REDUCING BAG OPERATOR'S DUST EXPOSURE IN MINERAL PROCESSING PLANTS

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INTRODUCTION

The purpose of this paper is to summarize a number of different research projects performed over the last few years that deal directly with lowering the dust exposure of the bagger operating fluidized air bag machines. Each of these projects investigated the possibility of using completely different methods and approaches. The first approach was to use a different type of bag valve. The next two approaches involved engineering controls which were implemented in and around the bag loading area. The last approach dealt with the control of dust sources from other areas of the plant or mill. The bag operator's function is to place empty bags on the fill nozzles as filled bags are ejected from the machine. This is quite a common practice since most mineral processing plants bag at least some of their products. In many cases, especially when bagging extremely fine product, the bag operator's dust exposure is one of the highest for the entire plant. In performing this job, the bag operator is exposed to two primary dust sources. The first is product blowback during the bag-filling cycle. As excess pressure is released from around the fill nozzle during filling, the excess air and product are forced out of the bag, creating a considerable amount of dust. The second major source is the sudden plume of product, commonly called a "rooster tail," thrown from the bag valve and fill nozzle as the pressurized bag is ejected from the machine. Individuals wishing to lower the bag operator's dust exposure should be able to do so by using one or more of the techniques evaluated by the Bureau of Mines over the past few years and shown to significantly lower operator dust exposure.

EVALUATION TECHNIQUES

In all cases, respirable dust concentrations in air at the bag operator's station were monitored by the same method. A 10-mm cyclone was attached either to the operator's lapel, or near the breathing zone. The 10-mm cyclone is used in the United States for compliance sampling of respirable dust as established by the Mine Safety and Health Administration. Threshold limit values for metal/nonmetal operations are listed in the Federal Register (CFR) Part 30-56-5-5 which is based on a 1973 recommendation from the American Conference of Government Industrial Hygienists.[1] The cyclone was connected to the dust monitor by tygon tubing to allow the operator to perform the job function with minimal interference. The tubing length was minimized to reduce any losses associated with dust adhesion to the inner walls of the tubing, although a previous laboratory evaluation showed negligible effects with various tubing lengths that were within reason (1 to 3 meters). The same length of tubing was used in all cases for each analysis to further minimize any biases. The RAM-1 real-time aerosol dust monitor, built by GCA Corp., was used for all monitoring.*[2] This device uses light scattering to determine the respirable dust concentration in an air sample drawn from the environment through the cyclone. This instrument was calibrated for respirable silica dust and was used to compare the relative change in the bag operator's respirable dust exposure determined before and after the implementation of each technique. The operator's exposure is a measure of the dust in the worker's breathing zone and not the actual dust breathed by the worker since most workers wear some type of respirator protection at these operations.

THE FOUR RESEARCH PROJECTS

The following four research projects were conducted.

Bag Valve Modification

The bag valve design plays an important role in the degree of dust generated from blowback during the bag filling process, the rooster-tail as the bag is discharged from the fill station, and the later dust exposure of workers loading the bags onto pallets. The effectiveness of five commercially available bag valves in reducing dust generated during bag filling, conveying, and the pallet loading process was evaluated. The five valves tested included standard paper, polyethylene, extended polyethylene, double trap, and foam. Two factors appeared to determine valve effectiveness. The first was the valve length; the longer the valve, the more effective it was in reducing product blowback and bag-generated dust. The second factor was the valve material. Foam appears to be the most effective material for reducing dust generation, followed by polyethylene, and then standard paper. Considering both length and material, the extended polyethylene was the most effective valve tested and resulted in a 62% reduction in operator exposure.[3] An additional benefit with this valve is the dust reductions achieved at various locations throughout the bag conveying and pallet loading process (Figure 1). The extended polyethylene valve was also one of the most cost-effective of those tested, with an increase in cost of approximately $6.85 per thousand bags (0.7 cent per bag) over that of the standard paper valve (Table I).

Dual Bag Nozzle System

A dual bag nozzle system was designed to reduce the major dust sources of the bag filling process. The inner nozzle is the

Table I
Increase in Valve Cost Above the Cost of the Standard Paper Valve

Valve	Additional cost per 1000 bags, $	Additional cost per bag, cents
Polyethylene	6.85	0.7
Extended polyethylene	6.85	0.7
Double trap	11.17	1.1
Foam	214.98	21.5

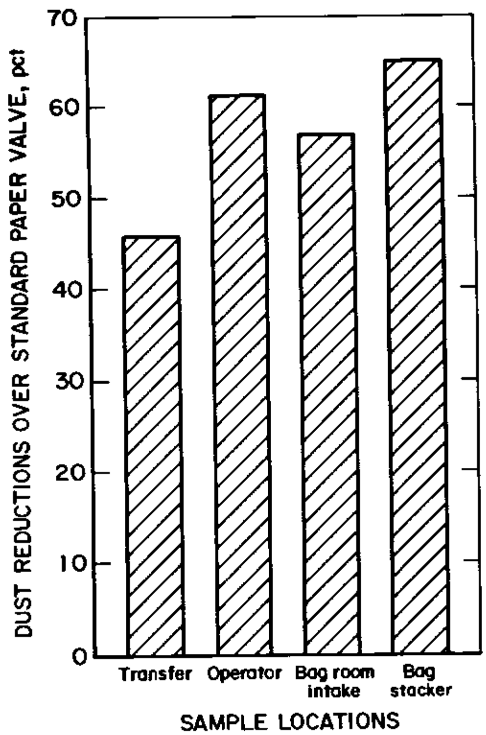

Figure 1. Airborne respirable dust reductions with extended polyethylene compared with that of standard paper valve.

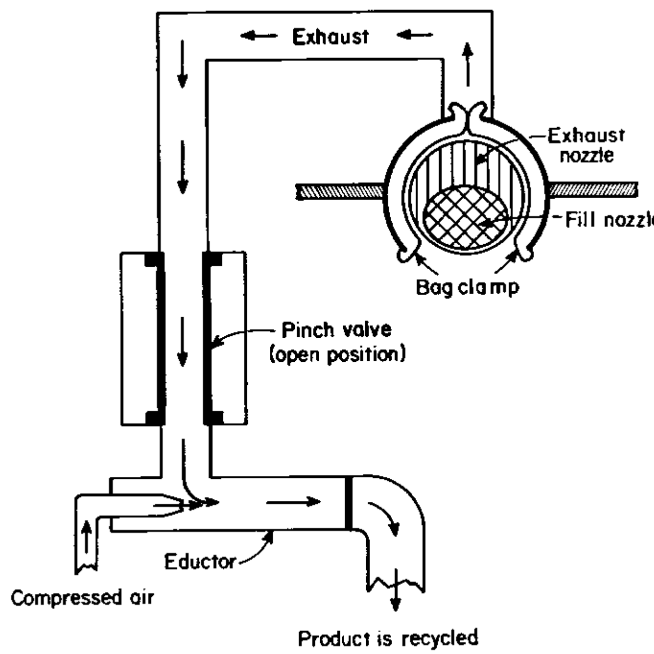

Figure 2. Dual bag nozzle system.

normal fill nozzle; the outer nozzle serves as an exhaust nozzle (Figure 2). The exhaust system is operated after completion of the bag filling process to remove excess pressure from the bag. The exhaust is powered by an eductor, which uses a venturi effect to exhaust the bag at approximately 1.42 m^3/min (50 ft^3/min). The exhaust airstream goes into a bucket elevator, which recycles the exhausted product. A pinch valve opens and closes the exhaust outlet. An improved bag clamp which makes direct contact with about 80% of the nozzle reduces the amount of product blowback during bag filling.[4,5] A field evaluation was performed on this dual bag nozzle system during the second week of a 2-week test on a four-station bagging operation. During the first week, the conventional system was monitored to determine the amount of dust generated. Over the weekend, the new system was installed and the identical test was performed for the second week of testing. Figure 3 shows the bag operator's dust exposure with the conventional system and the new dual-nozzle system when bagging 325-mesh product. There was an 83% reduction in dust exposure with the dual bag nozzle system. There was a 90% reduction in respirable dust concentrations measured in the hopper below the fill station which determined the reduction in product blowback during bag filling; this can result in tremendous product savings. A significant decrease in dust accumulation on the outside of the bag resulted in a 90% reduction in dust exposure of workers subsequently stacking the bags onto pallets in enclosed vehicles. This system is suggested only for operations in which the bag operator fills bags from three or four stations. The production rate would decrease substantially for a one or two station system since the bag operator would be waiting on each bag as the exhaust system is operating, and thus would not be acceptable to most operations. The different components of this system can be fabricated by the mineral processing operations themselves or can be purchased from Foster-Miller, Inc., Waltham, Massachusetts, in which case the price would be dependent on the actual components necessary in each situation.*

Overhead Air Supply Island (OASIS)

The OASIS is an air cleaning device that is suspended over the bag operator and provides a flow of filtered air over the work station. It operates independently of the product processing equipment used. Mill air is drawn into the system and passed through a primary cartridge filter. This primary filter is self-cleaning, automatically using the reverse pulse technique when excessive filter restriction is sensed. The air can then pass through a heating or cooling chamber (optional), depending on the air temperature, and from there into a distribution manifold, which also serves as a secondary filter (Figure 4). The resulting filtered air flows down over the operator at an average velocity of 1.9 m/s (375 fpm), which restricts mill air from entering the clean air core.[6] The OASIS was evaluated at two different operations by monitoring the bag operator's dust exposure with the device turned on and off. Figure 5 is a segment of strip chart that shows the operator's dust exposure during actual testing at the first operation. The dust reductions for these two operations were 98% and 82%, respectively. The primary reason for the difference between these two values were the lower background levels, or off concentrations, at the second plant. At both plants, the dust concentration with the OASIS operating remained under 0.04 mg/m^3. An additional benefit with this system is the overall reduction in dust levels in the mill building as a result of the OASIS's cleaning action which averaged approximately 12%. This system is commercially available from Donaldson Company, Inc., from Minneapolis, Minnesota, at an approximate cost of $10,000 for a basic 6,000-cfm version; heating and air conditioning requirements are optional. The unit can also be fabricated in 3,000-cfm increments.*

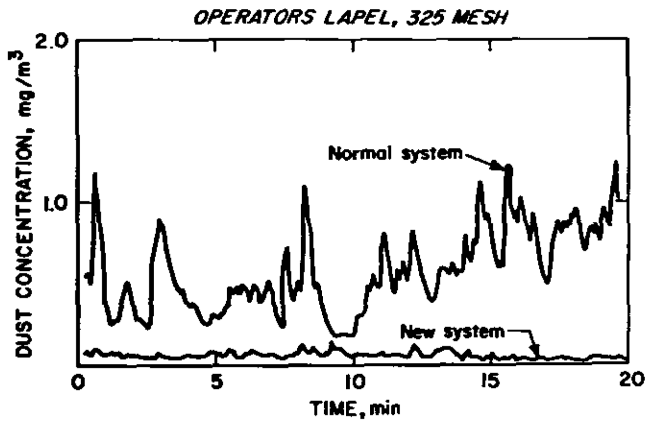

Figure 3. Operator's respirable dust exposure with normal system and dual nozzle system.

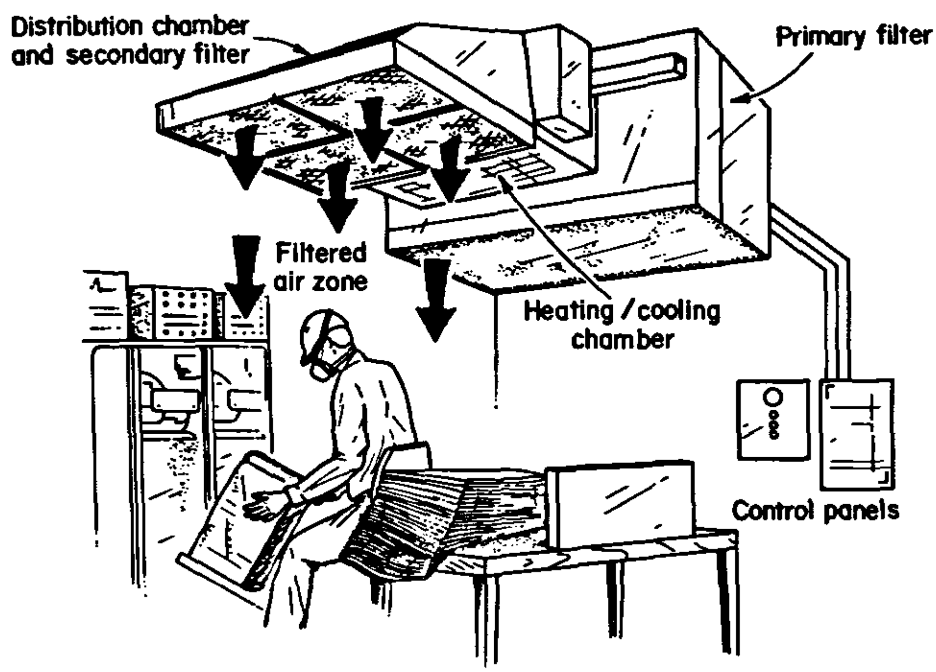

Figure 4. Overhead air supply island (OASIS).

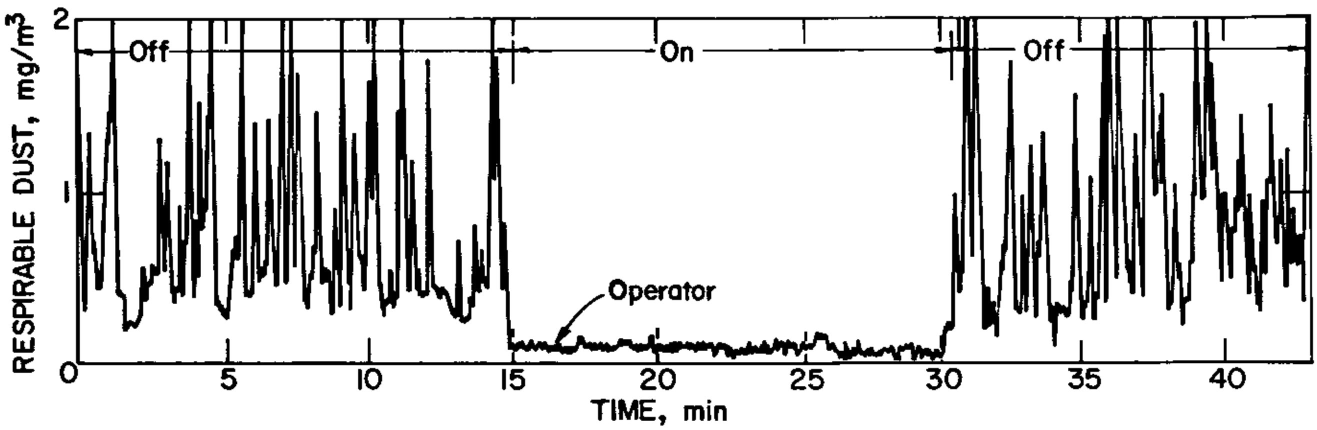

Figure 5. Operator's respirable dust exposure during bagging without and with OASIS.

