

Monitoring Procedures for Determining Components of Salt Dust and Evaluating Worker Exposure Potential

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ABSTRACT

Salt dust is currently classified as a nuisance particulate. Therefore, worker exposure is limited to an airborne concentration of 10 mg/m³ as an eight-hour time-weighted average. Since the dust standard was developed to cover a broad range of nuisance particulates, this limit may be too restrictive for salt dust. The paper discusses the health effects and the safety concerns

of salt dust in light of the above standard, as well as the feasibility of increasing the permissible exposure limit without compromising worker health. The paper also deals with the possible impurities of salt such as free crystalline silica and arsenic. Such contaminants would not pose any special problems even if the allowable concentrations of salt exposure were increased.

INTRODUCTION

In 1982, the U.S. Mine Safety and Health Administration (MSHA) issued a memo stating that the agency would enforce only those substances that are specifically listed in Appendix E of the (ACGIH) TLV booklet. Because salt dust is not listed, it is no longer subject to the 10 mg/m³ limit. However, MSHA has suggested that the composition of airborne salt dust may be somewhat different from the parent material and that certain hazardous substances warrant additional investigation. Because of these statements, the International Salt Company (ISCO) decided to conduct a study to characterize airborne salt dust and determine whether the components of the dust present a health hazard. This paper discusses not only the results of the study but also the sampling and analytical methods used to monitor total and respirable dust, toxic contaminants such as free-crystalline silica and trace metals, plus total solubles and insolubles.

BACKGROUND

Before getting into the details of the salt dust study, it is important to provide some background information concerning my (Leonard's) involvement with International Salt Company and the salt dust issue. Four years ago, during an MSHA inspection of one of ISCO's mines, the

MSHA inspector stated that he was going to monitor worker exposure to salt dust and that he would be using the ACGIH recommended exposure limit for nuisance dust, which is 10 mg/m³, as the criteria for allowable exposure. When the dust samples were analyzed, it was found that the total dust levels ranged from 15 mg/m³ to 80 mg/m³. MSHA issued a citation and gave us a time limit to abate the problem. Equipment modifications were made to reduce the amount of dust generated; however, in spite of these improvements, subsequent air monitoring showed that the dust levels were still not below 10 mg/m³.

Because salt dust was not specifically listed as a nuisance dust, Robert Baldeck asked for my assistance in evaluating the total dust concentrations, as well as the method used to measure the dust. He questioned whether the method was giving erroneously high results and whether the nuisance dust standard was appropriate for salt dust. It seemed that if salt dust concentrations greater than 10 mg/m³ were potentially harmful to the miners, why was it that our workers appeared to be so healthy. The other perplexing point was that the mine, upon visual inspection, did not appear to be as "dusty" as the data suggested. Even areas where the dust levels were measured at 50–80 mg/m³, the miners were not having difficulty breathing, irritation, or significant visibility problems.

Last year, MSHA issued a memo stating that the agency would enforce only those substances that are specifically listed in Appendix E of the (ACGIH) TLV booklet. Since salt dust is not listed, it is no longer subject to the 10 mg/m³ limit. However, MSHA stated that it would concentrate on the visibility aspect. In a 1982 informal study by MSHA, some additional questions concerning salt dust exposure were raised. The agency suggested that the composition of airborne salt dust may be somewhat different from the parent material and that certain hazardous substances warrant additional investigation. Because of these statements, ISCO decided to conduct a study to characterize airborne salt dust and determine whether the components of the dust present a health hazard. This paper discusses not only the results of the study but also the sampling and analytical methods used to monitor worker exposure to salt dust. In our conclusions, we would like to explain the reasons why we find total dust monitoring alone to be an inappropriate method for evaluating worker exposure to salt dust. Also, we would like to propose an alternative method that may be more valuable in determining potential risk of exposure to salt dust and may even explain the lack of respiratory problems associated with inhalation of salt dust.

MONITORING PROCEDURES

Total dust samples were collected on pre-weighed polyvinyl chloride (PVC) membrane filters having a pore size of five microns. The samples were collected at a flow rate of 2.0 liters per minute for the entire workshift. In high dust exposure areas, shorter sampling intervals are recommended in order to improve laboratory filter weighing accuracy.

Respirable dust samples were collected on pre-weighed PVC membrane filters having a pore size of five microns. The filters were preceded by a ten millimeter cyclone to separate the non-respirable dust. The samples were collected at a flow rate of 1.7 liters per minute for the entire workshift. This long sampling time is necessary so that the filter loading is sufficient for the determination of a 1% free silica level.

