U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 77-10-412

AMERICAN SMELTING AND REFINING COMPANY
DENVER, COLORADO

AUGUST 1977

I. TOXICITY DETERMINATION

It has been determined, based on environmental and medical evidence, that a hazard to the health of workers exposed to lead and cadmium existed at the American Smelting and Refining Company (ASARCO) Denver, Colorado, during the period of a Health Hazard Evaluation conducted by NIOSH on December 6-9, 1976 and March 28-30, 1977.

The evaluation revealed symptoms of breathing difficulty, chest pain, sinus congestion, renal stones, hypertension and kidney infection. A majority of workers examined had blood cadmium levels significantly above the normal range and were excreting cadmium in concentrations higher than is generally accepted as safe. Beta-2 microglobulin excretion in urine was found to be markedly increased, particularly in workers with greater than 16 years employment in this plant.

Environmental sampling indicated that fifty percent of 51 cadmium breathing zone samples exceeded the OSHA Standard of 0.1 mg/M^3, while sixty percent exceeded the NIOSH recommended Standard of 0.04 mg/M^3 and the American Conference of Governmental Industrial Hygienists 1976 TLV of 0.005 mg/M^3.

The existing OSHA Standard for lead in air of 0.2 mg/M^3, as well as the NIOSH recommended Standard of 0.1 mg/M^3 and the 1976 TLV of 0.15 mg/M^3 were exceeded in approximately ten percent of the breathing zone samples. All zinc concentrations were well within the most recent evaluation criteria.

Recommendations are included to assist in ensuring worker safety and health.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this determination report are currently available upon request from NIOSH, Division of Technical Services, Information and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office, at the Cincinnati address.

Copies of this report have been sent to:

American Smelting and Refining Company
United Steelworkers Union, Denver, Colorado
U.S. Department of Labor - Region VIII
NIOSH - Region VIII

For the purpose of informing the 70 affected employees, copies of the report shall be posted in a prominent place accessible to the employees for a period of 30 calendar days.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

NIOSH received such a request from the United Steelworkers Union, Denver, Colorado, to evaluate potential hazards associated with exposures to cadmium, lead, and zinc during the operation of a secondary smelter which produces primarily cadmium. This request was precipitated by employees concerned with the possible relationship of such symptoms as breathing difficulty, chest pain, sinus congestion, renal stones, hypertension, and kidney infection with occupational exposure.

IV. HEALTH HAZARD EVALUATION

A. Process Evaluated (Smelting)

The Globe Plant of ASARCO, Inc., is a secondary smelter which produces primarily cadmium. Concentrated ores are shipped to the plant, where they are refined into a high grade of cadmium. Other heavy metals such as lead and zinc are also produced but not to any large extent. However, environmental samples were collected for these metals, since the ores are contaminated with lead and zinc. This plant has an active respirator program. However, it does not meet all the OSHA requirements as outlined in 1910.134.

B. Environmental and Medical Evaluation Design and Methods

1. Environmental

During the environmental evaluation, breathing zone samples were taken on 51 workers. There was a total of 65 workers; however, only 51 workers wanted to participate in the environmental phase of this investigation. Workers in all areas of the plant were included in this study. Cadmium, lead, and zinc samples were collected on 3-piece closed face cassettes using AA filters. Flow rates were at 1.5 liters per minute. The workers were monitored during the usual 8-hour work period. The environmental samples were analyzed by standard NIOSH methods utilizing atomic absorption spectroscopy.

2. Medical

The total number of workers participating in the medical evaluation was 58, which represents greater than 90% of the work force with heavy metal exposure. All workers were males, their ages ranging from 19 to 62 years, with a mean of 39.7 years. The mean length of employment of the plant is 11.5 years.

The initial design of the study anticipated defining a high and low exposure group to cadmium within the plant based on air sampling data and previous biological monitoring records. This was found not to be feasible. We therefore attempted to correlate degree of exposure with evidence of organ dysfunction. Four persons with no previous cadmium or lead exposure were used as controls for biological samples in which well accepted normals were not documented.

The medical evaluation consisted of questionnaires administered to each worker, a directed physical examination, pulmonary function tests, and blood and urine analyses. The specific analyses performed were as follows:

Blood Cadmium
Blood Lead
Free Erythrocyte Protoporphyrin (FEP)
Hematocrit
Serum Creatinine
Blood Urea Nitrogen

Urine Cadmium
Urine B_2 microglobulin excretion
Urine Specific gravity and pH.
Urine Protein (qualitative estimate by dip stick)
Urine Creatinine

Forced Vital Capacity (FVC)
Forced Expiratory Volume, 1 second (FEV_1)
Maximal Mid-Expiratory Flow (MMEF)

The questionnaire attempted to define work history, other possible fume or dust exposure, general health problems and medications. Questions regarding past elevated levels of exposures to heavy metals and treatment received for such were asked. Work habits, such as eating or smoking at the plant, as well as respirator usage were also sought. Symptoms of pulmonary, renal, gastro intestinal, cardio vascular, and central nervous system disorders were asked each worker, as well as more general symptoms such as fatigue, weight loss, or joint complaints.

