HETA 88-104-2207
APRIL, 1992
ASARCO - TROY UNIT MINE
TROY, MONTANA

NIOSH INVESTIGATORS:
RONNIE J. CORNWELL, CIH
ELIZABETH B. KNUTTI, RN

I. Summary

In December 1987, the Division of Respiratory Disease Studies (DRDS), National Institute for Occupational Safety and Health (NIOSH) received a request from the United Mine Workers of America (UMWA) to conduct a health hazard evaluation at ASARCO's Troy Unit Mine near Troy, Montana. Potential exposures identified in the request were diesel exhaust, silica, and noise.

NIOSH investigators conducted an initial site visit and walk-through inspection on February 2, 1988. An environmental and medical survey was conducted July 13-20, 1988.

Personal breathing zone and area environmental samples were collected to characterize employees' exposures to oxides of nitrogen (NO, NO_2), coal tar pitch volatiles (CTPV's), polynuclear aromatic hydrocarbons (PNA's), diesel particulates, carbon monoxide (CO), aldehydes, respirable silica, and noise. The 54 passive dosimeters analyzed for oxides of nitrogen indicated that the full shift exposure levels of NO_2 ranged from 0.16 ppm to 4.61 ppm with a mean exposure of 1.45 ppm. These results indicate that exposures were in excess of the NIOSH recommended ceiling level of 1 ppm. Five of the 54 samples also exceeded the 1991 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 3 ppm.

Results of sampling for CTPV's ranged from 0.11 mg/m^3 to 1.67 mg/m^3. Twelve (67%) of the 18 sample concentrations exceeded the 1991 ACGIH TLV of 0.2 mg/m^3. Also 77% of the samples contained quantifiable amounts of the following PNA's: acenaphthene, phenanthrene, anthracene, fluoranthene, pyrene, and chrysene.

Exposure to diesel particulates ranged from 0.22 mg/m^3 to 3.99 mg/m^3, with a mean concentration of 1.60 mg/m^3. The mean exposure for respirable dust in the underground operation was 2.24 mg/m^3, with a range of 0.26 mg/m^3 to 16.74 mg/m^3. The mean exposure for the surface operations was 0.38 mg/m^3; range 0.06 mg/m^3 to 3.36 mg/m^3. Forty-seven percent of all underground sample results exceeded the calculated MSHA TLV, and 59% exceeded the NIOSH REL for respirable silica. Seventeen percent of the surface sample results exceeded the calculated MSHA TLV, and 39% exceeded the NIOSH REL for respirable silica.

Eight-hour time-weighted average (TWA) noise exposures ranged from 65.5 dBA to 103.8 dBA. Twenty-one of the 22 personal dosimeter readings obtained underground and 6 of the 19 readings obtained on the surface exceeded the NIOSH REL and the 1991 ACGIH TLV of 85 dBA. Fifty-four percent of the dosimeter readings exceeded the 1973 ACGIH TLV of 90 dBA adopted by the Mine Safety and Health Administration (MSHA).

Results of the area samples for CO appeared to be well below the evaluation criteria. A concentration of 0.1 ppm was recorded on 2 of the 17 area measurements for formaldehyde.

The medical portion of the survey consisted of a medical questionnaire, spirometry, and a review of company collected chest radiographs and audiograms. One hundred twenty-two of the 314 (39%) employees participated in the study. When compared to a group of nonexposed blue-collar workers, there was an increased prevalence of chronic respiratory symptoms. Review of 293 radiographs revealed 18 cases of ILO category 1/0 or greater small radiographic opacities and no cases of large opacities. Analysis of the audiograms revealed a pattern typical of a population which has been exposed to excessive noise and suggested deficiencies in the company's hearing conservation program.

The medical findings suggested a pattern of obstructive airways disease and pneumoconiosis. Acute symptoms were consistent with exposure to diesel particulate. Whether the chronic health problems have been the result of exposures in the Troy Mine is unclear. Because of the low participation rate, a selection bias may exist.

On the basis of the environmental data obtained during the survey, NIOSH has determined that a health hazard existed due to employee exposure to respirable silica, noise, and products of diesel combustion. Recommendations for reducing potential exposures and enhancing the company's medical surveillance program are included in this report.

KEYWORDS: SIC 1044 (Silver Ores), Diesel Exhaust, Noise, Polynuclear Aromatic Hydrocarbons, Nitrogen Dioxide, Silica

II. Introduction

In December 1987, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the Deputy Administrator, Occupational Health, United Mine Workers of America (UMWA). The UMWA representative asked NIOSH to evaluate employee exposures to diesel exhaust, respirable silica, and noise for the workers at ASARCO's Troy Unit Mine near Troy, Montana.

On February 2, 1988, a NIOSH industrial hygienist made an initial site visit of the Troy facility. The NIOSH representative discussed with the company and union representatives the request and ensuing evaluation and conducted a walk-through survey of the mine and mill facilities.

During July 13-20, 1988, a medical and environmental survey was conducted. The medical portion of the survey consisted of a respiratory questionnaire and pre and post shift pulmonary function testing. Also, chest radiographs and audiograms from the employees' medical records were obtained for review. The environmental portion of the survey consisted of collecting personal breathing zone and area environmental samples and measurements to determine workers' exposures to diesel exhaust, respirable silica, and noise.

An interim report of the environmental results, conclusions, and recommendations was sent to the company and union officials in July 1989. Employees were notified of their medical findings in January and February 1990.

III. Process Description[1]

The Troy Unit Mine is one of the largest silver mines in the United States and is also a significant copper producer. It employs approximately 314 people in its two basic operations of mining and ore concentration. Approximately 140 of the 314 individuals are employed in the underground mining operation.

The ore is mined by the "room-and-pillar method". This entails extracting ore from huge rooms within which vertical supporting pillars are left. Each pillar is approximately 45 feet square and extends from the floor to the roof of the ore body. Excavation of the rooms is started by mining out a 20-foot horizontal slice at the top of the ore. As mining progresses, miners work from this top slice to drill down and blast the remaining 40 feet of ore in vertical benches.

The extraction process consists of drilling, blasting, scaling and roof bolting, mucking and hauling. Two-boom jumbo drills are used to bore horizontal holes into the face of the ore body in the top slice. For vertical cuts hydraulic bench drills bore vertically to the bottom of the ore body. Explosive charges are placed in the drill holes and detonated. Loose rock in the roof and walls of the blasted area are removed using scaling equipment and rock bolts are placed in the roof where necessary to forestall any subsequent loosening of the scaled rock surface. The blasted ore is then "mucked" from the area by diesel-powered front-end loaders. The ore is loaded onto 35-ton diesel trucks which transport it to the underground crusher facility. The ore is separated into oversize and undersize pieces. The oversize material is fed into a jaw crusher and crushed to less than 6 inches. This material is then transported by conveyor belt to the secondary crusher on the surface where the material is crushed to approximately 1/2 inch dimension. The next stop in the milling process consists of feeding the fine ore into ball mills, where it is mixed with water and ground to the fineness of talcum powder.

In the ensuing step, the slurry of pulverized ore is pumped into the flotation process, where the mineral is separated from the waste material. The copper-silver mineral froth is deposited into a concentrate thickener tank, where it is thickened to 65% solids. The slurry is then filtered to separate the concentrate mineral from the liquid. The solid concentrate is then loaded by a front-end loader onto trucks for transport to a smelter.

IV. Methods and Materials

A. Environmental

During the period July 13-15, 1988, environmental samples were collected during typical working shifts (day, evening, night) in the mine in an attempt to evaluate the workers' exposures to nitric oxide (NO), nitrogen dioxide (NO_2), coal tar pitch volatiles (CTPV's), polynuclear aromatic hydrocarbons (PNA's), diesel particulate, carbon monoxide (CO), aldehydes, respirable silica, and noise. Personal breathing zone samples were obtained on the equipment operators, and area samplers were placed on the equipment (loaders, trucks, drills) adjacent to or in front of the operator within approximately three feet of their breathing zone. Area samplers were also placed in the maintenance area (Pad) in the mine. During July 18-19, 1988 (day shift), personal samplers were placed on the workers in the secondary crusher and mill buildings. These samplers measured the workers' exposures to respirable silica, NO, NO_2, and noise. The sampling and analytical methodologies[2,3,4,5,6] are presented in Table 1.

B. Medical

Data were collected from three sources. All 314 employees of the mine were asked to participate in the medical survey, which included spirometry and a medical questionnaire. Additionally, the most recent chest radiographs which were taken as part of the company's periodic medical examination program were collected and reviewed for 293 workers. Finally, audiograms performed by the company were obtained from the employees' medical records.

NIOSH Examinations

The questionnaire (Appendix I) addressed job history, cigarette smoking history, chronic respiratory symptoms, and acute symptoms which developed during the workshift. Spirometric examinations were administered according to American Thoracic Society Guidelines[7] employing a waterless rolling seal spirometer (Ohio Model 840) with a paper chart drive operated at 20 mm per second. Each participant performed five forced expirations. The forced expired volume in one second (FEV_1) and forced vital capacity (FVC), converted to body temperature and ambient pressure saturated with water vapor (BTPS), were recorded from each maneuver. The highest FEV_1 and FVC from the 5 maneuvers were selected for analysis.

In addition to their before-shift examinations, 82 employees were asked to participate in a post-shift examination which consisted of questions on acute symptoms during the work day (see Appendix I-Part D of questionnaire on acute symptoms today) and a follow-up spirometry test. These participants were all the workers who were potentially exposed to diesel exhaust underground and a group of surface workers who were considered not to be exposed to diesel exhaust. There were no data on the nonparticipants to determine whether results were biased with respect to disease or exposure.

The prevalence of chronic respiratory symptoms (cough, phlegm, and dyspnea) and the average FEV_1 and FVC were compared between Troy workers and a non-dust exposed population in order to estimate possible dust or diesel particulate effects. "Chronic cough" was defined as a cough on most days for as much as three months each year. "Chronic phlegm" was defined as the production of phlegm on most days for as much as three months each year. "Chronic dyspnea" was positive if the subject answered yes to having to stop for breath when walking at own pace on the level. Data on respiratory symptoms and pulmonary function from a study of unexposed blue-collar workers were available for this purpose. Although some results from the blue-collar study have been published,[8,9,10] the data were retabulated for this health hazard evaluation. FEV_1 and FVC in Troy miners were compared to predicted values for current, former, and nonsmoking blue-collar workers[9] and to predicted values for nonsmokers.[11]

The prevalences of acute symptoms often associated with work and arising during the workshift were compared between workers who were currently employed in surface versus underground locations.

Company Radiographic Examinations

The company's most recent posteroanterior chest radiographs, which had been taken by a local hospital on 293 current Troy Mine employees, were collected by the NIOSH investigators. Over 50% of the radiographs had been taken within one year prior to the NIOSH survey, and over 76% had been taken within the preceding 3 years.

