COAL RANK AND DURATION OF EXPOSURE AS DETERMINANTS OF TOXICITY IN INHALATION EXPERIMENTS WITH RATS

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ABSTRACT

In a first series of experiments, four ranks of coal were tested by exposing the animals during 6 months to 300 mg/m^3 of respirable dust. In all dusts the quartz content was below 0.5% and the mineral matter content below 17%. Groups of animals were killed 6, 12 and 18 months after the start of the experiment. Independently of the coal rank, it was observed in the lung: a) a high dust retention (100 mg in average per rat) with undetectable clearance, b) an increase in lung weight progressing after the exposure period, c) a five times increase in lipids content, d) a slight production of collagen, e) no histological signs of fibrosis but alveolar aggregation of dust-laden macrophages.

In order to document the importance of exposure duration, similar experiments were then carried out with one of the four types of coal, animals being exposed for 2, 4 and 6 months. The pulmonary dust retention, the rate of lung weight progression and the collagen production were all positively related to exposure.

In these inhalation experiments, the pulmonary reaction to coal dust was essentially characterized by an inflammatory reaction leading to an increase in lung weight. It was related to the duration of exposure but not to the coal rank.

No Paper provided.

ALUMINUM-INDUCED LUNG DISEASE

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ABSTRACT

Different lung diseases were diagnosed in two patients exposed to aluminum dusts: a severe lung fibrosis (61 year old patient) and a granulomatosis (32 year old patient).

In both cases, large amounts of respirable Al particles were present in BAL and lung tissue, and Al was identified within the lesions. In the second case, sarcoid-like aspect of granulomas, T-helper lymphocyte alveolitis and positive transformation test of lymphocytes with Al compounds suggest that in some patients, Al dust can induce an immune granulomatosis similar to beryIliosis.

Since pulmonary disease due to aluminum is very uncommon even in heavily exposed workers, host response seems to be a factor in its development. Further observations will be necessary to confirm if aluminum-induced granulomatosis can evoluate towards lung fibrosis.

BAL appears to be useful in this type of problem for detecting retention of aluminum particles and cellular abnormalities, and for the recovery of lymphocytes for immunological studies. Moreover, it could serve as a monitoring tool after eviction and/or treatment.

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PLANNING A DUST FREE COAL MINE

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ABSTRACT

Silica and coal dust have been responsible for the death of more miners than all other mining hazards together. Progress in dust control has been made but, still today, air ventilating many underground coal mines is too dusty to be really safe for the unexposed miners!

Some new techniques such as water jet cutting, foam generation, air scrubbing, and remote control, will still bring some progress. However, achieving a dust free mine requires recognizing respirable dust as the main concern at the stage of mine design and planning. Water being the common mean to fight dust, any coal moisture limitation should be eliminated from the working face to the power plant including the preparation plant. Replacing belt conveyors by an hydraulic transport is the optimum solution. Slurry density control and regulation by an expert system make this solution technically and economically feasible. Hydraulic transport will permit to maximize the efficiency of all dust control techniques using water.

Progress in dust control in underground coal mines has been made but, still today, air of many mines is too dusty. The amount of 2 mg of respirable coal dust per m^3 of air, considered as dangerous, represents only half of a millionth of the coal produced if one considers 1,000 tons per shift in a face with a ventilation of 8 m^3/s (13,000 cfm). As demonstrated by the experience of the last forty years, dust control is a problem which will probably never be solved while using current mining methods.

It is time to design and develop economically competitive dust free mines.

Dust sources are many, and their contribution to miners dust exposure may be very different from one mine to another. Among these sources of respirable dust, coal cutting, coal handling, coal transport, roof caving and roof drilling for bolting are the main sources. If we take the example of longwall mining, Figures 1 and 2 illustrate dust concentration distributions measured in longwall faces with the position of the exposed miners.

Three basic approaches are used to reduce the exposure of miners to respirable dust:

- Reduce the respirable dust production.
- Suppress the airborne dust produced.
- Keep the miners in areas of lower dust concentration.

The last approach, helped by the development of remotely controlled equipment is efficient for one dust source only and should be used as the last resource.

It appears that water is the common mean to fight dust: water injection in the solid coal, water sprays on the cutting drums, water sprays at each coal transfer point.... That results in a major problem because mines are designed to handle and produce coal with a limited moisture content for either technical or commercial reasons. In the mine itself, the main limitation comes from the belt transport system but, outside it may come from the cleaning plant or from the power plant. In the U.S. the coal preparation plants are, by chance, equipped with wet screening, but it is worth mentioning that dry screening in a cleaning plant limits the moisture content of the "run of mine" coal at a 6% level and prevents a good dust control in the mine.

Today, a dust free mine is a real possibility but achieving this goal requires, first of all, to recognize respirable dust as a top priority at the mine planning and design stage. Trying to control respirable dust in mines not adequately designed is almost impossible.

Taking this novel approach, several mining methods can be selected and appropriate equipment developed.