The physical examination included blood pressure measurement, brief examination of teeth and skin, auscultation of the lungs, and examination for nervous system dysfunction including sense of smell, deep tendon reflexes, wrist and ankle strength, and presence or absence of tremor.

Analysis of the blood and urine samples for lead and cadmium were performed by the Utah Biomedical Test Labs, Salt Lake City. A second set of the blood and urine specimens were sent to National Health Labs, Denver, for hematocrit, BUN, creatinines, FEP, and urine B_2 microglobins. Metal determinations in blood were performed by the Delves cup atomic absorption method. Urine cadmium was chelated with APDC, extracted into M.I.B.K., and analyzed by atomic absorption. B_2 microglobulins were measured using the Pharmacia R I A kit. Pulmonary function studies were performed using the "Vitalograph" machines, and predicted normal values for height, sex, weight, and age were taken from Kamburoff et al.[1]

Normal values used are as follows:

1. Blood lead levels above 40 ug/100 ml are considered elevated and above 60 ug/100 ml are considered harmful.

2. FEP (Free Erythrocity Protoporphrin). For this study, a blood lead of 40 ug/100 ml roughly corresponds to an FEP reading of 90 ug/100 ml rbc's and a blood lead of 60 ug/100 ml roughly corresponds to an FEP reading of 180 ug/100 ml rbc's. Significant differences may be seen when past lead exposure is higher than the current exposure.

3. BUN (11-23 mg/100 ml)

4. Serum Creatinine (.7-1.5 mg/100 ml)

5. Hematocrit - for males, 41-54 is normal at the Denver altitude.

6. Blood Cadmium - Levels in blood for non-exposed persons are less than one microgram per 100 ml.

7. Urine Cadmium - (per gram creatinine excreted) although no "normal" levels exist, a level of below 15 ug /gram creatinine excretion is considered to carry no risk.[2]

8. $Beta_2$ Micro globulin - Normal values by the R I A method used are from 4-370 ug/liter. In this study, the B_2 micro globulin was adjusted to grams creatinine excreted.

9. FVC/pred FVC - If less than 80% is considered an abnormal value.

10. FEV_1/FVC - If less than 70% is considered an abnormal value.

C. Criteria for Assessing Workroom Concentrations of Air Contaminants

The three sources of criteria used to assess workroom concentrations of air contaminants in this evaluation are:

(1) NIOSH recommended criteria for occupational exposures.

(2) Recommended threshold limit values (TLV's) and their supporting documentation as set forth by the American Conference of Governmental Industrial Hygienists (ACGIH), 1976.

(3) OSHA safety and health standards (29 CFR 1910), January 1976.

Substance	NIOSH Criteria	1976 TLV	OSHA Standard
	Permissible Exposures 8-Hour Time-Weighted Exposure Basis mg/M^3		
Cadmium	0.04	0.05	0.1
Lead	0.10	0.15	0.2 (0.10)*
Zinc	5.0	5.0	----

mg/M^3 = approximate milligrams of substance per cubic meter of air

* = OSHA has proposed, and NIOSH supported, lowering the lead standard to 0.10 mg/M^3

Occupational health standards and criteria for standards are established at levels designed to protect individuals occupationally exposed to individual toxic substances on an 8-hour per day, 40-hour per week basis over a normal working lifetime.

D. Toxicology [5,6,7,8,9,10,11,12]

Cadmium--The toxicity of cadmium may be divided into the acute effects of high exposures and the long-term effects of chronic poisoning. In acute poisoning with airborne cadmium, the respiratory system is the only system severely injured, although throat irritation, chest pain, headache, cough, dizziness, chills, nausea, vomiting, and diarrhea all may occur. Pulmonary edema and death may occur at high levels of exposure. There is a complete absence of significant immediate symptoms that can serve to warn workers that they are receiving hazardous exposure. The effects of chronic cadmium poisoning include renal tubular dysfunction, olfactory nerve damage, bone changes, and rhinitis; alleged pulmonary emphysema, anemia, and possible increased hypertension may be included in this group. There is an increased incidence of renal stones in workers exposed to significant cadmium levels. Surveys have indicated that carcinoma of the prostate may be found more frequently in cadmium-exposed workers, and an increased incidence of respiratory tract tumors may also be associated with increasing cadmium exposure, although this has not been definitely established.

