

PROJECT ADMINISTRATION DATA SHEET

ORIGINAL REVISION NO. _____

Project No. A-3955 GTRC ~~CTA/ENR~~ DATE 10 / 18 / 84

Project Director: M. Black/P. Middendorf ~~ENR/ENR~~ Lab EDL

Sponsor: Army Corps of Engineers

Type Agreement: P.O. No. DACW21-84-M-0951

Award Period: From 8/28/84 To 10/31/84 (Performance) 10/31/84 (Reports)

Sponsor Amount: This Change Total to Date

Estimated: \$ 3,000 \$ 3,000

Funded: \$ 3,000 \$ 3,000

Cost Sharing Amount: \$ _____ Cost Sharing No: _____

Title: Environmental/Industrial Hygiene Monitoring

ADMINISTRATIVE DATA

OCA Contact William F. Brown X4820

1) Sponsor Technical Contact:

2) Sponsor Admin/Contractual Matters:

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Richard B. Russell Area Office
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Corps of Engineers
P. O. Box 889
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Defense Priority Rating: N/A Military Security Classification: N/A

(or) Company/Industrial Proprietary: N/A

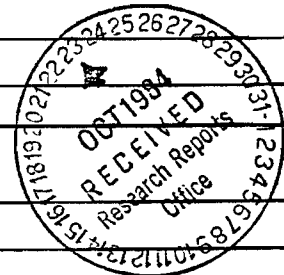
RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of \$500 or 125% of approved proposal budget category.

Equipment: Title vests with None proposed or anticipated

COMMENTS:



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SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 12/13/84

Project No. A-3955 ~~SPND~~/Lab EDL

Includes Subproject No.(s) N/A

Project Director(s) M. Block/P. Middendorf GTRC / ~~GTX~~

Sponsor Army Corps of Engineers

Title Environmental/Industrial Hygiene Monitoring

Effective Completion Date: 10/31/84 (Performance) 10/31/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- None
- Final Invoice or Final Fiscal Report
- Closing Documents
- Final Report of Inventions
- Govt. Property Inventory & Related Certificate
- Classified Material Certificate
- Other _____

Continues Project No. _____ Continued by Project No. _____

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✓ A-5-111



Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
Atlanta, Georgia 30332

October 4, 1984

Mr. Tom List
U.S. Army Corps of Engineers
Richard B. Russell Area Office
Route #4, Box 244A
Elberton, Georgia 30635-9245

Dear Mr. List:

The Analytical Laboratory has completed analyses of air samples and metal scrapings collected at the Russell Dam site.

Air samples from five locations were collected and analyzed for gaseous sulfur compounds and particulate sulfates (as sulfuric acid). Analytical results are given in Table I. Hydrogen sulfide (H₂S) and dimethyl sulfide (DMS) were the gaseous sulfur species identified and quantitated. Both species were detected in parts-per-billion levels in the air. These concentrations are low with respect to occupational exposures. Sulfates, as sulfuric acid, were non-detectable in these five sampling locations. Mr. Paul Middendorf, the industrial hygienist, who visited the dam site and conducted the initial survey and sampling, will be sending a follow-up report on ventilation concerns and occupational exposures to the detected sulfur species.

Results of the metal scraping analyses are given in Table II. Sample #1 had significant lead, iron and sulfate concentrations and evidence of metallic compound formation. Sample #2 contained iron as a primary element with evidence of sulfide and oxide formation. Sample #3 was an apparent copper tag with sulfate and sulfide formation on the surface. Sample #4 contained high levels of lead and copper with apparent metal compound formation. Sulfate formation was greatest on this particular #4 sample. It was evident from the physical appearance of all the metallic surfaces and chemical studies that the metallic surfaces are reacting with atmospheric contaminants and constituents. Metallic surfaces in this particular environment should be protected from the atmospheric sulfur load. It is suggested that a high quality marine type urethane coating or similar treatment be used for this. You should contact a corrosion expert to obtain further information on this subject.

The environmental impact at the Russell Dam site is a very interesting topic. Although sulfur emissions appear low in terms of occupational exposures, they may be significant in atmospheric contributions. A study of the lake and atmosphere is recommended. High sulfate levels in the lake would be contributing to the

Mr. Tom List
October 4, 1984
Page 2

atmospheric sulfur emissions. The source of this sulfate, if found, might be correctable. Is there any source of geological hydrogen sulfide from underlying rock formations? Hydrogen sulfide can often be present in artesian aquifers. Many facts could be environmentally studied and we would be interested in pursuing these studies with you.

If you have any further questions, please contact me.

Sincerely,

Marilyn S. Black, Ph.D.
Head, Analytical and
Instrumentation Group

MSB:sek

Attachments

TABLE I
ANALYTICAL RESULTS OF AIR SAMPLES

<u>Sample Identification</u>	<u>Gaseous Sulfur</u>		<u>Particulate Sulfate (as H₂SO₄)</u>
	<u>H₂S, ppb</u>	<u>DMS, ppb</u>	
(1) Dam Block 15, Elevation 300'	nd	5	nd (< 1 mg/m ³)
(2) Sump Area Block 19C Elevation 305'	40	22	nd (< 1 mg/m ³)
(3) Powerhouse Elevation 297'	70	10	nd (< 1 mg/m ³)
(4) Spiral Case	100	124	nd (< 1 mg/m ³)
(5) Outside Dike	3	5	nd (< 1 mg/m ³)

H₂S determinations by methylene blue spectrophotometric method

DMS determinations by solid adsorbent/flame photometric gas chromatography

Particulate sulfate determinations by filter collection/ion chromatography

TABLE II
ANALYTICAL RESULTS OF
METAL SCRAPINGS

<u>Sample Identification</u>	<u>Metals Detected (mg/g)</u>				<u>Primary Metallic Species</u>
	<u>Pb</u>	<u>Cu</u>	<u>Cr</u>	<u>Fe</u>	
(1) Pipe galley - from unit 2 corroded paint	190	0.01	0.07	110	PbSO ₄ , PbS, PbO, Fe ₂ O ₃
(2) Powerhouse - well pipe elevation 279	0.01	0.01	0.01	44	Fe ₂ O ₃ , Fe ₂ (SO ₄) ₃
(3) Tag #11	nd	320 ug	nd	nd	CuS, CuSO ₄
(4) Powerhouse - Tail Water depressant pipe elevation 279	20	0.13	0.004	23	PbSO ₄ , Fe ₂ O ₃ , PbO, PbS

Analysis by ICP/AES

**OCCUPATIONAL EXPOSURE
TO SULFUR COMPOUNDS
at
Richard B. Russell Dam and Powerhouse**

**A Report Prepared For
U.S. Army Corps of Engineers
Savannah District**

**BY
Paul J. Middendorf, CIH
Research Scientist**

**GEORGIA INSTITUTE OF TECHNOLOGY
Georgia Tech Research Institute
Environmental Health and Safety Division
Atlanta, Georgia
November, 1984**

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INTRODUCTION

In August of 1984 Army Corps of Engineers employees at the Richard B. Russell Dam and Powerhouse Project on the Savannah River had noticed a stronger than usual sulfur smell in the dam and in the powerhouse. They had also noticed that some of the primer paints had changed from a bright red color to a "silvery" red color.

