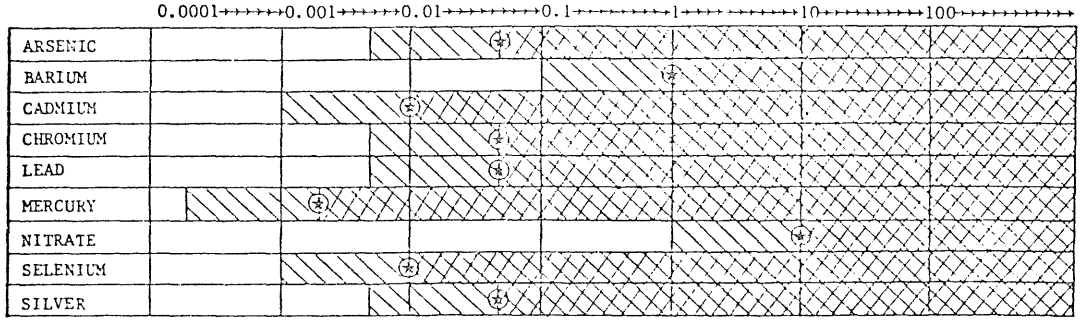
- HEALTH OF GENERAL COMMUNITY MAY BE AFFECTED IN THIS ORDER OF MAGNITUDE

- HEALTH OF WORKERS AND COMMUNITY MAY BE AFFECTED IN THIS ORDER OF MAGNITUDE

March, 1978

WATER QUALITY GUIDELINES FOR HUMAN HEALTH*

PRIMARY MAXIMUM CONTAMINANT LEVELS (MCL)
CONCENTRATION (mg/1)

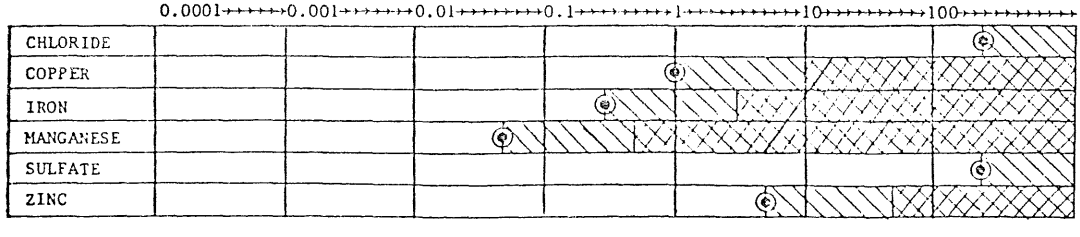


⊛ - PRIMARY MCL TO PROTECT HEALTH OF CONSUMERS

▨ - ACTION TO PREVENT FURTHER CONATMINATION MAY BE DESIRABLE

▩ - WATER CAN NOT LEGALLY BE SERVED TO THE PUBLIC

SECONDARY MAXIMUM CONTAMINAT LEVELS (MCL)
CONCENTRATION (mg/1)



◎ - SECONDARY MCL TO ENSURE ESTHETIC QUALITIES OF DRINKING WATER

▨ - CONTAMINANTS DETECTABLE BY A SMALL PROPORTION OF CONSUMERS

▩ - CONTAMINANTS DETECTABLE BY MOST CONSUMERS

* Source: Environmental Protection Agency, Federal Register, 40(248):59570 (12/24/75)
42(62):17146 (3/31/77).

SUMMARY OF STANDARDS

Agent	TLV (mg/m^3)*	Short term exposure limit (mg/m^3)	MCL in Drinking Water (mg/l)	Air Quality Standards (Minnesota)
Aluminum	10	20	---	
Arsenic (As_2O_3)	0.05	---	0.05	
Asbestos (all forms)	2 fibers/cm^3,** > 5 µm in length	---	under consideration	
Cadmium (oxide fume)	0.05	0.05****	0.01	
Carbon Monoxide	55	440	---	9 ppm-maximum 8 hour concentration 30 ppm-maximum 1 hour concentration
Cobalt	0.1	---	---	
Copper (fume)	0.2	---	1.0***	
Copper (dust & mists)	1	2	---	
Iron Oxide	5	10	---	
Iron salts (as Fe)	1	2	0.3***	
Lead (as Pb)	0.15	0.45	0.05	
Manganese (as Mn)	5	5****	0.05***	
Mercury (all forms except alkyl) (as Hg)	0.05	0.15	0.002	
Nickel soluble compounds (as Ni)	0.1	0.3	---	
Nickel Carbonyl	0.35	---	---	
Nickel, metal	1	---	---	
Nitrogen dioxide	9	9****	---	(Nitrogen oxides) 0.05 ppm-annual arithmetic average
Noise	85 dBA	115 dBA	---	
Particulates	---	---	---	75 µg/m^3 -annual geometric mean 260 µg/m^3 -24 hour maximum
Silica	3 (total); 1 (dust < 5µm)	---	---	
Sulfur dioxide	13	---	---	sulfur oxides 0.02 ppm-annual arithmetic mean 0.1 ppm-maximum 24 hour concentratic 0.25 ppm-maximum 3 hour concentratior
Zinc (oxide fume)	5	10	5***	