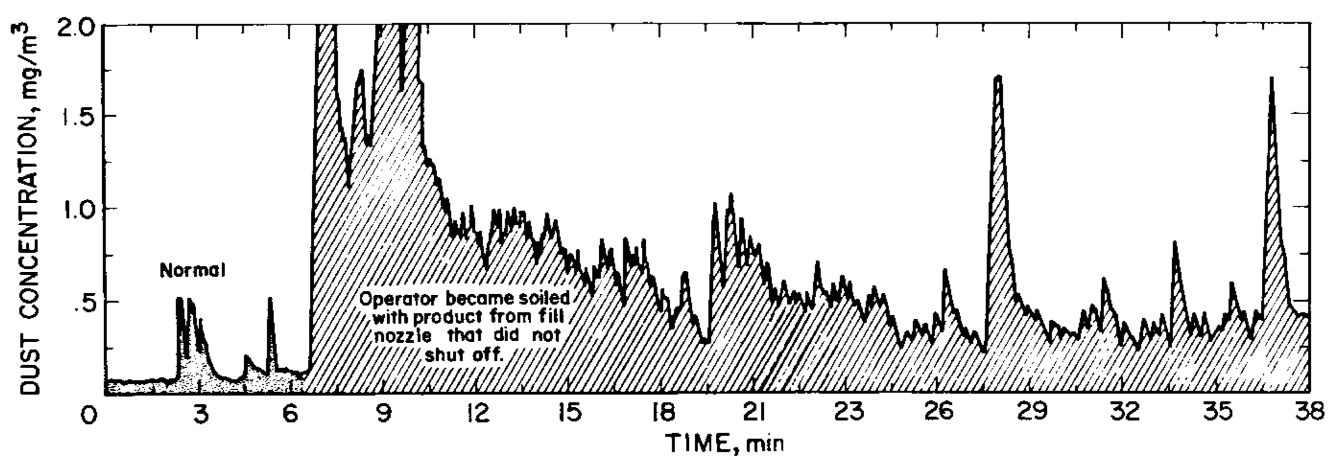

Figure 6. Operator's respirable dust exposure after becoming soiled with product from fill nozzle that did not shut off.

Control of Background Dust Sources

In addition to dust at the bagging station, a number of common background dust sources were identified in and around the bag filling area. These background dust sources, which are often unrecognized, can cause more contamination than the bagging process itself. Bag operators were monitored at their work station to determine different background contamination sources over the period of a workday. A number of different dust sources were observed to substantially increase the bag operator's exposure, in many cases as much as 5 to 10 times above the job function.[7] These background sources include work clothes soiled with product material, blowing work clothes off with compressed air, bag breakage during loading and conveying, bulk loading outside, bag hopper overflow, and sweeping with brooms. Figure 6 shows a case in which the bag operator became soiled with product from a fill nozzle that did not shut off after the bag ejected from the fill machine. The bag operator's respirable dust exposure before this occurred was approximately 0.1 mg/m^3; this increased to 1.01 mg/m^3 after the operator became soiled with product. Another example occurred while a truck was being bulk-loaded outside a mill where the bagging was performed. The dust generated from this bulk-loading process traveled through an open door into the mill, increasing the bag operator's exposure from 0.17 mg/m^3 before bulk loading began to 0.42 mg/m^3 (Figure 7). Over the period of the day, a substantial number of trucks may be bulk-loaded at this position, depending on customer orders. Thus, events not directly related to the bagging operation can be more significant sources of dust exposure to the bag operator than the bagging process itself. To effectively keep the operator exposure at acceptable dust levels, these background dust sources must be identified and controlled.

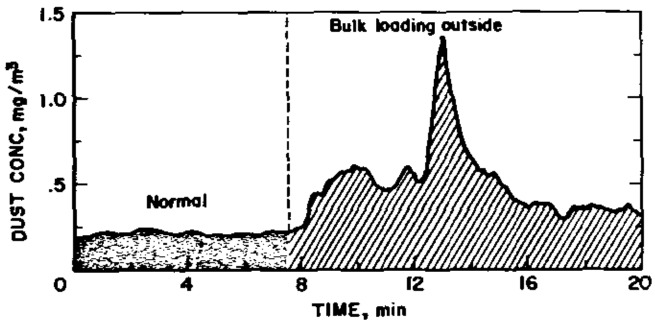

Figure 7. Bag operator's exposure from bulk loading outside.

DISCUSSION

The OASIS and dual bag nozzle system are available commercially. The dual bag nozzle system can also be fabricated at the plant, using the basic technology provided. Both of these engineering control techniques can lower the bag operator's dust exposure from 82-98%. The OASIS can also restrict dust from other sources from penetrating into the filtered envelope of air that flows down over the operator. Over a period of time, it also acts as a general air cleaner. The dual bag nozzle system significantly reduces the amount of product blowback during bag filling, which can also account for substantial product savings when lost product is not recycled. Since the system depressurizes the bag, much less product accumulates on the outside of the bag, thus substantially reducing dust generated during the conveyor and pallet loading processes. A 90% reduction in the dust exposure of workers stacking the bags into enclosed vehicles was also measured. The extended polyethylene bag valve is commercially available at an additional cost of 0.7 cent per bag, or $3.36 per standard truck load of 480 bags. It is a cost effective way to reduce workers' dust exposure. There are basically two types of background sources. The first is operator induced dust, the second involves dust from external sources being drawn over the bag operator. Operator-induced dust sources include soiled work clothes, blowing clothes off with compressed air, and bag breakage on the fill station due to improper pressure settings. Soiled work clothes can be an especially significant factor in winter, when heavy coats may be worn for long periods without cleaning. Dust from the second type of source occurs when the exhaust ventilation system captures dust generated from other areas of the plant. This is applicable in those cases where an exhaust ventilation system is located below the bag operator to capture any machine and bag-generated dust at the fill station. This creates a negative pressure which can draw dust from the mill over the bag operator unless a clean makeup air source is supplied. This was the case when bags were broken during conveying, during bulk loading outside, and when the bag hopper overflowed.

RECOMMENDATIONS

For mineral processing plants to keep bag machine operators' dust exposure at acceptable levels, plant operators must be aware of the different dust sources and methods to reduce these sources. Recent Bureau of Mines research has shown ways in which operator exposure can be reduced 62% to 98%. This information can be useful to any facility that packages product material into 50- to 100-pound bags. Comparison of various techniques in the actual working environment allows plant and mill operators to select methods best suited to their needs. Two of these techniques involve engineering controls that can be purchased commercially or fabricated at the plant. One technique involves simply acquiring a more efficient bag valve. The substantial effect of a number of different background dust sources on the bag operator's exposure must be recognized, and these dust sources must be identified and controlled.

REFERENCES

1. *Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH.* ISBN 0-936712-45-7, American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Cincinnati, OH 45211, 1973.
2. Williams, K. L., and R. J. Timko: *Performance Evaluation of Real-Time Aerosol Monitor.* Bureau of Mines IC 8968 (1984).
3. Cecala, A.B., Covelli, A., Thimons, E.D.: *Dust Reduction Capabilities of Five Commercially Available Bag Valves.* Bureau of Mines IC 9068 (1986).
4. Cecala, A.B., Volkwein, J.C., Thimons, E.D.: *New Bag Nozzle To Reduce Dust From Fluidized Air Bag Machines.* Bureau of Mines RI 8886 (1984).
5. Muldoon, T.L., Valentine, J.W., Burnett, M.: *Bag Machine Dust Controls and Bag Sealing.* USBM Contract Report H0318013, NTIS PB86-153558 (1986).
6. Volkwein, J.C., Engel, M.R., Raether, T.D.: *Get Away From the Dust With Clean Air From an Overhead Air Supply Island (OASIS).* Rock Products, July 1986.
7. Cecala, A.B., Thimons, E.D.: *Impact of Background Sources on Dust Exposure of Bag Machine Operator.* Bureau of Mines IC 9089 (1986).

*Reference to a specific manufacturer does not imply endorsement by the Bureau of Mines.

RECONSTRUCTION OF THIRTY YEARS OF FREE SILICA DUST EXPOSURE IN THE TACONITE INDUSTRY

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INTRODUCTION

The School of Public Health of The University of Minnesota[1] conducted a study to evaluate the impact of past and present mining and processing activities on employee health in the taconite industry. The University of Minnesota health study proposed to examine cancer mortality in Northern Minnesota, develop mine worker rosters, and develop research proposals for the study of lung and heart diseases. One of the most important objectives of the health study is to associate current health effects with known levels of past and current exposures to potentially toxic agents in the taconite industry. As a result, an exposure profile by job title for silica containing dust was developed for taconite workers.

Eighty-eight percent of iron ore used in iron and steel making (1978) in the United States comes from taconite, a hard, fine-grained iron-bearing rock.[1-4] The taconite mines and mills on the Mesabi Range in Minnesota produce 63 percent of U.S. iron ore and employ 14,000 workers. The Mesabi Range[3] is located 65 miles north of Duluth and northwest of Lake Superior and extends 120 miles from east to west. All the taconite mines are open pit mines.

This paper presents a summary of the exposure levels for silica containing dust for taconite mining and is based on respirable mass sampling data collected for the past 15 years, and impinger sample results collected from 1957 to 1975. From this data base, a matrix of respirable silica dust exposures over time and by job classification has been prepared.

METHODS

The establishment of current and past exposures to silica containing dust consisted of two major tasks: (1) compilation and summary statistics for a large amount of environmental sampling data by plant, job title, and time period; and (2) development of a model for converting historical environmental measurement data (impinger samples) into a form consistent with the current respirable mass sampling method. The results from the first task—a matrix of silica dust sample results—are summarized here; the development of the model is presented in a previous paper.[5] The model was evaluated from parallel impinger and respirable mass sampling data using multiple regression techniques.

In this study, records of 16,000 dust samples for four taconite plants (designated as Plants 1, 5, 7, and 8) were obtained from the mining companies. These samples were taken by the taconite companies and the Mine Safety and Health Administration (formerly Mine Enforcement Safety Administration) from 1957 to 1983; the authors also collected environmental samples in 1983-84 at taconite Plant 7. About 10,000 samples were impinger-particle count samples and the remainder were filter-respirable mass samples. From 1957 to 1975, impinger samples (nearly all midget impinger) were collected at the Minnesota iron range taconite plants. The impinger method was recommended[6] by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1942, as the standard for environmental studies in dusty industries. In the Northern Minnesota taconite plants, the filter respirable mass sampling method replaced the impinger sampling method in the early and mid 1970's.

With the impinger sampler, dust particles are collected in a liquid in a glass impinger flask at 0.1 cubic feet per minute (cfm) or 2.8 liters per minute (Lpm) for between 10 and 30 minutes, and the particles are counted with an optical microscope. Impinger results are reported in million particles per cubic foot (mppcf). The impinger sampling data in this study were all from area samples.

Filter samplers consist of a filter preceded by the 10-mm cyclone, operated at an airflow of 1.7 Lpm. Filter samples are analyzed gravimetrically and are reported as milligrams per cubic meter (mg/m^3) total respirable mass. Both personal and area filter samples, which were collected at these plants, were used in this study. Hi-volume samples were collected once or twice a year at Plants 1, 7, and 8 and analyzed for percent quartz.

The sampling data were compiled, entered on the computer, and a matrix of exposures by job title was prepared from respirable mass sample results. The validity of combining MSHA and company data were determined from nonparametric tests. Details of this analysis is reported previously.[7] A matrix of area dust concentrations by sample location were determined from impinger sample results. In addition, job titles, job descriptions, and time-motion information were obtained from the plants through conversations with company workers, supervisors, and industrial hygienists. Time-motion information and geometric mean area impinger dust concentrations were used to determine an average impinger dust exposure for selected job titles.

Descriptive statistics consisting of the number of samples, geometric mean, log of the geometric standard error, and minimum and maximum concentration, were obtained for the respirable mass data for 105 job titles. Respirable mass statistics for selected job titles are presented in this paper; the statistics for all 105 job titles are presented in a previous paper.[7] In addition, for the most often sampled job titles, respirable mass exposures were determined for 3-5 year time periods. Impinger sample concentrations (1957-1975), by location, were determined. The geometric mean concentrations are reported for the data in this study because statistical analysis using various mathematical transformations, as well as original scale, showed that the dust sampling data were log normally distributed.[7]

RESULTS

Sample data, collected at the four taconite plants studied, show the potential for high crystalline silica exposure. Percent silica quartz levels, averaged over time for each of the taconite mine and mill departments, are shown in Table I. These results are based on high-volume total dust samples (Plants 1, 7, and 8) and respirable quartz filter samples (Plant 5). The average quartz levels were 18-34 percent in the mine, 28-37 percent in the crushers, 14-37 percent in the concentrators, and 5 percent or less in the pellet plant. Changes over time in percent free silica were not observed.

The NIOSH Recommended Exposure Limit (REL)[8] for crystalline silica is a time-weighted average (TWA) concentration of 50 $\mu g/m^3$ respirable free silica. However, because all silica samples in this study were analyzed by weight and not quartz, the NIOSH REL has been converted to a respirable mass TWA concentration by dividing the allowable quartz concentration of 0.05 mg/m^3 by the maximum percent quartz level for each department. The OSHA Permissible Exposure Limit (PEL) and the MSHA Metal and Nonmetal Mining and Milling standard[9,10] for respirable crystalline silica is 10 mg/m^3 divided by the quantity (percent SiO_2 plus 2), averaged over an 8-hour work shift. For example, if the respirable dust contained 100 percent silica, the calculated standard would be 0.10 mg/m^3. Using the highest average quartz level in each of the taconite plant departments resulted in a PEL of 0.28 mg/m^3 respirable dust for the mine, 0.25 mg/m^3 for the crushers and concentrator, and 1.43 mg/m^3 in the pellet plant. Some taconite plants, which show a lower average quartz content, may have a higher allowable TWA (PEL); however, because the silica quartz content may vary, the higher percent quartz value should normally be applied. The NIOSH REL, when converted to a respirable mass value, ranges from half to two-thirds the respirable mass concentration allowed by the OSHA PEL.