In response to this situation the Savannah District of the Army Corps of Engineers contracted with Georgia Tech Research Corporation to survey and evaluate the conditions on an occupational health basis. Mr. Paul Middendorf visited the site on August 28, 1984 and was assisted in sampling by Ms. Nancy Willoughby on August 30, 1984. Both individuals are with the Environmental Health and Safety Division of the Georgia Tech Research Institute.

The observed conditions and results of air sampling are described and discussed in the following sections. It should be noted, however, that the results of the survey are highly dependent on the environmental conditions in the air and the lake. As these conditions change the presence and concentrations of sulfur compounds may change.

RESULTS AND DISCUSSION

Air Samples

Air Samples were taken in 5 locations throughout the dam, powerhouse and diked area. Two of the samples were taken in the lower parts of the dam area. The first was taken at elevation 300.0 feet, block 15 F, and the second was taken at elevation 305.0 feet, block 19 C, near the sump. These two areas were chosen because they are in the lowest part of the dam and sulfur compounds would tend to settle into the lower areas. Also, there was a large amount of water turbulently flowing into both areas from leaks in the dam. Dissolved sulfur compounds would tend to come out of solution more easily in these locations.

Two locations in the powerhouse were also chosen. One location was inside the spiral case, and the second was at elevation 297.0 feet, just below the staircase leading to the spiral case. These locations were chosen because they represented the highest ascertainable odor levels.

One set of samples was put on the dike which runs parallel to the flow of water, between the water and the powerhouse. The location chosen on the dike was in an area which was frequently misted from the water coming over the dam.

The sample results at the dike indicate that both hydrogen sulfide (H_2S) and dimethyl sulfide (DMS) were present in the water. This is supported by the presence of a large mass growing in the water which runs in the troughs throughout the dam area. It is suggested that this growth may be thiobacilli. Thiobacilli make cellular energy by converting sulfur to sulfuric acid (H_2SO_4). When the oxygen in the water is used up, sulfate reduction takes place, releasing H_2S . If the pH of the water is 7-8, then H_2S exists mainly as HS^- and H_3O^+ . Water samples could verify the presence of H_2SO_4 and H_2S .

The sample results (summarized in Appendix C) indicate that H_2S was present at all locations sampled. The highest results were found in the spiral case and in the powerhouse. However, even these levels were below the currently accepted guidelines for occupational health (see Table 1). Of the samples taken, the lowest

levels of H₂S were found at Elevation 300.0 feet. In one of the samples the levels were below the detection limit. In the other sample the level was determined to be 1 part per billion of air (ppb). This may have had lower concentrations because the ventilation system had been turned off only two days before and the concentration of H₂S may not have had a chance to build up. Levels at the sump were higher, possibly because the turbulent flow of water in the area allowed for a greater rate of release of H₂S.

No sulfates were found above the detection limit of the sampling and analytical method.

Please note that the air sample results presented in the letter to Mr. Tom List from Dr. Marilyn Black dated October 4, 1984 are slightly different than those reported here. Dr. Black estimated 2 hours on each sample; however, actual times varied slightly from that figure. The results presented here are the more accurate results. The interpretations of the results, however, are not changed.

Ventilation

Ventilation measurements were taken with an anemotherm, a type of air velocity meter, and air flow patterns were observed using ventilation smoke tubes. Volumetric* flows were calculated from estimated inlet and outlet areas, and average linear air flows were measured with the anemotherm.

The ventilation fan was set in a passageway leading to the outside. The calculated volumetric flow rate at the fan inlet was 35,400 cubic feet per minute (cfm). At the doorway to the outside, the volumetric flow was calculated at 12,755 cfm. A ventilation shaft was designed into the structure of the dam leading from the 327.0 foot elevation (Block 28D) up to the passageway and the doorway. Air was flowing through this shaft down to the 327.0 foot elevation level; the calculated volumetric flow through the shaft was 21,600 cfm. Obviously, a large portion (about 60%) of the air being exhausted by the fan was recirculated to the level below, thus limiting the effectiveness of the fan in removing contaminants from the dam area. This indicates that the resistance to flow is less through the ventilation shaft than through the passage to the outside.

<u>*Calculated Flow Rate Out (cfm)</u>		<u>At Fan Inlet (cfm)</u>
Doorway to Outside	12,755	35,400
Ventilation Shaft	21,600	
	<u>34,355</u>	

The differences between the calculated flow rates in and out of the system are within the errors associated with the measurement techniques.

Air flow patterns were checked at several locations on elevations 300.0 feet, 305.0, and 327.0 feet. The flow rates were found to range from 40 feet per minute at the locations furthest from the fan, up to 160 fpm at locations closer to the fan. The air flow patterns were generally laminar rather than turbulent, indicating that the existing flow rates were efficient, from an energy viewpoint, at moving air through the passages.

Recommendations

1. Although airborne levels of sulfur compounds are well below any of the current occupational health guidelines, occasions may arise where it is necessary to reevaluate the levels of these compounds. Unfortunately, the employees of the dam and powerhouse do not have immediate access to the services of an industrial hygienist. However, it may be possible for them - the site personnel - to screen the levels of various sulfur compounds when there is concern. Screening can be accomplished by a number of different methods including: indicator tubes, passive monitoring devices, and calibrated H₂S detectors such as sewer district workers use. Of the three methods, the indicator tube may be the best for the purpose of spot checking. The passive monitors must remain in an area for a significant period of time and analysis may take several hours. The H₂S detectors are battery-operated and the batteries would need regular charging, as well as periodic calibration. Sampling with indicator tubes takes a very short period of time, gives immediate results and can be stored in a refrigerator for periods up to three years.

Several employees would have to be trained in the use of whichever method is chosen. If readings indicate levels in excess of one-half the TLV, an in-depth industrial hygiene investigation should follow.

2. The monitored levels of air contaminants do not indicate that immediately dangerous to life or health (IDLH) levels are likely to be encountered. However, if the conditions change substantially, the possibility should be included in the development of any emergency preparedness documents and employees should be prepared for the event through training. Table 2 gives the IDLH levels and minimum acceptable respiratory protection for various sulfur compounds according to the National Institute for Occupational Safety and Health (NIOSH).