In some instances, both the total dust and respirable dust samples were placed on the same employee for side-by-side comparison of the dust concentrations. Respirable and total particulates were analyzed using gravimetric procedures. Silica content of filters and bulk samples were determined using the modified Talvitic method (NIOSH P & CAM 106 procedure). To determine the soluble and insoluble salt fractions, the samples had to be pretreated prior to the silica analysis. This was done by taking the pre-weighed PVC sample filters and placing them in Erlenmeyer flasks in which 100 milliliters of distilled water was added. The flasks were placed in an ultrasonic bath for ten minutes. The samples and wash-

ings were then filtered through a weighed 0.45 micron cellulose filter typically used in the NIOSH (National Institute of Occupational Safety and Health) colorimetric silica procedure. The 0.45 micron filter was then dried, reweighed and added to the original flask along with the PVC filter. The two filters were then digested for silica determination using the NIOSH colorimetric procedure. The filtrate and washings were diluted and analyzed for salt using atomic absorption spectrophotometry.

MSHA suggested that arsenic may be a potential exposure problem in some salt mines. Therefore, several air samples representing worker exposures and a bulk sample were analyzed for arsenic by atomic absorption.

RESULTS

Total dust exposure concentrations, which range between 6.0 to 95.3 mg/m³, vary considerably from day to day and are operation dependent. Analyzing total dust samples presents a problem because the filter cassettes may contain so much dust that accurate weighing of total particulate cannot be obtained. This is because some of the particulate matter was left in the filter cassette after the filter was removed. Also, during the monitoring period, the salt tends to cake and chip off or form little balls that could fall out of the cassette. A comparison of total dust concentrations for identical operations vary so much that it suggests that some large particles may not be drawn into the filter cassette by virtue of the air flow from the pump, but rather, it seems as though these particles are propelled into the cassette from the momentum they receive from the mining equipment (Table 1). These particulates that have inadvertently been "caught" in the filter cassette add considerable weight to the filter and result in erroneously high dust concentrations. And, although the total dust concentrations appear to be high, the random particles that cause the additional weight on the filter may, in fact, never be inhaled by miners due to the particles' large size and rapid descent to the ground.

Conversely, there does not appear to be a significant deviation in respirable dust exposures (Table 2). These levels, which range between 0.9 and 3.6 mg/m³, seem to suggest that there exists a uniform respirable dust concentration throughout the mines we monitored. Later, I

TABLE 1
Variations in Total Dust Exposures (mg/m³)
for Different Operations (Mine A)

Shuttle Car Operator	Powderman	Jeffrey Loader	Driller	Under-cutter
6.0	21.6	32.1	45.2	6.5
7.7	23.2	72.0	55.7	35.0
13.0	25.7	79.2	57.6	78.8
19.0	34.9	95.3	75.0	

TABLE 2

Uniformity of Respirable Dust Concentrations (mg/m³)
Throughout Mine A and Mine B

Mine A	Mine B
Driller2.9	Vert. Driller3.6
Undercutter2.0	Undercutter1.0
Powderman2.1	Belt Maintenance1.6
Jeffrey Loader2.0	Front End Loader1.4
Shuttle Car (#6)0.9	Hauler (#1)1.4
Shuttle Car (#10)1.0	Hauler (#2)1.3
	Hauler (#3)2.0
	Salt Processor2.1
	Laborer Processor1.2

will discuss more about the significance of this observation with respect to potential health effects.

In comparing the side-by-side samples for total and respirable dusts, we found that when the total dust concentrations were high, the respirable dust concentrations were not correspondingly elevated (Table 3). There was no statistically significant linear correlation between total and respirable dust concentration data. To determine whether the percent salt (soluble fraction) was significantly different between respirable and total dust samples, paired samples were pretreated to extract the soluble fraction prior to the silica analysis.

