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SUMMITVILLE CONSOLIDATED MINING COMPANY, INC.
DEL NORTE, COLORADO

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I. SUMMARY

On October 15, 1987, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate exposures to cyanide at a surface gold mine operated by the Summitville Consolidated Mining Company, Inc., Del Norte, Colorado. The request was prompted by an incident during which a heavy equipment operator working in a cyanide leaching pad experienced symptoms suggestive of cyanide poisoning.

In October 1987, NIOSH investigators conducted an environmental and medical survey at the mine site. During this survey, air samples for hydrogen cyanide and cyanide salts were collected. In addition, confidential employee interviews were conducted and pre- and post-shift blood and urine samples were collected for thiocyanate analysis for the four employees working in the leach field area.

The results of the air samples collected to evaluate employee exposures revealed total cyanide concentrations ranging from 0.02 milligrams of cyanide per cubic meter of air (mg/M^3) for the bulldozer operator to 0.004 mg/M^3 for a roadgrader operator. All results were below the NIOSH Recommended Exposure Limit (REL) of 5.0 mg/M^3 cyanide as a ten-minute ceiling. These results were also below the Mine Safety and Health Administration (MSHA) standard and the American Conference of Governmental Hygienists (ACGIH) Threshold Limit Value (TLV) of 11 mg/M^3 hydrogen cyanide as an 8-hour time-weighted average (TWA) and a ceiling limit, respectively.

Pre- and post-shift serum and urine thiocyanate concentrations were within the normal range, with the exception of the bulldozer operator whose post-shift urine thiocyanate concentration (20.5 mg/liter) was only slightly above the upper end of the normal range for cigarette smokers (20.0 mg/liter).

Medical interviews revealed that the workers had been employed at the site for up to two years with no reported health problems until an incident occuring on October 1, 1987 during which an employee experienced dryness of the mouth, numbness of the fingers and ears, headache, dizziness, noted odor of almonds, difficulty moving and unconsciousness. These symptoms are typical of cyanide poisoning and fairly specific. At the time of the incident, minimal air movement was reported on the leach pad. Due to the many variables involved, it was not possible to determine that cyanide exposure was the cause of this employees health problems, although it is the most likely explanation. Because of the high acute toxicity of cyanide compounds, it is necessary to take all possible steps to minimize the risk of further exposure.

On the basis of the data collected, no overexposures to airborne cyanide were found to exist at the time of this survey. It is likely that in past there was at least one serious episode of cyanide overexposure. Due to the high acute toxicity of cyanide compounds, recommendations regarding employee training, work practices, environmental monitoring, and engineering controls are included in this report.

KEY WORDS: SIC 1041 (Metal Mining, Gold Ores), cyanide, HCN, sodium cyanide, heap leaching, gold mining, thiocyanate, cyanide poisoning.

II. INTRODUCTION

On October 15, 1987, NIOSH received a request from the Summitville Consolidated Mining Company, Inc., Del Norte, Colorado, to conduct a health hazard evaluation. The requestor was concerned with potential cyanide exposures among heavy equipment operators working on a leach pad at a surface gold mine. The request was prompted by two incidents during which several heavy equipment operators working in the leach pad experienced symptoms consistent with cyanide poisoning.

NIOSH investigators conducted a site visit to the mine on October 21 and 22, 1987. An opening conference was held with representatives of Summitville Mining Company and the contractor who was responsible for operation of the heavy equipment in the leach field. During this meeting, background information was obtained on the nature of the mining operations and the incident which had prompted the request. Afterward, environmental and medical surveys were conducted. The environmental survey included the collection of air samples for hydrogen cyanide and cyanide salts. The medical survey included confidential employee interviews and the collection of pre- and post-shift blood and urine samples for thiocyanate analysis.

III. BACKGROUND

Summitville Consolidated Mining Company, Inc., Del Norte, Colorado, is a subsidiary of Galactic Resources Incorporated. The company is involved in gold and silver mining operations. The Summitville mine is a surface gold mine located in southwestern Colorado. It became fully operational in June 1986. Although Galactic Resources Inc. has several of its own employees at this site, a subcontractor, Industrial Constructors, is employed to operate all heavy equipment at the mine. The focus of the health hazard evaluation request centered on the potential cyanide exposure of the heavy equipment operators working in the heap leaching operations.

In order to understand the potential hazards present in this operation, a basic understanding of gold cyanidization and heap leaching is necessary. A brief description of these processes follows.