Respirable mass personal sample results collected during 1972-1984 for selected job classes are summarized in Table II. The jobs with the lowest exposure (averaged for the four taconite plants) were in the mine. The truck driver, shovel operator, and dozer operator, respirable mass exposures were approximately 0.20 mg/m^3 respirable mass. Individual plant geometric mean exposures were lowest (0.07 mg/m^3) for the truck driver and the highest (1.26 mg/m^3) for the crusher laborer.

For the jobs in Table II, the highest respirable mass geometric mean concentration exceeded the NIOSH REL and the PEL for silica in all departments, except the pellet plant. The geometric mean concentration for the crusher laborer, the concentrator laborer, and concentrator maintenance man exceeded the NIOSH REL at all four plants. In the pellet plant, the highest geometric mean concentration for respirable dust was 1.0 mg/m^3 for the pellet laborer, which is at the NIOSH REL and below the PEL of 1.43 mg/m^3 for the pellet department.

Table I
(%) Silica Quartz Levels by Department from High Volume Samples

	Plant			
Location	1	5[(a)]	7	8
Mine	-	18	28	34
Coarse Crusher	32	33	32	37
Fines Crusher	35	28	(b)	(b)
Concentrator	20	14	22	37
Pellet	4	5	2	3

(a) Respirable mass filter samples
(b) Plant does not have Fines crusher

Table II
Respirable Mass Exposures by Job Title for Four Taconite Plants (mg/m³)

Job Title	Average 4 plants	Minimum	Maximum	NIOSH REL(a)	PEL
Shovel Operator	0.18	0.08	0.34	0.15	0.28
Truck Driver	0.20	0.07	0.33	0.15	0.28
Dozer Operator	0.20	0.14	0.29	0.15	0.28
Crusher Operator	0.30	0.11	0.59	0.14	0.25
Crusher Laborer	0.56	0.24	1.26	0.14	0.25
Conc Attendant	0.38	0.14	0.63	0.14	0.25
Conc Laborer	0.56	0.52	0.64	0.14	0.25
Conc Maintenance	0.43	0.37	0.47	0.14	0.25
Furnace Attendant	0.41	0.13	0.61	1.00	1.43
Laborer Pellet	0.61	0.43	1.00	1.00	1.43

(a) Adjusted NIOSH REL = $\frac{0.05 \text{ mg/m}^3}{\text{\% quartz (area sample)}}$

Table II includes the more frequently sampled job titles.

Respirable dust concentrations (geometric mean) among jobs in the open pit for the four taconite plants are compared in Figure 1. The exposures for the shovel operator, truck driver, dozer operator, and drill operator were lowest at Plant 1 and highest at Plant 5. Within individual plants, exposures among job titles in the mines were very similar. Exposures to respirable dust for three jobs in the crushers are compared in Figure 2. The mean respirable dust concentrations for the crusher operator were generally lower than for the coarse crusher laborer and fines crusher attendant. The geometric mean respirable mass concentration for the Plant 5 crusher laborer was 1.26 mg/m³, more than 3 times the exposure of the crusher laborers at the other three plants. Plants 7 and 8 did not have a fines crusher. Figure 3 shows respirable dust concentrations (geometric mean) for the concentrator attendant, laborer, and maintenance man. The laborer and maintenance man's exposures were nearly identical at Plants 5, 7, and 8, while the attendant's exposure at Plants 7 and 8 were 4 times greater than at Plants 1 and 5.

In addition to stratification by job class, respirable dust exposures were grouped into three time periods. The results for five job titles, presented in Table III, show differences in some exposures between the period 1972-1976 and 1980-1983. For some jobs, such as the truck driver at Plant 7, there were almost no changes in respirable dust exposures over time. On the other hand, exposures well above the PEL for the concentrator laborer, decreased by as much as 74 percent from 1972-76 to 1980-83 (t-test results show a highly significant difference in geometric mean respirable mass concentrations between the two time periods). This reduced the concentrator laborer's exposure from much above the standard to 0.27 mg/m³; which is between the NIOSH REL of 0.23 mg/m³ and the OSHA PEL of 0.42 mg/m³ for Plant 7 concentrator. The decrease in dust exposures appeared to be the result of introducing wet methods in grinding operations in the concentrator.

Figures 4 and 5 show changes in respirable dust exposures for jobs in the Plant 1 coarse crusher and Plant 7 concentrator. In general, respirable dust exposures for jobs in the coarse crusher of Plant 1 did not decrease over time, whereas respirable dust levels for all three jobs in the concentrator of Plant 7 showed significant decreases in the 12 year period.

Before the early 1970's, only impinger dust samples were collected at the taconite facilities. Several taconite plants have operated since 1957 and three others since 1968. During this period, a large number of impinger samples were taken at Plants 1, 7, and 8. The geometric mean impinger dust count concentrations for ten sample locations in the concentrator at Plant 1 are presented in Table IV. The results are shown for five time periods from 1957 to 1975, and are based on a minimum of three samples per location for each time period.

Because impinger dust samples are area samples and are collected by a different sampling method, two steps were required to make impinger sample results comparable to the respirable mass sample data: (1) the geometric mean impinger sample concentration for each location is multiplied by the percentage of time worked at each location and then summed for a particular job title; and (2) the mean impinger dust count concentration (mppcf) for the particular job title is then multiplied by a ratio (developed by the authors) of filter respirable mass concentration to impinger dust count concentration. The latter step is presented in an earlier paper.[5]

Table III
Changes over Time in Respirable Mass Exposures* (mg/m^3)

Job	Plant	1972-76	1977-79	1980-83
Truck Operator	1	0.10	0.08	0.06
	7	0.27	0.23	0.25
	8	0.09	0.19	0.14
Shovel Operator	1	0.17	0.08	0.05
	5	0.34	0.37	0.27
	7	0.17	-	0.06
Concentrator Secondary Attendant	5	0.25	0.22	0.38
	7	0.61	0.27	0.21
	8	0.57	-	0.24
Concentrator Laborer	5	0.76	0.53	0.27
	7	1.05	0.37	0.27
	8	0.99	0.67	0.40
Furnace Attendant	1	0.12	0.16	0.10
	5	0.59	0.62	0.65

* Geometric mean concentration

Table IV
Dust Count Concentrations at Locations Where the
Concentrator Laborer Worked (mppcf)

Sample Location (in Concentrator of Plant 1)	Geometric Mean				
	1957-59	1960-63	1964-67	1968-71	1972-75
Conveyors #7 & 107	1.5	3.4	3.1	3.5	-
West Conveyor #8	0.4	0.4	0.6	0.6	0.8
West Rod Mill	0.5	0.6	0.5	0.6	0.5
West Filter Floor	0.2	0.4	0.6	0.9	1.0
West Conveyor #10	0.4	0.3	1.1	1.7	-
East Conveyor #108	-	-	0.6	-	-
East Conveyor #109	-	-	0.6	0.8	0.7
East Rod Mill	-	-	0.5	1.0	0.7
East Filter Floor	-	-	-	1.0	1.2
East Conveyor #110	-	-	-	2.6	-

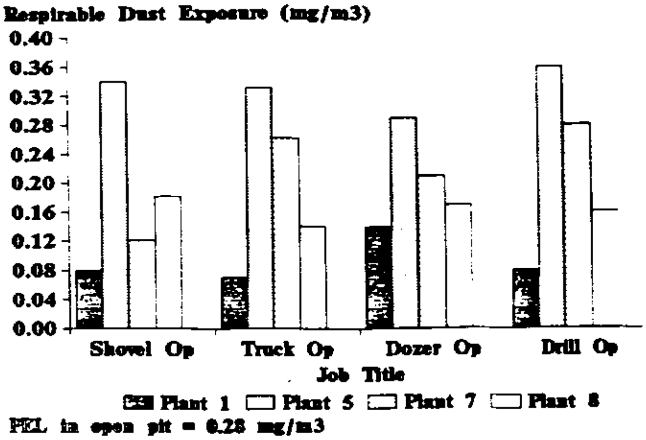

Figure 1. Respirable dust exposures in the open pit.

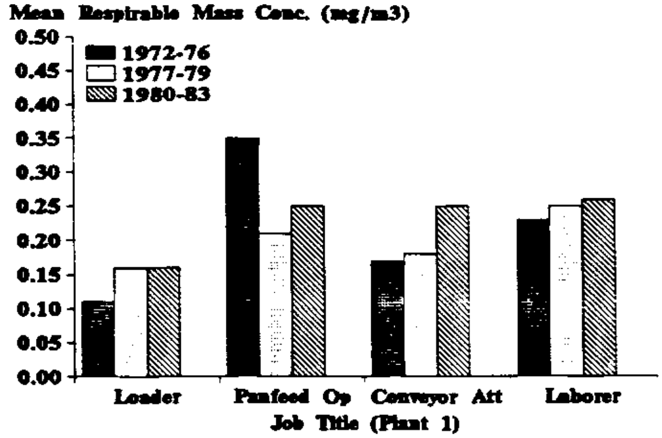

Figure 4. Respirable dust exposures over time in coarse crusher.

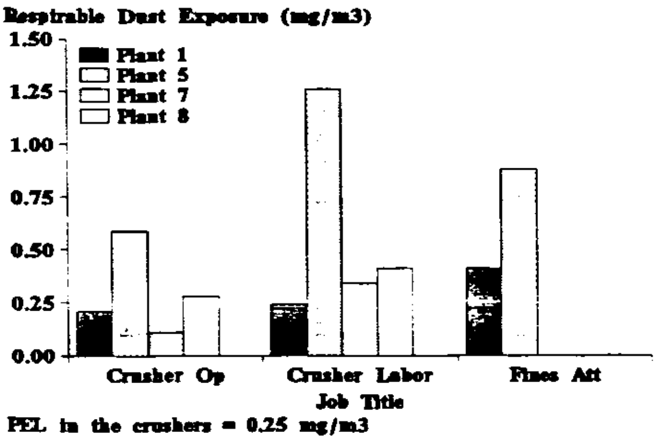

Figure 2. Respirable dust exposures in the crushers.

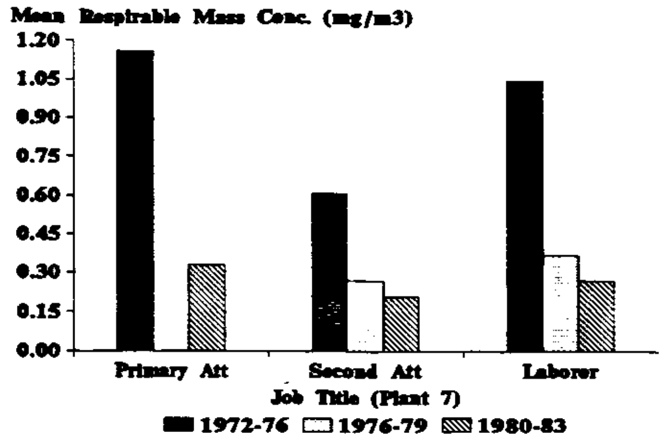

Figure 5. Respirable dust exposures over time in concentrator.

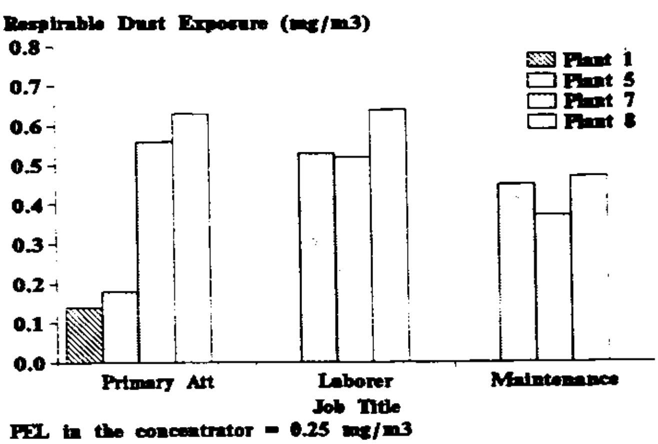

Figure 3. Respirable dust exposures in the concentrator.

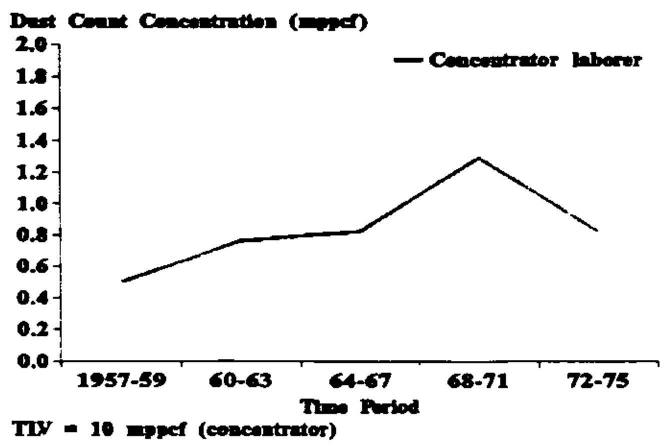

Figure 6. Estimated impinger dust exposures for conc. laborer at Plant 1.

To accomplish the first step mentioned above, the percentage of time the concentrator laborer spent at each location was determined. This percentage of time was then multiplied by the impinger area sample concentrations in Table IV to obtain an estimated impinger dust count exposure for the time period. An estimated impinger dust count exposure (mppcf) versus time for the concentrator laborer (solid line) is plotted in Figure 6. It shows the laborer's dust count exposure increased until 1968–71 and then decreased.

CONCLUSIONS

Quantitative exposure levels to silica-containing dust were determined for the taconite mines in Minnesota by analyzing both respirable mass and impinger dust count samples. These quantitative exposure data, briefly summarized here, are now available to epidemiologists attempting to determine the relationship of dose (quartz) to disease in the taconite industry, especially diseases with long latency such as cancer and silicosis.

A major task in analyzing the sample data collected before 1976, was to estimate personal respirable mass exposures from area impinger dust samples. This was accomplished by calculating geometric mean dust count concentrations at the sample locations and factoring in time-motion information for specific job titles.

Exposures to silica containing dusts in the mine, crushers, and concentrator exceeded the NIOSH REL and the OSHA PEL at some of the taconite plants. Exposures for jobs in the concentrator exceeded the REL and PEL at all 4 plants. Jobs in the pellet plant were below the REL and PEL.