*ACGIH, 1977

**OSHA standard

***Secondary MCL, not based on health effects

****If the sum of $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n} > 1$, (where C_i = time weighted concentration, T_i = TLV)

then the TLV for the mixture has been exceeded. Other agents not on this list are included in the formula. (For sample calculations, see appendix.)

ALUMINUM

1. Standards

TLVs - Alundum and Corundum (both Al_2O_3) = 10 mg/m^3 or 30 mppcf - classified as nuisance particulates.
Drinking Water - No standard.

2. Observed Health Effects

Occupational:

a) Respiratory disease was observed in workers manufacturing ammunition in World War II. Apparently this disease was observed only when the particle size was below 7 μm. No concentrations given.

Nonoccupational:

a) All adverse effects that have been reported can be attributed to medicinal uses of aluminum. Encephalopathy has been observed in uremic patients on dialysis who have been treated with phosphate-binding gels for more than 3 years. Aluminum hydroxide may cause phosphate deficiency.

Animal Studies:

a) have produced respiratory disease in rats
b) dermatitis produced by $AlCl_3$ and $Al(NO)_3$ in mice, rabbits, and pigs
c) high doses of aluminum can produce a negative phosphorus balance

Target Organs: respiratory tract
Typical Adult Intake: 10-100 mg/day ---- virtually all through the diet

ASBESTOS

1. Standards

TLV (all forms) - 2 fibers/cm^3, > 5 μm in length
(There is currently discussion to lower this by a factor of 4)

Drinking Water - No standard; however, EPA has studies in progress to determine if a standard should be set.

2. Observed Health Effects

Occupational:

a) asbestosis - a respiratory disease which has been observed in almost every occupational group working with asbestos.

b) lung cancer - has been frequently observed; this excess risk may be attributed predominantly to smokers, but nonsmokers may have excess risk as well

c) malignant mesothelioma - a rare type of cancer; the normal risk is 1 in 100,000 - 1,000,000 (estimates)

d) gastrointestinal cancer - excess cases have been observed in asbestos workers

Nonoccupational:

a) asbestos-related diseases have been observed in some segments of the population, particularly in families of workers and those living near an asbestos industrial plant

Animal Studies: asbestosis, lung cancer, and mesothelioma have been produced in laboratory animals

NOTES:
1) the TLV has been lowered twice in the past 10 years
2) all forms of asbestos are associated with excess risk of disease
3) longer, thinner fibers may be more carcinogenic
4) if there are thresholds for causation of disease, the threshold for mesothelioma is probably lower than that for lung cancer, which in turn probably has a lower threshold than that for asbestosis.

ARSENIC

1. Standards

TLVs - Arsenic trioxide (As_2O_3) production = 0.05 mg/m^3
Arsine (AsH_3) = 0.2 mg/m^3
(NIOSH has recommended lowering the TLV to 0.002 mg/m^3)

Drinking water - 0.05 mg/l

2. Observed Health Effects

Occupational:

a) cancer of the lung (observed at concentrations as low as 3 $\mu g/m^3$ for less than one year of exposure; apparently won't occur for at least 15 years from initial exposure)
b) dermatitis
c) arsenic poisoning - severe gastrointestinal effects, may also affect kidney
d) chronic arsenic poisoning causes neurological effects

Nonoccupational:

a) one epidemiology study demonstrated increased lung cancer in high arsenic areas
b) dermatitis in community with industrially caused arsenic contamination

Animal studies:

a) arsenic is the only human carcinogen which has not produced cancer in animals
b) dermatitis produced in rabbits only when moisture present

Target Organs: gastrointestinal tract, respiratory tract, central nervous system, liver, skin, blood and endocrine system

Typical Adult Intake -900 µg/day (sea food is loaded with arsenic) arsenates (As_2O_5) are considered much less toxic than arsenites (As_2O_3)

NOTE:

Arsenic is a very common constituent of copper-sulfide ores.