Absorbed cadmium is retained in the body primarily in the kidney and liver. Excretion is slow. Urinary concentrations of cadmium have no diagnostic significance in terms of severity or duration of exposure and indicate only increased absorption of cadmium. With increasing exposure, however, renal excretion may increase markedly. One of the earliest changes indicating cadmium damage to the kidneys is the excretion of a low molecular weight protein in the urine called beta-2 microglobulin. Blood levels of cadmium indicate increased exposure but do not correlate well with organ damage or symptoms.

Lead--Lead poisoning may occur through the inhalation and/or ingestion of lead fumes or dust. This results in the deposition of lead in the bones and tissues of the body and alterations in normal physiological functions. No single sign or symptom may be considered daignostic of lead poisoning. Lead poisoning may present such symptoms as a metallic taste in the mouth, loss of appetite, indigestion, nausea, vomiting, constipation, abdominal cramps, nervousness, and insomnia.

Many of the sources of lead poisoning are industrial, but man also absorbs lead in small amounts not normally leading to poisoning from his food and water and from the air. These sources lead to the "normal" body burden of lead. The normal burden in workmen is 27-30 micrograms of lead per 100 milliliters of blood (ug/100 ml). Thus the lead absorbed in the course of occupational exposure is superimposed on lead absorbed from other sources. Lead poisoning is preceded by a stage of lead absorption, but lead absorption is not always followed by lead poisoning.[3]

Zinc Oxide--High exposures to zinc oxide may produce metal fume fever, which is characterized by chills, tremors of the hands and arms, which usually disappear overnight.

Maintaining occupational exposures to zinc oxide below 5 mg/M^3 will protect a worker for a 40-hour work week over a normal working lifetime.

E. Medical and Environmental Results and Discussion

1. Medical

Fifty-eight workers participated in the medical evaluation. Fifty-one men had participated in breathing zone air sampling in the initial environmental survey, but nine of the environmental survey participants were not present in the medical evaluation. Sixteen men present in the medical evaluation were not present in the breathing zone sampling group done on the initial visit.

The data gathered was analyzed in several ways. Correlation coefficients were calculated for continuous variables such as blood cadmium levels and beta-2 microglobulins. In addition to the laboratory values listed, other continuous variables such as age, smoking history, and number of months at the plant were also entered in producing correlation coefficients. Workers with previous histories of organ system abnormality were eliminated from statistical consideration; for example, workers with previous histories of working in coal mines were eliminated from the pulmonary function testing analysis.

For data such as physical signs or symptoms where frequencies of occurrence are studied, Chi square analysis was performed. In addition, selected groups are identified such as all workers in a particular plant area, or workers with long histories of exposure to cadmium at the plant, and these groups are studied for common abnormalities.

Table I gives the mean value, standard deviation, and number of samples analyzed for the laboratory analyses listed. Tables II and III show incidences of signs and symptoms elicited.

All of the blood lead levels were below 40 ug/100 ml, except for five workers; only one blood lead level was above 60 ug/100 ml. None of these workers had been at the plant longer than three years. One worker demonstrated unilateral wrist extensor weakness and one worker demonstrated a slight tremor, but no other signs of lead toxicity were noted in this group. No other laboratory values were abnormal in this group except elevation of the FEP values, and no increased incidence of gastrointestinal or nervous system symptoms was reported.

Correlations of FEP measurements with blood lead levels revealed a rough correlation of 40 ug/100 ml blood lead with FEP value of 90 ug/100 ml rbc's, and a blood lead of 60 ug/100 ml blood lead with an FEP value of 180 ug/100 ml rbc's. All of the workers with elevated lead levels had elevated FEP levels above 90 ug/100 ml rbc's except for one. Six additional workers showed FEP readings above 90 ug/100 ml rbc's without elevated blood lead levels. There was no significant incidence of signs or symptoms of lead toxicity in this group, the length of time at the plant was much closer to the eleven year average for all workers, and the job descriptions for these workers were quite varied. The only statistically significant correlation of either lead or FEP data and other variables was a correlation between serum creatinine and blood lead level, but this was quite small. Table IV lists elevated blood lead and FEP data.