DUST SOURCES AND CONTROL

We saw from Figures 1 and 2 that, in a longwall face there are three dust sources of almost equal importance: coal cutting and loading, roof caving, belt conveyor and transfer points. In room and pillar mining there is generally no roof caving but roof bolting may be a main source of respirable dust.

We will briefly review for each dust source, promising development and techniques already tested, such as water jet cutting, foam generation, hydraulic transport, which could eliminate dust sources and be combined to obtain a global approach to the development of a dust free mining method, but, also could be used individually to improve dust control in existing mines.

Coal Cutting

Coal cutting is the first dust source. As shown on Figure 3 each bit is crushing coal in very fine dust at its top. The major steps to reduce this source of dust were:

- The development of "wet drums" where water sprays are located on the cutting drum itself;
- The use of a small number of larger bits allowing to fit each bit with a water spray;
- Water injection in the solid coal ahead of the face.

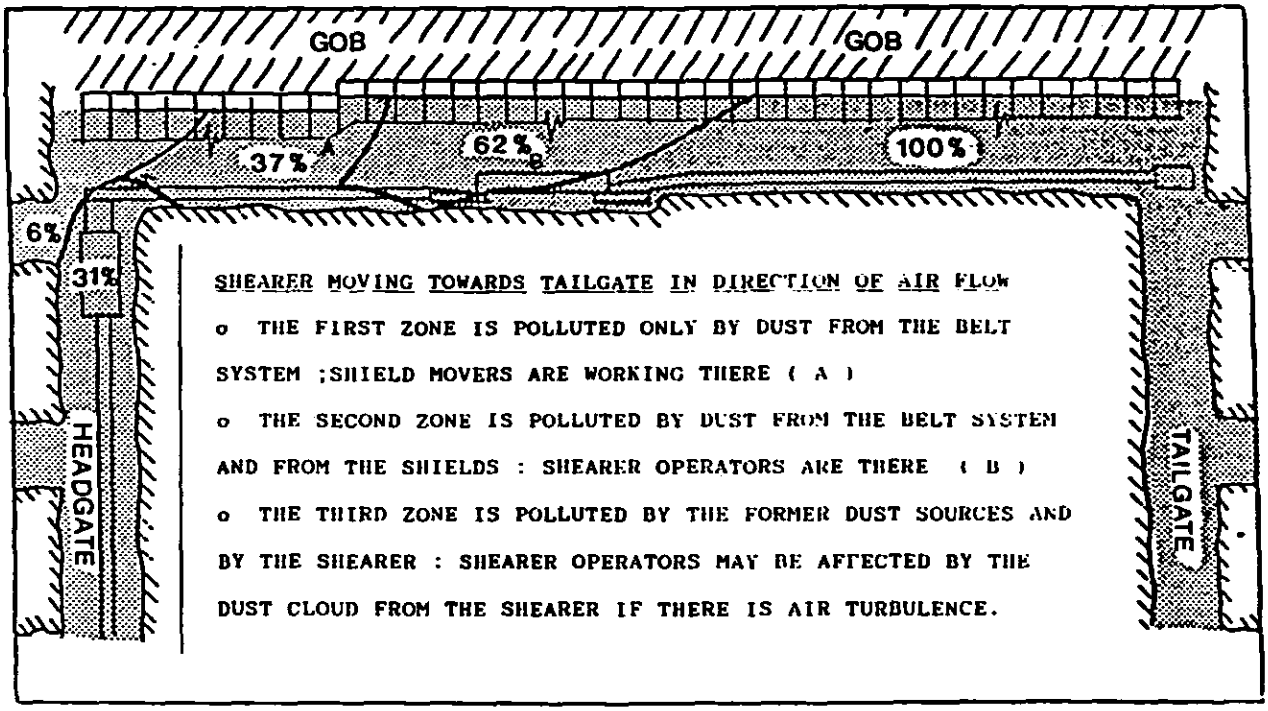


Figure 1. Longwall dust source contribution of total dust make for head-to-tail passes.