3. In the event that the ventilation system in place on August 28, 1984 is needed again, it would be better placed several levels higher in the same stairwell, beyond the air shaft. This placement would prevent the recirculation of air through the shaft from the level below. It would also increase the total ventilation of the lower levels of the dam.

This Report Was Prepared By: _____

Paul G. Middendorf,
Research Scientist *A*

This Report Was Reviewed By: _____

Kenneth A. Smith, Head
Industrial Hygiene Branch

PJM:dI

TABLE 1

OCCUPATIONAL HEALTH GUIDELINES

<u>COMPOUND</u>	OSHA		ACGIH			NIOSH	
	<u>PEL</u>	<u>CEILING</u>	<u>10 MIN. CEILING</u>	<u>TLV</u>	<u>STEL</u>	<u>TWA</u>	<u>10 MIN. CEILING</u>
Hydrogen Sulfide	--	20ppm	50ppm	10ppm	15ppm	--	10ppm
Sulfuric Acid	1mg/M ³	--	--	1mg/M ³	--	1mg/M ³	--
Dimethyl Sulfide	--	--	--	--	--	--	--

TABLE 2

	<u>IDLH Level</u>	<u>Minimum Acceptable Respiratory Protection at IDLH Level</u>
Hydrogen Sulfide	300 ppm	Full-Face Supplied Air Respirator
Carbon Disulfide	500 ppm	Full-Face with Org. Vapor Chemical Cartridge
Sulfide Acid	80 mg/M ³	Gas Mask with Acid Gas Canister and HEPA filter
Sulfur Dioxide	100 ppm	Chemical Cartridge Respirator with Sulfur Absorbent

APPENDIX A

Federal Occupational Safety and Health Regulations

29CFR1910.1000 Air Contaminants

OCCUPATIONAL SAFETY AND HEALTH STANDARDS SUBPART Z — TOXIC AND HAZARDOUS SUBSTANCES

(Code of Federal Regulations, Title 29, Chapter XVII, Part 1910, Subpart Z;
Revised as of July 1, 1979; corrected by 44 FR 50338, August 28, 1979; amended by 44
FR 60980, October 23, 1979; corrected by 44 FR 68827, November 30, 1979; amended
by 45 FR 12416, February 26, 1980; 45 FR 35212, May 23, 1980; corrected by 45 FR
54333, August 15, 1980; amended by 45 FR 67340, October 10, 1980; 46 FR 6228, Jan-
uary 21, 1981; 46 FR 32021, June 19, 1981; 46 FR 60775, December 11, 1981; 47 FR
51117, November 12, 1982; 48 FR 2768, January 21, 1983; corrected by 48 FR 9641,
March 8, 1983; amended by 48 FR 53280, November 25, 1983; 49 FR 25796; June 22,
1984)

Subpart Z—Toxic and Hazardous Substances

Sec.:

1910.1000	Air Contaminants.
1910.1001	Asbestos
1910.1002	Coal tar pitch volatiles; interpre- tation of term.
1910.1003	4-Nitrobiphenyl.
1910.1004	alpha-Naphthylamine.
1910.1005	4,4'-Methylene bis (2-chloroani- line). [Deleted]
1910.1006	Methyl chloromethyl ether.
1910.1007	3,3'-Dichlorobenzidine (and its salt)
1910.1008	bis-Chloromethyl ether.
1910.1009	beta-Naphthylamine.
1910.1010	Benzidine
1910.1011	4-Aminodiphenyl.
1910.1012	Ethyleneimine.
1910.1013	beta-Propiolactone.
1910.1014	2-Acetylaminofluorene
1910.1015	4-Dimethylaminoazobenzene.
1910.1016	N-Nitrosodimethylamine.
1910.1017	Vinyl chloride
1910.1018	Inorganic arsenic
1910.1025	Lead
1910.1028	Benzene [Deleted]
1910.1029	Coke oven emissions
1910.1043	Cotton dust
1910.1044	1,2-dibromo-3-chloropropane
1910.1045	Acrylonitrile
1910.1046	Exposure to cotton dust in cotton gins [Deleted]
1910.1047	Ethylene oxide
1910.1200	Hazard Communication
1910.1499	Source of standards
1910.1500	Standards organizations

§1910.1000 Air contaminants
An employee's exposure to any mate-
rial listed in table Z-1, Z-2, or Z-3 of

this section shall be limited in accord-
ance with the requirements of the follow-
ing paragraphs of this section.

(a) Table Z-1:

(1) *Materials with names preceded by "C"—Ceiling Values.* An employee's ex-
posure to any material in table Z-1, the
name of which is preceded by a "C" (e.g.,
C Boron trifluoride), shall at no time
exceed the ceiling value given for that
material in the table.

(2) *Other materials—8-hour time
weighted averages.* An employee's expo-
sure to any material in table Z-1, the
name of which is not preceded by "C", in
any 8-hour work shift of a 40-hour work
week, shall not exceed the 8-hour time
weighted average given for that material
in the table.

(b) Table Z-2:

(1) *8-hour time weighted averages.* An
employee's exposure to any material
listed in table Z-2, in any 8-hour work
shift of a 40-hour work week, shall not
exceed the 8-hour time weighted average
limit given for that material in the table.

(2) *Acceptable ceiling concentrations.*
An employee's exposure to a material
listed in table Z-2, shall not exceed at
any time during an 8-hour shift the ac-
ceptable ceiling concentration limit given
for the material in the table, except for
a time period, and up to a concentration
not exceeding the maximum duration
and concentration allowed in the column
under "acceptable maximum peak above
the acceptable ceiling concentration for
an 8-hour shift".

(3) *Example.* During an 8-hour work
shift, an employee may be exposed to a
concentration of Benzene above 25 p.p.m.
(but never above 50 p.p.m.) only for a
maximum period of 10 minutes. Such ex-
posure must be compensated by expo-
sures to concentrations less than 10
p.p.m. so that the cumulative exposure
for the entire 8-hour work shift does not
exceed a weighted average of 10 p.p.m.

(c) Table Z-3: An employee's expo-
sure to any material listed in table Z-3,
in any 8-hour work shift of a 40-hour
work week, shall not exceed the 8-hour
time weighted average limit given for
that material in the table.

(d) Computation formulae

(1)(i) the cumulative exposure for an 8-
hour work shift shall be computed as
follows:

$$E = \frac{C_1 T_1 + C_2 T_2 + \dots + C_n T_n}{8}$$

where:

E is the equivalent exposure for the work-
ing shift.

C is the concentration during any period
of time T where the concentration remains
constant.

T is the duration in hours of the exposure
at the concentration C.

The value of E shall not exceed the 8-
hour time weighted average limit in table

[Sec. 1910.1000(d)(1)]

Z-1, Z-2, or Z-3 for the material in involved.