A. Cyanidization

Cyanidization is a hydrometallurgical process in which gold and other precious metals are dissolved from ore using a cyanide solution, usually made from sodium cyanide. The following equation represents the chemical reaction which takes place in this process;

$$4Au + 8\ NaCN + O_2 + 2H_2O = 4\ NaAu(CN)_2 + 4\ NaOH$$

where Au = gold, NaCN = sodium cyanide, O_2 = oxygen, H_2O = water, $NaAU(CN)_2$ = sodium gold cyanide, and NaOH = sodium hydroxide. The gold, which is bound in the sodium gold cyanide complex, can then be recovered by one of several commercial gold extraction processes.

B. Heap Leaching

In heap leaching operations, a cyanide solution is sprayed over piles of ore arranged on a leach pad. The cyanide solution dissolves the gold and other precious metals as it percolates through the ore pile. The "pregnant" cyanide solution is collected by a drainage system at the bottom of the ore pile, and pumped to a recovery plant where the gold and silver are extracted.

In order for heap leaching to be effective, the ore must be prepared properly. This involves crushing or grinding the ore to expose the metallic gold. At this point, lime is added to the ore to provide a protective alkalinity to the ore. This is because cyanides may react with several substances, including mineral acids in the ore and carbon dioxide in the air, to form hydrogen cyanide (HCN), a highly toxic gas. The formation of HCN is extremely dependent on pH. Therefore, it is necessary to maintain a highly alkaline pH.
Figure 1 illustrates the rapid liberation of HCN when the pH falls over a narrow range. At pH 7 or less, NaCN solutions are hydrolyzed, resulting in virtually all cyanide being liberated as HCN.[1] It is recommended that the pH of cyanide solutions be kept at 10.5 or higher.[1] In addition to posing an acute health hazard, the formation of hydrogen cyanide reduces the cyanide concentration of the solution, leading to increased reagent consumption, and therefore, operating costs.

Next, the crushed ore and lime is piled onto an impervious pad. The pad usually is constructed on a smooth surface, using layers of clay, sand, polyethylene, and geotextile. The sides of the leach pad are sloped inward, to prevent the escape of the pregnant solution. A drain is located in the center, under the leach pad, for the collection of the pregnant solution. Ore must be distributed evenly and at the right depth to allow for optimum dissolution of the gold from the ore. If the ore is piled too high, the cyanide solution will contain insufficient oxygen to dissolve the gold at the lower depths of the ore heap.

The cyanide solution used in heap leaching processes is generally a weak solution of sodium cyanide at a concentration ranging from 0.5 to 1 pound per ton of solution (250 to 500 ppm).[1] The solution usually is transported throughout the leach pad using plastic pipe. Sprinkler heads are then spaced evenly around the leach pad to ensure uniform saturation of the ore.

Following percolation through the ore pile, the pregnant cyanide solution is collected and pumped to a recovery plant where the gold and silver are freed from the cyanide-metal complex. The cyanide concentration of the solution is restored to its initial concentration, and the solution is recirculated through the ore.

C. Company Operations

During the survey, the company indicated that the amount of ore being processed was approximately 23 tons per day (as measured by crusher output). The cyanide solution being fed to the leach pad was reportedly maintained at a concentration of approximately 0.3 lbs of free cyanide per ton of solution, with the pH kept in the range of 10.8 to 11. These parameters were regularly checked by the plant operators and verified by the mine laboratory using daily composite samples.

D. Employee Duties

During the evening shift, five employees worked in the leach pad area. Three of these employees were truck drivers and were responsible for transporting crushed ore from the ore hoppers to the adjacent leach pad. The dumped ore was moved to the appropriate area by the bulldozer operator. The bulldozer operator spent the entire shift on the leach pad distributing the ore in preparation for the leaching process. A roadgrader operator also worked in the leach pad area was responsible for maintaining the surface of the roadway for the ore trucks. This employee was on the leach pad for approximately 30 minutes during the shift. All of the heavy equipment operated by these employees was equipped with enclosed cabs.

E. Description of Incident Prompting Request

On the evening of October 1, 1987, a bulldozer operator experienced dryness of the mouth, numbness of the fingers and ears, a headache, dizziness, unsteady gait, weakness of extremities, and loss of consciousness. Information contained in the supervisor's accident report indicated that the operator also reported the smell of almonds and a rusty taste when drinking water. The operator was subsequently taken from the leach pad area, administered oxygen, and transported to a hospital. Based on a physicians examination, no cyanide antidote was administered. The employee was released and returned to work the following day.