Table I shows the mean blood cadmium level to be 2.99 ug/100 ml, and the mean urinary cadmium excretion to be 30.08 ug Cd per gram of creatinine excreted. The statistically significant correlation coefficients with these variables included:

1. Urine cadmium excretion per gram creatinine and B_2 microglobulin excretion per gram of creatinine

2. Blood cadmium and urinary cadmium excretion

There was no significant relationship between B_2 microglobulin excretion and blood cadmium level, nor was there any significant correlation between serum creatinines and either blood or urine cadmium levels. Correlation coefficients between blood cadmium and number of months of plant exposure, and between urine cadmium were not significant for the total plant population of workers. The correlation coefficient between blood cadmium and urinary cadmium excretion while statistically significant, was quite small.

The environmental sampling of cadmium air levels had shown greater than the TLV values in one half or more of samples taken in every area of the plant except the electrolytic area. Table V demonstrates this data. A small but statistically significant correlation was shown between cadmium air levels and levels of serum creatinine, but other correlations were not significant. Although the electrolytic workers had lower blood (1.9 ug/100 ml) and urine (25.8 ug/gram) creatinine cadmium levels than the plant as a whole, the small size of this group and the rotation of jobs among the workers prevented the use this group as a control population.

The pulmonary function data showed only 3 workers with evidence of obstructive disease alone ($FEV_1/FVC < 70\%$), after exclusion of those men with histories of coal mining. Two of three of these men had less than five pack years history smoking cigarettes. One of these men had an elevated level of B_2 micro globulin excretion as well as an elevated blood cadmium level of 5.9 ug/100 ml. None of the 3 workers with evidence of restrictive lung disease (FVC/pred FVC < 80%) had any elevation of cadmium or B_2 microglobulin excretion.

Five workers reported having passed renal stones in the past, but no relationship existed between this and cadmium levels, B_2 microglobulin excretion, or plant exposure.

There were 5 workers identified with abnormal biceps reflexes, three workers with resting tremors, and 8 workers present with decreased wrist or ankle strength. Only two of these had elevated lead levels (41 ug/100 ml and 56 ug/100 ml); six of these workers had elevated B_2 microglobulin levels.

There was no correlation between hypertension by history or on physical exam and cadmium levels. Three workers had suffered myocardial infarctions in the past, and two of these workers had significant elevations of B_2 microglobulin excretion (> 2000 ug/gm) as well as elevations of blood cadmium (> 3 ug/100 ml creatinine) and urinary cadmium excretion (> 35 ug/gm creatinine). Unfortunately, questionnaire data was too imprecise to distinguish anginal symptoms from pulmonary symptoms.

No apparent correlations between joint symptoms and other symptoms such as muscle aches or fatigue were found. Examination of all workers teeth was performed but was non-contributory.

Due to worker mobility among jobs in the plant, limited use could be made of the individual breathing zone samples of cadmium in identifying higher versus lower exposure groups. Therefore, since elevated breathing zone samples were found in all areas except the electrolytic department, the total number of months at the plant was judged to be the best index of exposure. Some interesting patterns emerge from this approach, discussed below.

The average time at the plant was 137.7 months. Statistically significant correlation coefficients exist between the number of months at the plant and B_2 microglobulin excretion, serum creatinine, and FEV_1/FVC for the total plant population. If workers who have worked at the plant for 16 years (192 months) or longer are identified, some consistent abnormalities are noted. Table VI lists these findings.

The average blood cadmium and urine cadmium values are above the plant average, and the B_2 microglobulin excretion is far above the plant average. The serum creatinine is higher and the FEV_1/FVC is lower than the plant average as well, although the latter may be related to the longer smoking histories of these workers. Five of the 12 workers with proteinuria detectable by dipstick method were in this group. All of the workers in the plant with elevated beta-2 microglobulin excretion are found in this group. The incidence of neurological abnormalities such as asymmetric reflexes and wrist or ankle weakness was also higher in this group. Of the ten workers at the plant who reported noticing decrease in ability to smell, or who were unable to smell selected scents on the physical exam, five of these were among this group with long-term cadmium exposure in Table VI. Other symptoms were not present in significantly greater numbers in this group than in the plant population as a whole.

2. Environmental Results

Environmental data collected on December 6-9, 1976, showed high exposure to cadmium and lead. Sixty percent of the cadmium samples exceeded the most recent NIOSH evaluation criteria of 0.04 mg/M^3, and 50% of the cadmium samples exceeded the OSHA standard of 0.1 mg/M^3. Ten percent of the samples for lead exceeded the NIOSH and OSHA recommended standard of 0.10 mg/M^3. Results of the environmental samples may be reviewed in Table VII.

F. Biological Results

A variety of biomedical tests were performed in the evaluation to determine whether workers have experienced health effects from either lead or cadmium exposure. The environmental evaluation established that high levels of cadmium existed in almost all areas of the plant, and elevated air lead levels existed in a few areas.