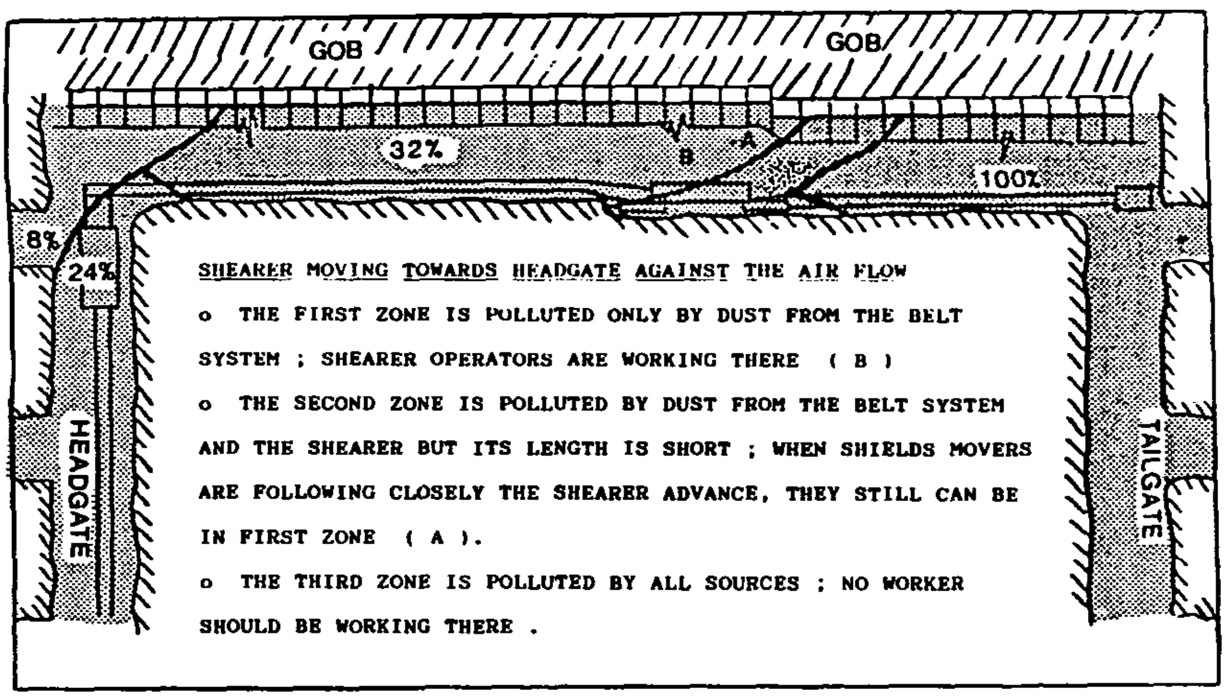
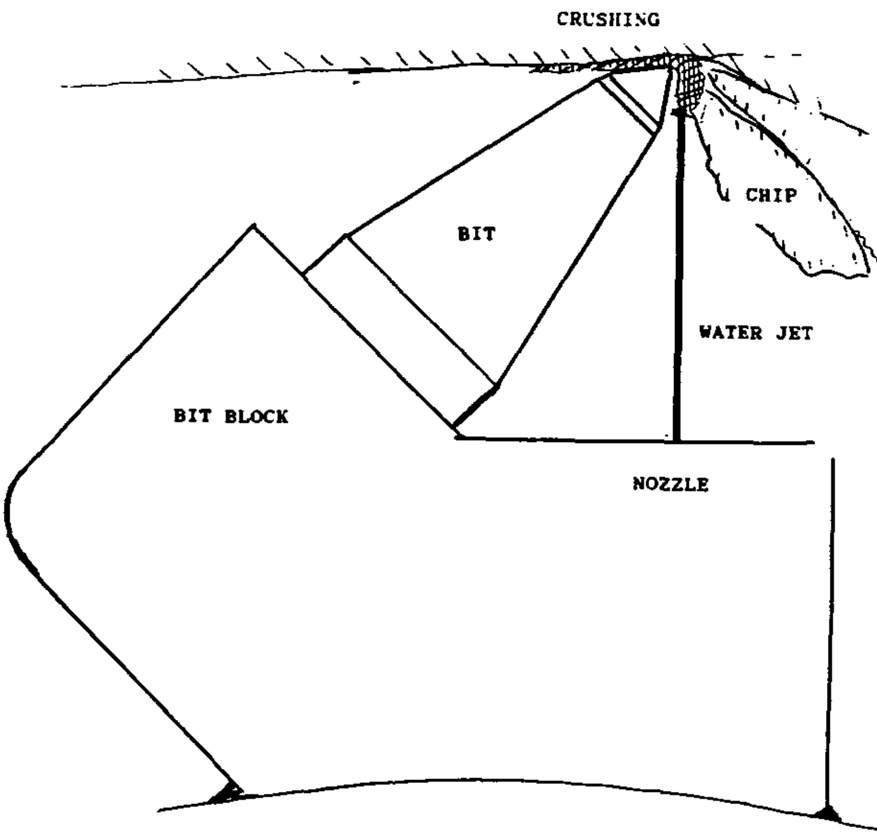


Figure 2. Longwall dust source contribution of total dust make for tail-to-head passes.



CUTTING ACTION OF A CONICAL BIT

THERE IS A CRUSHED AREA AT THE BIT TOP WHICH IS ASSUMED TO BE THE MAIN SOURCE OF DUST FROM CUTTING OPERATION. A HIGH PRESSURE WATER JET AS REPRESENTED IN FRONT OF THE BIT WAS FOUND VERY EFFICIENT FOR DUST ABATMENT .

Figure 3. Cutting action of a conical bit.

The next step will probably be:

- Water jet assist cutting; a jet of high pressure water is directed at the source of dust, the tip of the bit. Surface and underground tests showed a 75% reduction of the dust produced without exceeding a 3000 psi water pressure.[1] The development was retarded by technological problems but at least three projects are ongoing;

- A joint research by Eickhoff and the U.S. Bureau of Mines using high pressure rotating seal and phasing system to supply the HP water to the bits;[2]

- Two solutions to intensify the water pressure in the cutting head to avoid HP rotating seal and phasing system. One of them developed by R.A. Systems, Figure 4, with the support of Pennsylvania Energy Development Authority allows retrofitting existing machines with new cutting drums.[3] The other one[4] is proposed by Minnovation (G.B.).