Information contained in the supervisor's accident report indicated that at the time of the incident the bulldozer operator was working in a low area of the leach pad and was surrounded by higher areas where barren solution was being applied. The night of the incident, the ambient temperature over the leach pad was reportedly warmer than at the higher elevations of the mine, and there was little wind movement on the leach pad. The operator reported a buildup of heavy diesel smoke from the bulldozer in the area in which he was working. The accident report concluded that the incident may have resulted from a build up of hydrogen cyanide due to an atmospheric inversion.

Three days after the initial incident, several truck drivers working in the leach field complained of dizziness, nausea, headache and weakness several hours after coming to work. They tolerated these symptoms and were not sent to the hospital.

F. Actions Taken Following the Incidents

Following the incidents, the contractor implemented a number of procedures related to the leach field operations. This included the placement of indicator flags around the leach field to allow the leach field employees to determine the direction and relative intensity of wind movement. When warranted by environmental conditions (lack of wind movement), supervisors were instructed to check with the leach field employees every 20 minutes, and conduct periodic monitoring for HCN. In addition, the bulldozer operator was issued a respirator to use if symptoms of cyanide poisoning occurred, or a high concentration of HCN was present.

IV. METHODS

A. Environmental

In order to determine employee exposures to cyanide, area air samples were collected in the operator cabs of the heavy equipment being used in the leach pad area, as well as at various locations around the leach pad. Samples were collected using battery-powered pumps operating at 1.0 liters per minute attached with Tygon tubing to the collection media. The collection media consisted of a 37-millimeter cellulose ester membrane filter followed in-line by an impinger containing 10 milliliters of 0.1 N potassium hydroxide (KOH) solution. The location and duration of the collected samples are provided in Table 1.

After sampling, the impinger stems were washed with two ml of 0.1 N KOH. The impinger contents then were transferred to a 20 ml vial along with one-half of a KOH pellet. The samples were packed in ice and shipped via overnight mail to the laboratory. The filters and impinger solutions were analyzed for cyanide using visible absorption spectroscopy. During the analysis, cyanides were released from complexes by ultraviolet digestion and reaction with chloramine-T to produce cyanogen chloride. Cyanogen chloride was reacted with pyridine and barbituric acid to produce a colored complex. The intensity of the colored complex was measured at 570 nanometers.

B. Medical

On October 20 and 21, 1987, personal interviews were conducted with one bulldozer operator and three dump truck drivers who worked on the leach field during the evening shift. Following the interviews, pre- and post-shift blood and urine samples were obtained from these workers. For comparison purpose, samples were also collected from two employees who did not work in the leach pad area.

V. EVALUATION CRITERIA

A. Environmental Exposure Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. It is important, however, to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects often are not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes and, thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PEL's)], 4) and the Mine Safety and Health Administration (MSHA) standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA or MSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA and MSHA standards. Also, in some cases, the OSHA standards may be more restrictive than the corresponding MSHA standards. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that the company is required by the Mine Safety and Health Administration to meet those levels specified in an MSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday.

A brief discussion of the toxicity of hydrogen cyanide and cyanide salts, as well as the environmental and medical criteria for these substances, is presented below.

B. Cyanide

Hydrogen cyanide is a colorless gas at room temperature, with a faint odor similar to that of bitter almonds.[2] In a study of 244 individuals, 88% were able to smell HCN, but of those, approximately one-fourth made the determination with great difficulty, which indicates a lack of good warning properties.[3] HCN is commercially synthesized for a wide variety of industrial uses. It also naturally occurs as a hydrolysis product in some plants, and is present in cigarette smoke and automobile exhaust.[3]

Sodium cyanide, is a white crystalline solid at room temperature. Like the other commercially important inorganic cyanide salts (potassium cyanide and calcium cyanide), sodium cyanide appreciably dissociates in aqueous solutions to produce cyanide ion or HCN. The presence of a significant source of hydrogen ions (i.e., strong mineral acids), along with a cyanide salt, can lead to the rapid production of large amounts of hydrogen cyanide.[2]

The dusts of cyanide salts are irritating to the eyes, nose, and skin. Strong solutions of alkaline cyanide are highly corrosive to human tissues and can cause skin ulcers. At low levels of exposure, early symptoms of cyanide exposure (both to hydrogen cyanide and cyanide salts) include weakness, headache, confusion, nausea, and vomiting. Larger doses of cyanide may cause the person to rapidly lose consciousness, stop breathing, and die.[4] The following table illustrates the human response to various concentrations of hydrogen cyanide in air.