1. The risk of lead toxicity in the plant currently appears to be quite limited. Areas in which elevated air levels or blood levels were found included the solution room, leeching area, and casting area. These workers should be followed carefully for evidence of lead poisoning.

2. The elevated air levels of cadmium dust or fumes represent a potential threat to workers in all areas of the plant, with the possible exception of the cadmium sulfate fumes in the electrolytic department.

3. In spite of reported high compliance with existing respirator requirements at the plant, a majority of the workers have blood cadmium levels significantly above the normal range and are excreting cadmium in concentrations higher than is universally accepted as safe.

4. There exists definite evidence of cadmium renal toxicity in a group of workers who have had long-term exposure to cadmium at the plant. The primary evidence for this conclusion is the markedly elevated excretion of beta-2 microglobulin in the urine of the workers with greater than sixteen years plant exposure. It is felt that current levels of cadmium exposure represent a significant risk to the majority of workers with chronic exposure.

5. As has been noted in previous studies, there is poor correlation between blood cadmium or urine cadmium levels with signs or symptoms of toxicity.

6. While there existed a small statistically significant negative correlation between plant exposure and FEV_1/FVC, the group of workers with maximal plant exposure and renal toxicity did not demonstrate significantly reduced values, i.e., below 70%.

7. The high incidence of neurological abnormalities such as unilateral decrease in reflexes or wrist strength among the group of workers with greater than sixteen years of plant exposure is unexplained in terms of cadmium effect. This may represent evidence of past high lead exposure or other toxic injury of unknown origin.

8. While zinc is present in the plant, all measured levels were below the TLV and pose no hazard to employee health. The zinc may or may not exert a protective effect on the workers exposed to cadmium or lead as has been reported.[4]

9. There were two workers who reported vague prostatic abnormalities, one of whom had a high beta-2 microglobulin excretion.

10. Elevated cadmium levels and prolonged exposure may accelerate cardiovascular disease, although no definite conclusions can be drawn from the few workers with documented myocardial infarctions seen in this study.

V. RECOMMENDATIONS

The following recommendations are offered to ensure worker safety and health:

1. Routine pre-employment medical examinations should be performed as well as periodic physical examinations. A suggested timetable is every two years for workers below 40 years of age, then on a yearly basis thereafter.

2. The examination should consist of a medical history, physical examination, and appropriate biomedical testing. Suggested tests include:

a. Blood pressure measurement
b. Pulmonary function studies
c. Chest x-ray
d. Complete blood count
e. Urinalysis
f. Serum multiphasic analysis - 12 (SMA - 12)
g. Urine for cadmium (24 collection)
h. Urine for beta-2 microglobulin
i. Blood lead, if work area indicates
j. Examination of prostate glands in all male workers greater than 40 years of age
k. Individual worker's ability to effectively use positive or negative pressure respiratory protective equipment provided

1. Urine protein determinations capable of detecting low molecular weight proteins should be done at least twice a year on all exposed workers.

3. Workers with evidence of high cadmium exposure should be followed closely for health effects. The following guidelines are suggested:

a. Workers with cadmium excretion of from 15 ug/gram creatinine to 35 ug/gram creatinine should have these levels repeated within four to eight months, as well as urinary beta-2 microglobulin excretion measured concurrently if the worker has had greater than five years of plant exposure.

b. Workers excreting more than 35 ug Cd/gram creatinine should be transferred to areas of lower cadmium exposure. Repeat measurements of cadmium excretion and beta-2 microglobulin excretion should be performed within four to six months.

c. All workers with elevated excretion of beta-2 microglobulin should be removed from areas of significant cadmium exposure, a complete physical examination performed, and repeat excretion measurements performed to assess the extent of renal damage or reversibility present.

4. Primary emphasis should be placed upon modification of the cadmium exposure itself. Work practices, as outlined in the NIOSH Cadmium Criteria Document, should be studied and enforced and engineering modifications employed at appropriate areas of concern. Additional ventilation systems or modifications of existing systems, as well as review of the respirator program and enforcement of existing requirements of usage, may be necessary. Worker education regarding the risks of cadmium exposure and proper hygienic practices should be stressed. Administrative manipulation of exposure to higher or lower areas of exposure should be relied upon only after other means have proven inadequate.

5. Workers with elevated blood lead levels should have these repeated within six months, and work practices should be reviewed. Workers with blood levels greater than 60 ug/100 ml should be removed from areas of significant lead exposure and a physical examination performed to determine any toxicity and need for possible treatment.

6. The respirator program should be monitored and enforced, including proper fitting as well as instructing the workers on things that prevent a good respirator fit such as beards, moustaches, and any stubble on the face. A respirator program must meet OSHA requirements stated in 1910.134.