Each radiograph was classified for pneumoconiosis by 3 "B" readers according to the 1980 ILO classification.[12] A consensus of the three readers as to type and profusion of small opacities, size of large opacities, and evidence of pleural thickening on the chest wall, diaphragm, and costophrenic angle was derived for analysis.

Company Audiograms

The audiograms were not reviewed in order to determine individual's auditory responses to their noise environment. Rather, the tests were viewed in a way that NIOSH could make some statements about the efficacy of the company's hearing conservation program. A total of 251 sets of audiograms were reviewed. Each set consisted of a number of audiometric examinations ranging from one test to 5-6 tests over a period of the individual's work history. Generally, the first tests were conducted in 1983, and results were posted up to 1988 for those employees still at the mine. One initial difficulty encountered in the analysis was an inability to read the strip paper which contained the microprocessor audiometer test results. The photocopying of the paper was very poor, and in several instances, some, or even all, of the test values were illegible. Of those tests which could be deciphered, only those individuals who had received audiometric testing in late 1983 or early 1984 and who had a repeat audiogram in late 1985 or early 1986 were included in further analyses. The reason for choosing these particular dates was to minimize early learning effects or test anxiety which might be present in the first reported tests of 1983. The later test date was chosen because the company would include only partial audiometric results for the 1987 and 1988 tests. Thus, 74 audiometric test results were selected for analysis.

Potential hearing loss in workers was evaluated by employing data on the mean hearing level in decibels (dB HL) in both ears at the seven frequencies tested by the audiometer. Additionally, the statistic for the percent better/worse (%BW)[13] was also employed. This statistic is established by determining the percentage of the tested population that shows a hearing level shift or change of 15 dB HL in either ear when sequential audiometric examinations are compared to one another. This statistic falls in an acceptable range if the percentage of the tested population is 30% or less.[13] The rationale behind this statistic is that people who are responding correctly to the audiometric examination and who are either exposed to non-damaging noise or who are adequately protected from the noise will exhibit minimal changes over the short-term time period. Conversely, if people are being over exposed to noise, or are not properly instructed in audiometric test taking, they will be prone to show hearing level changes in excess of 15 dB HL on successive tests.

For the 74 sets of tests, the values from the 1984 examinations were subtracted from the values in 1986. A residual positive value would represent a change for the worse since the 1986 hearing level would have to be higher than the 1984 test value in order for this to occur. A change for the better would be indicated by a negative residual value resulting from the 1984 test values being greater than the 1986 test results.

V. Evaluation Criteria and Toxicology

A. Criteria

Evaluation criteria are used as guidelines to assess the potential health effects of occupational exposures to substances and conditions found in the work environment. These criteria are generally established at levels that can be tolerated by most healthy workers occupationally exposed day after day for a working lifetime without adverse effects. Because of variation in individual susceptibility, a small percentage of workers may experience health problems or discomfort at exposure levels below these existing criteria. Consequently, it is important to understand that these evaluation criteria are guidelines, not absolute limits between safe and dangerous levels of exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria considered in this report are: (1) NIOSH recommended exposure limits (REL's)[14,15,16], (2) the 1991 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's)[17], and (3) the 1973 ACGIH TLV's adopted by the Mine Safety and Health Administration (MSHA) for metal and nonmetallic underground mining.[18,19] The NIOSH recommendations and the current ACGIH TLV's are often lower than the corresponding MSHA standards.

The exposure criteria are reported as: time-weighted average (TWA) exposure recommendations averaged over the full work shift; short-term exposure limit (STEL) recommendations for a 10-15 minute exposure period; and ceiling levels (C) not to be exceeded for any amount of time. These exposure criteria and standards are commonly reported as parts contaminant per million parts air (PPM), or milligrams of contaminant per cubic meter of air (mg/m^3). For the substances monitored during this survey, the environmental criteria are listed in Table 2.

B. Toxicology

This section describes the possible toxicological and physiological effects in workers exposed to the substances monitored during the survey. These effects are described so workers will be familiar with the symptoms and health consequences of overexposure. The effects depend upon such factors as concentration of the material, length of exposure, individual susceptibility, workload, and possible synergistic or additive effects of more than one substance.

Oxides of Nitrogen

There does not appear to be any definitive data in the scientific literature concerned with the chronic effects in humans or animals exposed to NO at low concentrations. It is known that exposures at high concentrations of NO interferes with the oxygen carrying capacity of blood in both humans and experimental animals. It is also improbable that exposures to NO alone, as opposed to a mixture of NO and NO_2, would occur in an occupational setting.[20] Animal experimental data suggest that NO is about one-fifth as toxic as NO_2 and that in mixtures with carbon monoxide, as well as NO_2, additive effects should be assumed.[21]

It is difficult to extrapolate animal data to occupational exposure. However, two important etiologies have emerged from animal research. First, a specific concentration of NO_2 with intermittent exposure is less toxic than with continuous exposure. Second, the toxic hazard associated with NO_2 during continuous exposure is primarily determined by the peak and not by the average concentration of exposure. There are data which indicate nearly equivalent effect on the severity of experimental respiratory infections from continuous exposure at 2.0 ppm and from continuous exposure at 0.5 ppm with 1-hour peaks at 2.0 ppm, and that brief high-level exposures are more hazardous than longer exposures at low concentrations.[20]

Studies conducted on persons with chronic respiratory disease (bronchitis) indicate that 15-minute exposure to NO_2 at concentrations above 1.5 ppm result in an increase in small airway resistance resulting in decreased pulmonary function. Similar changes have been observed in healthy subjects exposed at 4-5 ppm. The specific concentration at which these changes begin to occur in normal human subjects is unknown, but it is likely to be at about the same concentration as the one inducing pulmonary changes in persons with existing chronic bronchitis.[20]

Inhalation of NO_2 ranging from 50-100 ppm causes irritant cough, headache, and breathlessness. If the concentration is high enough (100-500 ppm), acute pulmonary edema may develop after a characteristic delay of up to 12 hours.[20,22]

Coal Tar Pitch Volatiles/Polynuclear Aromatic Hydrocarbons

CTPV's include the fused polycyclic hydrocarbons (PNA's) that volatilize from the distillation residues of coal, petroleum (excluding asphalt), wood and other organic matter.[23] The potential adverse health effects of PNA's are well recognized.[23,24] Repeated exposure to CTPV's has been associated with an increased risk of developing bronchitis and cancer of the lungs, skin, bladder, and kidneys.[14] Several of the PNA's which have been found in gasoline and diesel exhaust are known to be carcinogenic based on animal studies.[24,25] Also, ACGIH includes chrysene and benzo(a)pyrene in its list of industrial substances suspect of carcinogenic potential for man.[17]

Diesel Particulate

Diesel particulates are submicron in size and are comprised of insoluble carbonaceous matter and adsorbed soluble hydrocarbons. It has been suggested that the particulates act as carriers of other diesel exhaust pollutants (sulfur dioxide, nitrogen dioxide, sulfates) and transport the irritants into the deeper, and more sensitive, recesses of the lung. Therefore, diesel particulate appears to promote synergistic adverse health effects.[26,27]

In 1986, NIOSH issued a document which stated that workers exposed to diesel exhaust experienced eye irritation and reversible decrements in pulmonary function. There did not appear to be a causal relationship between exposure to whole diesel exhaust and cancer; but, based on animal studies, such a relationship was plausible.[27] Based on additional animal studies, NIOSH in 1988 recommended that whole diesel exhaust be regarded as "a potential occupational carcinogen" and that worker exposure be reduced to the lowest feasible limits.[27]

Carbon Monoxide

The main effect of CO exposure is its effect in lowering the oxygen-carrying capacity of blood. The early typical signs and symptoms of acute CO poisoning are headache, dizziness, fatigue and nausea.[28] Generally speaking, employee exposure to CO at less than the NIOSH recommended exposure limit of 35 ppm will prevent acute CO poisoning and provide protection from adverse health effects.

Formaldehyde

Formaldehyde is an intense irritant of the upper respiratory passages. For this reason, systemic poisoning is unlikely since workers would be compelled to leave the exposure area before levels sufficient to cause systemic poisoning were reached. Acute exposure to formaldehyde can cause a variety of symptoms. The first symptoms noticed on exposure to concentrations ranging from 0.1 to 5 ppm are burning of the eyes, tearing, and general irritation of the upper respiratory passages.[29]

Currently, NIOSH recommends that, "formaldehyde be handled as a potential occupational carcinogen" based on studies in which laboratory rats exposed to formaldehyde vapor developed nasal cancer. Based on these studies and formaldehyde's demonstrated mutagenic capabilities, NIOSH recommends the reduction of occupational exposure to "the lowest feasible limit".[29]

Respirable Dust/Free Silica

Crystalline silica, referred to as free silica, is defined as silicon dioxide (SiO_2) in the form of quartz, tridymite, and cristobalite. The chief concern of excessive free silica exposure is the development of silicosis. This form of pneumoconiosis is characterized by a nodular pulmonary fibrosis caused by the inhalation and pulmonary deposition of dust containing crystalline silicon dioxide. In silicosis, as in many other pneumoconioses, the various stages of progression of silicotic lesions are related to the degree of exposure to free silica, the duration of exposure, and the length of time the dust is permitted to react with the lung tissue. Clinical symptoms of silicosis may include, cough, sputum production, and shortness of breath. There may be little or no symptoms or decrements in pulmonary function when only discrete nodular (simple) silicosis is present. The two main complications of simple silicosis are the development of complicated forms of disease and tuberculosis. Simple silicosis has a definite tendency to progress even in the absence of further exposure to dust containing free silica.[30] NIOSH also considers silica to be a potential occupational carcinogen.[16]

Noise

Exposure to excessive noise causes hearing loss which may be temporary or permanent, depending on the level and frequency characteristics of the noise, duration of exposure, and the susceptibility of the individual.[31] Temporary hearing loss means that the person's hearing sensitivities will return to normal, given adequate time away from significant sources of noise.[31,32] Permanent losses are irreversible and cannot be corrected by conventional therapeutic procedure.[31]

Noise-induced hearing loss is a difficult problem because, as a rule, the damage develops over a long period of time and the loss of hearing may not be apparent until a considerable amount of damage has been done.

Excessive noise exposure may also evoke extra-auditory effects. These can include elevations in blood pressure and increased nervous tension. Work in a noisy environment may also effect the quality and efficiency of job performance and may have safety implications.[32]

VI. Results and Discussion

A. Environmental

Samples, for which TWA's were computed, were collected over the length of a normal work period. For some of the area samples, the sampling period was less than eight hours; however, a zero value was not assigned to the unsampled portion of the work shift in computing the TWA's because it was assumed that there was exposure throughout the work shift.