(H) To illustrate the formula prescribed in subdivision (i) of this subparagraph, note that isoamyl acetate has an 8-hour time weighted average limit of 100 p.p.m. (table Z-1). Assume that an employee is subject to the following exposure:

- Two hours exposure at 150 p.p.m.
- Two hours exposure at 75 p.p.m.
- Four hours exposure at 50 p.p.m.

Substituting this information in the formula, we have

$$E = \frac{2 \times 150 + 2 \times 75 + 4 \times 50}{8} = 81.25 \text{ p.p.m.}$$

Since 81.25 p.p.m. is less than 100 p.p.m., the 8-hour time weighted average limit, the exposure is acceptable.

(2) (i) In case of a mixture of air contaminants an employer shall compute the equivalent exposure as follows:

$$E = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \dots + \frac{C_n}{L_n}$$

Where:

E is the equivalent exposure for the mixture.

C is the concentration of a particular contaminant.

L is the exposure limit for that contaminant, from table Z-1, Z-1, or Z-3.

The value of E shall not exceed unity (1).

(ii) To illustrate the formula prescribed in subdivision (i) of this subparagraph, consider the following exposures:

Material	Actual concentration of 8-hour exposure	8-hour time weighted average exposure limit
Acetone (Table Z-1)	800 p.p.m.	1,000 p.p.m.
2-Butanone (Table Z-1)	45 p.p.m.	300 p.p.m.
Toluene (Table Z-2)	40 p.p.m.	300 p.p.m.

Substituting in the formula, we have:

$$E = \frac{800}{1,000} + \frac{45}{300} + \frac{40}{300}$$

$$E = 0.800 + 0.225 + 0.200$$

$$E = 0.925$$

Since E is less than unity (1), the exposure combination is within acceptable limits.

(e) To achieve compliance with paragraph (a) through (d) of this section, administrative or engineering controls must first be determined and implemented whenever feasible. When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposure of employees to air contaminants within the limits prescribed in this section. Any equipment and/or technical measures used for this purpose must be approved for each particular use by a competent industrial hygienist or other technically qualified person. Whenever respirators are used, their use shall comply with § 1910.134.

Table Z-1-

Substance	P.P.M.	Mg./M ³
Acetaldehyde	300	300
Acetic acid	10	25
Acetic anhydride	5	20
Acetone	1,000	2,000
Acetonitrile	60	70
Acetylene dichloride, sec. 1,2-Dichloroethylene		
Acetylene tetrabromide	1	14
Acrolein	0.1	0.25
Acrylonitrile - Skin		0.3
Alirin - Skin		0.18
Allyl alcohol - Skin	2	5
Allyl chloride	1	3
C Allylglycidyl ether (AGE)	10	45
Allylpropyl disulfide	2	12
2-Aminoethanol, sec. Ethanolamine		
2-Aminopyridine	0.5	2
Ammonia	80	25
Ammonium sulfamate (Am-sulf)		15
n-Amyl acetate	100	825
sec-Amyl acetate	125	650
Aniline - Skin	5	19
Antisidine (o, p-isomers) - Skin		0.8
Antimony and compounds (as Sb)		0.8
ANTU (alpha naphthylthiourea)		0.3
(Organic) Arsenic compounds (as As)		0.5
Arsine	0.05	0.2
Azinphos-methyl - Skin		0.2
Barium (soluble compounds)		0.5
p-Benzocoumarin, sec. Quinone		
Benzoyl peroxide	1	5
Benzyl chloride	1	5
Biphenyl, sec. Diphenyl		
Boron oxide		15
C Boron trifluoride	1	3
Bronine	0.1	0.7
Bromoform - Skin	0.5	5
Butadiene (1,3-butadiene)	1,000	2,200
Butanethiol, sec. Butyl mercaptan		
2-Butanone	200	600
2-Butoxy ethanol (Butyl Cellosolve) - Skin	50	340
Butyl acetate (n-butyl acetate)	150	710
sec-Butyl acetate	200	950
tert-Butyl acetate	200	950
Butyl alcohol	100	200
sec-Butyl alcohol	150	450
tert-Butyl alcohol	100	200
C Butylamine - Skin	5	15
C tert-Butyl chromate (as CrO ₃) - Skin		0.1
n-Butyl glycidyl ether (BGE)	50	270
Butyl mercaptan	10	25
p-tert-Butyltoluene	10	60
Calcium arsenate		1
Calcium oxide		2
Camphor (See §)		5
Carbon black		5
Carbon dioxide	5,000	9,000
Carbon monoxide	50	65
Chloroform - Skin		0.5
Chlorinated camphene - Skin		0.5
Chlorinated diphenyl oxide		0.5
C Chlorine	1	3
Chlorine dioxide	0.1	0.3
C Chlorine trifluoride	0.1	0.4
C Chloroacetaldehyde	1	3
o-Chloroacetophenone (phenylchloride)	0.05	0.3
Chlorobenzene (monochlorobenzene)	75	250
o-Chlorobenzylidene malononitrile (OCBM)	0.05	0.4
Chlorobromomethane	200	1,050
2-Chloro-1,3-butadiene, sec. Chloroprene		
Chlorodiphenyl (42 percent Chlorine) - Skin		1
Chlorodiphenyl (54 percent Chlorine) - Skin		0.5
1-Chloro-2,3-epoxypropane, sec. Epichlorohydrin		
2-Chloroethanol, sec. Ethylene chlorohydrin		
Chloroethylene, sec. Vinyl chloride		
C Chloroform (trichloromethane)	80	240
1-Chloro-1-nitropropane	20	100
Chloroform	0.1	0.7
Chloroprene (2-chloro-1,3-butadiene) - Skin	25	90