The free silica analysis did indicate the presence of a small amount of quartz. The concentration ranged from 2.1% to 2.6% for respirable dust samples, and less than 1% in the corresponding total dust samples (Table 4). If free silica were present in the respirable dust samples, it should also be present in the total dust samples. Since this was not the case, the free silica detected in the respirable dust samples may be an artifact of the analytical technique or procedures used. Furthermore, another set of samples (these were not paired), were an-

TABLE 3

Paired Sample Data for Total and Respirable Dusts (mg/m³)

Location	Resp. dust	Total Dust
Mine A		
Driller	2.9	75.0
Undercutter	2.0	6.5
Powderman	2.1	24.0
Jeffrey Loader	2.0	72.0
Shuttle Car (#6)	0.91	19.0
Shuttle Car (#10)	1.0	13.0
Mine B		
Vert. Driller	3.6	4.2
Hauler	2.0	10.0
Laborer Processor	1.2	78.++
Salt Processor	2.1	76.++
Front End Loader	1.4	56.++

TABLE 4

Free Silica (% Quartz) In Respirable and Total Dust Samples

Location (Paired Samples*)	Resp. Dust (% Quartz)	Total Dust (% Quartz)
Vert. Driller	2.6	< .01
Laborer Processor	2.1	< .02
Salt Processor	2.3	< .01
Front End Loader	2.6	< .01
Hauler (#1)	< .58	...
Hauler (#2)	< .77	...
Belt Maintenance	< .69	...
Trenchman	...	< .04
Undercutter Helper	...	< .16
Hauler (#3)	...	< .07

*Paired samples were pretreated to extract the soluble fraction prior to silica analysis.

alyzed for free silica and none was detected in either the respirable or total dust samples. Since these samples were not pretreated, it is possible that for the treated samples some free silica may have been picked up from the glassware during all the transfers and filtrations. In as much as the total dust samples in the paired group and all the non-pre-treated samples did not contain free silica, we felt that the silica content reported for the paired respirable dust samples could be discounted.

One other point to note is that these samples were collected in a salt dome where silica is not expected to be present. Analysis of bulk samples confirms this. We chose this location to test the acceptability of the colorimetric method. Although this method has been very accurate for non-salt-related surveys we have conducted, the random presence of possible false positives suggests further investigation into this matter. MSHA recommends X-ray diffraction to analyze for free silica; however, it had only been used for total dust samples because the sample size of the respirable dust samples is too small. For the technique to be sensitive enough, a minimum sample size of 1 mg of dust is necessary to detect low free silica concentrations. Therefore, using a flow rate of 1.7 liters per minute and an eight-hour sampling time, the respirable dust concentration would need to be at least 5 mg/m³. Further, since the respirable dust levels were below this level, X-ray diffraction did not appear to have the sensitivity we needed.

Soluble and insoluble fractions were determined on a weight basis (Table 5). The variation in weighing and stabilizing filters was too great to determine accurately insoluble percents for the majority of respirable dust samples. After extracting the soluble fraction from the respirable dust sample the insoluble fraction was such a small amount that it was not significantly greater than the variation in filter weighing and filter stabilization. Therefore, it is listed as non-detected (N.D.). Insolubles for the

TABLE 5
Soluble and Insoluble Percents

Location	Respirable Dust		Total Dust	
	Soluble %	Insoluble %	Soluble %	Insoluble %
Driller	79.0	21.0	100+	.01
Undercutter	68.0	33.0	84.0	16.00
Powderman	100+	ND	96.0	4.40
Jeffrey Loader	99.0	ND	97.0	3.20
Shuttle Car (#6)	100+	ND	94.0	5.90
Shuttle Car (#10)	100+	ND	95.0	2.60

ND = non-detectable.

first two samples could be quantified. The 21% and 33% insoluble fractions for these samples are considerably greater than the insoluble percent found in the total dust samples. This does suggest that the respirable dust composition is different from total dust; however, additional samples would help define this observation.

Respirable dust composition is likely to differ from total dust for the following reason. When drilling or fracturing salt, less force will be required because the solid salt fractures easily. However, when drilling harder material such as the rock around the salt vein, more force will be required to fracture the harder material. The greater force will produce the smaller respirable particulate. Large amounts of respirable dust would not be expected when drilling or fracturing the salt because it would tend to fracture along the crystalline lattice and theoretically not produce large volumes of respirable dust. We feel this may be one explanation of the relatively low respirable dust concentrations observed and the high total dust concentrations observed.

When comparing the percent salt found in respirable dust samples (Table 6), it can be seen that the percent salt in respirable dust is significantly lower than that found in the total dust. Also, the percent soluble fraction for respirable dust is lower than total dust soluble fractions. This suggests that the respirable dust has more insoluble material than does total dust.

Bulk samples were collected at operations that were representative of mining activity (Table 7). They are representative of what mining workers are exposed to. In addition to bulk dust samples a piece of rock was taken from the mine, ground and analyzed. The rock appeared to be a solid piece of strata which looked representative of the strata surrounding the salt vein. When drilling in the mottle (a mixture of rock and salt) surrounding the vein, this rock will be penetrated by the drill.