Water jet assisting cutting is a solution to decrease dust production while using a small amount of water and could be used on shearers in longwall as well as on continuous miners in room and pillars sections.

Coal Handling and Transport

In addition to the dust generated by mechanical cutting each time coal falls by itself from the face or is mechanically loaded, coal breakage produces dust unless coal is very wet. To avoid using a large amount of water, water infusion ahead of the face is the most efficient way to reduce dust production during coal loading with an added moisture of about 3% only.[5] The same apply for coal transport: unless coal is very wet, transport on belt conveyor generates dust at least at each transfer point. Dust generation is due to secondary breakage but also to the air drying the coal transported. From the dust control point of view, belt transport is not a good solution. It is a major source of pollution of the air intake and it is obviously very difficult to reduce the exposure to sources polluting the air intake.

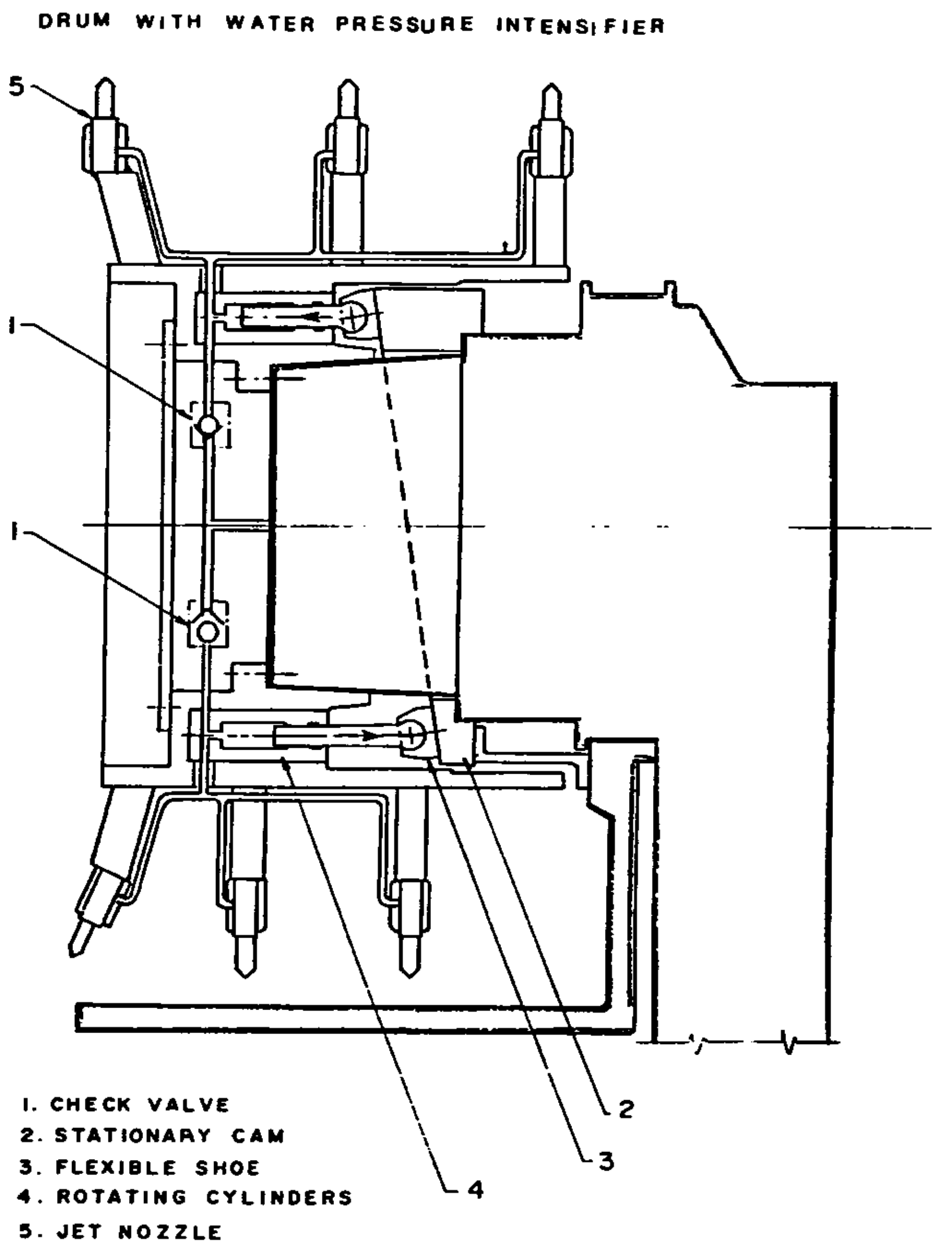


Figure 4. Cutting drum with water pressure intensifier to retrofit shearers with water jet assisted cutting

In planning a dust free mine, there is no doubt that no belt conveyor should be used; they should be replaced by hydraulic transport for two main reasons:

- Hydraulic transport can economically replace the usual belt system and suppress a major respirable dust source.
- It will eliminate the limits a belt conveyor system imposes on the amount of water used for dust control during cutting and loading operations. It is also suitable for hydraulic mining. We do not have to detail the advantages of hydraulic transport. So much has already been said and published on the subject.[6] The replacement of belt conveyors by hydraulic pipelines will have an impact on the mine design by elimination of neutral entries. It would alleviate the regulatory problem in the use of a two entries system. It will also improve mine safety by suppressing the risks of mine fire associated with belt conveyors. However, these numerous studies and the mentioned advantages had little result on the development of hydraulic transport in underground coal mines. Only Consolidation Coal Company conducted underground testing.[6]

We should examine why, currently, hydraulic transport is not used more often for handling coal.

- A problem results from the discontinuity of the coal production (even by "continuous" miners) compared to the continuity requirements of a hydraulic transport network.
- Another problem is the ever-recurring change of length of the pipeline branches during mine operations.
- More important is the need for a good control of the slurry density not only to improve the system efficiency but essentially to prevent plugging pipelines.

Existing mine equipment can be modified to provide a steady flow of product to be injected immediately in a pipeline. The transformation can proceed step by step.

In a first phase, storage capability could help matching current equipment with hydraulic transport. As an example, in a room and pillar section, a continuous miner with water jet cutting and no limit of coal moisture could still load in shuttle cars but, at the transfer point, an increased storage capacity could provide a steady flow of coal in the pipeline. A good control of slurry density and automatic adjustment of the flow with a simple expert system will do the rest. In a longwall method the flow of coal is more steady compared to the case where a continuous miner stops producing every five feet for bolting and moving from one entry to another. Injecting coal in a pipeline was studied by Foster Miller and Ingersoll Rand under Government Contracts. Consolidation Coal Company used a crusher/pump vehicle for direct loading behind a continuous miner.[6,7]

The problem of pipeline extension can be solved, or at least made easier, by using a flexible pipeline similar to the prototype developed and tested by Consolidation Coal company to be attached to a continuous miner to follow it.[6] Only one flexible section per branch will be required as shown on the conceptual design on Figure 6.

Another important point is the need for a control system of the hydraulic network. Density control is the key point to prevent any risk of plugging the pipelines and also to keep an optimum solid concentration. If the slurry density is accurately measured at each loading point, it is simple to establish an algorythm to regulate all the network using pumps with variable speed drives.[8]

Roof Caving and Shield Support

Shield support brought progress in longwall roof control, but improvements in safety and productivity were paid by an increase of respirable dust generated when the shields are advanced, compared to other types of powdered roof support. Tentative solutions were better designs of the seal between shields and water sprays on the gob side; still the dust production remains important. Two approaches are possible; if it is the only dust source at the face, the exposure to this source could be avoided by keeping all miners upstream. If not, we suggest testing foam generation behind the shields instead of using only water sprays.

Roof Bolting

Most of the roofbolters used in the U.S. mines are drilling with aspiration and filtration of the dust. It was shown that careful maintenance of the dust collection system could take care of the dust problem.[9] Still a better approach should be wet drilling with or without water jet cutting. In low seams, water jet cutting requires a flexible drill because use of rod extension is not possible. R.A. SYSTEMS is developing such a flexible drill which could also allow prebolting[10] (Figure 5).

Economic Considerations

Some of the proposed solutions such as water jet assist cutting are inexpensive to implement: a shearer or a continuous miner could be retrofitted with water jet assist cutting by changing the drums and using drums with a pressure intensifier which will cost only twice the price of a normal drum. The expense, about five percent of the machine cost, will lower operating costs by increasing bit life and production. Foam generation on shields can be done by using the existing water spray system with no expenses but dust measurements for efficiency control and parameters selection. However, hydraulic transport is a different problem because it will not only result in essential changes of the mine design and in a high moisture content of the run of mine coal, but will also require an important investment in special equipment and appropriate training of all personnel. There is little experience on running an extensive hydraulic network transporting a coarse slurry, with varying factors from the