Physiological Response to Various Concentrations of
Hydrogen Cyanide in Air[2]

	Concentration	
Response	mg/M3	ppm
Immediately fatal	300	270
Fatal after 10 minutes	200	181
Fatal after 30 minutes	150	135
Fatal after 0.5 to 1 hour or later, or dangerous to life	120-150	110-135
Tolerated for 0.5 to 1 hour without immediate or late effects	50-60	45-54
Slight symptoms after several hours	20-40	18-36

Cyanides are readily absorbed following inhalation, and are rapidly distributed throughout the body by the blood. Cyanide compounds ingested orally are readily absorbed across the gastrointestinal tract. Cyanides are also considered to be moderately lipid soluble, which allows them to penetrate the skin rapidly. Cut or abraded skin increases the likelihood of absorption of these compounds.

Hydrogen cyanide and cyanide salts appear to have a common mechanism of action. Once absorbed into the body, the cyanide compounds dissociate to form cyanide ions. The cyanide ions then bind with the heavy metal ions which are present in several of the body's enzyme systems, resulting in a disturbance of the body's functions.[2]

The most pronounced toxic effect from cyanide compounds is due to the reaction of the cyanide ion with the ferric iron (Fe^{+3}) contained in the enzyme cytochrome oxidase. Cytochrome oxidase occupies a key position in the process of cellular respiration by allowing the transfer of electrons to oxygen in the cells. Inhibition of the action of cytochrome oxidase effectively halts cellular respiration, resulting in chemical asphyxiation.[4]

In addition to it's inhibition of the cytochrome oxidase enzyme, cyanide compounds react with several other substances in the body. Cyanide ion has been shown to bind with catalase, peroxide, ascorbic acid oxidase, methemoglobin, hydroxycobalamin, phosphatase, tyrosinase, xanthine oxidase, and succinic dehydrogenase. The reaction of the cyanide ion with these substances affects many processes other than respiration, and no doubt further contributes to the overall toxicity of the cyanide compounds.[5]

Most of the cyanides which are absorbed into the body are eventually converted to the much less toxic thiocyanate, which is then excreted in the urine. Other minor pathways for detoxification and excretion of cyanide compounds include exhalation of HCN in the breath, direct secretions of the cyanide ion, oxidation to formic acid, metal coordination, and condensation with cystine.[3]

There are several substances which induce chemical binding of cyanide, and are therefore, used in the treatment of cyanide poisoning. One example is amyl nitrite, a substance which causes the generation of methemoglobin in the body. The methemoglobin then competes for the free cyanide ions, forming a cyanomethemoglobin.[5] This dramatically reduces the amount of cyanide ion available to bind to cytochrome oxidase, and lessens its effect on cellular respiration. The NIOSH Recommended Exposure Limit (REL) for HCN is 5 milligrams per cubic meter of air (mg/M^3) expressed as CN, determined as a ceiling concentration based on a 10-minute sampling period. The NIOSH REL for employee exposure to cyanide salts (defined as sodium cyanide, potassium cyanide, or calcium cyanide) is a ceiling value of 5 mg/M^3 (expressed as CN), based upon a 10-minute sampling period. NIOSH also recommends that whenever air is analyzed for cyanide salts, it should also be analyzed for HCN, and the combined concentration for CN should not exceed 5 mg/M^3.[3]

The current Mine Safety and Health Administration (MSHA) standard for HCN is 11 mg/M^3 as an 8-hour TWA. The ACGIH recommends a Threshold Limit Value (TLV) of 11 mg/M^3 as a ceiling limit. The MSHA standard and ACGIH TLV for cyanide salts are both 5 mg/M^3 as an 8-hour TWA.[6,7]

Exposure to cyanide and cyanogenic vapors can cause an increased concentration of thiocyanate in plasma and urine and of cyanide in blood.[8] Since cyanide is quite unstable within the blood, it is not practical to use blood cyanide concentration as an indication of environmental exposure. Therefore, measurements for thiocyanate, a metabolite of cyanide, are generally used. Since hydrogen cyanide is present in tobacco smoke, the "normal" level of thiocyanate is higher in smokers than in non-smokers. For non-smokers, the reference range of serum and urine thiocyanate concentrations are 1.0-4.0 milligrams per liter (mg/L) and 0.0-2.0 mg/L, respectively.[9] For smokers, the reference ranges are 3.0-12.0 mg/L and 2.0-20.0 mg/L.[9]

VI. RESULTS

A. Environmental

The results of the air samples for cyanide are presented in Table 1. The exposures for the heavy equipment operators, as measured by area samples collected in the operator cabs, ranged from 0.02 milligrams per cubic meter of air (mg/M^3) for the bulldozer operator to 0.004 mg/M^3 for the roadgrader operator. All results are below the NIOSH REL for cyanide of 5.0 mg/M^3 as a ten-minute ceiling, as well as the MSHA and ACGIH criteria. These results appear consistent with the amount of time each of these individuals spent on the leach pad. Due to the sample volumes required by the analytical method used in this survey, samples were collected for periods ranging from 93 to 180 minutes. Since environmental and operational conditions remained constant throughout the sampling period, the resulting data was used to approximate short-term exposures (as specified in the NIOSH REL), as well as the longer term exposures (as specified in the OSHA and ACGIH criteria).