However, these mean exposure values, encompassing exposures from about the 1970's to the early 1980's, hide changes in exposures such as those due to improved control technology. For example, jobs in the concentrator of Plant 7 showed significant decreases in exposure over 12 years due, in part at least, to the introduction of wet grinding methods.

REFERENCES

1. *Proposal—Mineral Resources Health Assessment Program.* Division of Epidemiology, School of Public Health, University of Minnesota. March, 1980.
2. West, R.: *Mining Environmental Target Investigation Taconite.* National Institute for Occupational Safety and Health. (Draft). May, 1982.
3. *Making, Shaping, and Treating of Steel.* United States Steel Corporation. Pittsburgh. 1971. pp. 178-239.
4. Minnesota's Iron Mining Industry. *The Iron Mining Industry of Minnesota.* 4th printing. 1978.
5. Sheehy, J.W., McJilton, C.E.: Development of a Model to Aid in Reconstruction of Historical Silica Dust Exposures in the Taconite Industry. *Am. Ind. Hyg. Assoc. J.* 48(11):914-918. November, 1987.
6. Davis, I.H., Ayer, H.E.: *Panel on Evaluation of Exposures to Mineral Dusts.* U.S. Department of Health, Education, and Welfare, PHS. Cincinnati, Ohio. May 1966.
7. Sheehy, J.W.: *Reconstruction of Occupational Exposure to Silica Containing Dust in the Taconite Industry.* Doctoral Dissertation. University of Minnesota, Minneapolis, Minnesota (February 1986).
8. NIOSH. *Criteria for a Recommended Standard... Occupational Exposure to Crystalline Silica.* HEW Publication No. (NIOSH) 75-120, GPO No. 017-033-00050, U.S. Government Printing Office, Washington, D.C. 1974.
9. Silica Flour: *Silicosis Current Intelligence Bulletin 36.* US Dept. Health and Human Services (NIOSH). June 30, 1981.
10. *Occupational Health Guidelines for Chemical Hazards.* DHHS (NIOSH)/DOL (OSHA) Publ. 81-123. Cincinnati, Ohio. 1981.

ONE SOLUTION TO CONTROL—CAREFUL APPLICATION OF KNOWN TECHNOLOGY

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ABSTRACT

The crushing plant for an open-pit copper mine had a one-year old conventional blast-gate-balanced dust collecting system which was requiring high maintenance due to eroding ducts and elbows. Dust concentrations were about 4 times the allowable by British Columbia standards, consequently workers were required to wear respirators.

A new ore body was being developed which assayed 25% quartz, as compared to the old ore body at 10% quartz.

Corrections consisted of a new balanced dust collecting system using the existing wet scrubber; revisions to belt transfer chutes and hoods; a vacuum cleaning system; and a make-up air system. Roof beams and wall girts inaccessible for vacuum cleaning were provided with sloped sheet metal covers. Relatively minor revisions to inlet and outlet ducts permitted the scrubber to operate at full capacity.

These revisions resulted in a 10-fold reduction in dust exposure and a 4-fold reduction in dust load to the collector. In the first year of operation, one duct elbow required replacement.

These results were achieved by competent, careful application of known technology in dust collection and bulk material handling. All but one ventilation design point is included in the ACGIH Ventilation Manual; and that point was in the nature of solving a difficult design problem, not "new technology."

Specific design improvements are described and/or illustrated, and dust concentrations tabulated.

No Paper provided.

DUST CONTROL AND OCCUPATIONAL EXPOSURE TO SILICA IN THE UNITED KINGDOM

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INTRODUCTION

In the United Kingdom, measures to limit exposures to crystalline silica have been incorporated in industrial health and safety legislation for well over 100 years. In general, statutory requirements for dust control have appeared in Regulations relating to individual industries such as potteries or foundries and have specified the means by which control is to be applied (e.g. the use of extract ventilation or the wetting of dusty materials).

The development of quantitative techniques for dust sampling, together with procedures for assessing exposures and the evolution of exposure limit philosophies opened up possibilities for determining the practical effectiveness of control measures. For the past 10 years or so, comprehensive reviews of occupational exposures have been prepared by the Health and Safety Executive for a wide range of substances hazardous to health. These reviews are presented to the Advisory Committee on Toxic Substances (ACTS), which is a tripartite body set up to advise the Health and Safety Commission and which determines occupational exposure limits for the United Kingdom.

In 1987, a review of exposure to crystalline silica was prepared, which considered sampling data and information on control measures from a variety of sources. Much of the data in this paper is based on that review.

DEVELOPMENTS IN LEGISLATION

At the same time as the ACTS review of crystalline silica was in progress, proposals for an important new set of Regulations were reaching a critical stage in their development. Until now, the conventional historical pattern for health and safety legislation has been to make Regulations for specific substances (e.g. asbestos, lead), or for individual industries such as ship building or construction. This meant that provisions for safeguarding occupational health often appeared in piecemeal fashion and controls required in one industry would not necessarily be required in the same form in similar circumstances in another.

New legislation, to be known as the Control of Substances Hazardous to Health Regulations is now proposed which will require adequate control of all substances hazardous to health wherever they are used at work. For a substance such as silica, which is found in a wide range of industries, the new Regulations should be of great assistance in achieving a uniform standard of control to meet formal occupational exposure limits.

THE INCIDENCE OF EXPOSURE TO SILICA

Crystalline silica is found in a wide range of materials used for a variety of purposes in manufacturing industry as well as in quarrying and tunnelling activities. The United Kingdom has long had experience of the traditional "dusty trades" such as potteries and foundries, which make extensive use of silica-containing materials and there is also extensive manufacture of bricks, tiles and refractory materials. Significant silica exposure is also found in stonemasons' work. The size of the industrial sectors where exposure to crystalline silica is found has changed considerably over the past 30 years. A general diminution in the extent of manufacturing industry has led to a corresponding reduction in the numbers of persons exposed to silica in some industries. In potteries for example, the total number of persons employed in the industry is estimated to be 30,000 - 40,000 which is about half the total employed in the early 1950s. For foundries, the decline is considered to be even more marked.

For non-manufacturing industry, quarrying is the largest sector where exposure to silica occurs. Significant exposure is found during the working of a wide variety of materials including granite, basalt, sandstone, coal and limestone. Tunnelling can also produce extensive exposure during major civil engineering projects.

DISTRIBUTION OF EXPOSURE DATA

Because of the wide range of industrial activities where silica exposure is found, the quantity of personal sampling data and the assessment of exposures and control measures are very variable. In some sectors, such as brick and tile manufacture, only limited data is available while for others, detailed assessment of specific processes have been made. Foundry data, for example, covers a wide range of activities including knockout, fettling and grinding, where control problems have been difficult to solve.

A total of some 3,000 personal exposure samples were assessed for the ACTS Silica Review. The data was all collected by Health and Safety Executive staff, usually by an occupational hygiene Specialist Inspector directing a small team of scientific staff who collected and analysed the samples. Much of the data was obtained in the period 1979–1986 and resulted from factory and site visits made for one of two purposes:

1. As part of a prospective survey of particular industries such as potteries in order to determine the extent and patterns of exposure.

2. In response to requests from HM Inspectors of Factories to assess conditions at specific premises. In these cases, the Specialist Inspector would undertake a comprehensive occupational hygiene survey, sampling as necessary, and make recommendations for improvements and/or enforcement action based on his professional judgement.

In general only a small proportion of the results obtained were taken over an 8-hour sampling period but many of the work activities involved were such that 8-hour time weighted averages could be reliably assessed from exposures of shorter duration. In some instances, notably stonemasons work, airborne crystalline silica is generated intermittently and the estimation of a true time-weighted average is more difficult unless sampling extends over the full 8 hours.

Samples obtained for enforcement purposes tend to be biased towards higher levels of exposure, as the survey request will have followed from an initial observation that airborne concentrations appear to be high. It is also true that high levels of airborne silica may not always indicate high exposure as the sampling does not take into account whether respiratory protective equipment is being worn.

Of the total number of samples, approximately 1100 were obtained for manufacturing industry in all forms, 1300 for tunnelling and 500 for quarrying. In manufacturing industry, approximately 46% of the samples were obtained in foundries, 37% in potteries, 10% in brick and tile manufacturing and the remainder in refractory and stonemasons work. This distribution of samples does not reflect the distribution of the exposed population, and is biased towards the foundry industry, partly because high airborne silica concentrations have been found and partly because there is a variety of processes in foundries at which silica-bearing dust is generated.

AIRBORNE DUST CONCENTRATIONS

In considering the sampling data, it may be useful for comparison purposes to record the relevant current United Kingdom occupational exposure limits. These are:

1. 0.1mg/m^3 for respirable crystalline silica.
2. 5mg/m^3 for respirable dust for which no lower limit is specified elsewhere.
3. 10mg/m^3 for total inhalable dust for which no lower limit is specified elsewhere.

Most of the 3000 or so samples covered by the review were analysed to determine airborne dust concentrations for each of these categories.

For manufacturing industry, 65% of 1058 samples indicated less than 0.1mg/m^3 respirable crystalline silica and 19% were in excess of twice the exposure limit. The majority of the higher dust concentrations occurred in the foundry industry, largely at fettling processes. Tunnelling gave a similar distribution of samples for respirable crystalline silica, with 35% of 1292 samples in excess of 0.1mg/m^3 and 15% above 0.2mg/m^3. In quarrying, higher dust concentrations were generally found—64% of 474 samples exceeded 0.1mg/m^3, with 10% in excess of 0.5mg/m^3.

For respirable dust, the proportion of samples exceeding the 5mg/m^3 limit was in the range 5%—10% for all industries, with variations within this range dependent upon the proportion of silica in the material being worked. A uniform pattern of total inhalable dust concentrations was also observed for all industries, with 75% of samples less than the 10mg/m^3 exposure limit.

CONTROL MEASURES

Partly as a result of developments in legislation, renewed attention is being paid to the control of occupational exposure to hazardous substances in the United Kingdom at present. Effective control is perceived as encompassing a wide range of factors including both "hardware" such as extract ventilation and engineering modifications to process plant and the supporting "software" which ensures that the hardware is used to the best effect. The overall management health and safety structure, line management supervision, the provision of adequate training in the use of control measures and a good system of preventive maintenance are all part of this support system without which the control measures installed will inevitably lose their effectiveness.

All the major conventional means of preventing and controlling the generation of dust were found in the industries surveyed, including substitution, enclosure, control at source by local exhaust ventilation and process modification. In some circumstances, respiratory protective equipment was also needed in order to reduce exposures to less than the appropriate occupational exposure limit. In common with most other countries, however, the United Kingdom Health and Safety Executive policy regarding the use of respiratory protective equipment is to accept it only as a solution of last resort and to seek effective control by other means wherever possible.

For most of the processes and activities surveyed, effective control of airborne respirable silica to less than 0.1mg/m^3 could be achieved without great difficulty. In potteries, for example, high silica-content material can often be replaced by less hazardous alternatives (e.g. the substitution of calcined flint by calcined alumina) and wetting of materials is a very effective way of inhibiting dust generation during handling. However, a good standard of general cleanliness and housekeeplng is still required to ensure that scrap spillages are effectively removed and not allowed to dry out and create a potential dust problem.

Foundry processes are more difficult to control effectively, problems are much reduced in modern plant of good design. Fettling remains the most problematic of processes, although advances have been made recently in the automatic fettling of small simple castings, which remove the operator from the source of dust. For larger castings, fettling must still be done with a hand-held or swing-frame grinder. Where the work can be done in a booth with an efficient extraction system, good control should be possible but for very large castings there may be no practicable alternative to the use of respiratory protective equipment to supplement conventional control measures. A similar situation occurs with repair and re-lining work on furnaces and ladles, where high concentrations of crystalline silica are generated during work on refractory linings. Again, at present it will often be necessary to supplement a good standard of ventilation with the use of respiratory protective equipment.

The major activity in the quarrying industry is the production of large quantities of low-value minerals such as roadstone. Plants with throughputs of 500 tonnes per hour are not uncommon and airborne dust quantities produced during mechanised processing are large—up to 0.5% of the process mineral throughput can be retrieved by dust collection. Wet suppression, enclosure and local exhaust ventilation techniques are used as circumstances demand, but are not always able to achieve control of exposures to the same standard as manufacturing industry.

CONCLUSIONS

Personal sampling data over a wide range of industries in which crystalline silica-containing material are used indicate that for many processes effective control of airborne dust can be achieved to current United Kingdom occupational exposure limits. Some problems remain difficult to solve, and in these cases respiratory protective equipment is used to supplement engineering control measures.

Control measures are not always used to their maximum effectiveness. Where this occurs, there is usually a need for improving the general awareness of the importance of dust control from the occupational health and safety viewpoint and securing greater commitment to the effective use of existing control measures. Developments in legislation in the United Kingdom and the preparation of supporting technical guidance by the Health and Safety Executive should assist in generally raising standards of control in industry.

AUXILIARY VENTILATION PLANT AND AIR DISPERSED PARTICULATES: AN EXPERIMENTAL STUDY IN THE STOPES OF AN ITALIAN TALC MINE

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SUMMARY

The paper refers to the results of an experimental research developed at the most important Italian talc mine of Fontane. A prealable series of tests confirmed the substantial absence of asbestos fibres, and the consequent exhaustivity of gravimetric samples to evaluate the particulate content in the atmosphere; on the basis of extended sampling work as performed in an experimental and in other working stopes, a correlation has been identified between the scheme of auxiliary ventilation plant at various flow rates and the dust concentration. It was also possible to show a good efficiency of the exhausting system, as compared with the blowing system, owing to a quicker removal of particles from the workplaces, to a reduction in air dispersed dust up to about 20%, and to the absence of secondary dust production and annoyance of miners. On the basis of research results in the future the exhaust ventilation system will be as much generalized as possible in the mine.

INTRODUCTION

The Fontane talc mine, located in the Germanasca valley 80km West of the city of Turin, is exploited by Talco e Grafite Val Chisone Co. The mine is one of the most important talc mines in Europe in terms of both the tonnage and the quality of talc produced (about 40000 t/y of pure white talc); for instance specifications of Extra Superiore brand quality are summarized in Figure 1.

The orebody has a typical "rosary" structure—a series of lenses en echelon—which strikes N20 W and dips towards the West at an average slope of 20°–22°.

The lenses can be large, but are extremely irregular, varying in width from a few centimeters up to 5–8 m, exceptionally to 15 m.