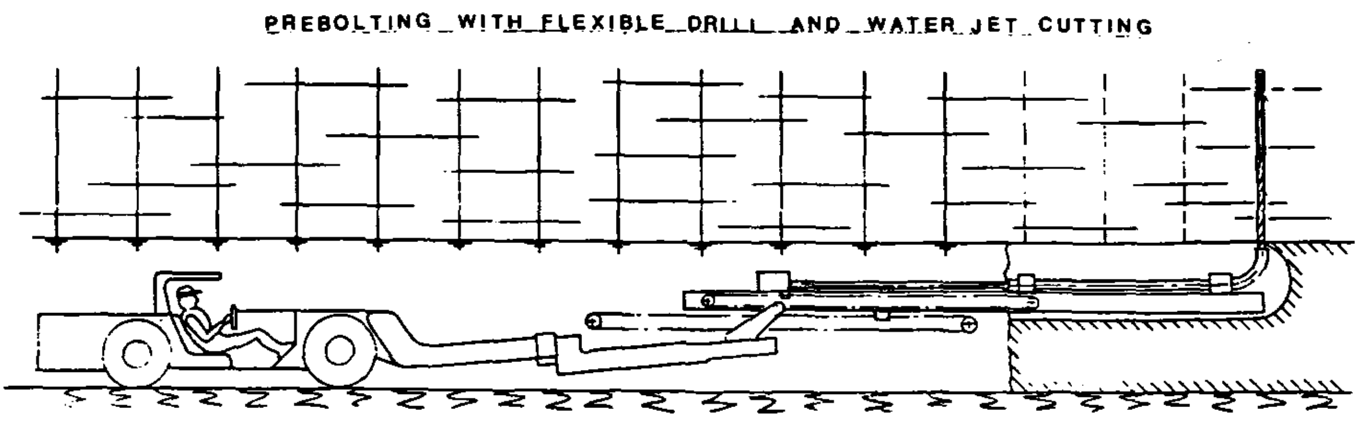


Figure 5. Roof prebolting concept.

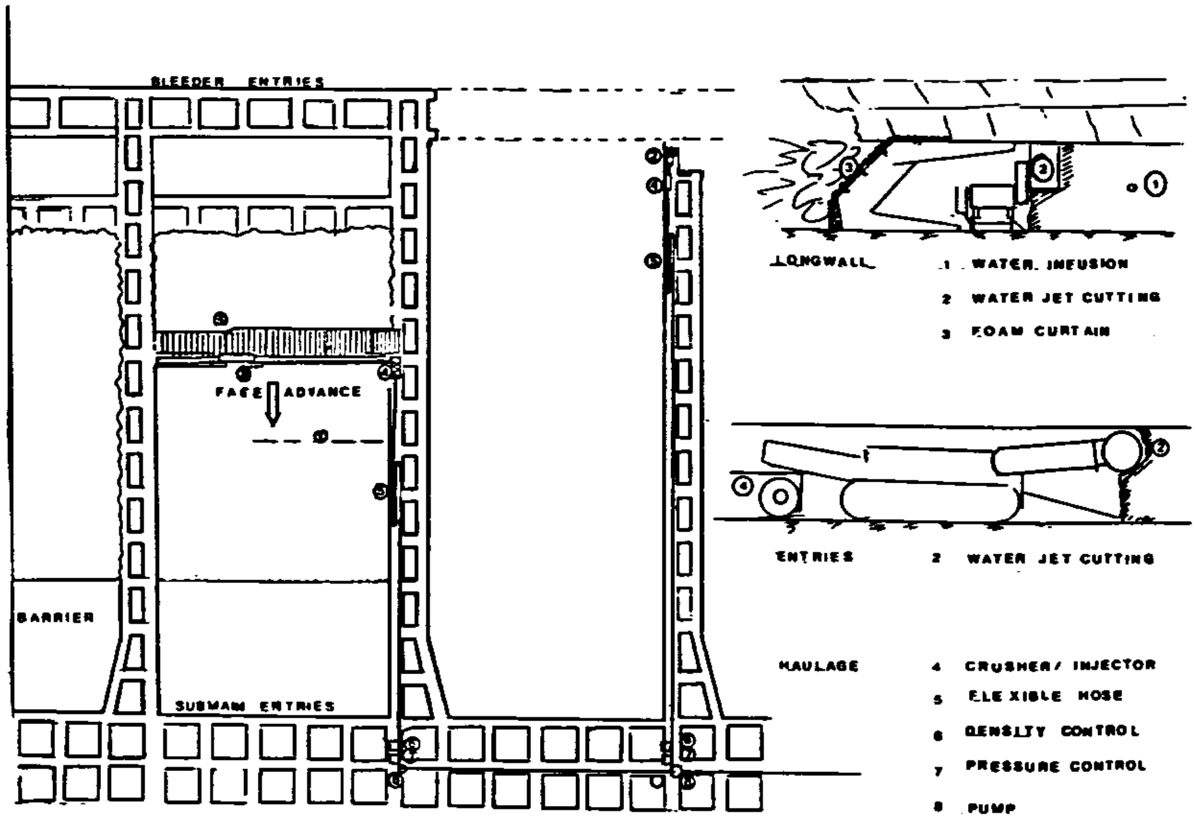


Figure 6. Overview of a dust free coal mine.

size consist and the nature of the raw coal to the length of each branch of the network.

The investment required for hydraulic transport is only half of the cost of the equivalent belt system but there is always a risk factor when comparing a conventional system to a new one. Whatever the risk, it creates a psychological barrier even though the anticipated problems are technically easy to solve:

- Speed control of each pump to maintain an appropriate slurry density to avoid settling of the products; an expert program can be based on accurate density measurements at each produce inlet.

- Pressure control of the network to detect plugging or leaks.

The most difficult problem is to start the network full of slurry after an unexpected stop due, for instance, to a power failure, but several solutions exist.