CADMIUM

1. Standards

TLV - Cadmium dusts and salts (as Cd) = 0.05 mg/m^3
Cadmium oxide production = 0.05 mg/m^3
Drinking Water - maximum contaminant level = 0.01 mg/l

2. Observed Health Effects

Occupational:
a) acute poisoning from inhalation of cadmium fume characterized by pneumonitis and pulmonary edema 4-20 hrs after exposure (lethal dose in one case calculated at 8.6 mg/m^3 for 5 hours)
b) chronic poisoning causing respiratory, hematological, gastrointestinal + other effects (this has been observed at concentrations between .05 and .2 mg/m^3)
c) proteinuria caused by .04-.05 mg/m^3 CdO fume for long term exposures

Nonoccupational:
a) cadmium poisoning from food and water - Cd leached out of pipes and metal cans (67-530 ppm)
b) Itai-itai disease in Japan from cadmium concentrated by rice (water contained <0.01 ppm, rice contained 0.37-3.36 ppm)
c) may be a factor in hypertension, heart disease, and kidney disease

Animal Studies:
a) support findings in humans
b) have demonstrated teratogenic effects and interferred w/ spermatogenesis

Target Organs: gastrointestinal tract, respiratory tract, central nervous system, cardiovascular system, kidney, and bone

Typical Adult Intake: 4-60 µg/day

NOTE: cadmium has no known beneficial effect, unlike most trace metals.

CARBON MONOXIDE

1. Standards

TLV = 55 mg/m^3 (50 ppm)
Air Quality = 9 ppm (maximum 8 hour concentration)
30 ppm (maximum 1 hour concentration)

2. Observed Health Effects

Occupational:
a) carbon monoxide inhibits oxygen transport-has neurological effects at low concentrations, will induce coma at high concentrations
b) aggravates heart conditions

Nonoccupational:
a) sequelae of CO poisoning includes neuropsychiatric abnormalities
b) CO aggravates angina pectoris at low concentrations
c) blindness may occur after CO poisoning

Animal Studies:
a) support human findings
b) dogs and rabbits adapted to higher CO concentrations

Relationships between carbon monoxide in air and carboxyhemoglobin levels in blood are well established.

Relationships between carboxyhemoglobin levels in blood and effects on health are also well established.

COBALT

1. Standards

TLV - Cobalt, metal fume and dust = 0.1 mg/m^3
Drinking Water - No standard

2. Observed Health Effects

Occupational:
a) has caused respiratory diseases (bronchitis and other pneumoconioses) in tungsten carbide workers
b) dermatitis caused by metallic cobalt and, possibly, cobalt compounds
c) gastric disturbances caused by inhalation of powdered cobalt acetate

Nonoccupational:
a) an outbreak of myocardiopathy (disease of the heart muscle) found in heavy beer drinkers in the late 1960's in Quebec, Omaha, and Minneapolis was attributed to the addition of 1-1.5 mg/l of cobalt chloride to the beer to enhance foaming. Victims appeared to have sensitive hearts because therapeutic treatment for other conditions is often considerably more than the 5-10 mg/day consumed in the beer poisoning.

Animal Studies:
a) cobalt metal powder induced tumors (cancer) in rats
b) cobalt oxide in nickel refinery flue dust caused tumors (cancer) in rats, but not mice (cobalt sulfide may be a more potent carcinogen than cobalt oxide)
c) cobalt oxide caused respiratory disease in guinea pigs (reversible) as did cobalt powder in miniature swine

Typical Adult Intake - 300 µg/day
Target Organs - gastrointestinal tract, respiratory tract, central nervous system, cardiovascular system, skin, endocrine system

COPPER

1. Standards

TLVs - Copper fume = 0.2 mg/m^3

Copper dusts and mists = 1 mg/m^3

Drinking Water - 1.0 mg/l (secondary MCL, based on aesthetics)

2. Observed Health Effects

Occupational - metal fume fever observed in metal polishers and other workers exposed to copper dust