7. Smoking and eating should be prohibited in all work areas. Cigarettes should not be allowed on the worksite.

VI. REFERENCES

1. Kamburoff, P.L., and Woitowitz, H.J. & R.H.: "Predictions of Spirometric Indices", Brit. J. of Diseases of the Chest, 1977.

2. Lauwerys, Robert, et al.: "Epidemiological Survey of Workers Exposed to Cadmium", Arch. Environ. Health, Vol. 28, March 1974, pp 145-148.

3. Anania, Thomas "Lead Exposure at an Indoor Firing Range: NIOSH publication, pub. # 74-100 p 6, 7

4. Haegen-Aronsen, B. Schutz, A. Abdella, M.
Antagonistic Effect in Vivo of Zinc on Inhalation of Delta Aminolevalisinc Acid Dehydratase by Lead.
July-August 1976, Archives of Env. Health

5. Prince, Frank A Study of Industrial Exposures to Cadmium.
Journal of Industrial Hygiene and Toxicology. Vol 29 p 320

6. Ulander, Arne et al. "Measurement of Blood-Cadmium Levels:
Lancet, April 13, 1974 pp 682, 683

7. Buell, George "Some Biochemical Aspects of Cadmium Toxicology"
Journal of Occupational Medicine Vol 17 No. 3, March 1975

8. Hardy, Harriet et al. "The Possibility of Chronic Cadmium Poisoning"
Journal of Industrial Hygiene and Toxicology Vol 29, No 5. p 321, 324

9. Bonnell, J. A. et al. "A Follow-up Study of Men Exposed to Cadmium Oxide Fume" Brit. J. Industrial Med. 1959, 16, 135.

10. Zenz, C. Occupational Medicine,
Yearbook Publishers 1975

11. Patty, F. A. ed. Industrial Hygiene and Toxicology, 2nd Revised Ed.
Interscience Publishers. New York 1963

12. NIOSH Criteria for a Recommended Standard...Occupational Exposure to Cadmium

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TABLE I

Laboratory Data

March 28-30, 1977

Globe Plant, ASARCO, Inc.,
Denver, Colorado

Variable	Number of Cases	Mean	Standard Deviation
Blood Lead (ug/100ml)	47	25.3	10.3
Blood Cadmium (ug/100ml)	47	2.99	1.57
Urine Cadmium (ug Cd/per gram Creatinine)	50	30.08	19.18
B_2 microglobulin excretion (ug/per gram Creatinine)	50	391.8	896.68
Hematocrit	58	46.5	2.8
Serum Creatinine	58	1.076	0.167
FVC/pred FVC (%)	55*	95.5	13.7
FEV_1/FVC (%)	55*	83.6	5.27
Age (years)	58	39.7	14.3
No. of months at plant	58	137.7	135.2
Pack-years smoking	54	9.8	20.4
Cadmium air levels (mg/M^3)	28**	0.285	0.465
Free Erythocyte Protoporphrin (ug/100 red blood cells)	58	62.75	not cal.

	Number of cases	Amount
Proteinuria by dip stick	10	trace positive
	1	1+ positive
	1	2+ positive

	No. of workers excreting > 35 ug/gm Creatinine	No. of workers excreting > 15 ug/gm Creatinine
Cadmuim excretion	14 of 50	37 of 50

	No. of workers with > 370 ug/liter	No. of workers with > 370 ug/gram Creatinine
B_2 microglobulin excretion	10	10

* Excludes 2 workers with abnormal pulmonary function test and history of prolonged work in coal mining.

** Represents the number of workers who participated in both medical and environmental evaluations, and who had not changed jobs in the past year.