Table Z-1-Continued

Substance	P.P.M.	Mg./M ³
Chromium, mol. chromic, chromium salts or Cr		0.1
Metal and metal salts		1
Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene		0.2
Cobalt, metal fume and dust		0.1
Copper fume		0.1
Dusts and Mists		1
Cotton dust (raw)		10
Crac ² hexahide		15
Croal (all isomers) - Skin	2	22
Crotonaldehyde	5	6
Cumene - Skin	60	245
Cyanide (as CN ⁻) - Skin		5
Cyclohexane	300	1,050
Cyclohexanol	80	260
Cyclohexanone	80	260
Cyclohexene	300	1,015
Cyclopentadiene	75	260
2,4-D		30
DDT - Skin		1
DDVP - Skin		1
Decaborane - Skin	0.05	0.3
Demeton - Skin		0.1
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	80	260
1,2-diaminoethane, sec. Ethylenediamine		
Diazomethane	0.2	0.4
Diborane	0.1	0.1
Diethyl phosphate	1	5
Diethyl phthalate		5
C-Dichlorobenzene	80	260
p-Dichlorobenzene	75	450
Dichlorodifluoromethane	1,000	4,950
1,2-Dichloro-3,5-dimethylhydantoin		0.2
1,1-Dichloroethane	100	400
1,2-Dichloroethylene	200	700
C Dichloroethyl ether - Skin	15	90
Dichloromethane, sec. Methylenechloride		
Dichloromonofluoromethane	1,000	4,200
C 1,1-Dichloro-1-nitroethane	10	60
1,2-Dichloropropane, sec. Propylenechloride		
Dichlorotetrafluoroethane	1,000	7,000
Diethrin - Skin		0.25
Diethylamine	25	75
Diethylamino ethanol - Skin	10	30
Diethylether, sec. Ethyl ether		
Difluorodibromomethane	100	600
C Dicyclic ether (DGE)	0.5	2.8
Dihydroxyacetone, sec. Hydroquinone		
Diisobutyl ketone	80	260
Diosophylamine - Skin	5	20
Dimethoxyethane, sec. Methylal		
Dimethyl acetamide - Skin	10	25
Dimethylamine	10	15
Dimethylarobenzene, sec. Xylidene		
Dimethylarsine (N-dimethyl) - Skin	5	25
Dimethylbenzene, sec. Xylene		
Dimethyl 1,4-dibromo-2,5-dichloroethyl phosphate, Diton		3
Dimethylformamide - Skin	10	20
2,6-Dimethylpiperone, sec. Disobutyl ketone		
1,1-Dimethylhydrazine - Skin	0.5	1
Dimethylphthalate		5
Dimethylsulfate - Skin	1	5
Dinitrobenzene (all isomers) - Skin		1
Dinitro-cresol - Skin		0.2
Dinitrotoluene - Skin		1.5
Dioxane (Diethylene dioxide) - Skin	100	260
Diphenyl	0.2	1
Diphenylmethane diisocyanate (sec. Methylene bisphenyl isocyanate (MDI))		
Dipropylene glycol methyl ether - Skin	100	600
Di-sec-octyl phthalate (Di-2-ethylhexyl phthalate)		5
Endrin - Skin		0.1
Epichlorohydrin - Skin	5	75
EPN - Skin		0.5
1,2-Epoxypropane, sec. Propyleneoxide		
2,3-Epoxy-1-propanol, sec. Glycidol		

See footnotes at end of table

Table Z-1-Continued

Substance	p.p.m.	mg./M ³
Ethanolol, see Ethylmercaptan		
Ethanolamine	5	5
2-Ethoxyethanol—Skin	200	700
2-Ethoxyethylacetate (Cellulose acetate)—Skin	100	600
Ethyl acetate	400	1,400
Ethyl acrylate—Skin	25	100
Ethyl alcohol (ethanol)	1,000	1,000
Ethylamine	10	10
Ethyl sec-amyl ketone (2-methyl-3-heptanone)	25	120
Ethyl benzene	100	425
Ethyl bromide	200	200
Ethyl butyl ketone (2-Heptanone)	80	280
Ethyl chloride	1,000	2,000
Ethyl ether	400	1,200
Ethyl formate	100	200
C Ethyl mercaptan	10	25
Ethyl succinate	100	650
Ethylene chlorohydrin—Skin	5	15
Ethylene diamine	10	25
C Ethylene glycol dinitrate and/or Nitroglycerin—Skin	0.2	1
Ethylene glycol monomethyl ether: acetate, see Methyl cellosolve acetate		
Ethylene glycol—Skin	0.5	
Ethylidene chloride, see 1,1-Dichloroethane		
N-Ethylmorpholine—Skin	20	90
Perbenz		15
Ferrovandium dust		1
Fluoride (as F)		2.5
Fluorine	0.1	0.2
Fluorotrichloromethane	1,000	4,000
Formic acid	5	20
Furfural—Skin	5	5
Furfuryl alcohol	50	200
Glycidol (2,3-Epoxy-1-propanol)	50	180
Glycol monoethyl ether, see Ethoxyethanol		
Glycolol, see Azinphos-methyl		
Aluminum		4.5
Heptachlor—Skin		0.5
Heptane (n-heptane)	800	2,000
Hexachloroethane—Skin	1	15
Hexachloronaphthalene—Skin		0.2
Hexane (n-hexane)	800	1,800
2-Hexanone	100	410
Hexone (Methyl isobutyl ketone)	100	410
sec-Heptyl acetate	80	800
Hydrazine—Skin	1	1.5
Hydrogen bromide	5	10
C Hydrogen chloride	5	7
Hydrogen cyanide—Skin	10	11
Hydrogen peroxide (30%)	1	1.4
Hydrogen selenide	0.05	0.2
Hydroquinone		2
C Iodine	0.1	1
Iron oxide fume		10
Isomyl acetate	100	825
Isomyl alcohol	100	200
Isobutyl acetate	150	70
Isobutyl alcohol	100	200
Isophorone	25	140
Isopropyl acetate	250	95
Isopropyl alcohol	5	12
Isopropylamine	800	2,100
Isopropyl ether	80	24
Isopropyl glycidyl ether (IGE)		0.5
Ketone		0.9
Lindane—Skin		0.5
Lithium hydride		0.022
L.P.G. (Liquefied petroleum gas)	1,000	1,000
Magnesium oxide fume		15
Malathion—Skin		15
Maleic anhydride	0.25	1
C Manganese		5
Mesityl oxide	25	100
Methanethiol, see Methyl mercaptan		
Methoxychlor		15
2-Methoxyethanol, see Methyl cellosolve		
Methyl acetate	200	610
Methyl acetylene (propyne)	1,000	1,050
Methyl acetylene-propadiene mixture (MAFP)	1,000	1,000
Methyl acrylate—Skin	10	25
Methylal (dimethoxymethane)	1,000	2,100
Methyl alcohol (methanol)	200	200
Methylamine	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol		
Methyl (n-amyl) ketone (2-Heptanone)	100	425
C Methyl bromide—Skin	20	80
Methyl butyl ketone, see 2-Hexanone		