Nonoccupational - a. dermatitis from exposure to brass occasionally reported

b. $CuSO_4$ occasionally used in suicide attempts

c. copper wire is used with IUD's to improve contraceptive efficiency

Animal Studies - a. copper accumulates in liver, kidney, intestines, and brain when fed in excess to rats

b. copper and its compounds have not been found to be carcinogonic

c. copper interferes with spermatogenesis in rats

Target Organ: blood (found to be concentrated in the liver in certain diseases such as Wilson's Disease)

Typical Adult Intake: assumes soft drinking water and relatively uncontaminated air:

Food	3200 µg
Water	200 µg
Beverages	300 µg
Air	2 µg
	3702 µg/day ---> All is excreted, no accumulation

IRON

1. Standards

TLVs - Iron oxide fume - 5 mg/m^3

Iron salts, soluble (as Fe) - 1 mg/m^3

Drinking water - 0.3 mg/l (secondary MCL, based on aesthetics)

2. Observed Health Effects

Occupational: a. lung cancer has been observed in foundry workers, smiths, metal grinders and possibly underground hematite miners (N.B. taconite is magnetite)

b. siderosilicosis is a respiratory disease produced by iron oxide and silicosis

Nonoccupational: a. toxicity of iron salts ranges from 40-1600 mg/kg body weight

b. ferrous sulfate is 6th among medicines causing hospitalization of children under 5

Animal Studies: a. iron oxide is well established as a cancer-inciting agent possibly as a cocarcinogen or as a mode of transport for other carcinogens such as benzo(a)pyrene (a carcinogen found in cigarette smoke)

Recommended Daily Allowance

Adult males = 10 mg/day Adult females = 18 mg/day

(these levels can be difficult to achieve, especially for women)

Target Organs - gastrointestinal tract, respiratory tract, central nervous system, liver, blood, and endocrine system

MANGANESE

1. Standards

TLVs - Manganese and compounds (as Mn) - 5 mg/m^3

Drinking water - 0.05 mg/l (secondary MCL, based on aesthetics)

2. Observed Health Effects

Occupational: a. manganism is a neurological disease caused by inhalation of manganese. Chronic manganism has been observed at levels down to 30 $\mu g/m^3$ (note TLV).

b. manganic pneumonia may occur in response to inhalation. (concentrations ranged between 0.7 and 38.3 mg/m^3 MnO_2 --note TLV)

Nonoccupational: a. one instance of contamination of wells by manganese from old batteries buried nearby

b. manganese is replacing lead in gasoline and has been predicted to be a major health concern in the future

Animal Studies: a. manganese severely limited resistance of mice to bacterial and viral pneumonias

b. manganese caused patchy necrosis of the stomach and small intestines (guinea pigs)

c. Mn caused degeneration of seminiferous tubules in rats and, hence, sterility

d. neurological effects have been observed

Target Organs: respiratory tract, central nervous system

Typical Adult Intake: 3 mg/day - most through food

MERCURY

1. Standards

TLVs - Mercury (all forms except alkyl) as Hg - 0.05 mg/m^3
Drinking water- 0.002 mg/l

2. Observed Health Effects

Occupational (inorganic mercury):

a. bronchitis and other respiratory diseases from acute exposures
b. chronic exposures affect the central nervous system including the brain
c. permanent changes in affected organs and organ systems can occur from either chronic or acute exposure

Nonoccupational (methyl mercury):

a. neurological disturbances from the consumption of contaminated fish
b. mercury crosses the placenta during pregnancy and may cause mercury poisoning in fetuses even when the mothers show no clinical symptoms
c. food poisoning from ingestion of grains treated with organic mercury fungicides

Animal studies:

a. methyl mercury is mutagenic

Target Organs: respiratory tract, central nervous system, kidney

Typical Adult Intake: 1-20 µg/day (heavily dependent on fish consumption)

NICKEL

1. Standards

TLVs - Nickel carbonyl ($Ni(CO)_4$) = 0.35 mg/m^3
- Nickel, metal (as Ni) = 1 mg/m^3
- Nickel, soluble compounds (as Ni) = 0.1 mg/m^3

Drinking water - No standard

2. Observed Health Effects

Occupational:
a. lung and nasal cancers (may not occur until 20 or more years after initial exposure) in nickel refineries - attributed at first to $Ni(CO)_4$ but also observed in cases where $Ni(CO)_4$ process was not used. Environmental levels were not measured, but improved dust control appears to greatly reduce the problem. Ni_3S_2 is suspected of being carcinogenic. Other nickel compounds may be also.
b. Dermatitis, probably is due to nickel dust and is aggravated by heat.
c. $Ni(CO)_4$ is toxic and has caused acute poisonings (2-3 days after exposure) (once thought to cause Legionnaire's Disease)