Oxides of Nitrogen

Nitrogen dioxide and nitric oxide are components of diesel exhaust. Fifty-two personal breathing zone and two area passive dosimeters were collected in the mine and analyzed for oxides of nitrogen. Also, 13 detector tube samples for NO_2 were obtained. The full-shift exposure levels of NO_2 measured with the dosimeters ranged from 0.16 ppm to 4.61 ppm with a mean exposure of 1.45 ppm (Tables 3,4). These results indicate that exposures were in excess of the NIOSH recommended ceiling level of 1 ppm. Also five of the 54 samples exceeded the 1991 ACGIH TWA of 3 ppm. With TWA's greater than 3 and 4 ppm, it is likely that the MSHA ceiling standard of 5 ppm for NO_2 was also exceeded sometime during the work shift.

None of the 13 detector tube readings for NO_2 (Table 5) exceeded the MSHA TLV. However, nine exceeded the NIOSH recommended limit. The full shift NO exposure measured with the passive dosimeters (Table 3) ranged from 0.56 ppm to 24.76 ppm, with a mean exposure of 10.99 ppm. None of these measurements exceeded the current standard of 25 ppm TWA.

Twelve personal breathing zone samples were collected on workers in the surface operations using passive dosimeters. As indicated by the values recorded in Table 6, the surface workers were exposed to minimal amounts of oxides of nitrogen.

Review of the MSHA sampling data collected during the period November 1980 through August 1987 indicated that MSHA had taken 102 detector tube readings for NO_2 in the mine. Of the 102 samples, two exceeded the MSHA standard of 5 ppm (ceiling) and 57 (56%) equalled or exceeded the NIOSH REL of 1 ppm (ceiling). Values ranged from 0 ppm to 9 ppm, with a mean of 1.47 ppm.

Coal Tar Pitch Volatiles/Polynuclear Aromatic Hydrocarbons

Results of area sampling for CTPV's and PNA's are presented in Table 7. Fifteen filter samples were analyzed for benzene soluble CTPV's and 18 filter/solid sorbent tube samples were analyzed for 14 individual PNA's.

Results of sampling for CTPV's ranged from 0.11 mg/m^3 to 1.67 mg/m^3. Twelve (67%) of the eighteen sample concentrations were above the 1991 ACGIH TLV and the MSHA adopted 1973 ACGIH TLV of 0.2 mg/m^3.

The PNA concentrations presented in Table 7 are the sum of the particulate PNA's collected on the filter and the vapor state PNA's collected on the back-up sorbent tube. In some cases the compounds were detected only on the filter and in others only on the sorbent tube. No PNA's were detected on the two samples collected outside the mine. Of the 14 different PNA's analyzed for, only six (acenaphthene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene) were detected.

The 1973 ACGIH TLV's, which MSHA requires metal and nonmetallic underground mines to abide by, consider CTPV's to be (benzene soluble fraction) anthracene, benzo(a)pyrene, phenanthrene, acridine, chrysene, and pyrene. It seems from this context that the presence of any of these or similar compounds would establish the aerosol as a CTPV. However, MSHA does not consider 'petroleum (diesel) combustion to be a source of CTPV.

PNA's are perhaps the most ubiquitous of carcinogenic agents that have been detected in the atmosphere. It is not possible to quantitate the potential human health risks incurred by the interaction of PNA's either among themselves or with other agents in the environment.[33] However, in developing its criteria document for carbon black, NIOSH concluded that carbon black by itself had not been shown to cause cancer, but the carcinogenicity of the benzene extracts of carbon black was well documented. Reports on the carcinogenicity of the PNA's absorbed on the carbon blacks, their elutability by human plasma, and the ability of carbon black to enhance retention of known carcinogens indicated that occupational exposure to carbon black posed a significant carcinogenic hazard.[34] Based on these NIOSH conclusions and the opinion that diesel particulates are very similar to carbon black in size, structure, composition and method of generation, it would be prudent to consider the level of PNA's and CTPV's detected during the survey as toxicologically significant. Whether they are of significant magnitude to increase cancer rates is not known.

Diesel Particulates

A total of 30 personal breathing zone and area samples were collected in the mine in an effort to determine the diesel fraction of respirable dust. In addition to the samples being collected and analyzed as described by Cocalis, J. et al[6], 23 of the filters were subjected to low temperature ashing (LTA) per NIOSH Analytical Method 7500[5] in an attempt to determine or verify what percentage of the sub-micrometer particles collected was actually of organic/diesel origin.

As can be seen in Table 8, a major portion of the total respirable mass collected consisted of sub-micrometer particles (diesel fraction). Diesel fraction concentrations ranged from 0.22 mg/m^3 to 3.99 mg/m^3 with a mean concentration of 1.60 mg/m^3. Low temperature ashing of the filters indicated that the particulate on the filters was apparently organic/diesel particulate and not hard rock dust, since in almost all cases, more than 90% of the particulate weight was lost after washing.

Carbon Monoxide

The results for carbon monoxide, as shown in Table 9, varied from approximately 2 ppm to greater than 25 ppm. The investigators were unable to determine definite concentrations for eight of the nineteen samples collected because the maximum readable amount on the detector tube was exceeded. The range of measurement in ppm for maximum duration of use (• 4 hours at 20 cc/min) is 2.5 to 25 ppm. It did not appear that the 1973 ACGIH (MSHA) and the 1991 ACGIH TLV of 50 ppm, or the NIOSH REL of 35 ppm were exceeded.

Formaldehyde

Seventeen area measurements for formaldehyde were collected. Results for all but two of the samples were less than the limit of quantitation (0.09 ppm). A concentration of 0.1 ppm was recorded for a sample on a loader and a truck.

Respirable Silica

Tables 10, 11, and 12 presents and/or summarizes the results of respirable dust samples collected for the various job categories in the underground and surface operations. A total of 34 personal breathing zone and area air samples were collected underground and 23 personal breathing zone samples for the surface operation. These samples were analyzed both gravimetrically and for free silica content by x-ray diffraction. No cristobalite was found in any of the samples. Quartz was the only form of crystalline silica identified. The limit of detection for both quartz and cristobalite was 0.018 mg/m^3.

The overall mean exposure for respirable dust in the underground operation was 2.24 mg/m^3 with a range of 0.26 mg/m^3 to 16.74 mg/m^3. The personal breathing zone samples collected in the surface operations had a mean respirable dust concentration of 0.38 mg/m^3; the range was 0.06 mg/m^3 to 3.36 mg/m^3. The samples collected in the surface operations had a greater mean quartz content (percent by weight) than the samples collected underground. The surface samples had a mean quartz content of approximately 24%, as compared to 7% for the underground samples. Forty-seven percent of all the underground samples exceeded the calculated MSHA TLV, and 59% exceeded the NIOSH REL for respirable silica. Seventeen percent of the surface samples exceeded the calculated MSHA TLV, and 39% exceeded the NIOSH REL for respirable silica.

Review of the MSHA sampling data revealed that from 1980 through 1987, approximately 85 respirable dust samples had been collected in the underground and surface operations at the Troy Unit. Approximately 26% of all the MSHA samples exceeded the MSHA calculated TLV, and approximately 35% exceeded the NIOSH REL for respirable silica.

Noise

Results presented in Table 13 show that the workers in both the underground and surface operations, especially the underground operation, were potentially exposed to excessive noise. Eight-hour TWA exposures ranged from 65.5 dBA to 103.8 dBA. Twenty-one of the 22 personal dosimeters readings obtained underground and six of the 19 readings obtained on the surface exceeded the NIOSH REL and the 1991 ACGIH TLV of 85 dBA for an eight hour exposure. Eighteen of the 22 and 4 of the 19 also exceeded the 1973 ACGIH (MSHA) TLV of 90 dBA for an eight-hour exposure.

During the period 1980 through 1987, MSHA collected approximately 103 personal noise dosimeter measurements at the Troy Unit. Approximately 44% of the measurements exceeded the MSHA standard. In 1982, representatives of MSHA's Physical Agents Division, Denver, Colorado conducted a noise survey at the Troy Unit. They evaluated the Wagner 35-ton truck, Caterpillar-Rome truck and Caterpillar 980 loader to determine if any engineering controls could be implemented to reduce the operators' noise exposure. It was determined that certain modifications could be and were implemented to reduce the noise levels on these pieces of equipment. However, there are many other pieces of equipment (i.e. Caterpillar Front End Loaders 930 and 910, Atlas Copco track drills ROC

808's and 812's) used at the Troy Unit which apparently have not been evaluated since no information on these pieces of equipment is provided in MSHA's Noise Control Abstracts[(35)]. Also, the Atlas Copco Jumbo Drills used at the Troy Unit do not have operator cabs. Information provided in the Noise Control Abstracts indicates a significant noise reduction when cabs are present. Therefore, if the equipment has not been evaluated and in the case of the jumbo drills, it would be inappropriate to state that all feasible engineering controls were being used.

ASARCO conducts audiometric testing for all new employees and periodic testing of individuals employed in areas designated by the company as noise hazardous. Personal hearing protection is also provided for all the workers at the Troy Unit.

Respiratory Protection

During the survey, it was apparent that the company relies on the use of personal respiratory protection to protect the health of the worker. The respiratory protective devices provided are approved to protect the worker from the particulates and organic vapors that may be present in the work environment. However, based on discussions with the workers, at least two problems exist. First, the workers either are not adequately informed about the proper use of the respirators provided and/or they do not trust the information provided by the respirator manufacturer and/or the company. Secondly, there is no established/written respiratory protection program at the Troy Unit. A respirator program consistent with the requirements of ANSI Z88.2-1980, published by the American National Standards Institute and entitled "American National Standards Practices for Respiratory Protection" would insure that the workers are properly informed and protected.

B. Medical

Questionnaire and Spirometry

Because only 122 (39%) of the 314 current employees participated in the NIOSH medical survey, the applicability of the HHE results to the entire Troy Mine work force is unclear.

The estimated prevalence of chronic cough and phlegm in the 122 workers was higher in Troy miners than in the unexposed blue-collar (BC) workers regardless of cigarette smoking habit (Table 14). There did not appear to be a higher prevalence of chronic dyspnea in Troy miners than BC workers.

Observed baseline values of FEV_1 and FVC in the Troy miners were either equal to or significantly higher than the BC and Knudson (KN) predicted values, regardless of cigarette smoking habit and age group (Table 15).

The workers were asked about the frequency of acute symptoms while at work. Table 16 presents the prevalences of those symptoms reported occurring often by surface or underground job category. Surface workers reported cough and sneeze more frequently, while underground miners had higher prevalences of work-related eye irritation, upset stomach, and headache. Although there are no norms for prevalences of these symptoms in unexposed workers, many of the symptoms are consistent with exposure to airborne irritants, including diesel exposures.[(36)] On the other hand, these symptoms could also be due to etiologic factors other than Troy Mine exposures.