Table Z-1-Continued

Substance	p.p.m.	mg./M ³
Methyl cellosolve—Skin	25	20
Methyl cellosolve acetate—Skin	25	120
Methyl chloroform	200	1,000
Methyl cyclohexane	200	2,000
Methyl cyclohexanol	100	470
o-Methyl cyclohexanone—Skin	100	480
Methyl ethyl ketone (M.E.K.), see 2-Butanone		
Methyl formate	100	280
Methyl iodide—Skin	5	25
Methyl isobutyl carbinol—Skin	25	180
Methyl isobutyl ketone, see Hexone		
Methyl isocyanate—Skin	0.02	0.05
C Methyl mercaptan	10	20
Methyl methacrylate	100	410
Methyl propyl ketone, see 2-Pentanone		
C Methyl styrene	100	480
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2
Molybdenum		5
Soluble compounds		5
Insoluble compounds		15
Monomethyl aniline—Skin	5	5
C Monomethyl hydrazine—Skin		0.2
Morpholine—Skin	20	70
Naphtha (coal tar)	100	680
Naphthalene	10	20
Nickel carbonyl	0.001	0.007
Nickel, metal and soluble compds, as Ni		1
Nitrocellulose—Skin		0.5
Nitric acid	2	5
Nitric oxide	25	20
p-Nitroaniline—Skin	1	5
Nitrobenzene—Skin	1	5
p-Nitrochlorobenzene—Skin		1
Nitroethane	100	210
C Nitrogen dioxide	5	5
Nitrogen trifluoride	10	20
C Nitroglycerin—Skin	0.2	2
Nitromethane	100	280
1-Nitropropane	25	90
2-Nitropropane	25	90
Nitrotoluene—Skin	5	20
Nitrotrichloromethane, see Chloropicrin		
Octachloronaphthalene—Skin		0.1
Octane	800	2,200
Oil mist, mineral		5
Oxmium tetroxide		0.002
Oxalic acid		1
Oxygen difluoride	0.05	0.1
Ozone	0.1	0.2
Parquat—Skin		0.5
Parathion—Skin		0.1
Parathion	0.005	0.01
Pentachloronaphthalene—Skin		0.5
Pentachloropheno—Skin		0.5
Pentane	1,000	2,950
2-Pentanone	200	780
Perchloromethyl mercaptan	0.1	0.6
Perchloro fluoride	3	13.5
Petroleum distillates (naphtha)	800	2,000
Phenol—Skin	5	19
p-Phenylene diamine—Skin		0.1
Phenyl ether (vapor)	1	7
Phenyl ether-biphenyl mixture (vapor)	1	7
Phenylethylene, see Styrene		
Phenyl glycidyl ether (PGE)	10	60
Phenylhydrazine—Skin	5	22
Phosgen (Metaphos G)—Skin		0.1
Phosgene (carbonyl chloride)	0.1	0.4
Phosphine	0.3	0.4
Phosphoric acid		1
Phosphorus (yellow)		0.1
Phosphorus pentachloride		1
Phosphorus pentasulfide		1
Phosphorus trichloride	0.5	3
Phthalic anhydride	2	12
Picric acid—Skin		0.1
Pival G (2-Pivalyl-1,3-indandione)		0.1
Platinum (Soluble Salts) as Pt		0.002
Propaone	1,000	1,000
n-Propyl acetate	200	840
Propyl alcohol	200	800
n-Propyl nitrate	25	110
Propylene dichloride	75	280
Propylene imine—Skin	2	5
Propylene oxide	100	240
Propyne, see Methylacetylene		
Pyrethrum		5
Pyridine	5	15
Quinone	0.1	0.4
Rhodium, Metal fume and dusts, as Rh		0.1
Soluble salts		0.001
Rouge		15
Rotenone (commercial)		5
Selenium compounds (as Se)		0.2
Selenium hexafluoride	0.05	0.4
Silver, metal and soluble compounds		0.01

Table Z-1-Continued

Substance	p.p.m.	mg./M ³
Sodium fluorosulfate (100%)-Skin		0.05
Sodium hydroxide		2
Stibine	0.1	0.5
Stoddard solvent	500	1,000
Strychnine		0.15
Sulfur dioxide	5	15
Sulfur hexafluoride	1,000	0,000
Sulfuric acid		1
Sulfur monochloride	1	5
Sulfur pentafluoride	0.025	0.25
Sulfuryl fluoride	5	20
Syston, see Demeton G		
2,4,6-T		10
Tantalum		5
TEDP—Skin		0.2
Tellurium		0.1
Tellurium hexafluoride	0.02	0.2
TEPP—Skin		0.05
C Terphenyls	1	5
1,1,1,2-Tetrachloro-2,2-difluoroethane	800	4,170
1,1,2,2-Tetrachloro-1,2-difluoroethane	800	4,170
1,1,2,2-Tetrachloroethane—Skin	5	25
Tetrachloroethane, see Carbon tetrachloride		
Tetrachloronaphthalene—Skin		5
Tetramethyl lead (as Pb)—Skin		0.075
Tetrahydrofuran	200	800
Tetramethyl lead (as Pb)—Skin		0.075
Tetramethyl succinonitrile—Skin	0.5	2
Tetranitromethane	1	5
Tetryl (2,4,6-trinitrophenyl-methyl nitramine)—Skin		1.5
Thallium (soluble compounds)—Skin as Tl		0.1
Thiram		5
Tin (inorganic compds, except oxides)		2
Tin (organic compds)		0.1
C Toluene-2,4-dithiocyanate	0.02	0.14
o-Tolidine—Skin	5	22
Toxaphene, see Chlorinated camphene		
Tributyl phosphate		5
1,1,1-Trichloroethane, see Methyl chloroform		
1,1,2-Trichloroethane—Skin	10	45
Thallium dioxide		15
Trichloromethane, see Chloroform		
Trichloronaphthalene—Skin		5
1,2,3-Trichloropropane	50	200
1,1,2-Trichloro-1,2,2-trifluoroethane	1,000	7,800
Triethylamine	25	100
Trifluoromonomethane	1,000	6,100
2,4,6-Trinitrophenol, see Picric acid		
2,4,6-Trinitrophenylmethyl nitramine, see Tetryl		
Trinitroethene—Skin		1.5
Triorthocresyl phosphate		0.1
Triphenyl phosphate		2
Turpentine	100	280
Uranium (soluble compounds)		0.05
Uranium (insoluble compounds)		0.25
C Vanadium		0.5
V ₂ O ₅ dust		0.1
Vinyl benzene, see Styrene		
Vinyl cyanide, see Acrylonitrile		
Vinyl toluene	100	45
Warfarin		0.1
Xylene (xylo)	100	45
Xylidine—Skin	5	25
Yttrium		1
Zinc chloride fume		1
Zinc oxide fume		5
Zirconium compounds (as Zr)		5

* Parts of vapor or gas per million parts of contaminated air by volume at 25° C. and 760 mm. Hg pressure.
 † Approximate milligrams of particulate per cubic meter of air.
 (No footnote "c" is used to avoid confusion with coding value notations.)
 ‡ An atmospheric concentration of not more than 0.02 p.p.m., or personal protection may be necessary to avoid headache.
 § This standard applies in cotton yarn manufacturing until compliance with §1910.1043 (c) and (e) is achieved.
 [Vinyl chloride deleted at 39 FR 12343, April 5, 1974, listing for arsenic amended at 43 FR 19624, May 5, 1978, acrylonitrile deleted at 43 FR 45809, October 3, 1978, footnote added for cotton dust at 43 FR 27394, June 23, 1978, official corrections to Table Z-1 at 43 FR 57601, December 8, 1978, chlorine ceiling stayed, 1 ppm TWA restored at 44 FR 7140, February 6, 1979, chlorine ceiling reinstated, administrative stay lifted at 44 FR 41427, July 17, 1979, effective October 15, 1979.]
 [Sec. 1910.1000, Table Z-1]