Nonoccupational: dermatitis-has been observed occasionally in cases of exposure to nickel-containing objects (e.g. jewelry)

Animal Studies:
a. confirmed effects of $Ni(CO)_4$ observed in humans
b. when injected, less soluble nickel compounds (e.g. Ni_3S_2) appear more carcinogenic then soluble nickel compounds (e.g. $NiSO_4$)
c. extrapolated LD_{50} of $Ni(CO)_4$ for humans (70 kg)estimated at 15 mg/l (in air), but the author suggests this may be too high.
d. 5 ppm nickel in drinking water of rats caused an increase in young deaths and runts in offspring

Target Organs - respiratory tract, central nervous system, skin

Typical Adult Intake - 300-600 µg/day of which air and water generally each supply 1 µg/day or less.

OXIDES OF NITROGEN

1. Standards

TLV - Nitrogen dioxide - 9 mg/m^3 (5ppm)

Air Quality - Nitrogen oxides (mostly NO and NO_2) = 0.05 ppm annual arithmetic average

2. Observed Health Effects

NO_2 concentration (ppm)	Length of Exposure	Observed Effect
1-3	immediate	odor detectable
13-15	<1 hour	eye & nasal irritation
25	<1 hour	pulmonary discomfort
25-75	<1 hour	bronchiolitis with focal pneumonitis
>100	?	acute pulmonary edema, sometimes death
150-200	"comparatively short"	fatal pulmonary fibrosis

Nonoccupational: a. major community study showed respiratory effects at concentrations of NO_2 between 0.055 and 0.083 ppm

b. nitrogen oxides are converted into nitrate particulates (similar to sulfur) if these are converted to nitrosamines (theoretically possible), there would be a risk of carcinogenesis

Animal Studies: have confirmed observations in humans

NOISE

1. Standards

TLV - { * Hours per day -> 16 8 4 2 1 ½ ¼ 1/8 (Ti)
Sound level dBA -> 80 85 90 95 100 105 110 115

No exposure permitted above 115 dBA (Ci=time exposed to the sound level)

*If the sum of: $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots + \frac{C_n}{T_n}$ exceeds 1, then mixture is above TLV

(for sample calculation see appendix)

General Community (recommended) ------> { Residential - 45-50 dBA (night) 50-55 dBA (day)
Commercial and industrial - 60-70 dBA depending on location and time of day

2. Observed Health Effects

Occupational: a. hearing loss (permanent or temporary)
b. may affect quality of work, but apparently not quantity

Nonoccupational: a. hearing loss
b. speech and sleep interference
c. annoyance and mental health (highly controversial)

PARTICULATES

1. Standards

TLV - Nuisance particulates - 10 mg/m^3

Air Quality - 75 $\mu g/m^3$ - annual geometric mean
260 $\mu g/m^3$ - 24 hour maximum

2. Observed Health Effects

Occupational: a. occupational studies are concerned with specific agents rather than general particulates

Nonoccupational: a. associated with respiratory disease
b. very high levels increase the death rates of all causes of death
c. children appear to be at increased risk of adverse effects

Experimental Evidence: a. deposition in the lung is greatest for particles 1-2 μm in diameter.
b. particles may act as carriers of toxic agents, or interfere with clearance of other particles from the lung
c. may be synergistic with other particles or gases

NOTE: the effects of particulates are difficult to distinguish from sulfur oxides because the two almost always exist together

SILICA
(SiO_2)

1. Standards

TLVs - Crystalline Silica

a. Quartz - TLV in mppcf = $\frac{300}{\%\ \text{quartz} + 10}$

- TLV for respirable dust in mg/m^3 = $\frac{10\ mg/m^3}{\%\ \text{respirable quartz} + 2}$

- TLV for "total dust" (respirable + nonrespirable)

= $\frac{30\ mg/m^3}{\%\ \text{quartz} + 3}$

b. Christobalite and Tridymite - TLV is ½ that calculated for quartz

c. Amorphous Silica - TLV = 20 mppcf

2. Observed Health Effects

Occupational: a. Silicosis is an occupational disease by definition. It usually takes 5-30 years to develop. At one time, studies of metal miners often found over 60% of the miners with silicosis. This disease has been virtually eliminated from the Minnesota iron and taconite industry by adequate dust control measures.