The prevalence of acute symptoms which were reported to have developed during the work day appear high in the 81 workers who completed the post-shift questionnaire (Table 17). Same day recall may have helped boost this number.

In the 81 workers who had performed pre- and post-shift spirometry (Table 18), the average decline in FEV_1 and FVC over the workshift was similar between workers employed underground and those at the surface. The average change in FEV_1 was statistically different than zero in underground workers, and the average change in FVC was statistically different than zero in both underground and surface workers. When compared to the shift changes observed in non-dust exposed blue-collar workers, underground workers had statistically larger average FEV_1 and FVC declines and surface workers had a statistically larger FVC decline. Overall, 14 (8 surface, 6 underground) of the 122 participants (11%) showed an obstructive pattern in their pulmonary function which is not statistically different from the 8% observed in the non-dust exposed blue-collar workers. Of these, six were current smokers, 7 former smokers, and one had never smoked. No cases of restriction were found.

Company Radiographic Examinations

In 293 workers with available radiographs, there were 18 (6%) cases of ILO category 1/0 or greater small radiographic opacities and no cases of large opacities (Table 19). Rounded and irregular small opacities were present in each case. Irregular opacities were the primary opacity in 6 cases, rounded in 9 cases, and no consensus (both types) in 3 cases. Pleural thickening on the chest wall and at the costophrenic angle was reported in one case who also had evidence of irregular opacities.

In 431 blue-collar workers with less than 1 year in a dusty job, the prevalence of small opacities was 0.2% (1/431) in the total group, 0.4% (1/226) in current cigarette smokers, and 2.3% (1/44) in current cigarette smokers over age 40.[37] Thus, the prevalence of radiographic small opacity cases was higher in the Troy miners than in the unexposed BC group. Whether radiographic findings are due to Troy Mine exposures or to dust exposures in other jobs could not be determined from these data. The short work tenures at Troy Mine and evidence of irregular opacities in many cases argue against Troy Mine dust exposures as the sole explanation for the findings.

Company Audiograms

In order to view the overall hearing levels of workers at this mine, the arithmetic mean value for the left and right ear test results from the 1986 examination were calculated and plotted. The pattern seen in Figure 1 is typical of a population which has been exposed to excessive noise. This pattern is typified by hearing level values in both the left and right ears near normal at low frequencies (500 to 2000 Hertz (Hz)) and with a rapidly sloping higher frequency loss at 3000, 4000, and 6000 Hz. Finally, a slight recovery is noted at the test frequency of 8000 Hz. This configuration is called a "noise notch" and represents a permanent, sensori-neural hearing loss usually from overexposure to noise.

It must be noted that this analysis can only be a first approximation to the typical hearing ability profile because of incomplete information in the audiometric tests which were sent for analysis. No age correlations were made on these data because not all tests included this information. Also, no allowance for the area where the worker was assigned at the time of the audiometric test or the amount of time the individual had been employed by the mine was included in the analysis. All of these latter variables can have an effect on the mean hearing level values but were not factored into this analysis because of their unavailability.

When these test data were calculated for the %BW statistic, this analysis showed a %BW value of 62.27, a result well into the unacceptable range.[13] Specifically, 15 individuals exhibited a change for the better, 23 individuals changed for the worse, and 8 people showed both a better and worse change at different frequencies. Thus, it appears that the validity of the tests being recorded was questionable. The fact that 8 of 74 individuals (10.8%) showed both positive and negative changes of 15 dB HL or greater leads one to believe that the audiometric examinations were not accurate representations of the workers' hearing abilities. Whether the changes for the worse in 23 workers were the result of the occupational noise exposure at the Troy Mine cannot be determined from these limited data.

Two major deficiencies were noted in the review of all of the audiometric test data sent to NIOSH. First is the inaccurate and incomplete recordkeeping seen on several of the audiometric tests. The company is using a form which asks several pertinent questions about the state of the worker's hearing. However, in most instances where more than one test was included for a given worker, the examiner failed to completely fill out the form for each annual examination. In some instances, only the worker's name was included with no additional information. Because several workers with common surnames are employed by this mine, it makes it very difficult to determine if the test results are from the same person. There were also variations observed in data on successive examinations for the same individual (same last name and social security number). These variations included birth date, age, and work and military histories. These data must be accurate in order to completely analyze the effectiveness of the hearing conservation program. The data of the audiometric test were also in question on several of the reported examinations. There were instances where the test date was not entered into the microprocessor as well as obviously incorrect test dates being entered. The dates of calibration of the audiometer were also missing from the data.

The second deficiency observed is the company's decision to limit the test frequencies being reported on the 1987 and 1988 audiometric tests. Results through 4000 Hz only were recorded on the workers' forms. This is a major flaw in the program. Test results at 6000 and 8000 Hertz are crucial if one is to determine if the changes in hearing are the result of noise exposure and also to determine the effectiveness of the company's decisions on the use of hearing protection devices, the types of these devices, and whether the employees are wearing them properly once they have been issued.

VII. Conclusion and Recommendations

A. Environmental

On the basis of the environmental information obtained during the survey at the Troy Unit, NIOSH has determined that a health hazard existed due to employee exposure to respirable silica, noise, and products of diesel combustion.

The following recommendations are offered to assure that the chronic exposures to the contaminants are kept to a minimum and/or eliminated:

1. From discussions with company officials and MSHA personnel, it is apparent that a large volume of forced air ventilation is provided to the mine. However, the mine is very large and there is not sufficient air velocity and/or the air is not properly directed to dilute or remove the contaminants from the working areas. A better ventilation plan should be designed and implemented to increase air movement in the working areas.

2. The excess cancer risk for workers exposed to diesel exhaust has not been quantified, but the probability of developing cancer should be decreased by minimizing exposure.[26] As a prudent health policy, employers should reduce exposures to the lowest feasible limits. This can be achieved by good mine ventilation, proper maintenance of the diesel engines, and installation of various engineering controls (scrubbers, catalytic purifiers, filters) on the engines to reduce the pollutants emitted.

3. In general, a noise control/hearing conservation program was present at the Troy Unit. Personal hearing protective equipment was provided and medical surveillance was conducted. However, it appeared that additional engineering controls should be implemented which would reduce the noise levels. It is recommended that representatives of MSHA's Physical Agents Division, Technical Support, be requested to assist the company in designing and evaluating noise controls on the equipment which was not included in their 1982 survey. It is also recommended that the feasible engineering controls be installed, maintained, and periodically evaluated.

4. Where accepted engineering control measures have not been developed or when necessary by the nature of the work involved (for example, while establishing controls or occasional entry into hazardous areas to perform maintenance), employees may work for reasonable periods of time in concentration of airborne contaminants exceeding permissible levels if they are protected by appropriate respiratory protective equipment. When respiratory protective equipment is used, an established program for selection, maintenance, training, fitting, supervision, cleaning, and use shall be established as required by MSHA regulations. It is recommended that a respirator program consistent with the requirements of ANSI Z88.2-1980, published by the American National Standards Institute and entitled "American National Standards Practices for Respiratory Protection ANSI Z88-2-1980", approved March 11, 1981 be established at the Troy Unit. The attached Appendix II provides a general description of the ANSI requirements for a respiratory protection program.

B. Medical

The prevalence of chronic respiratory symptoms was higher in Troy miners than in a previously reported study of unexposed blue-collar workers. Additionally, radiographic results indicated a higher prevalence of small radiographic opacities in Troy miners than in the unexposed workers after accounting for differences in age and cigarette smoking habit. Surface and underground workers showed a similar decline in average FEV_1 and FVC over the work shift. Both groups had a greater decline in average FVC and underground workers had a greater decline in average FEV_1 than that observed in the unexposed blue-collar workers.

Whether chronic health effects have been the result of exposure to diesel particulates and respirable dust in the Troy Mine is unclear for several reasons. First, the prevalence of symptoms and pulmonary function abnormalities may have been over or underestimated if non-participants in the NIOSH examinations were different than participants. Because the participation rate was only 39%, the applicability of the results to the entire workforce is unclear. Second, exposure from employment in other dusty jobs could contribute to the chronic disease findings.

The higher prevalences of chronic respiratory symptoms in the participants and decline in FEV_1/FVC ratios in 14 workers are consistent with chronic obstructive lung disease. However, whether these findings were caused by exposures at the Troy Mine is unclear. Exposures at the Troy Mine are an unlikely explanation because the mine was in operation only eight years.

Diesel exposures over longer periods of time have not been associated with chronic lung disease.[36] Silicosis typically requires an exposure period of 15 or more years to develop. Although dust exposures at Troy cannot be ruled out, more likely explanations are selection excluding a large number of healthy workers from the study or confounding from exposures in previous dusty jobs other than at the Troy Mine. In any event, these hypotheses cannot be verified from available information. Because some Troy miners have evidence of obstructive lung disease and small radiographic opacities characteristic of pneumoconiosis, there should be continued concern to prevent further development of dust-induced disease in these workers by adherence to federal exposure standards and NIOSH REL's.

Pneumoconiosis is a condition characterized by the deposition of dust in the lungs and the reaction of the lung tissue to this dust. It can frequently be detected in a preclinical phase before symptoms develop and the effected individual would otherwise seek medical attention. Intervention, primarily in the form of exposure reduction, is more beneficial in the preclinical phase than in a clinical phase. Early intervention will often limit permanent damage, a critical point since nearly all pneumoconioses have no effective treatment.

The screening method that is generally available to recognize pneumoconiosis is the chest x-ray. The chest radiograph is reproducible, acceptable, and widely available. Equipment, expertise, and experience to obtain and interpret chest x-rays satisfactory for the detection of pneumoconiosis is readily available. An international classification for evaluating chest x-rays for the presence of pneumoconiosis exists and includes standard x-ray example films. To increase the x-ray reader's expertise in interpretation, NIOSH has developed teaching materials and an examination (B reader) to document a reader's ability in this area.

Recommended methodology for x-ray surveillance would follow NIOSH guidelines for obtaining the x-rays and use NIOSH certified "B" readers, or radiologists with comparable expertise, to interpret the films. Agreement among two or three readers is suggested.

NIOSH recommends that medical examinations should be made available to all workers subject to dust and silica exposure prior to employee placement.[30] Examinations shall include as a minimum:

1. A medical and occupational history to elicit data on worker exposure to dust and signs and symptoms of respiratory disease.
2. A chest radiograph (posteroanterior 14" x 17") classified according to the 1980 ILO International Classification of Radiographs of Pneumoconioses. Repeat chest x-ray is recommended at 5-year intervals.
3. Pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume at one second (FEV_1) to provide a baseline for evaluation of pulmonary function and to help determine the advisability of the workers using negative- or positive-pressure respirators. Repeat spirometry is recommended at yearly intervals and at termination of potential exposure or of employment.
4. Body weight.
5. Height.
6. Age.