Table Z-2

Material	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift	
			Concentration	Maximum duration
Asbestos (Z37.6-1969)	10 p.p.m.	20 p.p.m.	50 p.p.m.	10 minutes
Beryllium and beryllium compounds (Z37.20-1970)	2 µg/M ³	6 µg/M ³	20 µg/M ³	30 minutes
Cadmium dust (Z37.6-1970)	0.2 mg/M ³	0.4 mg/M ³		
Cadmium fume (Z37.6-1970)	0.1 mg/M ³	0.3 mg/M ³		
Carbon disulfide (Z37.3-1968)	30 p.p.m.	80 p.p.m.	100 p.p.m.	30 minutes
Carbon tetrachloride (Z37.17-1970)	10 p.p.m.	70 p.p.m.	200 p.p.m.	8 minutes in any 4 hours
Chromic acid and chromates (Z37.7-1971)	1 mg/M ³			
Ethylene dichloride (Z37.21-1970)	30 p.p.m.	80 p.p.m.	100 p.p.m.	8 minutes
Ethylene dichloride (Z37.21-1969)	80 p.p.m.	100 p.p.m.	200 p.p.m.	8 minutes in any 2 hours
Fluoride as dust (Z37.24-1969)	2.5 mg/M ³			
Formaldehyde (Z37.16-1967)	3 p.p.m.	8 p.p.m.	10 p.p.m.	30 minutes
Hydrogen fluoride (Z37.22-1969)	3 p.p.m.			
Hydrogen sulfide (Z37.2-1966)		20 p.p.m.	80 p.p.m.	10 minutes once only if no other measurable exposure occurs
Lead and its inorganic compounds (Z37.11-1969)	0.2 mg/m ³			
Mercury (Z37.8-1971)		1 mg/10M ³		
Methyl chloride (Z37.18-1969)	100 p.p.m.	200 p.p.m.	300 p.p.m.	8 minutes in any 2 hours
Methylene chloride (Z37.23-1969)	800 p.p.m.	1,000 p.p.m.	2,000 p.p.m.	8 minutes in any 2 hours
Organic (alkyl) mercury (Z37.30-1968)	0.01 mg/M ³	0.04 mg/M ³		
Styrene (Z37.15-1969)	100 p.p.m.	200 p.p.m.	600 p.p.m.	8 minutes in any 2 hours
Tetrachloroethylene (Z37.22-1967)	100 p.p.m.	200 p.p.m.	300 p.p.m.	8 minutes in any 2 hours
Toluene (Z37.12-1967)	200 p.p.m.	300 p.p.m.	500 p.p.m.	10 minutes
Trichloroethylene (Z37.19-1967)	100 p.p.m.	200 p.p.m.	300 p.p.m.	8 minutes in any 2 hours

[Table Z-2, footnote 1 deleted by 46 FR 32021, June 19, 1981]

(c) *Methods of compliance*—(1) *Engineering methods*. (i) *Engineering controls*. Engineering controls, such as, but not limited to, isolation, enclosure, exhaust ventilation, and dust collection, shall be used to meet the exposure limits prescribed in paragraph (b) of this section.

(ii) *Local exhaust ventilation*. (a) Local exhaust ventilation and dust collection systems shall be designed, constructed, installed, and maintained in accordance with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971, which is incorporated by reference herein.

(b) See § 1910.6 concerning the availability of ANSI Z9.2-1971, and the maintenance of a historic file in connection therewith. The address of the American National Standards Institute is given in § 1910.100.

(iii) *Particular tools*. All hand-operated and power-operated tools which may produce or release asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, such as, but not limited to, saws, scorers, abrasive wheels, and drills, shall be provided with local exhaust ventilation systems in accordance with subdivision (ii) of this subparagraph.

(2) *Work practices*—(i) *Wet methods*. Insofar as practicable, asbestos shall be handled, mixed, applied, removed, cut, scored, or otherwise worked in a wet state sufficient to prevent the emission of airborne fibers in excess of the exposure limits prescribed in paragraph (b) of this section, unless the usefulness of the product would be diminished thereby.

(ii) *Particular products and operations*. No asbestos cement, mortar, coating, grout, plaster, or similar material containing asbestos shall be removed from bags, cartons, or other containers in which they are shipped, without being either wetted, or enclosed, or ventilated so as to prevent effectively the release of airborne asbestos fibers in excess of the limits prescribed in paragraph (b) of this section.

(iii) *Spraying, demolition, or removal*. Employees engaged in the spraying of asbestos, the removal, or demolition of pipes, structures, or equipment covered or insulated with asbestos, and in the removal or demolition of asbestos insulation or coverings shall be provided with respiratory equipment in accordance with paragraph (d) (2) (iii) of this section and with special clothing in accordance with paragraph (d) (3) of this section.

(d) *Personal protective equipment*—(i) Compliance with the exposure limits prescribed by paragraph (b) of this section may not be achieved by the use of respirators or shift rotation of employees, except:

(i) During the time period necessary to install the engineering controls and to institute the work practices required by paragraph (c) of this section;

(ii) In work situations in which the methods prescribed in paragraph (c) of

Table Z-3—Mineral Dusts

Substance	Mppcf*	Mg/M ³
Silica		
Crystalline		
Quartz (respirable)	250†	10mg/M ³ ‡
Quartz (total dust)	%SiO ₂ +8	%SiO ₂ +2 30mg/M ³
Crystalline		
Crocidolite	1/5 the value calculated from the count or mass formula for quartz	%SiO ₂ +2
Tridymite	1/5 the value calculated from the formula for quartz	
Amorphous, including natural diatomaceous earth	20	80mg/M ³ %SiO ₂
Silicates (less than 1% crystalline silica)		
Mica	20	
Soapstone	20	
Talc (non-asbestos form)	20†	
Talc (fibrous) Use asbestos limit		
Tremolite (see talc, fibrous)		
Portland cement	80	
Opalite (natural)	15	
Coal dust (respirable fraction less than 8% SiO ₂)		2.4mg/M ³ or 10mg/M ³
For more than 8% SiO ₂		%SiO ₂ +2
Inert or Nuisance Dust:		
Respirable fraction	15	60mg/M ³
Total dust	80	160mg/M ³

Note: Conversion factors—
Mppcf x 26.3 = million particles per cubic meter
µg/particles per cc

* Millions of particles per cubic foot of air based on impinger samples counted by light-field techniques.
† The percentage of crystalline silica in the formula is the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.