b. Silicosis appears to increase the risk of tuberculosis by a factor of 30.

c. Emphysema and other pneumoconioses are often seen. (pneumoconioses-chronic inflammations of the lungs)

Animal Studies: a. have been extensive and support observations in humans

b. particles in the size range 0.5-2 μm are of most concern

SULFUR OXIDES

1. Standards

TLV - Sulfur dioxide (SO_2) = 13 mg/m^3 (5 ppm)
Sulfuric acid (H_2SO_4) = 1 mg/m^3

Air Quality - These are state standards which are slightly more stringent than the national standards--
0.02 ppm - annual average arithmetic mean
0.1 ppm - maximum 24 hour concentration
0.25 ppm - maximum 3 hour concentration

2. Observed Health Effects

Occupational - associated with respiratory disease and increased pulmonary flow (air flow to and from the lung) resistance

Nonoccupational - a. associated with respiratory disease
b. very high levels increase the death rates of all causes of death
c. children appear to be at increased risk of adverse effects

Experimental Evidence - a. SO_2 is not a carcinogen, but may enhance the potency of carcinogens
b. sulfur acid and certain sulfates are greater respiratory irritants than SO_2

NOTE: the effects of sulfur oxides are difficult to distinquish from particulates because the two almost always exist together

ZINC

1. Standards

TLVs - zinc chloride fume - 1 mg/m^3
zinc oxide fume - 5 mg/m^3
Drinking water - 5 mg/l (secondary MCL, based on aesthetics)

2. Observed Health Effects

Occupational: a. metal fume fever, primarily from zinc oxide inhalation (apparently always transitory)
b. gastrointestinal effects (from inhalation) - cramps, loss of appetite, etc.
c. may cause dermatitis (controlled by daily baths)

Nonoccupational: a. food poisoning - diarrhea and abdominal cramps - zinc leached out of galvanized tub (dose calculated in one case as 225-450 mg)
b. zinc deficiency has been observed and possibly could be caused by excess copper

Animal Studies: a. have been inconclusive about respiratory effects
b. ingestion of high concentrations induced copper deficiency

Target Organs: gastrointestinal tract, blood, and bone

Typical Adult Intake: food - 12 mg
water - 0.5 mg
air - 0.1 mg
12.6 mg/day

APPENDIX - SAMPLE CALCULATIONS

1. TLV's of Mixtures

Air Contains: 0.03 mg/m^3 cadmium (TLV = 0.05)
2 mg/m^3 manganese (TLV = 5)
5 mg/m^3 nitrogen dioxide (TLV = 9)

Therefore $$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} = \frac{.03}{.05} + \frac{2}{5} + \frac{5}{9} = 1.6$$

Because 1.6 is greater than 1, the TLV has been exceeded (even though each agent is present at levels below the individual TLV's).

2. TLV of Noise

A worker is exposed to: 80 dBA for 4 hours ($T_1 = 16$)
90 dBA for 1½ hours ($T_2 = 4$)
100 dBA for ½ hour ($T_3 = 1$)
less than 80 dBA for 2 hours (not used in calculation)

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} = \frac{4}{16} + \frac{1.5}{4} + \frac{0.5}{1} = \frac{18}{16}$$

Because $\frac{18}{16}$ is greater than 1, the TLV has been exceeded.

REFERENCES

American Conference of Governmental Industrial Hygienists, 1977. TLVs threshold limit values for chemical substances and physical agents in the workroom environment with intended changes for 1977. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio.

PEDCo Environmental. 1976. Environmental assessment of the domestic primary copper, lead, and zinc industries. Volume II-Appendices. (Draft) Contract No. 68-02-1321. Task No. 38. Cincinnati, Ohio.

Regional Copper-Nickel Study. 1976. Schuman, L.M. and J.S. Mandel, S. Murray, A. Lawler and H. Weiss. Copper-nickel mining, smelting, and refining as an environmental hazard to human health. A review of epidemiologic literature and study recommendations on sulfur dioxide and particulates. Minnesota Environmental Quality Board.