The footwall bedrock is a compact augen-gneiss while the hanging wall comprises greenstones and mica schists.

At present the mine is being worked in two different sections: Gianna, on the left side of Germanasca river, and Crosetto, on its right (see Figure 2).

Since 1974 the exploitation method is underhand horizontal slicing with cemented backfill, taking the ore in strips running transversely to or parallel with the orebody, with stopes of up to 8 m^2 cross section (Figure 3).

The primary ventilation at Crosetto section, in an experimental stope of which the described tests were carried out, is based on a fan activated exhaust system, linking the main level (1400 m over sea level with an upper one at 1500 m).

At present blind stopes ventilation, in which faces may reach a distance of more than 120 m far from the main ventilation level, sometimes proved not to be quite satisfactory, in particular with regards to air velocity (Italian mining law requires a mean air velocity of 10 cm/s in the stopes), and comfort conditions.

A common research work has been carried out by Talcoe Grafite Val Chisone Co. and Mining Dept. of Technical University of Turin, to both identify a proper technique of dust measurements in the stopes of Fontane mine, and to achieve further improvements in the general environmental conditions.

DUST SAMPLING TECHNIQUE

A preliminary problem to be solved in order to organize systematic dust concentration surveys in the mine stopes was to identify a correct sampling organization, and suitable apparatus.

A more than two years long campaign, developed with battery powered Dupont P4000 samplers (flow rate 1 dm^3/min., open holders for 25 mm dia.—0.8 μm pore diameter cellulose filters) has been carried out, and made possible to achieve some preliminary results. First, some mining operations were identified, during which the maximum dust production occurs, in terms of gross air concentration (see Figure 4); furthermore it was confirmed that, in this case too, a proper evaluation of workers exposure may be obtained with personal sampling devices carried by the workers: the risk of unpredictable human behaviours has shown to be very low after two months of testings.

TALCO E GRAFITE VAL CHISONE S.P.A.

TALC: EXTRA SUPERIORE

Extra Superiore Talc is a hydrous magnesium silicate, platy in structure, which meets all pharmaceutical specifications (Eur. Pharm.) and does not contain asbestos minerals (C.T.F.A. J4-1)

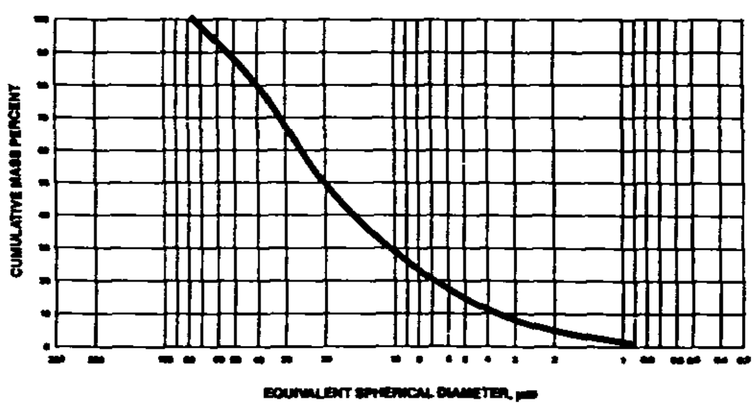
It is suitable for various applications where high purity and extremely platy talc is desired.

PHYSICAL DATA

Whiteness (FMY/C - Green Filter)	%:	90.5	Oil Absorption (DIN 53199/ASTM D281-31)	%:	32
(FMZ/C - Blue Filter)	%:	89.5			
Specific Gravity (DIN 53193)	g/cm^3:	2.8	B.E.T. Surface (DIN 66131/66132)	m^2/g:	4
Tapped Density (DIN 53194)	kg/dm^3:	0.79	Abrasivity (AT 1000 - 2 hours)	mg:	10
Loose Density (DIN 53468)	kg/dm^3:	0.45	Hardness (Mohs)	:	1

PARTICLE SIZE DISTRIBUTION

< µm		%
75	:	99.3
45	:	83.6
20	:	49.8
10	:	30.5
5	:	15.3
2	:	7.4
1	:	3.5



CHEMICAL DATA

SiO_2	%:	60.1	L.O.I. (1050°C)	%:	5.3
MgO	%:	31.8	pH (DIN 53200 - 10% slurry)	:	9.3
Al_2O_3	%:	1.5	Moisture (DIN 53198 - 105°C)	%:	0.2
Fe_2O_3	%:	0.9	Water Solubility (DIN 53197)	%:	0.1
CaO	%:	0.4	Acid Solubles (DIN 55920)	%:	2.3

Figure 1. Specifications of Extra Superiore brand quality.

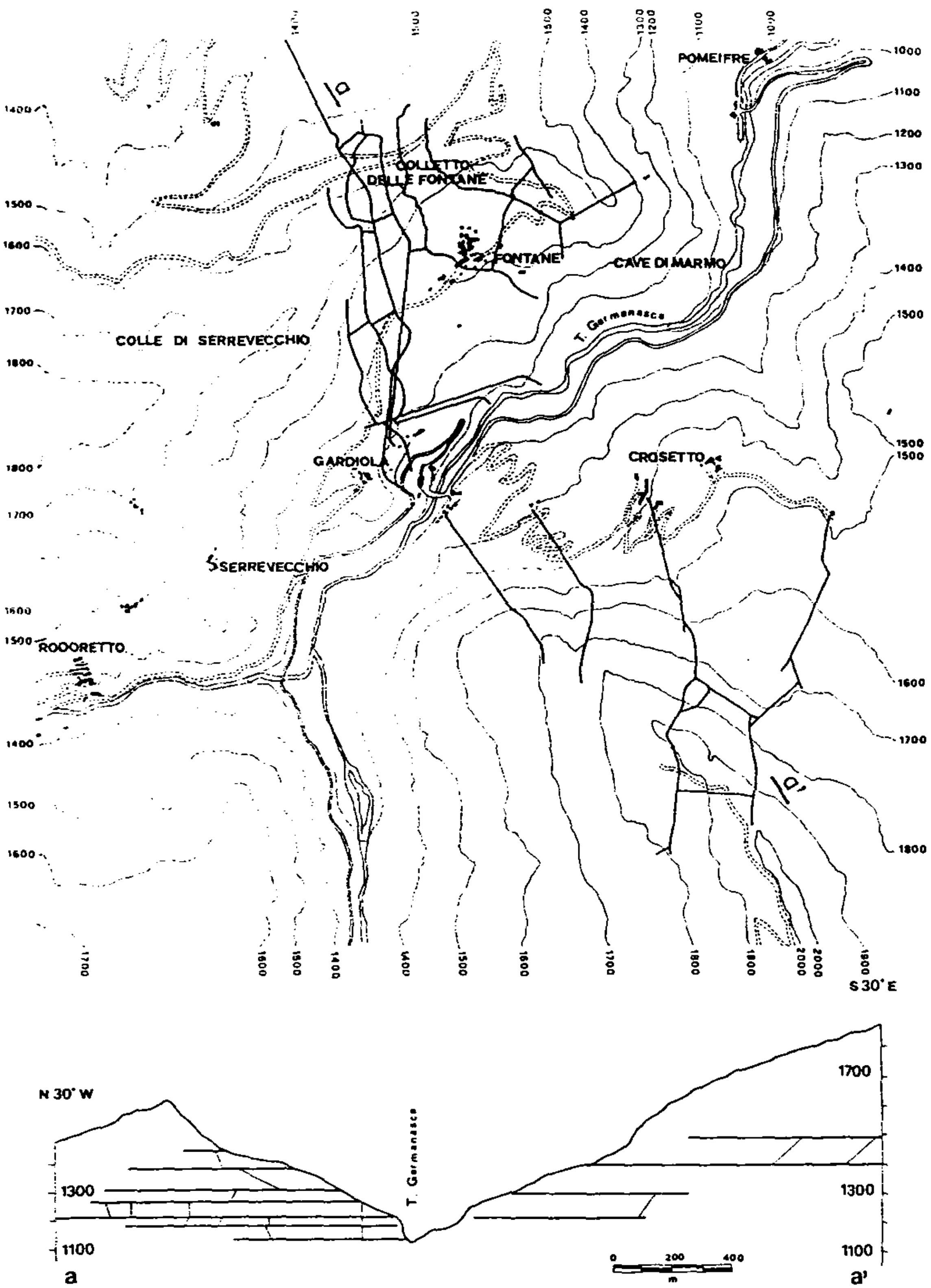


Figure 2. The Fontane talc mine, plan and section, showing the main underground levels.

At last a systematic microscope analysis on more than 200 samples from production stopes, carried out with phase contrast illumination (500x magnification), confirmed a respirable particle content of crystalline silica less than 1% (in mass).

X.R.D. analysis of samples proved the absence of asbestos minerals. Some fibrous shaped elements—from platy talc breakage—were sometimes identified, well less than 1% in number of respirable dust particles.

Owing to the shape of talc particles in respirable dust collectable in Fontane mine stopes, it has been necessary to verify the actual effectiveness of separating devices for this particular application.

In situ and laboratory tests (in a specially designed apparatus, see Figure 5) were carried on, to collect information on the performances of two different size-selectors, also in comparison with open holder samplings. The flow rates have been adjusted according to separators Constructor data, and 1 dm^3/min respectively.

The results of the above mentioned tests are summarized in Table I. The 10mm nylon cyclone separator confirmed its high efficiency with reference to Respirable Particulate definitions, however it has been possible to observe a remarkably greater (but with extremely dispersed data) content of respirable particles in the "not respirable" deposit. Sometimes, moreover, in long duration samplings in stopes with high humidity degree, particle agglomeration and partial obstructions were to be feared.

Consequently, it appeared at the moment preferable to select, as the most suitable for dust sampling in Fontane mine stopes, the stainless steel shell cyclone separator, in spite of some lower separation efficiency, considered that this overestimation may help technical improvements of the environmental conditions.

The analysis of the collected samples may properly be based on the mass determination criterium, according to International Standards, provided that the crystalline silica content and mineralogical nature of fibrous elements are periodically verified.

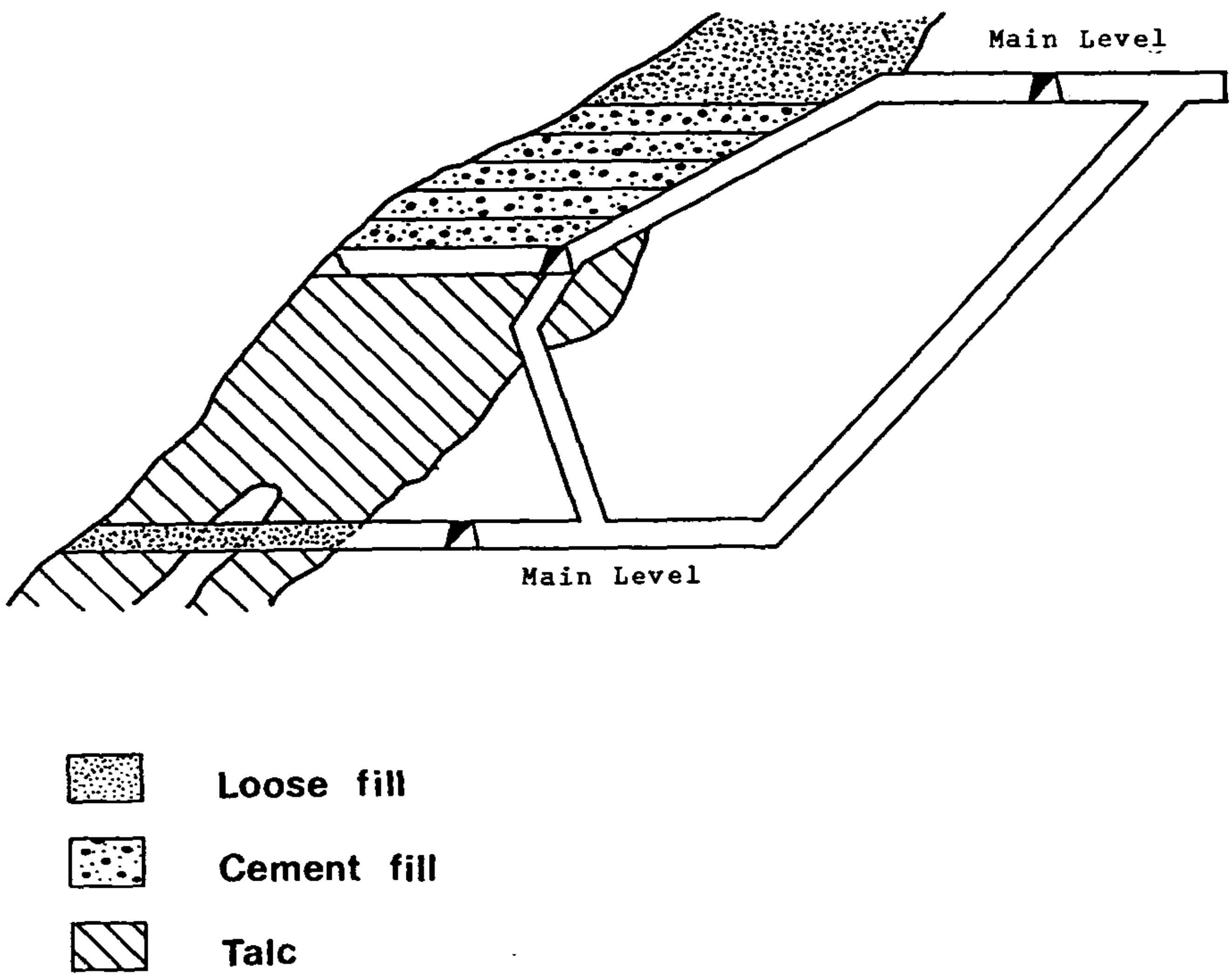


Figure 3. The mining technique employed: underhand method with cement fill.