If positive findings are found on the chest x-ray or spirometry tests or both, the worker should be notified and be referred for further clinical evaluation to establish whether the condition is work-related. If workplace-related airways obstruction or pneumoconiosis is confirmed by the clinical evaluation, the workplace environment should be evaluated, and the worker should no longer be exposed to the inciting agent(s).

In light of the many adverse health effects of smoking, it would seem prudent for the company to encourage cigarette abstinence and to provide smoking cessation and incentive programs for the employees.

A hearing conservation program should be designed and administered in a manner to protect workers with significant occupational noise exposures from suffering material hearing impairment even if they are subject to such noise exposure over their entire working life time. An important step or process in an effective hearing conservation program is audiometric testing. The deficiencies noted in our review of the ASARCO audiograms would lead one to question the validity and reliability of their audiometric testing program.

Currently MSHA does not have a requirement nor published guidelines for a hearing conservation program. However, they are planning to propose such a requirement. On the other hand, the Occupational Safety and Health Administration (OSHA) has a hearing conservation requirement for general industry which includes excellent guidelines for audiometric testing. NIOSH has a criteria document which also provides excellent guidelines for an effective hearing conservation program. We, therefore, recommend that ASARCO consult both the OSHA and NIOSH documents (references 15 and 38) for guidance in establishing and maintaining an effective hearing conservation program.

VIII. References

1. ASARCO The Troy Mine, ASARCO Incorporated, Troy, Montana.

2. Palmes, E.D., et al, Personal Sampler for Nitrogen Dioxide, American Industrial Hygiene Association Journal, No. 37, 570-577 (1976).

3. Palmes, E.D., Tomczyk, C. Personal Sampler for NOX, American Industrial Hygiene Association Journal, No. 40, 588-591 (1979).

4. Detector Tube Handbook, Air Investigations and Technical Gas Analysis with Drager Tubes, Dragerwerk AG Lubeck. 6th Edition, 1985.

5. NIOSH (1986). NIOSH Manual of Analytical Methods, 3rd Edition, U.S. Dept. of Health and Human Services, PHS, CDC, NIOSH, DHEW (NIOSH) Pub. No. 84-1000.

6. Cocalis, J. et al., The Diesel Fraction of Respirable Dust in Underground Diesel Coal Mines. Proceedings of the 18th Annual Institute on Coal Mining Health, Safety and Research, pp 63-75, Blacksburg, VA. August 1987.

7. American Thoracic Society. ATS Statement - Snowbird Workshop on Standardization of Spirometry. Am. Rev. Respir. Dis. 1979: 119:831-38.

8. Petersen, MR and Castellan, RM (1984): Prevalence of Chest Symptoms in Non-exposed Blue-Collar Workers. J. Occup. Med. 26:367-374.

9. Petersen, M and Hankinson, J (1985): Spirometry Reference Values for Non-exposed Blue-Collar Workers. J. Occup. Med., 27:644-650.

10. Ghio, AJ, Castellan, RM, Kinsley, KB, Hankinson, JL (1991): Changes in Forced Expiratory Volume in One Second and Peak Expiratory Flow Rate Acress a Work Shift Among Unexposed Blue-Collar Workers. Am. Rev. Respir. Dis. 143:1231-1234.

11. Knudson, RJ, Lebowitz, MD, Holberg, CJ, Burrows, B. (1983): Changes in the Normal Maximal Expiratory Flow-volume Curve with Growth and Aging. Am. Rev. Respir. Dis. 127:725-34.

12. ILO Committee on Pneumoconiosis (1981): Classification of Radiographs of the Pneumoconiosis. Med. Radiogr. Photogr. 57:2-17.

13. Royster, JD and Royster, LH. Noise and Hearing Conservation Manual, Chapter on Audiometric Data Base Analysis. 4th Edition, Ed EH Berger et al, Amer. Ind. Hyg. Assoc., Akron, Ohio 1986.

14. NIOSH/OSHA. Occupational Health Guidelines for Chemical Hazards. U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, U.S. Dept. of Labor. January 1981.

15. NIOSH. Criteria for a Recommended Standard; Occupational Exposure to Noise, DHEW (NIOSH) Publication No. 73-11001.

16. NIOSH. NIOSH Pocket Guide to Chemical Hazards. U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, Dept. of Health and Human Services (NIOSH). Publication No. 90-117.

17. ACGIH (1991). Threshold Limit Values and Biological Exposure Indices for 1991-1992. Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

18. ACGIH (1973). Threshold Limit Values for Chemical Substances in the Workroom Air Adopted by ACGIH for 1973, Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

19. Code of Federal Regulations. U.S. Dept. of Labor, Mine Safety and Health Administration. 30 CFR Part 57, 1977.

20. NIOSH. Criteria for a Recommended Standard; Occupational Exposure to Oxides of Nitrogen. HEW Publication No. (NIOSH) 76-149.

21. ACGIH. Documentation of the Threshold Limit Values and Biological Exposure Indices. Fifth Edition, 1986. Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

22. Encyclopedia of Occupational Health and Safety, Volumes I and II, International Labour Office, McGraw-Hill Book Company, 1976.

23. OSHA. Occupational Exposure to Coal Tar Pitch Volatiles; Modification of Interpretation. Federal Register, U.S. Dept. of Labor, Occupational Safety and Health Administration, Vol 48, No. 15, January 21, 1983.

24. NIOSH. Criteria for a Recommended Standard; Occupational Exposure to Coal Tar Products. DHEW (NIOSH), Publication No. 78-107.

25. Menster, M. and A.G. Sharky, Jr., Chemical Characterization of Diesel Exhaust Particulates: ERDA, RIMS, 07032, December 1976.

26. ACGIH. Vergeer, H.C., et al. Developments in Diesel Exhaust Emission Control Technology for Underground Mining. International Conference on the Health of Miners. Annals of the American Conference of Governmental Industrial Hygienists, Vol 14, 1986.

27. NIOSH. Current Intelligence Bulletin 50: Carcinogenic Effects of Exposure to Diesel Exhaust. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, August 1988.

28. NIOSH. Occupational Disease, A Guide to their Recognition, NIOSH Publication No. 77-181.

29. NIOSH/OSHA. Current Intelligence Bulletin 34-Formaldehyde: Evidence of Carcinogenicity. DHHS (NIOSH) Publication No. 81-111.

30. NIOSH. Criteria for a Recommended Standard; Occupational Exposure to Crystalline Silica, DHEW (NIOSH) Publication No. 75-120.

31. Patty, F.A., Industrial Hygiene and Toxicology, Vol. I, 1978, New York, John Wiley and Sons.

32. NIOSH. A Guide to the Work-Relatedness of Disease, DHEW (NIOSH) Publication No. 79-116.

33. NIOSH. Criteria for a Recommended Standard; Occupational Exposure to Coal Tar Products, DHEW (NIOSH) Publication No. 78-107.

34. NIOSH. Criteria for a Recommended Standard; Occupational Exposure to Carbon Black; DHEW (NIOSH) Publication No. 78-204.

35. MSHA. Noise Control Abstracts, Second Edition, U.S. Dept. of Labor Mine Safety and Health Administration, Denver Safety and Health Technology Center, Physical Agents Division.

36. Reger, RB and Attfield, MD. Diesel Emissions and Associated Respiratory Effects in Mining. Health Issues Related to Metal and Non-metallic Mining. Ed. W.L. Wagner et al. Butterworth Publishers, Boston 1983, Pg 393.

37. Castellan, RM, Sanderson, WT and Petersen, MR (1985): Prevalence of Radiographic Appearance of Pneumoconiosis in an Unexposed Blue-Collar Population. Am. Rev. Respir. Dis. 1985; 131:684-686.

38. Code of Federal Regulations. U.S. Dept. of Labor, Occupational Safety and Health Administration. 29 CFR 1910.95.

IX. Authorship and Acknowledgements

Evaluation Conducted and Report Prepared by:	Ronnie J. Cornwell, CIH Elizabeth B. Knutti, RN
Medical, Statistical and Industrial Hygiene Assistance:	Kathleen B. Kinsley Clinical Investigations Branch Division of Respiratory Disease Studies
	Harlan Amandus, Ph.D. Epidemiological Investigations Branch Division of Respiratory Disease Studies
	Randy L. Tubbs, Ph.D. Hazard Evaluation and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies
	Rick Ferguson Greg Kullman, CIH John Parker, M.D. Respiratory Disease Hazard Evaluation and Technical Assistance Program Clinical Investigation Branch Division of Respiratory Disease Studies
	Kurt Vandestouwe Technical Support Team Environmental Investigation Branch Division of Respiratory Disease Studies
Originating office:	Respiratory Disease Hazard Evaluation and Technical Assistance Program Clinical Investigations Branch Division of Respiratory Disease Studies National Institute for Occupational Safety and Health Morgantown, West Virginia 26505

X. Distribution and Availability of Report

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days from the date of this report from the NIOSH Publication Office, 4676 Columbia Parkway, Cincinnati, Ohio 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service, 5285 Port Royal, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. Deputy Administrator
   Occupational Health
   UMWA

2. Manager
   ASARCO Troy Unit Mine

3. Chairman, Health and Safety Committee
   Troy Local, UMWA

4. President
   Troy Local, UMWA

5. Senior Environmental Scientist
   ASARCO, Technical Services Center

6. MSHA
   Deputy Administrator for Metal
   and Nonmetal Mine Safety and Health

7. MSHA
   Rocky Mountain District Office

8. NIOSH Regional Office

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

Mention of brand names does not constitute endorsement by NIOSH, CDC, USPHS, or DHHS.

TABLE 1
SAMPLING AND ANALYTICAL METHODOLOGIES
Troy Unit Mine
Troy, Montana
RDHETA 88-104

Substance Sampled	Sampling Media / Analytical Method	Flow Rate (LPM)	Analytical Method Reference
Oxides of Nitrogen (NO_x, NO, NO_2	Triethanolamine Palmes, E.D[2,3] (Passive Dosimeter)	-	Visible Spectrophotometry
	Drager Short Term Drager [4] Detector Tube	-	Direct Reading
Coal Tar Pitch Volatiles	PTFE Laminated NIOSH Method 5023[5] Membrane Filter	1.0	Gravimetric
Polynuclear Aromatic Hydrocarbons	PTFE Laminated Membrane NIOSH Method 5515[5] Filter Plus ORBO 43 Tube	2.0	Gas Chromatography Capillary Column, FID
Diesel Particulates	Cyclone-Impactor-PVC Filter Cocalis, J[6] NIOSH Method 7500[5]	2.0	Gravimetric/LTA
Carbon Monoxide	Drager Long-term Detector Drager[4] Tube	0.02	Direct Reading
Aldehydes	ORBO 23 Tube NIOSH Method 2502[5]	0.05	Gas Chromatography (FID)/ Mass Spectrophotometry
Respirable Silica	PVC Filter NIOSH Method 0500 and 7500[5]	1.7	Gravimetric/X-Ray Powder Diffraction
Noise	Gen Rad Type 1954-9710 GR 1954 Noise Dosimeter, Personal Noise Dosimeter Gen Rad Inc. Concord, Mass. 1978	-	Direct Reading

NOTES: LPM - Liters per minute.
NO_x, NO, NO_2 - Oxides of nitrogen, nitric oxide, nitrogen dioxide.
References are listed in section VIII of the report.