CONCLUSION

The problem of respirable dust can probably be solved if there is enough will to do it. Some alleviations can be obtained easily but a dust free mine requires hydraulic transport. Such a change in underground coal mining means risks to face and problems to solve but will increase productivity, lower mining cost and protect miners' health.

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COMPARATIVE INHALATION HAZARDS OF TITANIUM DIOXIDE, SYNTHETIC AND NATURAL GRAPHITE

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Occupational exposure to airborne graphite may occur in manufacturing and application processes. Synthetic graphite (SG) is a pure crystalline form of carbon from high temperature treatment of petroleum products, contains less than 1% quartz and is regarded as a "nuisance" dust (ACGIH TLVs®). Natural graphite (NG) is the mineral form of graphitic carbon and contains associated silicate minerals. A series of inhalation studies were conducted to study the effects of crystalline silica on graphite pneumoconiosis; titanium dioxide (TiO_2) was used as a negative control. Fischer 344 rats were exposed by inhalation to 100 mg/m^3 SG, NG and TiO_2 for 4 hrs/day for 4 days. At 24 hrs and 14 days post-exposure (PE), exposed and air control rats were evaluated for bronchoalveolar lavage (BAL), physiological, pathological changes. Previous acute inhalation studies with crystalline silica resulted in persistent BAL changes correlated with adverse histopathology. BAL analysis detects differences between "nuisance" dusts and silica. Inhalation of NG containing 1–2% crystalline silica resulted in reversible BAL effects similar to other "nuisance" dusts (SG, TiO_2). Impairment of lung clearance from high dust burdens with greater silica content may be the causitive factor in graphite pneumoconiosis. (Supported by the U.S. Army Biomedical Research Development Laboratory.)

INTRODUCTION

Synthetic and/or natural graphite dust may have military applications which could result in inhalation hazards. CRDEC has tested synthetic (Asbury Micro 260) and natural (Asbury Micro 650) graphites and found that acute inhalation exposure in Fischer 344 rats resulted in a mild reversible inflammatory response at high concentrations (500 mg/m^3) for the synthetic material.[21]) A repeated inhalation study with the synthetic graphite also showed more changes at a lower concentration (100 mg/m^3) reversible at 3 months post-exposure (PE).[22] The purpose of this study was to compare the toxicity of natural and synthetic graphite using titanium dioxide as a negative control. Both synthetic graphite and titanium dioxide are classifed as "nuisance dusts" as defined by ACGIH.[3] Purported "nuisance" dusts have a history of little adverse effect and do not produce significant organic disease or toxic effect when exposures are kept under control. A Threshold Limit Value (TLV) of 10 mg/m^3 of total dust (less than 1% quartz) is recommended for "nuisance" dusts for a normal workday. For materials containing more than 1% quartz, the environment should be evaluated against the TLV of 0.1 mg/m^3 for respirable quartz. The natural graphite used in this study contains 1.85% silica and chemically may not meet the nuisance dust requirement; however, this material may behave biologically like other nuisance dusts (synthetic graphite and titanium dioxide). According to the ACGIH, the biological criteria of a nuisance dust is defined by the following lung tissue reaction: 1) the architecture of the air spaces remains intact; 2) collagen (scar tissue) is not formed to a significant extent; and 3) the tissue reaction is potentially reversible. In addition to these histopathological indicators of toxicity, pulmonary function and bronchoalveolar lavage (BAL) were used to compare the toxicity of these graphite dusts to titanium dioxide.

MATERIALS AND METHODS

Experimental Design and Test Materials

Groups of 20 male Fischer 344 rats (CDF/Crl BR), commercially procured from Charles River Laboratories, were exposed by whole body inhalation to 100 mg/m^3 of each test material on four consecutive days, four hours/day. At 24 hrs and 14 days PE, exposed and air control rats were evaluated for BAL, physiological and pathological changes. Toxic observations were recorded daily and weights were taken at weekly intervals.

The synthetic graphite used in this study is Asbur Micro 260 (less than 1% silica) and the natural graphite is Asbur Micro 650 (1.85% silica). The titanium dioxide was a gift from NL Chemicals Inc. and is a high purity rutile form of titanium dioxide. All three test materials contained negligible amounts of contaminants.

Chamber Operation

The Hazelton 2000 liter stainless steel inhalation chambers were used for this study. A unique feature of the chamber is the multi-tier arrangement of the cage units and catch pans which facilitates good mixing within the chamber and helps promote a nearly uniform aerosol concentration throughout the chamber.[12] This uniformity has been verified by both fixed point aerosol sampling measurements, residence time distribution measurements, and flow visualization studies.[2,13] Four Hazelton 2000 liter chambers were set up as shown in Figure 1 under climate controlled conditions (temperature = 74° ± 4°; relative humidity = 40% ± 10%). All four chambers were manifolded to a single blower unit which pulls air from the surrounding room through each of the chambers; all air was filtered prior to being exhausted