As would be expected, the area samples collected close to the surface of the leach pad revealed somewhat higher concentrations. The highest concentrations, 0.09 and 0.06 mg/M^3 were found in samples collected in a low area of the leach pad where pools of the cyanide solution had accumulated. A somewhat lower concentration of 0.03 mg/M^3 was found in an area sample collected in the vicinity where the bulldozer was working, which was not being sprinkled.

It should be noted that the ambient temperatures during the sampling period were much cooler than those described during the October 1, 1987 incident. In addition, strong wind conditions were also present at the time of the survey. However, these conditions were reported to be relatively normal for the time of year that the survey was conducted.

B. Medical

According to the interviews, the workers had been employed at the site for up to two years with no reported health problems until the previously discussed incidents which occurred on October 1 and October 4, 1987. All of the study participants were smokers. None had reported using salicylate (aspirin), which might interfere with the thiocyanate analysis, before the sampling period.

The results of pre- and post-shift blood and urine thiocyanate concentrations are listed in Table 2. All values were within the normal range for serum and urine thiocyanate, with the exception of the bulldozer operator, whose urine thiocyanate concentration (20.5 mg/liter) was only slightly above the upper end of the normal range for smoker (20.0 mg/liter). In addition, with the exception of the bulldozer operator, no employee had a significant increase between the pre-shift and post-shift thiocyanate concentrations. In the bulldozer operator, the urinary concentration of thiocyanate increased three fold after 9 hours of work. The lack of an increase in thiocyanate concentration among the other employees, all of whom smoke, indicates that smoking did not influence cross-shift thiocyanate concentration. If we generalize from this, it is unlikely that the three-fold increase of urinary thiocyanate concentration seen in the bulldozer operator was the result of smoking. Therefore, environmental exposure to cyanides and/or cyanogenic substances is the most likely explanation of the observed thiocyanate concentration increase.

The medical and first aid capabilities available at the mine were also reviewed. The nearest emergency facility available was reported to be approximately 40 miles away. The company has a cyanide antidote available on site for use by an emergency medical technician. However, the emergency medical technician interviewed during the evening shift did not seem familiar with the use of the cyanide antidote.

VII. DISCUSSION

The concentrations of cyanide in the air samples collected in the operators' cabs, as well as those in the area samples collected on the surface of the leach pad, were well below the evaluation criteria. In addition, the results of the medical survey did not reveal any serum or urine thiocyanate samples significantly above the normal range.

Since the NIOSH survey was conducted two weeks after the October 1, 1987 incident, it is difficult to determine whether cyanide was responsible for the affected employee's illness. While some of the symptoms reported by employees during incidents of October 1 and 4 are consistent with the known effects of cyanide poisoning (e.g., the smell of almonds, headache, unsteady gait, weakness of extremities, and loss of consciousness), the environmental levels found during the NIOSH survey were well below those concentrations that would cause health effects. In addition, past concentrations of HCN measured on the leach pad by the company were reported to be less than 0.5 ppm. Furthermore, employees had not previously reported any symptoms of this nature. Therefore, if cyanide was responsible for the employees' symptoms, the exposure would have resulted from some significant change in the "normal" work conditions.

In order to determine what might potentially alter the environmental conditions to allow for an increase in cyanide exposures, two areas should be examined. These include changes in either operational factors affecting the rate of contaminant generation, and/or meteorological factors (e.g., wind and temperature) which could influence the rate of contaminant dispersion or dilution. Although it is not possible to determine the extent to which these factors may have influenced HCN concentrations at the time of the incidents, a brief discussion of these factors, and how they might influence employee exposures, is provided below.

A. Operational Factors

As Figure 1 clearly illustrates, the regulation of pH plays a critical factor in controlling the amount of hydrogen cyanide which will be evolved from cyanide solutions. In operations such as heap leaching, where large amounts of cyanide solution are used, it is especially important to maintain control of the solution pH. A review of the daily log of the pH (as measured in the pregnant cyanide solution returning to the recovery plant) from the period of September 21 through October 31, 1987, did not indicate any difference between the solution pH on October 1, 1987 (10.5), and the average operating pH (10.5) for the 41-day period reviewed. However, the data reviewed represented a daily composite and would not reflect short-term changes in solution pH. Also, the data could not reflect localized changes in pH that may occur in certain areas of the leach pad. Such localized changes could be caused by the acidic nature of the ore (and its ability to lower the pH of the solution) or the absence of sufficient amounts of lime to provide protective alkalinity to the solution.