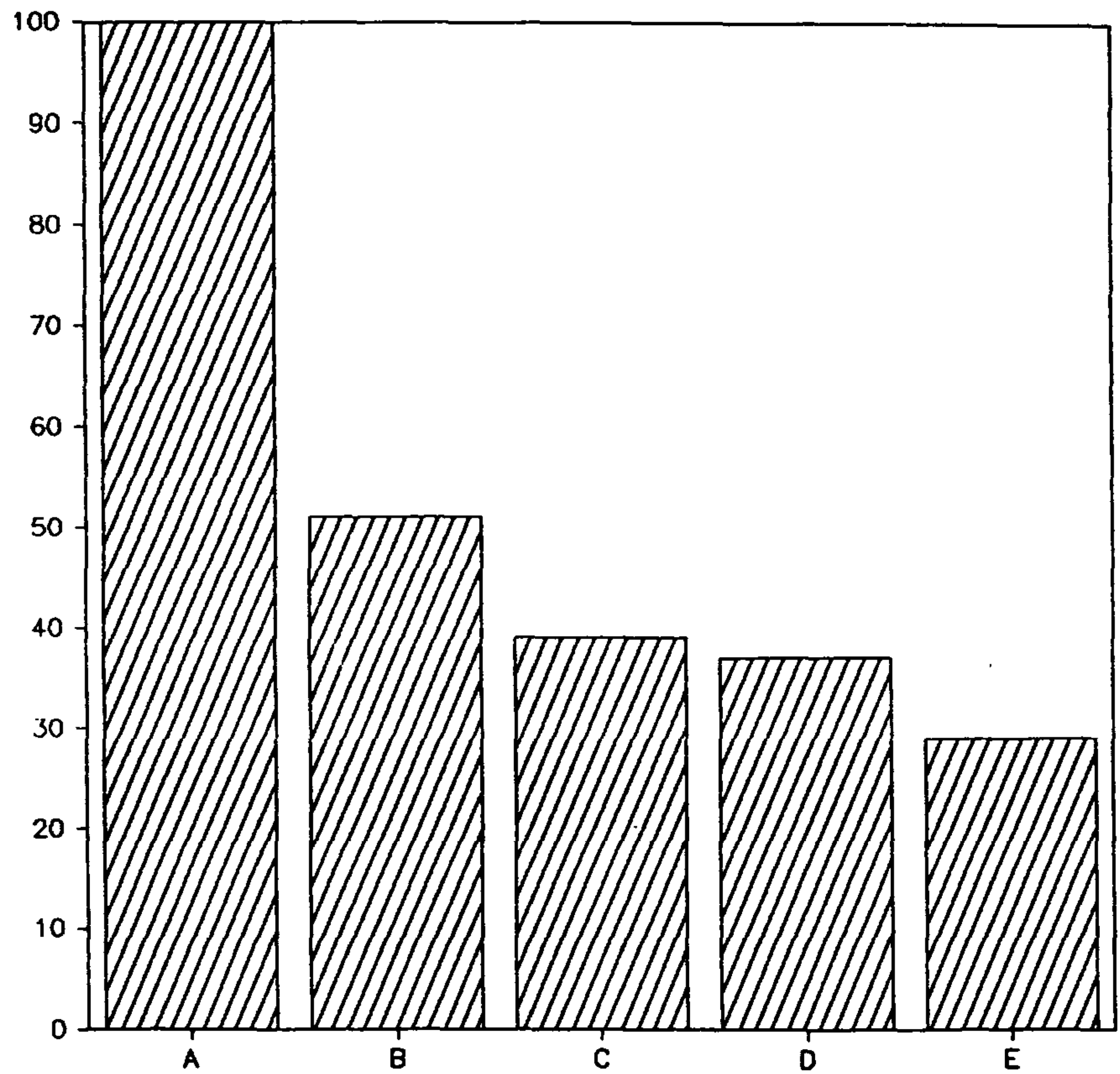


Figure 4. Comparative dust level, compared to case A:
A—breaking with hammerpick; B—loading with compressed air shovel (on rail); C—loading and hauling with rubber tyred electrohydraulic equipment; D—face and roof cleaning; E—others (maximum).

BLOWING AND EXHAUSTING AUXILIARY VENTILATION

In order to verify the possibilities of improving the environmental conditions in the mine stopes, an experimental stope of 4 m^2 cross section (Crosetto, n.7, Figure 6), in which the face was at a distance of about 40 m from the main ventilation level, has been equipped with a centrifugal fan (7.5 kW) and a flexible tubing (300 mm dia.) in rubberized nylon with metal springs.

The tubing was set in such a way that it was possible to attach it to the inlet or to the outlet of the fan.

The face end of the ventilation duct was set at a distance of 5 m from the face.

A series of tests has been carried on at various flow rates, obtained by properly positioning the regulation metal brattice of the fan, both in exhausting and in blowing configuration.

Dust concentration, air mean velocity and mioroclimate parameters at the face were recorded, and W.B.G.T. comfort index calculated for each plant regulation. Moreover explosive

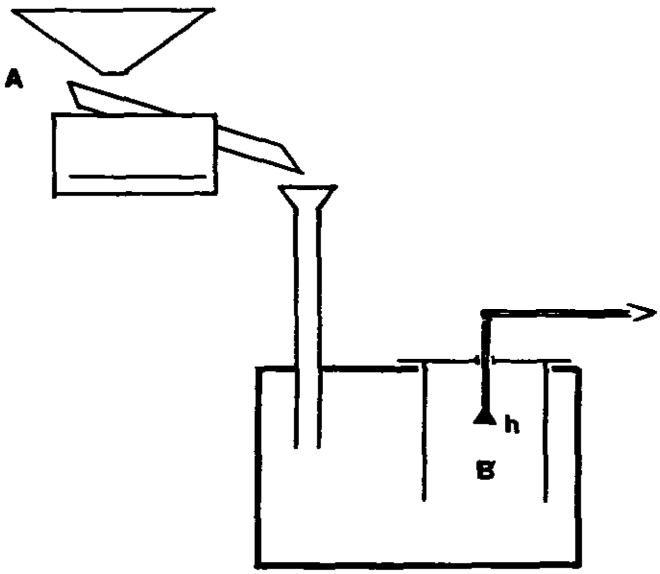


Figure 5. Layout of the apparatus used in laboratory tests (schematic): A—hopper and vibrating feeder; B—sampling room; h—sampling holders.

fumes concentration (NOx and CO) were systematically measured (with Drager test equipment) 15 minutes before the restarting of work (two hours after the blast).

For each test also dust concentration in the access way to the stope was measured, at a distance of about 20 m from the face.

Table II summarizes the most significant results of the above mentioned tests. As to thermal and humidity conditions it was observed that, in the period of testing, the mean temperatures resulted of 7–10°C and 10–14°C respectively in the main level and at the face, and the relative humidity in both sites was near to 100%; W.B.G.T. values at the face ranged from 10 to 14°C.

On the basis of the achieved results it must be observed in particular that dust concentration and comfort conditions at the face appear clearly not acceptable with the maximum flow rate in blowing plant configuration, due to the excessive air velocity.

Taken for granted that noxious fumes concentration is not a problem in any case, it may be assumed that satisfying environmental conditions at the face can be achieved both with a blowing scheme as in case 2, and with an exhausting scheme as in case 1.

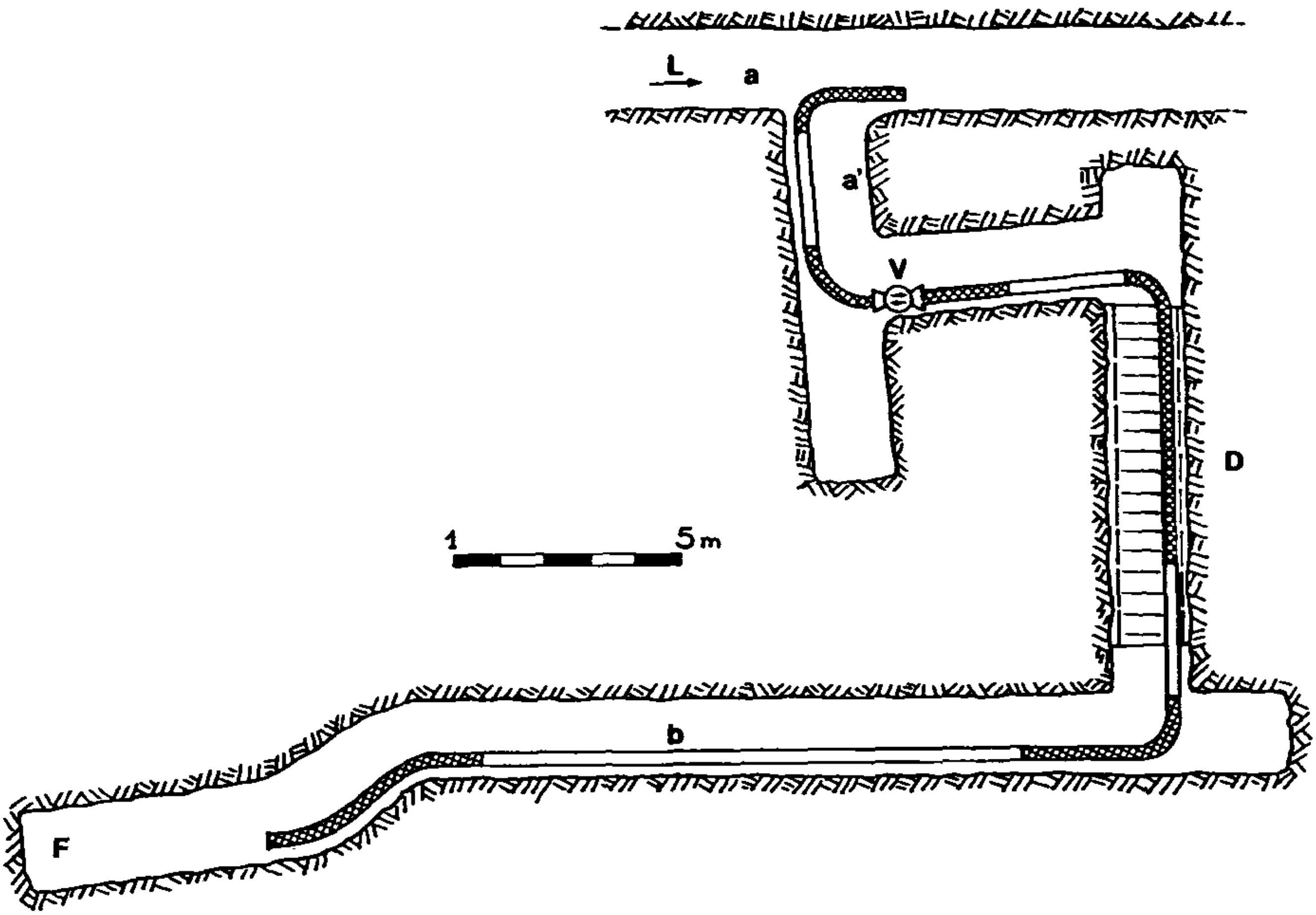


Figure 6. Diagram of stope n.7, Crosetto, where the tests were carried out: L—main level; F—stope face; D—slope; a, a', b, F—sites of measures.

Table I
Mean Size Distribution (Number of Particles) as Measured in the Samples Collected with Different Apparatus: A—Open Holder; B—Stainless Steel Cylindrical Shell Cyclone; C—10 mm Nylon Cyclone

	particle size (µm)	A (2)	B (3)	C (3)
Laboratory tests (1)	< 5	80.1	86.1	90.1
	5 - 10	17.4	13.0	9.7
	10 - 20	2.2	0.9	0.2
	> 20	0.3	----	----
	Dmax(4)	25	20	15
In-stope tests	< 5	93.5	97.1	98.1
	5 - 10	4.2	2.4	1.9
	10 - 20	1.8	0.4	----
	> 20	0.5	0.1	----
	Dmax(4)	60	30	15

(1) Performed on commercial product (0-80 µm)
(2) Flow rate 1 dm3/min.
(3) Flow rate according to Constructor data.
(4) Exceptional.

Table II
Results of the Tests Carried on at Crosetto n.7 Experimental Stope

	flow rate m3/s	mean air velocity (stope) m/s	max air velocity (stope) m/s (*)	tmax-tmin in stope °C	tmax(st)- -t(lev) °C	tm(st.acc.) -t(lev) °C	respirable dust conc. (**) mg/m3
exhausting system							
case 1	0.44	0.12	0.19	1	3	0	0.45
case 2	0.38	0.10	0.12	0	3	0	1.15
case 3	0.35	0.09	0.09	0	3	0	2.10
blowing system							
case 1	0.57	0.15	0.33	2	3	3	2.30
case 2	0.45	0.12	0.15	3	3	3	0.50
case 3	0.36	0.09	0.09	3	3	3	2.05

* Italian mining law ref. > 0.10 m/s
** samples collected during breaking with hammerpick.

The exhausting system—in the above mentioned conditions—has proved to be more efficient in particular with regards to comfort conditions in stopes where the temperature is remarkably warmer than in the ventilation level: annoying localized temperature variations are avoided both at the face and at the beginning of the stope access way from the main level.

Moreover, a lowering of dust concentration along the stope access way (about 20%) has been observed at equal air velocities in the different ventilation systems, even if in any case the absolute values were far from suggested T.L.V. for talc dusts.

On the basis of the previous considerations the use of the exhaust ventilation system will in future be generalized in the stopes with important differences between stope and main stream air temperature, while blowing system can be maintained (for economic and technical reasons, such as lower costs of tubing and installation) where this problem does not arise.

A research work has been undertaken to design a diffusive tubing outlet to be suggested for blowing system, to avoid a discomfortable localized air stream at the face.

CONCLUSIONS

A proper dust sampling technique has been tested, specially fitted for Fontane talc mine.

The results of tests on auxiliary ventilation systems made possible to identify the main plant features that may give good environmental conditions and stressed that, in particular where an important difference between face and level air flow temperature arises, the exhausting ventilation system must be preferred.

Research work is now being carried on to achieve further improvements.

A RESPIRABLE DUST SURVEY OF VARIOUS METALLIFEROUS MINE SITES IN QUEENSLAND, AUSTRALIA

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INTRODUCTION

This paper describes the current development of dust surveillance and respirable quartz monitoring in a range of metalliferous mines in Queensland, Australia. Gold mines and quarries are predominant in the study, although sand, nickel, limestone and bauxite mines are also covered. A Fourier Transform Infra-Red (FTIR) method was developed to measure quartz content in respirable dust samples. The matrix difficulties which are present with such a wide range of sample sources have been overcome using a specific interferent reduction program applicable to any type of material.

BACKGROUND

This program of mine surveillance began as recently as 1986 when the Safety in Mines Testing and Research Station (SIMTARS) was established to provide, amongst other things, an occupational hygiene service encompassing all types of Queensland mining operations. SIMTARS is also involved in electrical and flameproof testing of equipment destined for use in underground coal mining and other potentially hazardous areas. From its extensive, special gas analysis service, SIMTARS also provides an emergency gas analysis service for coal mines in event of a mine disaster.