The insoluble fractions for the first four bulk samples ranged between 0.4% and 2.3%. This indicates the samples are largely salt. This was confirmed by analyzing the samples for percent solubles and percent salt. The salt

TABLE 6
Salt Analysis

Location	Respirable (% Salt)	Total Dust (% Salt)
Driller	60.0	91.0
Undercutter	62.0	89.0
Powderman	40.0	86.0
Jeffrey Loader	47.0	77.0
Shuttle Car (#6)	43.0	100+
Shuttle Car (#10)	32.0	84.0

TABLE 7
Bulk Sample Analysis

Location	% Insolubles	% Silica	% Salt
Drill in Salt Vein	0.42	0.02	97.0
Drill in Mottle	0.68	*	91.0
Top of Stamler	1.40	0.08	100+
Screening	2.30	0.10	100.0
Ground Stone	78.00	1.30	9.3

*Sample flask broke during silica analysis.

Note: The data in the above tables was extracted from a larger data base. The authors feel that this data is a fair representation of the total data base.

content for the first four samples ranged between 97% and 100%.

The ground rock fragment, as expected, had a considerably different composition. It was only 9.3% salt and contained only 1.3% free silica. Dust generated when a drill bit fragments strata, such as ground rock, could not be classified as nuisance dust because it is greater than 1% free silica. Drilling is the only operation that would fragment the rock. The majority of drill holes are in the vein that has more pure salt. In addition, the strata around the vein is a combination of salt and strata such as the rock. As a result, the overall silica percent of dust produced in the drilling operation would be substantially less than 1.3%. Therefore, even though some rock in the mine may have more than 1% free silica, overall employee exposure is to dust with significantly less than 1% free silica.

Samples representing worker exposure to total and respirable dusts were analyzed for arsenic. Arsenic could not be detected in the samples. The detection limit was 0.75 micrograms per cubic meter. The recommended exposure limit is 200 micrograms per cubic meter. Arsenic was also not detected in a bulk sample taken from the salt processor area.

CONCLUSIONS

Although this study did not reveal any levels of trace contaminants (such as silica or arsenic), these contaminants

may exist in other mines. Therefore, it is recommended that bulk samples be taken to determine whether such substances are present, and if they are, air samples should be taken to evaluate worker exposure concentrations.

Total dust monitoring does not appear to accurately assess worker exposure to dust; however, until the analytical methods for free silica become more sensitive, total dust samples may be necessary to support the results of bulk samples for free silica determination.

In this study, we examined the percent solubles, percent insolubles, and percent salt concentrations. This was for informational purposes only; therefore, it is not necessary to perform these analyses during routine industrial hygiene surveys.

We feel the most important aspect of this study was the quantification of respirable dust exposures. We found it very interesting that all the respirable dust levels were less than 4 mg/m^3 . The ACGIH standard for respirable nuisance dust is 5 mg/m^3 . We feel that the levels measured are not limited to the mines we surveyed but may also be representative of the concentrations in other salt mines. The data generated by Dr. James Gamble and William Jones of the National Institute for Occupational Safety and Health (NIOSH) for their paper, entitled *Health Effects of Salt (NaCl) by Inhalation*, tends to support this observation. (This paper was presented at the Salt Institute Dust Seminar in November 1979 in Chicago, Illinois.) The NIOSH group monitored respirable dust and

plotted the individual worker concentrations against personal lung function performance. Although not specifically highlighted in the paper, most of the exposures were less than 2 mg/m^3 and a few were as high as 4 mg/m^3 . This correlates well with our results.

Therefore, we feel that respirable dust concentrations, which are fairly uniform throughout salt mining operations, are a better measure of worker exposure to salt dust. The differences that total salt dust samples exhibit from typical nuisance dusts, make it an unreliable measure of exposure. However, excessive total dust concentrations should be controlled so that they do not impair visibility or cause irritation to the worker.

In closing, it is appropriate to reiterate Gamble's and Jones' conclusions about salt dust exposure:

"Salt is an indispensable ingredient in body fluids. Taken in excess, NaCl can cause hypertension and toxic effects. Most salt intake occurs through the gastrointestinal tract from salt in the diet. Even in workers exposed to high airborne salt concentrations, only a small proportion of total salt intake occurs by inhalation. It is unlikely that inhalation of salt by occupational exposure will result in hypertension. . . . [And most importantly], there is no association of NaCl exposure with respiratory symptoms, reductions in baseline lung function or reductions in lung function over the shift."