------. 1977a. Schuman, L.M. and J.S. Mandel, M. Hanson and J. Nelms. Copper-nickel mining, smelting, and refining as an environmental hazard to human health. A review of epidemiologic literature and study recommendations on sulfur dioxide and particulates. Minnesota Environmental Quality Board.

------. 1977b. Schuman, L.M., J. Mandel and J. Wannamaker. Copper-nickel mining, smelting, and refining as an environmental hazard to human health. A review of epidemiology literature and study recommendations on asbestos. Minnesota Environmental Quality Board.

------. 1978a. Ashbrook, P. Arsenic and human health. Minnesota Environmental Quality Board.

------. 1978b. Ashbrook, P. Carbon monoxide and human health. Minnesota Environmental Quality Board.

------. 1978c. Ashbrook, P. Lead and human health. Minnesota Environmental Quality Board.

------. 1978d. Ashbrook, P. Nitrogen oxides and human health. Minnesota Environmental Quality Board.

------. 1978e. Ashbrook, P. Noise and human health. Minnesota Environmental Quality Board.

------. 1978f. Benzie, D. and P. Ashbrook. Aluminum and human health. Minnesota Environmental Quality Board.

------. 1978g. Benzie, D. and P. Ashbrook. Cadmium and human health. Minnesota Environmental Quality Board.

------. 1978h. Benzie, D. and P. Ashbrook. Cobalt and human health. Minnesota Environmental Quality Board.

REFERENCES (contd.)

Regional Copper-Nickel Study. 1978i. Benzie, D. and P. Ashbrook. Iron and human health. Minnesota Environmental Quality Board.

------. 1978j. Benzie, D. and P. Ashbrook. Manganese and human health. Minnesota Environmental Quality Board.

------. 1978k. Benzie, D. and P. Ashbrook. Silicosis. Minnesota Environmental Quality Board.

------. 1978l. Benzie, D. and P. Ashbrook. Zinc and human health. Minnesota Environmental Quality Board.

Ritchie, I. 1977. Minnesota air quality, 1971-1976. Division of Air Quality, Minnesota Pollution Control Agency.

United States Environmental Protection Agency. 1976. Quality criteria for water. U.S. Government Printing Office, Washington, D.C.

United States Environmental Protection Agency. 1977. Toxicology of metals--Volume II. EPA-600/1-77-022. National Technical Information Service. Springfield, Virginia.

SUMMARY OF STANDARDS

Agent	TLV (mg/m^3)*	Short term exposure limit (mg/m^3)	MCL in Drinking Water (mg/l)	Air Quality Standards (Minnesota)
Aluminum	10	20	---	
Arsenic (As_2O_3)	0.05	---	0.05	
Asbestos (all forms)	2 fibers/cm^3,** > 5 µm in length	---	under consideration	
Cadmium (oxide fume)	0.05	0.05****	0.01	
Carbon Monoxide	55	440	---	9 ppm-maximum 8 hour concentration 30 ppm-maximum 1 hour concentration
Cobalt	0.1	---	---	
Copper (fume)	0.2	---	1.0***	
Copper (dust & mists)	1	2	---	
Iron Oxide	5	10	---	
Iron salts (as Fe)	1	2	0.3***	
Lead (as Pb)	0.15	0.45	0.05	
Manganese (as Mn)	5	5****	0.05***	
Mercury (all forms except alkyl) (as Hg)	0.05	0.15	0.002	
Nickel soluble compounds (as Ni)	0.1	0.3	---	

Nickel Carbonyl	0.35	---	---	
Nickel, metal	1	---	---	
Nitrogen dioxide	9	9****	---	(Nitrogen oxides) 0.05 ppm-annual arithmetic average
Noise	85 dBA	115 dBA	---	
Particulates	---	---	---	75 $\mu g/m^3$ -annual geometric mean 260 $\mu g/m^3$ -24 hour maximum
Silica	3 (total); 1 (dust < 5µm)	---	---	
Sulfur dioxide	13	---	---	sulfur oxides 0.02 ppm-annual arithmetic mean 0.1 ppm-maximum 24 hour concentratio 0.25 ppm-maximum 3 hour concentration
Zinc (oxide fume)	5	10	5***	

*ACGIH, 1977

**OSHA standard

***Secondary MCL, not based on health effects

****If the sum of $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n} > 1$, (where C_i = time weighted concentration T_i = TLV

then the TLV for the mixture has been exceeded. Other agents not on this list are included in the formula. (For sample calculations, see appendix.)