While the workers in Queensland coal mines are sampled on a regular basis for respirable dust and quartz by officers attached to the Coal Mines Inspectorate (GRANTHAM and BELL, 1987), no regular systematic respirable dust sampling has ever been carried out at Queensland metalliferous mines. The reasons for this include the diversity of mining types and the geographical separation of mine sites in a very large state. Furthermore, many of the mining operations are small and employ few personnel, limiting the feasibility to survey these small mining operations in the past.

In the absence of any data on these mines, the opening gambit was to visit only the major sites to cover the largest concentration of workers and processes, with a few smaller sites included to determine if size affected dust exposure or dust control in any way. From these data, a suitable inspection frequency could be determined and immediate problem areas could be targetted for investigation and improvement. In the longer term, the information can be used in an epidemiological review of dust disease amongst these mining populations.

In addition to the respirable dust monitoring, noise measurements were also made. Collection and processing of the samples was undertaken by the small (5 member) hygiene group. The sampling technique, adapted where necessary to meet the commitments of mining schedules, has followed the Australian Standard 2985 1987 (Workplace Atmospheres—Method for Sampling and Gravimetric Determination of Respirable Dust), itself based on the familiar MDHS 14 of the UK Health and Safety Executive.

METHODOLOGY

Respirable dust measurements were carried out using Dupont P2500 sampling pumps entrained with Casella 37 mm cyclone elutriators. The dust samples collected were analysed for free silica using a Fourier Transform Infrared technique which utilizes computer controlled spectral subtraction of interfering minerals.

Previous techniques in respirable quartz analysis of dust samples containing interfering substances required computer subtraction of known interferents from the sample mixture. Dust samples obtained from mining environments often have interfering minerals which are difficult or impractical to analyse. Using computer software available with modern FTIR's (e.g. Perkin Elmer Model 1750), quartz in mixtures can be readily evaluated without knowing the exact nature of interfering substances. By spectrally subtracting pure quartz (Australian Standard 9950) from the sample mixture a spectrum of the interferent is generated. This interferent spectrum can then be subtracted from the mixture leaving a spectrum of quartz free from interference (see Figure 1). Viability of the resulting quartz spectrum can be determined by either the ratio of the peak heights in the doublet and/or the ratio of the peak heights in the doublet to the minor 690 cm^{-1} peak. While this interference free quartz spectrum can be quantitated using presently accepted methods (e.g. standard regression line and peak heights), it is not necessary since a user generated normalization factor can be used to calculate the quartz content directly. The theory is described briefly below.

Both the mixture and the pure quartz spectra are converted to absorbance. The difference between ordinate values of the two spectra at each data point is determined. These ordinate difference values represent the interferent spectrum and can be represented by

$$d_3 = d_1 - (d_2 \times f)$$

Where d_3 = ordinate values of the difference spectrum or in this case the interfering components of the mixture.

d_1 = ordinate values of the mixture.

d_2 = ordinate values of the pure quartz

f = normalization factor applied to the quartz std. spectrum to make it equal to the quartz component of the mixture.

When the quartz standard spectrum is subtracted from the mixture spectrum, only the interferent spectrum should remain. The true normalization factor is selected interactively by manipulating the difference (i.e. interferent) spectrum. The factor is correctly selected when all contributions from the quartz in the interferent spectrum are reduced to zero. In other words the standard quartz absorbance values are made the same as the absorbance contributed by quartz from the sample mixture. The content of quartz can be readily calculated by multiplying the known weight of quartz in the standard (Wq) by the normalization factor, f: This is

$$\text{Amount of quartz in mixture} = Wq \times f$$

Validation of this method is currently in progress and involves evaluating known percentages of quartz in mixtures prepared at SIMTARS followed by interlaboratory testing of standard samples.

DISCUSSION

All the dust data obtained was incorporated in a data base constructed specifically for this purpose. The results are presented in Tables I—VII. Almost 700 personal respirable dust samples were taken over a 14 month period and of those some 150 were analyzed for respirable quartz content. A significant number of mine types (limestone, nickel, bentonite etc) did not have a quartz problem and are not represented in the quartz histograms.

The present Threshold Limit Value (TLV) for respirable quartz is 0.2 mg/m^3 (although it will soon be lowered to 0.1 mg/m^3). This TLV is an Australian variation of the current ACGIH levels and results from a recommendation made by the National Health and Medical Research Council (NH & MRC, 1978). Epidemiological evidence in the Australian context has not yet been able to establilsh the validity of the NH&MRC recommended levels. Histogram representations of the data indicate that approximately 20% of occupations surveyed fail the respirable quartz TLV of 0.2 mg/m^3 while over 60% will fail when the level is lowered to 0.1 mg/m^3.

The situation with quarries and gold mines is generally worse with the figures being 40%/90% and 30%/50% respectively. In practice there is concern since in 92% of the personnel

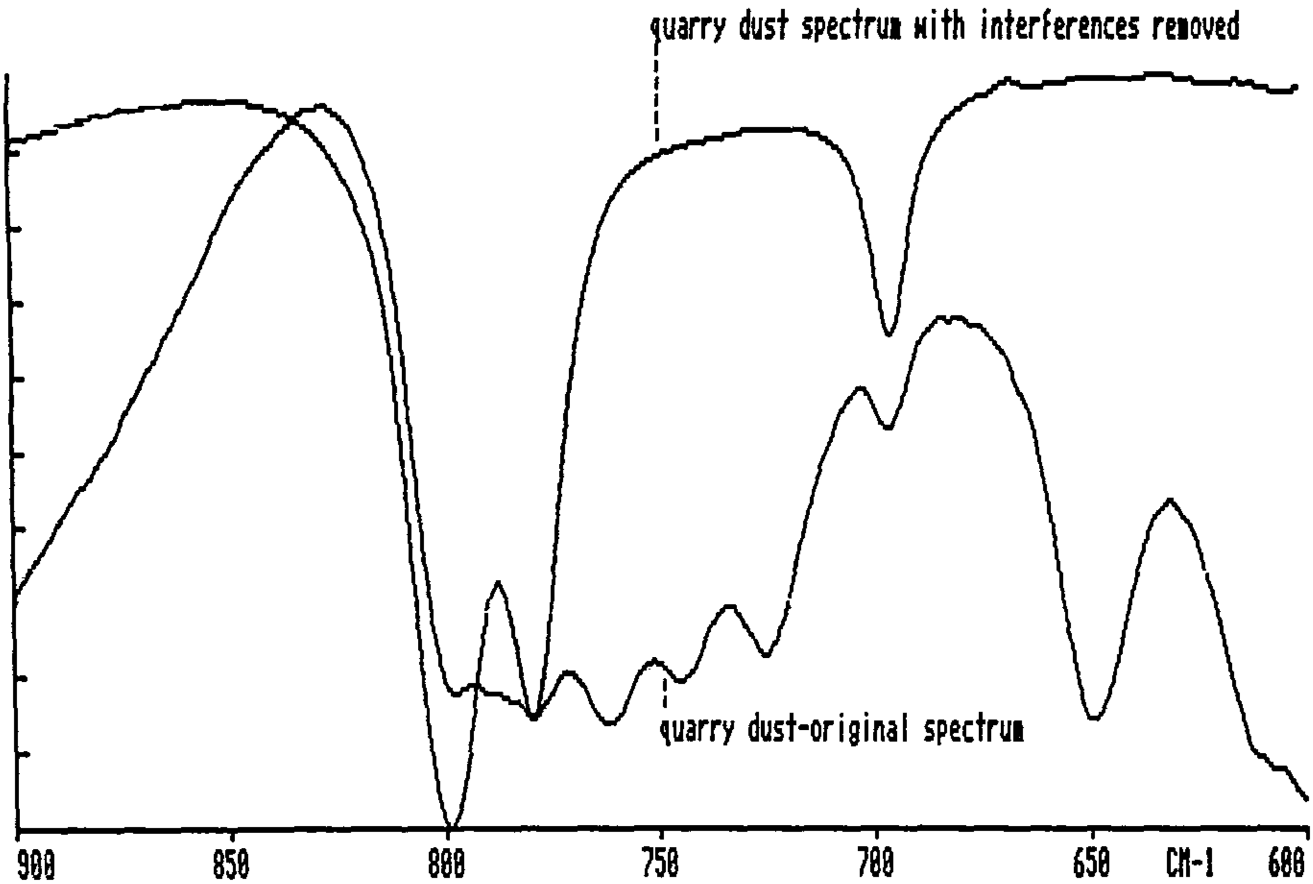
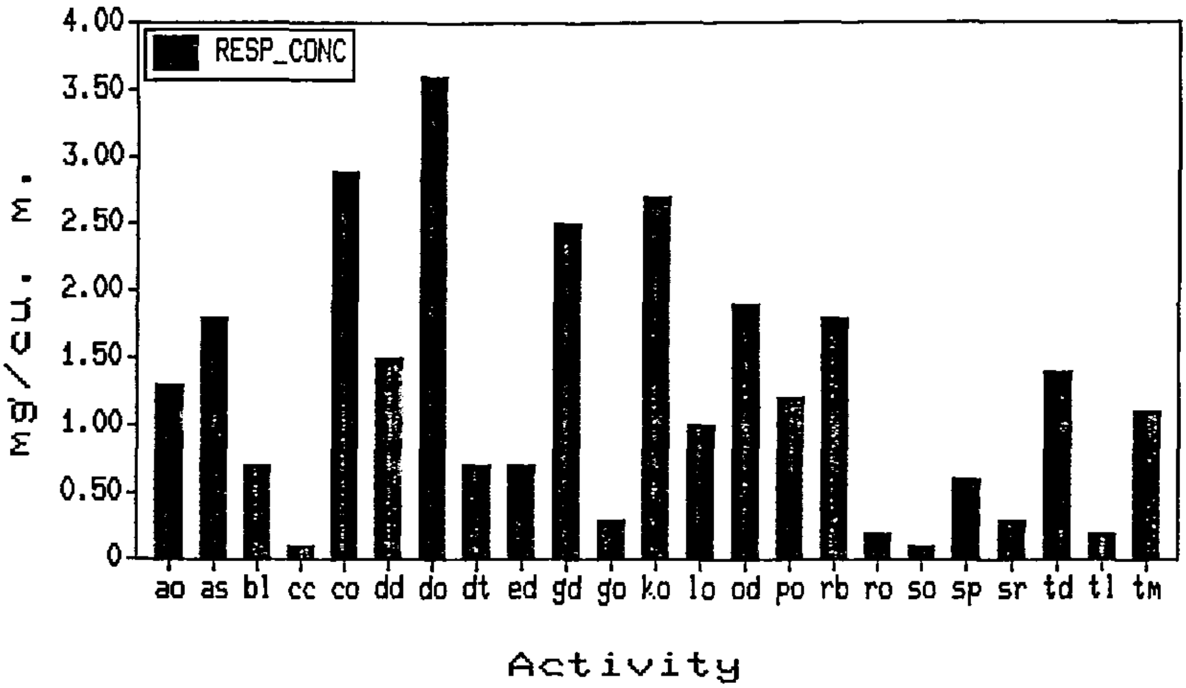


Figure 1.

Table I

Average Respirable Dust Concentration by Activity

(All Metalliferous Mines Surveyed)



ao - Agglomerator Op	as - Assayer/Sampler	bl - Blaster	cc - Conveyor Attendant	co - Crusher Operator
dd - Dozer Driver	do - Dragline Operator	dt - Dump Truck Driver	ed - Excavator Driver	gd - General Duties
go - General Operator	ko - Kiln Operator	lo - Loader Oper.	od - Overburden Driller	po - Plant Operator
rb - Rock Breaker	ro - Roller Operator	so - Saw Operator	sp - Spotter	sr - Scraper Operator
td - Truck Driver	tl - Train Loader	tm - Tradesman		

Table II

Average Free Silica Concentration by Activity

(All Metalliferous Mines Surveyed)

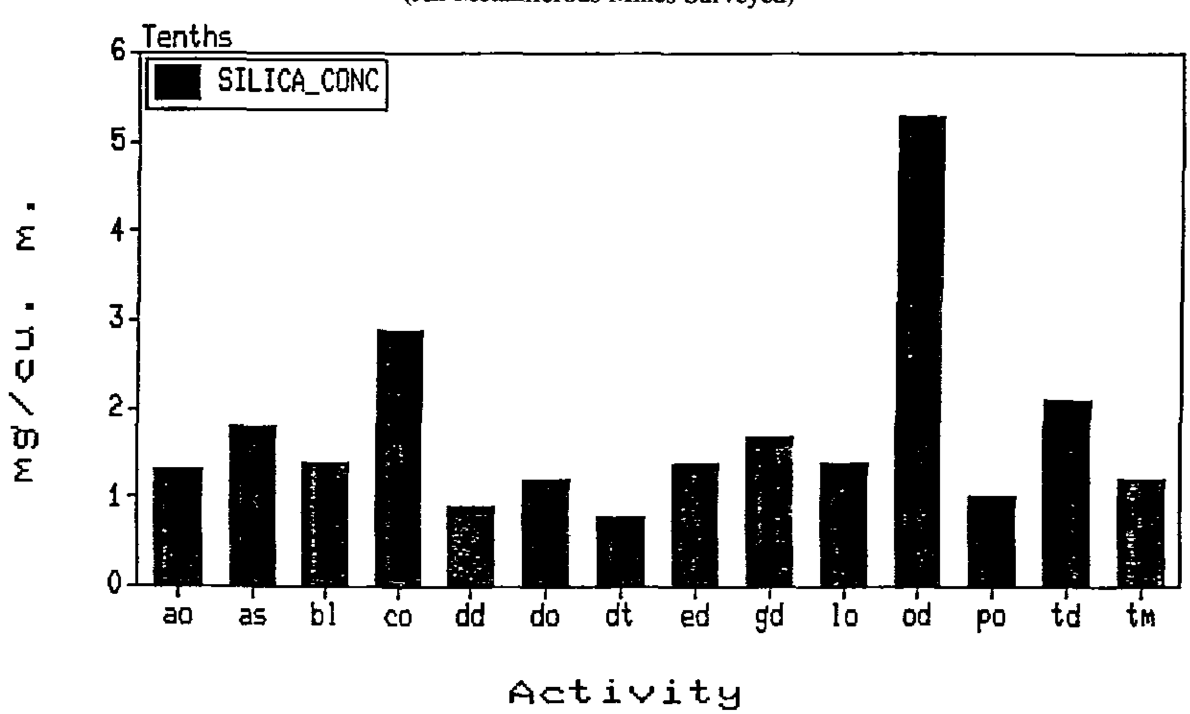


Table III
Average Respirable Dust Concentration by Activity
(All Gold Mines Surveyed)