Another operational factor which could influence the rate of contaminant generation is the cyanide concentration in the solution. A review of the composite data for the pregnant cyanide solution indicated that the cyanide concentration on October 1, 1987 was 195 ppm, which was approximately 30% above the average concentration of 150 ppm for the 41-day period from September 21 to October 31. While an increase in solution concentration would be expected to show a corresponding increase in HCN generation at a given pH, the degree to which this would have increased concentrations in the leach field can not be determined. And while this was the the highest concentration occurring during the 41-day period examined, no ill health effects were reported on other days when the solution concentration was only slightly lower (190 ppm). Here again, the data reviewed represented a daily composite, and would not reflect short-term changes in solution concentration which might have occurred throughout the day. In addition, these composite data show the cyanide concentration in the pregnant solution returning to the extraction plant, and do not reflect the actual concentration of the barren solution sprayed onto the leach pad.

Solution temperature would also be another factor which could influence the rate of HCN generation. Higher temperatures increase reaction rates, and thus would cause the liberation of more HCN. However, due to the large volume of solution being used, wide variations in solution temperature would not be expected.

B. Meteorological Factors

In addition to operational factors, meteorological or atmospheric factors could also influence exposures in the leach pad. Particularly in outdoor settings, meteorological factors play an important role in the dispersion of air contaminants. The magnitude to which these factors can influence contaminant dispersion was clearly illustrated by an air pollution episode which occurred in Donora, Pennsylvania in 1948. During this incident, a series of atmospheric conditions resulted in a prolonged stagnation of air over the town. Despite the fact that the types and sources of contaminants in the area had remained unchanged for decades, the atmospheric conditions which occurred in a short period of time confined the pollutants to the extent that a significant increase in the number of deaths and illness due to respiratory problems resulted.[10] While this incident reflects a large-scale air pollution episode, it illustrates the ability of atmospheric events to influence the buildup of surface pollutant concentrations.

The supervisors accident report of the October 1 incident indicated the probable cause of the incident was "atmospheric inversion due to temperature". However, the description of the warm temperatures in the leach field, and cooler temperatures in the higher areas of the mine do not coincide with the conditions normally associated with inversions. Radiational or nocturnal inversions generally occur as a result of cool low-level air being overridden by warmer air above.[10] The presence of the warm air over the cool air prevents the vertical mixing of the two air masses. Conversely, the opposite conditions, which were described to exist during the October 1 incident, would generally be expected to promote atmospheric mixing.

The descriptions provided in the accident report did indicate that little wind movement was present in the area where the bulldozer operator was working. This was verified by the reports by the bulldozer operator of an accumulation of diesel exhaust in the work area. In this instance, wind stagnation, more so than the air temperature differences, would have appeared to have had a greater influence on any contaminant buildup. The lack of wind would slow the mixing of the air in the leach pad with fresh air from the surrounding areas. This would slow the dilution and removal of any contaminants which were being generated in the leach pad area. In addition, this would also allow a buildup of diesel exhaust contaminants, which should not be overlooked as to a potential health hazard.

VIII. CONCLUSIONS

The results of the environmental and medical data collected did not indicate any health hazard from exposure to cyanide during the period of the NIOSH survey visit. Due to the many variables involved, it is not possible to determine if cyanide was the cause of the symptoms experienced by the employee during the incidents of October 1 and 4, 1987. However, the symptoms are typical of cyanide poisoning and were fairly specific. Due to the high acute toxicity of cyanide compounds, it is necessary to take all possible steps to minimize the risk of future exposure. Since the company has no control over the meteorological factors which contribute to the dilution and removal of contaminants generated on the leach pad, it is necessary to closely regulate the operational factors that contribute to this exposure. In addition, continued emphasis on employee training, coupled with additional environmental monitoring, should further help to prevent future episodes of this nature.

IX. RECOMMENDATIONS

1. The company should continue its training program for employees working in the cyanide leaching operations. This training should be conducted upon the initial employment or assignment of the employee, and periodically thereafter. The training should include information on the toxicity of cyanide, safe work practices, and appropriate emergency and first-aid procedures. Currently available training programs and materials, such as the Colorado Division of Mines "Cyanide and Caustic Soda Training Course", which specifically address the hazards of cyanide leaching operations, should be used when possible.