TABLE 2

ENVIRONMENTAL CRITERIA

Troy Unit Mine
Troy, Montana
RDHETA 88-104

SUBSTANCE	NIOSH	1991 ACGIH	1973 ACGIH (MSHA)
Nitrogen Dioxide	1 ppm (Ceiling)	3 ppm (TWA) 5 ppm (Ceiling)	5 ppm (Ceiling)
Nitric Oxide	25 ppm (TWA)	25 ppm (TWA)	25 ppm (TWA)
CTPV's	0.1 mg/m^3 (TWA) (cyclohexane-solubles)	0.2 mg/m^3 (TWA) (benzene-solubles)	0.2 mg/m^3 (TWA) (benzene-solubles)
PNA's	None	None	None
Diesel Particulates	Lowest Feasible Limits	None	None
Carbon Monoxide	35 ppm (TWA)	50 ppm (TWA)	50 ppm (TWA)
Formaldehyde	Lowest Feasible Limits	1 ppm (TWA)	2 ppm (Ceiling)
Respirable Crystalline (Quartz)	0.05 mg/m^3 (TWA)	0.1 mg/m^3 (TWA)	$\frac{10 \text{ mg/m}^3}{\text{\% Respirable quartz} + 2}$ Silica
Noise			
8 hr/day	85 dBA	85 dBA	90 dBA
6 hr/day	87 dBA	87 dBA	92 dBA
4 hr/day	90 dBA	90 dBA	95 dBA
2 hr/day	95 dBA	95 dBA	100 dBA
1 hr/day	100 dBA	100 dBA	102 dBA
1/4 hr/day	110 dBA	110 dBA	115 dBA
1/8 hr/day	115 dBA	115 dBA	

TABLE 3

$NO_x/NO/NO_2$ TWA EXPOSURE (MINE UNDERGROUND)
USING PASSIVE DOSIMETERS (PALMES METHOD)

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job	NO_x (ppm)	NO (ppm)	NO_2 (ppm)
7/13/88	Blade Operator	8.35	5.80	0.81
	Loader Operator	15.86	11.28	1.20
	Track Drill Operator	6.06	4.21	0.59
	Jumbo Drill Operator	15.86	10.59	2.09
	Loader Operator	24.26	17.31	1.76
	Powderman	7.54	4.83	1.26
	Truck Driver	8.60	6.10	0.67
	Truck Driver	14.66	10.60	0.88
	Truck Driver	15.08	10.74	1.11
	Bolter Operator	14.59	10.23	1.29
	Truck Driver	16.74	12.06	1.06
	Bolter Helper	9.04	-	-
	Truck Driver	-	-	1.25
7/14/88	Pad Area (Shop)	-	-	0.31
	Bolter Operator	35.11	24.76	2.92
	Truck Driver	18.91	13.48	1.39
	Loader Operator	23.23	15.45	3.15
	Loader Operator	9.58	6.81	0.73
	Truck Driver	23.99	16.72	2.26
	Truck Driver	18.22	12.88	1.48
	Truck Driver	18.41	12.68	1.93
	Powderman	15.08	10.42	1.53
	Jumbo Drill Operator	-	-	0.53
	Bolter Operator	11.34	7.88	1.10
	Powderman	16.94	11.77	1.64
	Water Truck Driver	21.12	15.26	1.28
	Track Drill Operator	31.77	21.82	3.41
	Primary Crusher Helper	0.89	0.56	0.16
	Track Drill Operator	14.43	10.42	0.88
	Bolter Helper	25.83	17.78	2.72
	Loader Operator	22.58	-	-
	Jumbo Drill Operator	-	-	1.08
	Bolter Helper	-	-	0.74
	Jumbo Drill (Area)	-	-	1.13

TABLE 3 (continued)

NO_x/NO/NO_2 TWA EXPOSURE (MINE UNDERGROUND)
USING PASSIVE DOSIMETERS (PALMES METHOD)

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	JOB	NO_x (ppm)	NO (ppm)	NO_2 (ppm)
7/15-16/88	Trash Loader Operator	1.13	0.67	0.26
	Clean-up Man	11.1	7.65	1.16
	Track Drill Operator	19.09	13.16	1.98
	Powderman	33.72	24.25	2.20
	Jumbo Drill Operator	17.07	12.25	1.14
	Bolter Operator	-	-	4.61
	Track Drill Operator	11.67	8.05	1.22
	Jumbo Drill Operator	18.23	12.69	1.73
	Bolter Helper	-	-	3.14
	Track Drill Operator	2.74	1.75	0.46
	Primary Crusher Operator	2.07	1.45	0.16
	Shifter	11.1	7.55	1.29
	Loader Operator	15.6	10.98	1.32
	Bolter Helper	7.62	5.45	0.53
	Truck Driver	12.43	8.60	1.25
	Truck Driver	16.74	11.55	1.73
	Blaster	24.01	15.91	3.33
	Loader Operator	25.49	17.52	2.71
	Truck Driver	10.68	-	-
	Truck Driver	13.83		
	Bolter Operator	-	-	2.1
	Blade Operator	-	-	0.90
	Primary Crusher Helper	-	-	0.16
	Loader Operator	-	-	0.59
	Range	35.11-0.89	24.76-0.56	4.61-0.16
	Mean	15.62	10.99	1.45
	Standard Deviation	7.99	5.74	0.94

NO_x - Total Oxides of Nitrogen
NO - Nitric Oxide
NO_2 - Nitrogen Dioxide
ppm - Parts Per Million Parts of Air
TWA - Time weighted average

TABLE 4

NO_2 TWA EXPOSURE (MINE)

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Job	Number of Samples	Range (ppm) High	Range (ppm) Low	Mean (ppm)	Standard Deviation	95% Lower Confidence Limit	95% Upper Confidence Limit
All	54	4.61	0.16	1.45	0.94	1.20	1.70
Truck Driver	12	2.26	0.67	1.36	0.44	1.11	1.61
Loader Operator	8	3.15	0.26	1.47	1.02	0.76	2.18
Bolter Op./Helper	9	4.61	0.53	2.13	1.34	1.25	3.01
Track Drillers	6	3.41	0.46	1.42	1.11	0.53	2.31
Jumbo Drillers	6	2.09	0.53	1.12	0.73	0.54	1.70
Powderman/Blaster	5	3.33	1.26	1.99	0.82	1.27	2.71
Primary Crusher Operator/Helper	3	0.16	0.16	0.16	0	-	-
Blade Operator	2	0.81	0.90	0.86	0.06	-	-
Clean-up	1	1.16	1.16	1.16	-	-	-
Shifter	1	1.29	1.29	1.29	-	-	-
Pad (Shop Area)	1	0.31	0.31	0.31	-	-	-

NO_2 - Nitrogen Dioxide
TWA - Time Weight Average
ppm - Parts Per Million Parts of Air

TABLE 5

RESULTS OF SAMPLING FOR NO_2 (MINE)
USING DRAGER DETECTOR TUBES

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Time	Area	Equipment in Area	NO_2 (ppm)
7/13/88		Haulageway	2 Trucks	2
		Heading East 68	1 Loader, 2 Trucks	1.5
7/14/88	1520	Pad	4 Trucks, 3 Loaders	0.5
	1850	Pad		0.5
	1610	West 1	Track Drill	1.5
	2110	West 1	Track Drill	2.0
7/15-16/88	2355	East 55 Bench	2 Trucks, 1 Loader	3.5
	0100	East 55 Bench	2 Trucks, 1 Loader	4
	0115	East 55 Bench	2 Trucks, 1 Loader	4
	0130	East 55 Bench	2 Trucks, 1 Loader	4
	0010	Lower West B39	3 Trucks, 1 Loader	4
	0025	Lower West B39	3 Trucks, 1 Loader	1
	2340	West 1	1 Track Drill, 1 Loader	1

NO_2 - Nitrogen Dioxide
ppm - Parts Per Million Parts of Air

TABLE 6

NO_x/NO/NO_2 TWA EXPOSURE (SURFACE)
USING PASSIVE DOSIMETERS (PALMES METHOD)

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job	NO_x (ppm)	NO (ppm)	NO_2 (ppm)
7/18/88	Crusher Maintenance	0.47	0.29	0.09
	Crusher Maintenance	0.40	0.30	0.01
	Crusher Maintenance	0.54	0.40	0.01
	Lubeman	0.12	0.09	ND
	Mill Maintenance	0.53	0.38	0.03
	Mill Maintenance	0.60	0.41	0.07
	Mill Maintenance	0.53	0.38	0.03
	Mill Maintenance	0.72	0.52	0.04
	Mill Maintenance	1.01	0.72	0.08
7/19/88	Mill Operator	0.42	0.28	0.05
	Float Operator	0.17	0.07	0.08
	Floatman	0.15	0.08	0.05
	Range	1.01-0.12	0.72-0.07	0.09-ND
	Mean	0.47	0.32	0.04
	Standard Deviation	0.25	0.19	0.03

NO_x - Total Oxides of Nitrogen
NO - Nitric Oxide
NO_2 - Nitrogen Dioxide
TWA - Time Weighted Average
ppm - Parts Per Million Parts of Air
ND - None Detected

TABLE 7
BENZENE SOLUBLE POLYNUCLEAR AROMATIC HYDROCARBONS
Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job/Location	Total Benzene Solubles (CTPV) (mg/m³)	Polynuclear Aromatic Compounds: Acenaphthene (µg/m³)	Phenanthrene (µg/m³)	Anthracene (µg/m³)	Fluroanthene (µg/m³)	Pyrene (µg/m³)	Chrysene (µg/m³)
7/13/88	Bolter (West C42)	0.38	1.56	1.40	0.37	0.21	ND	ND
	Loader #307 (East 68)	No Sample	1.96	2.64	0.33	0.43	0.60	ND
	Truck #436 (West 61)	0.15	0.83	1.07	0.17	0.24	0.35	ND
	Truck #437 (West 61)	0.28	0.86	1.16	0.17	0.24	0.37	ND
	Truck #434 (East 68)	0.33	1.03	1.23	0.21	0.28	0.36	ND
	Track Drill (West 1)	0.16	1.13	1.06	1.06	0.13	ND	ND
	Jumbo Drill (West C43)	0.48	1.17	1.15	0.55	0.26	ND	ND
	Outside Mine	No Sample	ND	ND	ND	ND	ND	ND
	Underground Shop	0.49	1.25	1.00	0.16	0.21	0.26	ND
	Loader #314 (West 40/43)	0.58	ND	ND	ND	ND	ND	ND
7/14/88	Bolter	0.36	1.04	1.00	0.32	0.13	ND	ND
	Track Drill (West 1)	1.67	1.47	2.05	0.57	0.43	0.50	0.12
	Outside Mine	No Sample	ND	ND	ND	ND	ND	ND
	Truck #435 (East 55)	0.11	ND	ND	ND	ND	ND	ND
	Truck #437	0.24	1.41	2.00	0.27	0.41	0.52	0.05
	Loader #314 (East 55)	0.39	1.63	2.61	0.40	0.45	0.58	0.03
	Underground Shop	0.23	1.23	1.05	0.16	0.20	0.32	ND
	Jumbo Drill	0.25	0.72	0.84	0.42	0.05	ND	ND
Limits of Detection (LOD)		0.05mg	0.1µg	0.1µg	0.03µg	0.03µg	0.03µg	0.03µg

CTPV - Coal Tar Pitch Volatiles
Mg/m³ - Milligrams Per Cubic Meter of Air
µg/m³ - Micrograms Per Cubic Meter of Air
ND - None Detected
NOTE - In addition to the above listed polynuclear aromatic compounds, the samples were also analyzed for Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(e)pyrene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene. and Benzo(ghi)perylene. Non of these analytes were detected (LOD 0.03 µg).