TABLE II

Symptoms Reported

March 28-30, 1977

Globe Plant, ASARCO, Inc.,
Denver, Colorado

Symptoms	No. of Positive Responses	% (to nearest%)
1. Pulmonary symptoms		
a. Cough	13	22
b. Sputum production	15	26
c. Chest tightness	18	31
d. Wheezing	11	20
e. Shortness of Breath	14	24
f. Increased incidence of Upper Respiratory Infections	9	15
- 33 of 58 reported at least one of the above positive symptoms		
- 12 of 58 reported at least three of the above positive symptoms		
2. Gastrointestinal Symptoms		
a. Nausea	12	21
b. Vomiting	5	9
c. Diarrhea	11	19
d. Constipation	11	19
e. Abdominal cramps	13	22
- 22 of 58 reported at least one of the above positive symptoms		
- 11 of 58 reported at least three of the above positive symptoms		
3. Renal Symptoms		
a. Renal stones	5	9
b. Blood in urine	2	3
c. Protein in urine	5	9
d. History of infections	1	2
e. Prostate abnormality	2	3
f. Increased frequency of urination (> 8 per day)	4	7
4. Cardiovascular Symptoms		
a. History of hypertension	11	19
b. History of myocardial infections	3	5
c. Recurrent chest pain	18	31
d. History of hypercholesterolemia	4	7
5. Central Nervous System Symptoms		
a. Frequent headaches	13	22
b. Irritability	17	29
c. Dizzyness	11	19
d. Sleeping difficulty	10	17
e. Tremor	8	14
f. Smell abnormality	6	10
g. Memory loss	10	17
6. General Symptoms		
History of:		
a. Anemia	1	1
b. Muscle cramps	23	40
c. Muscle weakness	14	24
d. Fatique	11	19
e. Decreased appetite	7	12
f. Skin rashes	14	24
g. Joint problems	22	38
h. Liver abnormalities	3	5
i. Unintentional weight loss	3	5

TABLE III

Physical Examination

March 28-30, 1977

Globe Plant, ASARCO, Inc.,
Denver, Colorado

Physical sign	No. of positive responses	%
Hypertension (> 140/90)	16	27
Skin abnormality (rash, discoloration or depigmentation)	7	12
Abnormal lung auscultation	2	3
Decreased sense of smell	4	7
Abnormality of bicept or brachioradialis reflexes	5	9
Tremor	3	5
Decreased wrist or ankle strength	8	14

TABLE IV

Abnormal Blood Lead or FEP Values

March 28-30, 1977

Globe Plant, ASARCO, Inc.,
Denver, Colorado

Blood Lead (ug/100ml)	FEP (ug/100ml red blood cells)
18	98
27	94
27	138
29	92
30	113
34	179
41	71
41	109
44	96
56	144
65	219

TABLE V

March 28-30, 1977

Environmental Sampling for Elevated Cadmium Levels

Globe Plant, ASARCO, Inc., Denver, Colorado

Plant Area	No. of air samples (worker breathing zone samples)	No. of air samples elevated above TLV	Average Cadmium air level (mg/M^3)
Solution Room	11	9	.44
Calcine Room	7	4	.52
Electrolytic Room	9	1	.08
Retort Area	2	2	.57
Leeching Area	6	5	.26
Casting Area	2	2	.16
Shop	14	10	.21

E VI

Evidence of Cadmium Effects In Workers W.   eater Than 16 Years History of Work At Plant

Globe Plant, ASARCO, Inc.,
Denver, Colorado

March 28-30, 1977

Worker	# of months at ASARCO	Blood Cadmium ug/100 ml	Serum Creatinine	Urine Cadmium ug/ per gram Creatinine	B_2 microglobulin excretion ug per/gram Creatine	Proteinuria by dip stick	Selected abnormal signs or symptoms	FEV_1/FVC
1	324	2.3	1.1	35.4	516	-	decreased smell	74
2	312	3.0	0.9	no sample	no sample	no sample	-	poor effort
3	360	1.1	1.2	30.0	75.4	-	-	82
4	192	1.2	2.2	43.6	3571	trace	slight tremor	90
5	348	4.8	1.2	46.9	1615	-	-	80
6	214	1.9	1.0	18.8	37.1	-	decreased smell decreased reflex in right bicep ? kidney abnormality	83
7	408	3.2	1.1	37.6	235.9	-	-	82
8	360	2.5	1.4	32.3	617	trace	decreased wrist reflex history of kidney infection	78
9	360	1.1	1.3	47.1	60	-	decreased smell ? ankle weakness	74
10	204	2.4	1.3	50	991.7	-	history of kidney infection	79
11	360	1.6	1.1	30	395	trace	decreased left wrist strength	82
12	348	3.5	1.0	28.7	30	-	history of proteinuria and glucosuria	80
13	354	3.7	1.1	80	2166	1+	decreased wrist and ankle strength skin depigmentation	87
14	354	4.3	1.2	34	116	-	-	87
15	192	4.5	1.0	64.6	2020	-	decreased smell	90
16	348	5.1	1.5	18.7	1962	2+	decreased smell decreased right wrist strength	80
17	351	5.9	1.5	below detection	4340	-	decreased reflex on right side	61
Averages	312	3.06	1.24	37.3	1172			79.9