2. Well trained medical personnel and cyanide emergency kits should be available on site throughout the working hours. The medical recommendations section contained in the NIOSH "Criteria for a Recommended Standard...Occupational Exposure to Hydrogen Cyanide and Cyanide Salts", should be referenced for specific details regarding medical treatment and first aid.[3]

3. Operational factors such as solution pH, concentration, and temperature should continue to be closely monitored. The pH of the solution should be monitored continuously, with the pH meter calibrated at the start of each shift in accordance with the manufacturers instructions.[11] The use of an audible alarm, to indicate if the pH falls below an acceptable level, would also be beneficial. Should the solution pH fall below an acceptable level, leach field operators and other critical personnel should be made aware of the change so that the appropriate precautions and environmental monitoring can be conducted.

4. During periods of diminished wind activity or other conditions which might lead to increased contaminant concentrations, a continuous reading monitor should be used in the bulldozer cab to monitor HCN concentrations. Such monitors, which provide a direct reading output as well as an alarm to warn the user when HCN levels rise above a certain preset limit, are commercially available.

5. In the event that environmental monitoring indicates that concentrations of HCN may possibly exceed the NIOSH REL, the bulldozer cab should be supplied with an emergency escape respirator, and the operator should be trained in its proper use.

6. Equipment operators should not leave their equipment cabs in the leach pad areas without the proper personal protective clothing (rubber boots, rubber gloves, and rubber splash suits).

7. Smoking, eating, and drinking should not be allowed on the cyanide leach pad. Employees should wash their hands, arms and face thoroughly before engaging in these activities.

While this evaluation encompassed only the heavy equipment operators, other mine employees such as the recovery plant workers, maintenance employees, and sprinkler crews face a greater risk of exposure to cyanide. These employees should also be provided with the appropriate training and safety equipment, and their work areas should be provided with the appropriate monitoring equipment. The NIOSH "Criteria for a Recommended Standard...Occupational Exposure to Hydrogen Cyanide and Cyanide Salts", the Mine Safety and Health Administration publication "Cyanide Mill Reagents", and the Colorado Division of Mines "The Safe Handling of Cyanide and Other Hazardous Materials and Wastes at Colorado Mines and Mills" should be consulted for further details.[1,3,11]

X. REFERENCES

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XII. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to the following:

A. Summitville Consolidated Mining Company, Inc., Del Norte, Colorado
B. Mine Safety and Health Administration - Region VIII
C. NIOSH Regional Offices/Divisions

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

TABLE 1

RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR AIRBORNE CYANIDE

Summitville Mining, Summitville, CO
October 20, 1987

SAMPLE TYPE	SAMPLE DESCRIPTION	MINUTES SAMPLED	LITERS SAMPLED	TWA CONCENTRATION CYANIDE (mg/M3)
Area	Leach Pad - Work Area	129	129	0.03
Area	Inside Bulldozer Cab	175	175	0.02
Area	Inside Roadgrader Cab	136	136	0.004
Area	Inside Truck Cab #74-6	170	170	0.01
Area	Inside Truck Cab #79-6**	180	180	0.004
Area	Inside Truck Cab #76-6 east side of room	168	168	0.01
Area	On leach pad near drainage pond	95	95	0.06
Area	On leach pad near drainage pond	93	93	0.09
NIOSH Recommended Exposure Limit			10 min ceiling	5.0
OSHA Permissible Exposure Limit				5.0
ACGIH Threshold Limit Value				5.0

Abbreviations and Key
TWA - Time-weighted average
mg/M^3 - milligrams per cubic meter of air
* - All values are expressed as TWA's for the period of sample collection.
** - This individual worked only for a portion of the sampling period.