‡ Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a sieve with the following characteristics:
• Containing < 1% quartz; if > 1% quartz, use quartz limit.

Aerodynamic diameter (unit density sphere)	Percent passing selector
2	90
2.5	75
3	50
3.5	25
4	0

The measurements under this note refer to the use of an AEF instrument. If the respirable fraction of coal dust is determined with a MRE the figure corresponding to that of 2.5 µg/M³ in the table for coal dust is 4.5 Mg/M³.

§ 1910.1001 Asbestos.

(a) *Definitions*. For the purpose of this section, (1) "Asbestos" includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

(2) "Asbestos fibers" means asbestos fibers longer than 5 micrometers.

(b) *Permissible exposure to airborne concentrations of asbestos fibers*—(1) *Standard effective July 7, 1972*. The 8-hour time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed five fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (c) of this section.

(2) *Standard effective July 1, 1976*. The 8-hour time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed two fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (c) of this section.

(3) *Ceiling concentration*. No employee shall be exposed at any time to airborne concentrations of asbestos fibers in excess of 10 fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (c) of this section.

APPENDIX B

Sampling and Analytical Methods

**Hydrogen Sulfide
Total Sulfates**

SULFIDES

Including Hydrogen Sulfide and Dimethyl Sulfide

Air Samples for sulfides were collected by pulling a known volume of air with MDA Accuhalers through a Tenax tube.

In the laboratory the adsorbent tubes were thermally desorbed and aliquots were injected into a gas chromatograph. The different sulfides were identified by their elution time and quantified by comparison to peak areas of known concentrations.

SULFATES
Including Sulfuric Acid

Air Samples for sulfates were collected on mixed cellulose ester filters by pulling known volumes of air through the filter. Calibrated DuPont - 2500 constant flow pumps were used to collect the samples.

In the laboratory the filters were extracted by immersion in solvent, and the resultant solution was injected into an ion chromatograph to determine the presence of sulfates.

APPENDIX C
Sample Results

APPENDIX D
TOXICITY DATA SHEETS

Hydrogen Sulfide
Sulfuric Acid
Dimethyl Sulfide

HYDROGEN SULFIDE

Hydrogen sulfide (H₂S) is a colorless gas having an odor characteristic of rotten eggs. Although characterized by an offensive odor, hydrogen sulfide rapidly fatigues the olfactory nerves to the extent that the odor is no longer noticeable. Therefore, odor cannot be used as a reliable indicator of the level of exposure.

The primary health hazard associated with this material is through inhalation of the gas, which causes respiratory paralysis and pulmonary irritation.

Hydrogen sulfide at high concentrations may cause death from paralysis of the respiratory centers in the brain. Even brief exposure to concentrations of about 600 ppm can rapidly proceed to unconsciousness and death. Exposure to moderate concentrations can produce other symptoms suggesting brain damage including headache, dizziness, rigidity, sensory impairment, sleep disturbances, loss of appetite, and weight loss.

Irritation to the eyes, lungs, and mucous membranes can occur as a result of exposure to concentrations as low as 10-20 ppm. Prolonged exposure to such concentrations can result in painful conjunctivitis and some photophobia.

The Occupational Safety and Health Administration has adopted the American National Standards Institute (ANSI) 237.2-1966 standard for exposure to hydrogen sulfide, which established a ceiling concentration limit of 20 ppm (to be exceeded only once per eight-hour shift for up to 10 minutes if no other measurable exposure occurs), and a peak concentration limit of 50 ppm, not to be exceeded for any length of time.

In a more recent version of the standard (237.2-1972), the American National Standards Institute also specifies an eight-hour, time-weighted average concentration limit of 10 ppm, in addition to the above ceiling and maximum peak concentrations. The American Conference of Governmental Industrial Hygienists has established an eight-hour, time-weighted average threshold limit value of 10 ppm by volume.

The National Institute for Occupational Safety and Health recommends a ceiling concentration standard of 15 mg/m³ (approximately 10 ppm), as determined with a sampling period of 10 minutes, for up to a 10-hour workshift in a 40-hour work week.

SULFURIC ACID

Sulfuric acid (H_2SO_4) is a clear, colorless oily liquid when pure but brownish in hue when impure; it is odorless and has a marked acid taste. Sulfuric acid is a strong acid which, when heated to above $300^{\circ}C$. gives off vapor and, above $200^{\circ}C$, emits sulfur trioxide.

Sulfuric acid is a powerful corrosive agent and when introduced into the body in liquid or vapor form, it causes intense irritation and chemical burning of the mucous membranes of the respiratory tract. The acid causes violent dehydration and releases heat in sufficient quantities to produce burns that are similar to thermal burns.

The depth of the lesions depends on the concentrations of the acid and the length of contact. Inhalation of vapors produces the following symptoms: nasal secretion, sneezing, a burning feeling in the throat and retrosternal region; these are followed by cough, respiratory distress, sometimes accompanied by spasm of the vocal cords, a burning sensation in the eyes with lacrimation and conjunctival congestion. High concentrations may cause bloody nasal secretion and sputum, hematemesis, gastritis, etc. Dental lesions are common; they affect mainly the incisors and result in brown staining enamel striation, caries and rapid, painless destruction of the tooth crown.

Chemical burns are the injury most commonly encountered in sulfuric acid production workers. Concentrated solutions cause deep burns of mucous membranes and skin; initially the zone of contact with the acid is bleached and turns brown prior to the formation of a clearly defined ulcer on a light red background. These wounds require a long time to heal, and frequently cause extensive scarring that results in functional inhibition. If burning is extensive, the outcome may prove fatal. Repeated skin contact with low concentrations of acid causes skin desiccation and ulceration of the hands, and paronychia or chronic purulent inflammation around the nails. Splashes of acid in the eyes may have particularly serious consequences.

The general toxic action of sulfuric acid is to cause alkaline depletion of the body, and acidosis which affects the nervous system and produces agitation, hesitant gait and generalized weakness.

DIMETHYL SULFIDE

Dimethyl sulfide, also known as methylsulfide, methylthiomethane and thiobismethane, is a colorless liquid with a disagreeable odor. Dimethyl sulfide originates from the decomposition of plants and animals and from sulfur - containing amino acids in rumen micro-organisms activity.

Dimethyl sulfide is a moderate eye irritant and can enter the body by ingestion or inhalation but is considered to have low toxicity. At low levels it is easily metabolised; however, larger doses can lower body temperature and inhibit enzyme activity. In concurrent exposures to ammonia it can cause hepatic coma.

Human odor threshold for dimethylsulfides ranges from 3 to 300 parts per billion. In water the odor detection is 0.1 per liter.

No occupational exposure guidelines have been established for dimethylsulfide at this time.