TABLE 8

DIESEL FRACTION OF RESPIRABLE DUST (TWA)

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job	Total Respirable Mass (mg/m^3)	Non-Diesel Fraction (mg/m^3)	Diesel Fraction (mg/m^3)	% of Diesel Fraction Lost After LTA
7/13/88	Loader (A)	4.80	1.00	3.80	NA
	Blade Operator (P)	1.28	0.25	1.03	92
	Loader Operator (P)	1.97	0.34	1.63	85
	Loader Operator (P)	4.61	0.73	3.88	89
	Truck Driver (P)	1.71	0.27	1.44	100
	Truck Driver (P)	1.16	0.16	1.00	96
	Truck Driver (P)	1.96	0.69	1.27	100
	Bolter Operator (P)	1.18	0.22	0.96	97
	Truck Driver (P)	1.51	0.38	1.13	91
7/14/88	Track Drill Operator (P)	1.57	0.42	1.15	90
	Bolter Operator (P)	1.79	0.35	1.44	99
	Truck Driver (P)	1.87	0.42	1.45	100
	Truck Driver (P)	2.08	0.38	1.70	90
	Loader Operator (P)	1.47	0.41	1.06	100
	Loader Operator (P)	VOID	VOID	3.45	92
	Truck Driver (P)	1.94	0.34	1.60	99
	Bolter Operator (P)	4.72	0.73	3.99	NA
	Truck Driver (P)	1.95	0.27	1.68	95
	Loader Operator (P)	3.00	0.81	2.19	94

TABLE 8 (continued)

DIESEL FRACTION OF RESPIRABLE DUST (TWA)

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job	Total Respirable Mass (mg/m^3)	Non-Diesel Fraction (mg/m^3)	Diesel Fraction (mg/m^3)	% of Diesel Fraction Lost After LTA
7/15-16/88	Pad (Shop) (A)	0.69	0.10	0.59	NA
	Bolter (A)	3.14	0.85	2.29	100
	Jumbo Drill (A)	1.33	0.21	1.12	100
	Track Drill (A)	0.30	0.08	0.22	NA
	Loader (A)	1.83	0.59	1.24	100
	Loader (A)	0.48	0.15	0.33	NA
	Truck (A)	1.83	0.29	1.54	99
	Truck (A)	0.43	0.13	0.30	NA
	Truck (A)	2.47	0.45	2.02	100
	Truck (A)	0.70	0.19	0.51	NA
	Loader (A)	2.53	0.67	1.86	100
	Range	4.80-0.30	1.00-0.10	3.99-0.22	
	Mean	1.94	0.41	1.60	
	Standard Deviation	1.18	0.23	1.02	

TWA - Time-weighted Average.
Total Respirable Mass - Aerosols having aerodynamic diameter of less than one micrometer up through ten micrometers.
Non-Diesel Fraction - Aerosols having aerodynamic diameter of one to ten micrometers.
Diesel Fraction - Aerosols having aerodynamic diameter of less than one micrometer (sub-micrometer).
LTA - Low Temperature Ashing - Filters containing the sub-micrometer particulate were subjected to LTA to determine what percent of the particulate was organic/diesel.
NA - Not analyzed.
mg/m^3 - milligrams per cubic meter of air.
(P) - Personal sample.
(A) - Area sample.

TABLE 9

RESULTS OF SAMPLING FOR CO
USING LONG TERM DETECTOR TUBES

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job	Location	Time	Concentration (ppm)
7/13/88	Bolter	West C42	0840-1300	++
	Loader #307	East 68	0818-1440	++
	Truck #436	West 61	0828-1400	6.02
	Truck #437	West 61	0812-1405	11.33
	Truck #434	East 68	0810-1415	++
	Track Drill	West 1	0820-1340	2.34
	Jumbo Drill	West C43	0850-1320	++
		Pad	0910-1418	8.11
	Loader #314	West 40/43	0902-1445	++
7/14/88	Bolter	-	1650-2128	17.98
	Track Drill	West 1	1610-2110	6.66
	Truck #435	East 55	1505-1839	13.55
	Truck #418	East 55	1509-1841	++
	Truck #437	-	1515-1836	19.90
	Truck #432	-	1510-1828	25.0
	Loader #307	-	1520-1848	9.61
	Loader #301	East 61,63,64	1510-1858	++
	Loader #314	East 55	1515-1854	++
	Jumbo Drill	-	1625-2145	9.37

CO - Carbon Monoxide
PPM - Part Per Million Parts of Air
++ - Unable to determine definite concentration because the maximum readable amount on the detector tube was exceeded. The range of measurement in PPM for maximum duration of use (•4 hours at 20 cc/min) is 2.5 to 25 ppm.

TABLE 10

RESPIRABLE PARTICULATE AND
FREE SILICA - UNDERGROUND OPERATION

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job/Location	Respirable Particulate TWA (mg/m^3)	Respirable Particulate TLV (mg/m^3)	% Free Silica	Respirable Free Silica TWA (mg/m^3)
7/13/88	(A) Truck 434/West 61 & East 68	1.90	2.70	1.70	0.03
	(A) Bolter/West C42	2.19	1.63	4.12	0.09
	(A) Loader 307/East 68	0.46	0.54	16.67	0.08
	(A) Truck 436/West 61	1.70	5.0	ND	0
	(P) Primary Crusher Helper	0.93	0.34	27.88	0.26
	(A) Track Drill/1 West	0.74	1.43	5.0	0.04
	(A) Jumbo Drill/West C43	2.03	2.41	2.15	0.04
	(A) Pad	0.90	1.19	6.38	0.06
	(A) Loader 314/West 40 & 43	0.26	5.0	ND	0
7/14/88	(A) Bolter	0.59	5.0	ND	0
	(A) Truck 435/East 55	2.50	2.19	2.56	0.06
	(A) Truck 418/East 55 Bench	2.31	1.31	5.65	0.13
	(A) Truck 437	1.84	2.35	2.26	0.04
	(A) Truck 432	2.41	2.30	2.34	0.06
	(A) Loader 307	2.47	1.92	3.21	0.08
	(A) Loader 301/E 61-3-4 Top Slice	3.53	1.37	5.28	0.19
	(A) Loader 314/ East 55 Bench	2.47	1.96	3.11	0.08
	(P) Bolter Helper	3.88	1.54	4.49	0.17
	(P) Bolter Helper	1.87	5.0	ND	0
	(P) Jumbo Drill Operator	0.43	0.99	8.11	0.03
	(P) Track Drill Operator	16.74	0.20	48.0	8.03
	(P) Primary Crusher Helper	2.37	0.56	15.77	0.37

TABLE 10 (continued)

RESPIRABLE PARTICULATE AND
FREE SILICA - UNDERGROUND OPERATION

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job/Location	Respirable Particulate TWA (mg/m^3)	Respirable Particulate TLV (mg/m^3)	% Free Silica	Respirable Free Silica TWA (mg/m^3)
7/15-16/88	(P) Track Drill Operator	2.63	1.73	3.77	0.10
	(P) Primary Crusher Helper	2.94	0.25	37.94	1.11
	(P) Jumbo Drill Operator	1.30	1.41	5.08	0.07
	(P) Bolter Operator	3.72	1.84	3.43	0.13
	(P) Bolter Operator	2.38	1.69	3.90	0.09
	(P) Truck Driver/West 40	0.70	1.88	3.33	0.02
	(P) Truck Driver	1.66	1.88	3.31	0.05
	(P) Loader Operator	1.69	2.51	1.99	0.03
	(P) Truck Driver	0.50	5.0	ND	0
	(P) Truck Driver/East 55	1.12	1.22	6.19	0.07
	(P) Loader Operator/East 55 Bench	2.41	1.62	4.19	0.10
	(P) Loader Operator	0.53	0.92	8.89	0.05
	Evaluation Criteria	$\frac{10\ mg/m^3}{\%\ Respirable\ Quartz + 2}$ (MSHA)			$0.05\ mg/m^3$ (NIOSH)

mg/m^3 - Milligrams per cubic meter of air
(A) - Area Sample
(P) - Personal Sample
ND - None Detected - Limit of Detection 0.018 mg/m^3

TABLE 11

PERSONAL RESPIRABLE PARTICULATE AND
FREE SILICA EXPOSURE - SURFACE OPERATION

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job/Location	Respirable Particulate TWA (mg/m^3)	Respirable Particulate TLV (mg/m^3)	% Free Silica	Respirable Free Silica TWA (mg/m^3)
7/18/88	Maintenance/Crusher	0.17	5.0	ND	0
	Maintenance/Crusher	0.40	0.36	25.81	0.10
	Maintenance/Crusher	0.14	0.26	36.36	0.05
	Lubeman/Crusher	0.10	0.33	28.57	0.03
	Maintenance/Mill	0.77	0.28	33.87	0.26
	Maintenance/Mill	3.36	2.37	2.22	0.07
	Maintenance/Mill	0.30	0.54	16.67	0.05
	Maintenance/Mill	0.19	0.65	13.33	0.02
	Maintenance/Mill	0.17	0.37	25.0	0.04
	Maintenance/Mill	0.37	0.44	20.69	0.08
	Maintenance/Mill	0.30	0.37	25.0	0.08
7/19/88	Crusher Helper/Crusher	0.33	0.26	36.0	0.12
	Crusher Helper/Crusher	0.19	0.43	21.43	0.04
	Crusher Operator/Crusher	0.08	0.17	57.14	0.05
	Maintenance/Crusher	0.31	0.66	13.04	0.04
	Maintenance/Crusher	0.10	0.37	25.0	0.03
	Maintenance/Crusher	0.43	0.58	15.15	0.07
	Float Operator/Mill	0.16	0.28	33.33	0.05
	Float Operator/Mill	0.06	0.24	40.0	0.03
	Sample Preparer/Mill	0.19	0.31	30.76	0.06
	Maintenance/Mill	0.17	0.28	33.33	0.06
	Maintenance/Mill	0.07	5.0	ND	0
	Maintenance/Mill	0.32	0.93	8.70	0.03
	Range	0.06-3.36		ND-40.00	0-0.03
	Mean	0.38		23.54	0.06
	Standard Deviation	0.67		13.87	0.05
	Evaluation Criteria	$\frac{10\ mg/m^3}{\%\ Respirable\ Silica + 2}$ (MSHA)			0.05 mg/m^3 (NIOSH)