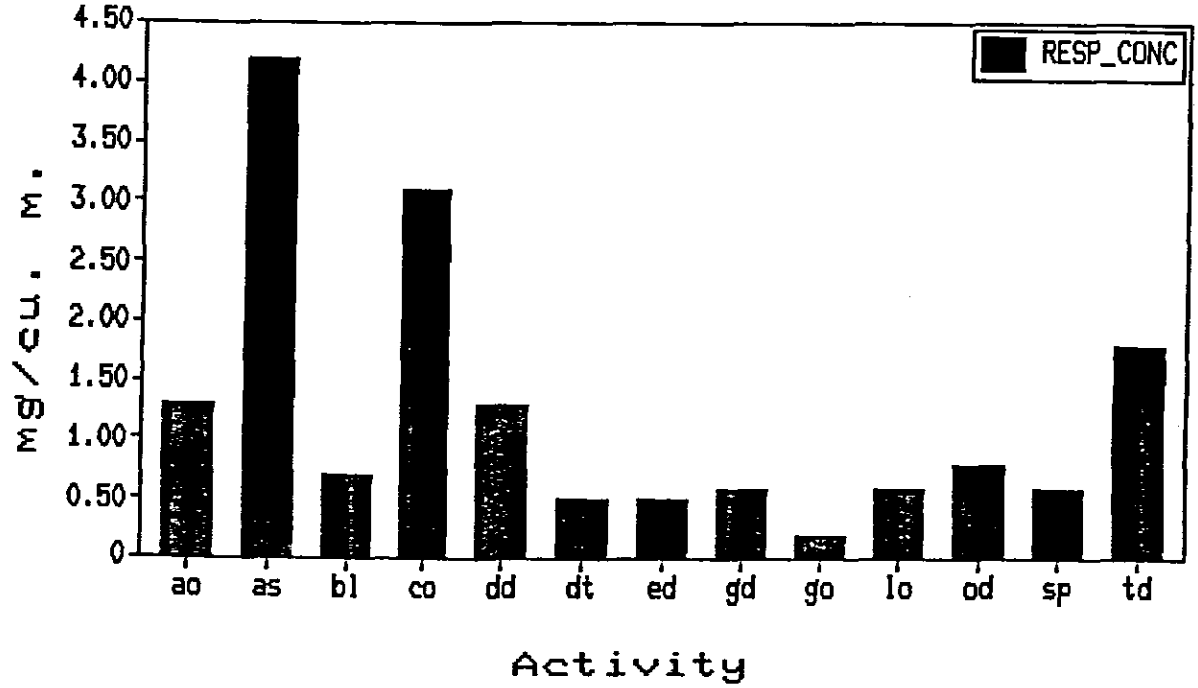


Table IV
Average Free Silica Concentration by Activity
(All Gold Mines Surveyed)

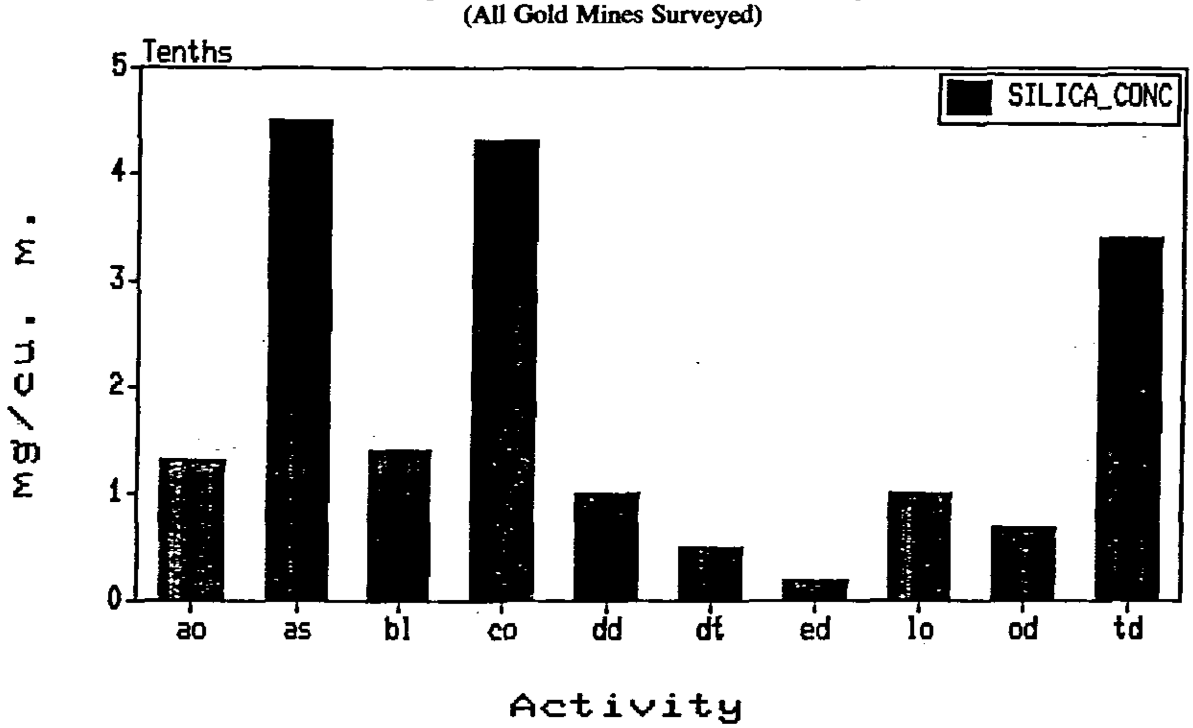


Table V
Average Respirable Dust Concentration by Activity
(All Quarries Surveyed)

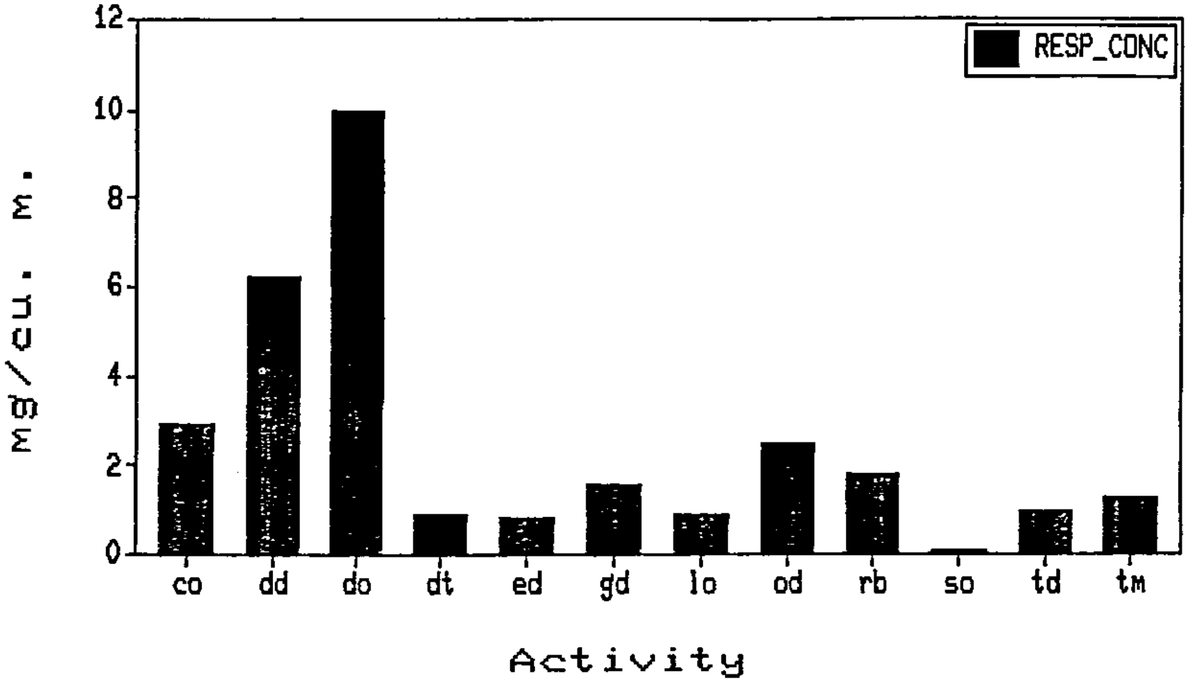


Table VI
Average Free Silica Concentration by Activity
(All Quarries Surveyed)

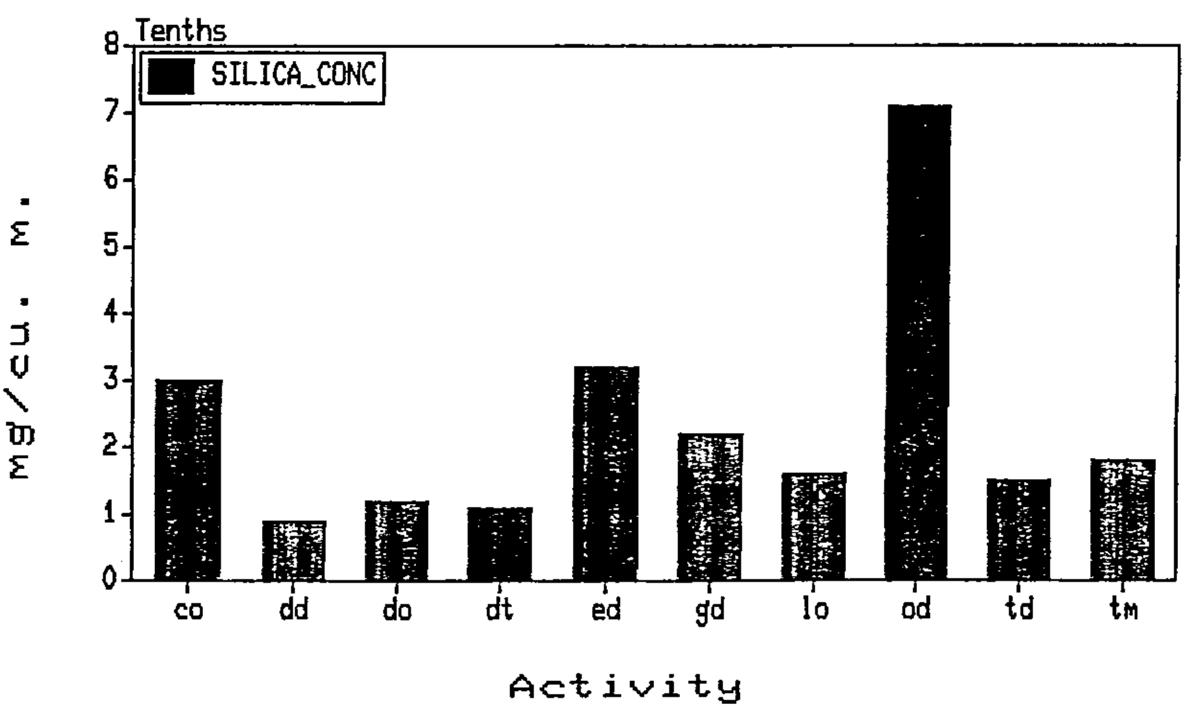
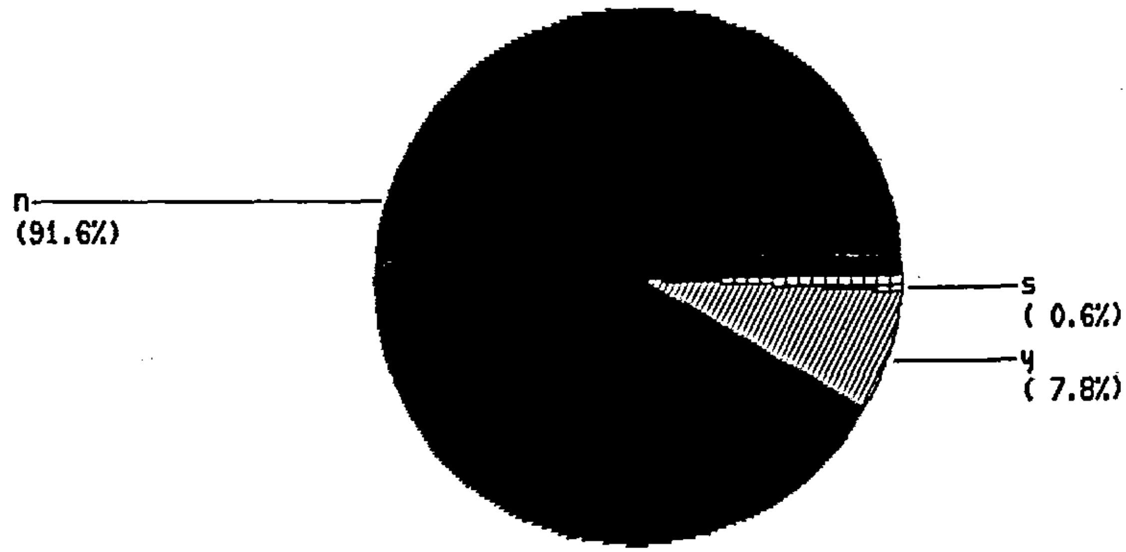


Table VII
Mask Usage
(All Metalliferous Mines Surveyed)



sampled, no respiratory protection was employed. This problem is now being addressed by SIMTARS with increased quartz monitoring to study quartz exposure by occupation by mine.

This survey represents the establishment of base respirable dust exposure levels in the Metalliferous Mining Industry which is in an expanding raw material resource economy. Compared with other hardrock mines within Queensland which have had the benefit of environmental and radiological surveys, a relatively greater problem exists in these more recently surveyed mines.

Pertinent data is being channelled to the regulating (Inspectorial) group within the Queensland Department of Mines. Some positive progress has been made in recent months with the installation of dust extraction systems on an errant crusher and several air track drilling systems. Impending occupational health legislative changes which will bring Queensland in line with the other Australian states should result in a more committed management safety philosophy.

Dust surveys of this nature will be carried out on an on-going basis. This information base will be continually updated and a series of annual reports will be produced which will demonstrate the efficacy (or otherwise) of this nascent hygiene management program.

REFERENCES

1. Grantham, D.L., Bell, S.L.: A decades experience with personal dust monitoring in Queensland's coal mines. Australian Journal of Coal Mining Technology and Research 1987; 18:1-20.