TABLE 2

RESULTS OF PRE- AND POST-SHIFT SERUM AND URINE SAMPLES FOR THIOCYANATE CONCENTRATION

Summitville Mining, Summitville, CO
October 20, 1987

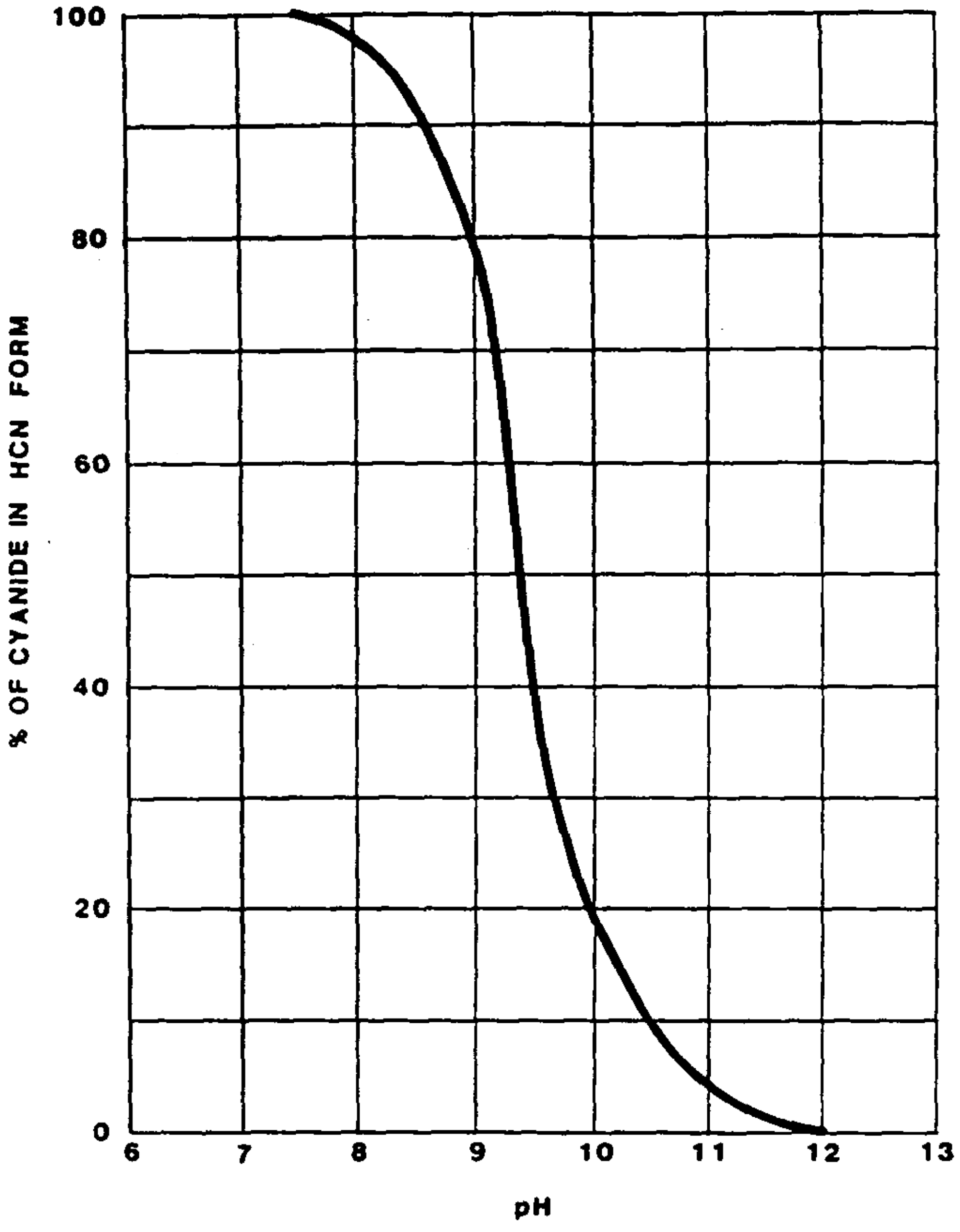
ID NO.	JOB TITLE	Pre/Post-shift Serum Thiocyanate Milligrams/Liter	Pre/Post-shift Urine Thiocyanate Milligrams/Liter	Number of Cigarettes per Day
003	Bulldozer Op.	7.70/-	7.0/20.5	40
006	Truck Driver	10.2/11.5	26.1/18.7	20
007	Truck Driver	7.40/7.90	11.4-	20
008	Truck Driver	-/-	12.3/-	30
009*	Control No. 1	9.80/7.60	12.7/11.8	20
010*	Control No. 2	-/9.40	18.7/13.2	20

Reference Range: Smokers 3.0-12.0 mg/L (serum), 2.0-20.0 mg/L (urine).

* Indicates unexposed workers as "Control".
\- Indicates that sample was not obtained.

FIGURE 1

EFFECT OF pH ON CYANIDE IONIZATION



DATA BASED ON WORK BY D. MILNE, 1950, FOR DILUTE SODIUM CYANIDE SOLUTIONS AT AMBIENT TEMPERATURE. TOXIC HCN FUMES INCREASE AS TEMPERATURES AND SOLUTION CONCENTRATIONS INCREASE REQUIRING HIGHER pH FOR SAFE OPERATION.

SOURCE:

Cyanide and Caustic Soda Safety and Training Course, Student's Manual
Colorado Division of Mines, Denver, Colorado
American Mine Services, Inc., Commerce City, Colorado 80022