TWA - Time-Weighted Average, TLV - Threshold Limit Value, mg/m^3 - Milligrams per cubic meter of air
ND - Non Detected, limit of detection 0.018 mg/m^3

TABLE 12

SUMMARY OF RESPIRABLE DUST SAMPLES

Troy Unit Mine
Troy, Montana
RDHETA 88-104

	Underground Operation			Surface Operation
	Personal	Area	All	Personal
Number of Samples	18	16	34	23
Mean Dust Concentration (Mg/m^3)	2.66 (0.43-16.74)	1.77 (0.26-3.53)	2.24 (0.43-16.74)	0.38 (0.06-3.36)
Mean Quartz Content (percent by weight)	10.3 (ND-37.94)	3.8 (ND-16.67)	7.3 (ND-37.94)	23.54 (ND-40.0)
Percent of Samples > MSHA TLV	50	44	47	17
Percent of Samples > NIOSH Recommended Standard for Respirable Silica	61	56	59	39

NOTES: Range of data is shown in parenthesis
ND - Non Detected - Limit of detection was 0.018 mg/m^3

TABLE 13

PERSONAL NOISE DOSIMETER RESULTS

Troy Unit Mine
Troy, Montana
RDHETA 88-104

Date	Job	8-Hour TWA Sound Level (dBA)
7/13/88	Blade Operator	91.8
	Primary Crusher Helper	89.2
	Track Drill Operator	91.4
	Bolter Operator	96.8
	Truck Driver	100.8
7/14/88	Primary Crusher Helper	85.6
	Track Drill Operator	101.1
	Truck Driver	103.8
	Loader Operator	92.1
	Truck Driver	100.6
	Bolter Operator	97.4
	Truck Driver	96.4
	Bolter Helper	97.3
	Loader Operator	91.3
	Jumbo Drill Operator	101.9
7/15-16/88	Track Drill Operator	95.6
	Primary Crusher Helper	77.6
	Jumbo Drill Operator	99.6
	Bolter Operator	95.2
	Truck Driver	96.1
	Loader Operator	95.5
	Bolter Helper	88.8
7/18/88	Secondary Crusher Maintenance	93.4
	Secondary Crusher Maintenance	75.4
	Secondary Crusher Maintenance	88
	Secondary Crusher Lubeman	65.5
	Mill Maintenance	95.2
	Mill Maintenance	79.6
	Mill Maintenance	78.2
	Mill Maintenance	83.1
	Mill Maintenance	77.8
	Mill Maintenance	84.0
7/19/88	Secondary Crusher Helper	73.6
	Secondary Crusher Helper	87.8
	Secondary Crusher Operator	90.6
	Secondary Crusher Maintenance	79.4
	Secondary Crusher Maintenance	94.5
	Mill Operator	80.3
	Float Operator	78.5
	Float Man	70.1
	Mill Maintenance	79.3

TWA - Time-Weighted Average
dBA - Decibel Level, A-Scale Weighted

TABLE 14

PREVALENCE OF CHRONIC COUGH, PHLEGM, AND DYSPNEA IN TROY MINERS AND BLUE-COLLAR (BC) WORKERS BY CIGARETTE SMOKING HABIT

TROY UNIT MINE
TROY, MONTANA
RDHETA 88-104

	Current Smoker		Former Smoker		Never Smoker	
	N	% Affected	N	% Affected	N	% Affected
Chronic Cough						
Troy	42	69	35	34	45	33
BC	651	20	207	8	512	8
Chronic Phlegm						
Troy	42	74	35	43	45	47
BC	648	18	206	13	512	8
Chronic Dyspnea						
Troy	42	0	35	3	45	0
BC	647	3	207	3	510	2

TABLE 15

AVERAGE DIFFERENCE** FROM PREDICTED FEV_1 (l) and FVC (l) BY AGE GROUP
AND CIGARETTE SMOKING HABIT

TROY UNIT MINE
TROY, MONTANA
RDHETA 88-104

	Comparison Group+	Number Subjects	FEV_1 Average Difference	SD of Difference	Number Subjects	FVC Average Difference	SD of Difference
Current Smoker	BC	42	0.12	0.47	42	0.32	0.56
	KN	42	-0.09	0.50	42	0.32	0.57
Former Smoker	BC	35	0.08	0.50	35	0.36	0.61
	KN	35	0.01	0.56	35	0.40	0.58
Never Smoker	BC	45	0.17	0.54	45	0.34	0.54
	KN	45	0.15	0.57	45	0.36	0.56
Age							
<30	BC	49	0.09	0.50	49	0.38	0.48
	KN	49	0.08	0.55	49	0.40	0.51
30-39	BC	42	0.23	0.47	42	0.43	0.51
	KN	42	0.14	0.47	42	0.41	0.49
>39	BC	31	0.04	0.53	31	0.14	0.71
	KN	31	-0.20	0.61	31	0.22	0.73
Total	BC	122	0.13	0.50	122	0.34	0.56
	KN	122	0.03	0.55	122	0.36	0.57

+ KN: Knudson Predicted Value; BC: Blue-collar Worker Predicted Value.
** Difference: Observed Minus Predicted Value.

TABLE 16

PREVALENCE OF ACUTE SYMPTOMS "OFTEN" OCCURRING AT WORK
REPORTED BY CURRENT JOB LOCATION

TROY UNIT MINE
TROY, MONTANA
RDHETA 88-104

	Surface N=32 % Affected	Underground N=89 % Affected	Total N=121 % Affected
Cough	22	16	17
Nose Tickled/Irritated	19	18	18
Sneeze	16	9	11
Eyes Itch/Burn	19	34	30
Eyes Tearing	9	16	14
Sore Throat	6	9	8
Difficulty Breathing	3	4	4
Chest Tightness	6	6	6
Upset Stomach	9	18	16
Wheezing	9	9	9
Headache	9	17	15

TABLE 17

PREVALENCE OF ACUTE SYMPTOMS OCCURRING AT WORK
ON THE DAY OF SHIFT SPIROMETRY
REPORTED BY CURRENT JOB LOCATION

TROY UNIT MINE
TROY, MONTANA
RDHETA 88-104

	Surface N=8 % Affected	Underground N=73 % Affected	Total N=81 % Affected
Cough	75	55	57
Nose Tickled/Irritated	38	33	33
Sneeze	62	33	36
Eyes Itch/Burn	50	42	43
Eyes Tearing	38	21	22
Sore Throat	50	10	14
Difficulty Breathing	25	15	16
Chest Tightness	25	15	16
Upset Stomach	38	15	17
Wheezing	62	18	22
Headache	22	19	19

TABLE 18

AVERAGE CHANGE** IN FEV_1 (l) and FVC (l) OVER THE WORKSHIFT
BY CURRENT JOB LOCATION COMPARED TO NON-DUST EXPOSED BLUE-COLLAR WORKERS

TROY UNIT MINE
TROY, MONTANA
RDHETA 88-104

	TROY		BLUE COLLAR
	SURFACE N=8 AVERAGE CHANGE (SD)	UNDERGROUND N=73 AVERAGE CHANGE (SD)	TOTAL N=944 AVERAGE CHANGE (SD)
FEV_1	-0.09 (0.22)	-0.08 (0.21)*+	-0.04 (0.19)
FVC	-0.10 (0.09)*+	-0.07 (0.17)*+	-0.02 (0.21)

**Change: After shift - Before shift.
*Average change different from zero (t-test; $p<0.05$).
+Average change different from blue-collar average change (t-test; $p<0.05$).

TABLE 19

CHEST RADIOGRAPHS
CUMULATIVE MEDIAN PROFUSION CATEGORY

TROY UNIT MINE
TROY, MONTANA
RDHETA 88-104

Reading	Frequency	Percent
0/0	250	85.3
0/1	25	8.5
1/0	15	5.1
1/1	3	1.0

APPENDIX II

RESPIRATORY PROTECTION PROGRAM

A written respirator program must include the following:

A. Specific procedures identifying who must wear respiratory protection, when and what type is to be worn.

The information can be organized as follows:

Job Class	Task	Respirator	Cartridge Type

Respirators must, of course, be selected according to the contaminants present and their expected concentrations.

B. Procedures for cleaning, maintaining, inspecting and storing respirators issued to individuals for their exclusive use.

Employees should clean, inspect and store such respirators following each day's use. Instructions for this should be developed along with procedures for replacing cartridges. The frequency of cartridge replacement should be stated clearly.

A schedule for central cleaning and inspection of these respirators should also be developed. Employees should turn their respirators over to a person at a central location periodically (and be given replacement respirators) for this purpose.

C. Procedures for cleaning, disinfecting, maintaining and inspecting respirators issued centrally to more than one individual.

These respirators should be returned to the central respirator location following each use and should not be used by more than one individual between cleanings.

Issuance of these respirators should be based on the information described in (A) above. Deviations from these procedures should not be permitted without approval of the plant industrial hygienist.

D. Training procedures.

These should specify annual training for all employees required to wear respirators. Training should include:

1. Hazard of contaminants.
2. Type of respirator (and cartridge if applicable) to wear, under what circumstances.
3. How to wear the respirator properly.
4. Fit testing.
5. How to clean, inspect, maintain, and store (for employees issued respirators for their exclusive use).

RESPIRATORY PROTECTION PROGRAM

A variety of respirator sizes and/or brands of respirators is usually needed to obtain good fits for several workers. Respirators found to fit an employee properly should be recorded for reference when issuing respirators.

E. Physician approval.

Each employee should be approved by a physician to wear a respirator before he/she is assigned to a job requiring respirator use.

F. Periodic program evaluation.

The person assigned to administer the respirator program should evaluate the program periodically. Specific items to be reviewed should be listed in this section of the written respirator program.