TABLE VII

ATMOSPHERIC CONCENTRATIONS OF LEAD, CADMIUM, AND ZINC

ASARCO Globe Smelter
December 6-9, 1976

DATE	SAMPLE NUMBER	LOCATION	JOB CLASSIFICATION	TIME OF SAMPLE	LEAD (mg/M³)	CADMIUM (mg/M³)	ZINC (mg/M³)	TYPE OF SAMPLE
Dec. 6	3	Solution	Solution Operator	11:03 P.M.-- 6:30 A.M.	0.01	0.18	0.02	BZ
"	2	Solution	Charger	11:03 P.M.-- 6:25 A.M.	*	0.01	0.004	BZ
"	4	Solution	Presser	11:01 P.M.-- 6:30 A.M.	0.01	0.13	0.01	BZ
"	1	Electrolytic	Checker	11:01 P.M.-- 6:29 A.M.	0.02	0.53	0.01	BZ
"	5	Retort	Retort Operator	11:02 P.M.-- 6:30 A.M.	0.14	1.05	0.10	BZ
"	170	Calcine	Asst. Furnace Operator	11:00 P.M.-- 7:00 A.M.	0.004	0.03	0.001	BZ (RESP).
"	176	Calcine	Furnace Operator	11:00 P.M.-- 6:28 A.M.	0.001	0.02	0.001	BZ (RESP)
Dec. 7	25	Calcine	Mixer Operator	2:51 P.M.--10:20 P.M.	0.25	1.65	0.15	BZ
"	14	Calcine	Furnace Operator	2:52 P.M.--10:48 P.M.	0.01	0.53	0.01	BZ
"	155	Calcine	Asst. Furnace Operator	2:59 P.M.--10:20 P.M.	0.003	0.04	0.002	BZ (RESP)
"	7	Solution	Solution Operator	2:56 P.M.--10:25 P.M.	0.22	0.25	0.02	BZ
"	20	Solution	Solution Charger	2:58 P.M.--10:27 P.M.	0.23	0.78	0.02	BZ
"	13	Solution	Solution Presser	2:59 P.M.--10:27 P.M.	0.25	0.12	0.01	BZ
"	12	Electrolytic	Checker	3:01 P.M.--10:40 P.M.	*	0.01	0.004	BZ
"	19	Electrolytic	Laborer	3:09 P.M.--10:30 P.M.	0.004	0.05	0.003	BZ
"	187	Retort	Operator	2:55 P.M.--10:31 P.M.	0.002	0.09	0.001	BZ (RESP)
"	183	Leaching	Operator	3:00 P.M.--10:30 P.M.	*	0.03	0.001	BZ (RESP)
"	18	Leaching	Charger	4:50 P.M.--10:20 P.M.	0.02	0.32	0.01	BZ
"	17	Leaching	Asst. Operator	2:57 P.M.--10:20 P.M.	0.03	0.58	0.01	BZ
Dec. 8-9	10	Shop	Mechanic	7:44 A.M.-- 3:08 P.M.	0.04	0.11	0.02	BZ
"	43	Leaching	Operator	7:06 A.M.-- 2:31 P.M.	0.02	0.32	0.007	BZ
"	48	Shop	Mechanic's Helper	7:48 A.M.-- 2:51 P.M.	0.01	0.04	0.21	BZ

(CONTINUED)

TABLE VII (continued)

ASARCO Globe Smelter
December 6-9, 1976

DATE	SAMPLE NUMBER	LOCATION	JOB CLASSIFICATION	TIME OF SAMPLE	LEAD	CADMIUM	ZINC	TYPE OF SAMPLE
					mg/M^3			
Dec. 8-9	30	Shop	Mechanic/First Class	8:04 A.M.-- 2:56 P.M.	1.95	1.56	0.13	BZ
"	22	Shop	Pipe Fitter	7:48 A.M.-- 2:58 P.M.	0.01	0.11	0.01	BZ
"	26	Calcine	Asst. Furnace Operator	7:53 A.M.-- 2:35 P.M.	0.08	0.83	0.03	BZ
"	45	Shop	Equipment Operator	7:50 A.M.-- 3:01 P.M.	0.02	0.50	0.04	BZ
"	38	Shop	Mechanic's Helper	7:47 A.M.-- 2:58 P.M.	0.01	0.03	0.01	BZ
"	23	Electrolytic	Crane Operator	7:01 A.M.-- 2:40 P.M.	0.01	0.04	0.01	BZ
"	41	Shop	Mechanic's Helper	7:50 A.M.-- 3:03 P.M.	0.05	0.13	0.02	BZ
				EVALUATION CRITERIA	0.10	0.05	5.0	
				NIOSH LIMIT OF DETECTION	0.3 µg/s	0.1 µg/s	0.1 µg/s	

mg/M^3 = approximate milligrams of substance per cubic meter of air

BZ = breathing zone

BZ (RESP) = breathing zone (respirable)

* = below the NIOSH lower limit of detection

µg/s = micrograms per sample