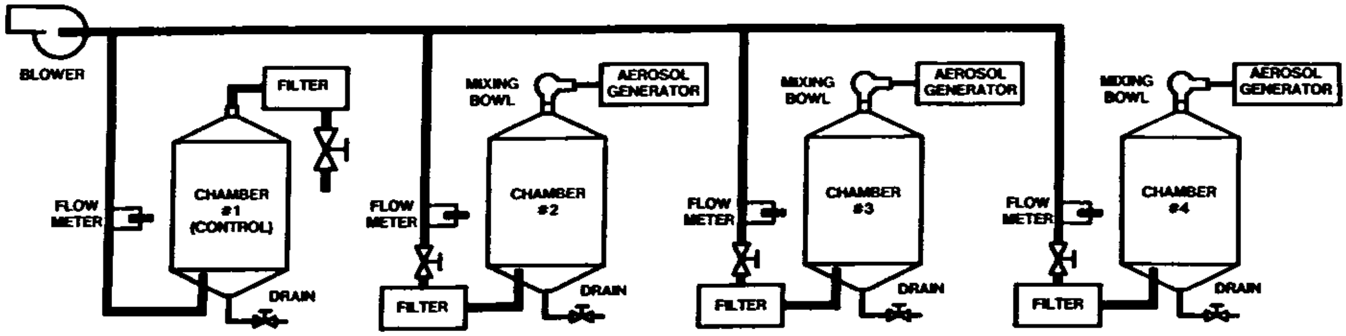


Figure 1. Exposure facility.

outside. The inlet ports to the exposure chambers were each fitted with 15 liter glass mixing bowls to aid in aerosol dispersal and the control chamber and was fitted with a particulate filter on its input in place of a mixing bowl. Each chamber exhaust line has an orifice meter downstream of the particulate filter for the purpose of monitoring chamber flow. Gate valves provided on each chamber enable course flow regulation.

The aerosol generation system for titanium dioxide consisted of an AccuRate series 300 screw feeder and attached vibration device which metered the dust at a uniform rate to a Jet-O-Mizer aerosol mill depicted in Figure 2. The aerosol mill was equipped with air jets supplied with compressed air at 55 psig. High velocity air emanating from the jets resulted in high particle to particle shear forces which readily caused the break up of agglomerates. Consequently, a relatively highly dispersed aerosol was produced at the outlet of the aerosol mill.

The AccuRate series 300 feeders were also used to deliver the graphites to the dust generators. Dispersion of the graphite dusts was accomplished using a Metronics aerosol generator depicted in Figure 3. This device is in essence a centrifugal blower with a deep bladed impellor. Feed material falls into the center of the impellor and is driven against the blades by centrifugal force resulting in particle deagglomeration and dispersion. The resultant aerosol was fed directly into the chamber mixing bowl. The appropriate blower speed was determined during the calibration phase and was regulated by means of a variance.

Prior to the start of exposures, calibration of the chamber was conducted to assure a stable concentration. The aerodynamic particle size of each test material was determined using a Sierra® Instruments cascade impactor (Model 2210-K, 10 stage). The mass median aerodynamic diameter (MMAD) and geometric standard deviation (Qg) of each test material were determined during the calibration and exposure phases of the study. The MMAD in micrometers and the (Qg) were 2.38 (2.61) for natural graphite, 2.27 (2.57) for synthetic graphite, and 1.50 (2.25) for titanium dioxide.

The average concentrations for the four days of exposure for each test material were: 102.1 mg/m^3, natural graphite; 100.4 mg/m^3, synthetic graphite; and 101.5 mg/m^3, titanium dioxide. The overall coefficient of variation for concentration was less than 15 percent.

Biological Evaluations and Data Analysis

Lung lavage and pulmonary physiological testing were performed on the same animal to enable correlation of biochemical changes with functional changes. The details of the physiological evaluations and BAL analyses were previously described by Thomson et al.[18] Macrophage concentration was determined in a hemocytometer and cell viability was conducted via the trypan blue exclusion test.[7]

At 24 hours and 14 days PE, the test and control rats identified for pathological evaluation were killed using carbon dioxide gas and complete necropsies were performed by Pathology Associates Inc., Ijamsville, Md. All tissues were fixed in 10% neutral buffered formalin, trimmed, dehydrated, embedded in paraffin, sectioned at 6 *m and stained with hematoxylin and eosin. Representative sections were examined for all test groups and controls.

Data analysis was conducted according to a statistical "decision tree" as described by Gad and Weil.[5] First, Bartletts' Test for homogenicity of variance was used as a check of the assumption of equivalent variances, followed by the use of ANOVA (analysis of variances). Non-parametric, heterogeneous data was analyzed by the Kruskal-Wallis nonparametric ANOVA. Finally, Dunnett's Test was used on parametric homogeneous data to identify significantly different groups.

RESULTS

Physiological and Bronchoalveolar Response

Throughout the entire study, the control and test animals gained weight at the same rate; there were no statistically significant differences between the groups. There were no adverse toxic signs exhibited by the animals, normal activity occurred pre and post exposure. The graphite exposed rats were charcoal colored following exposure and remained "dirty" looking throughout the 14 day post exposure period despite some preening. The pulmonary physiological evaluation of the rats exposed to titanium dioxide and graphite dusts

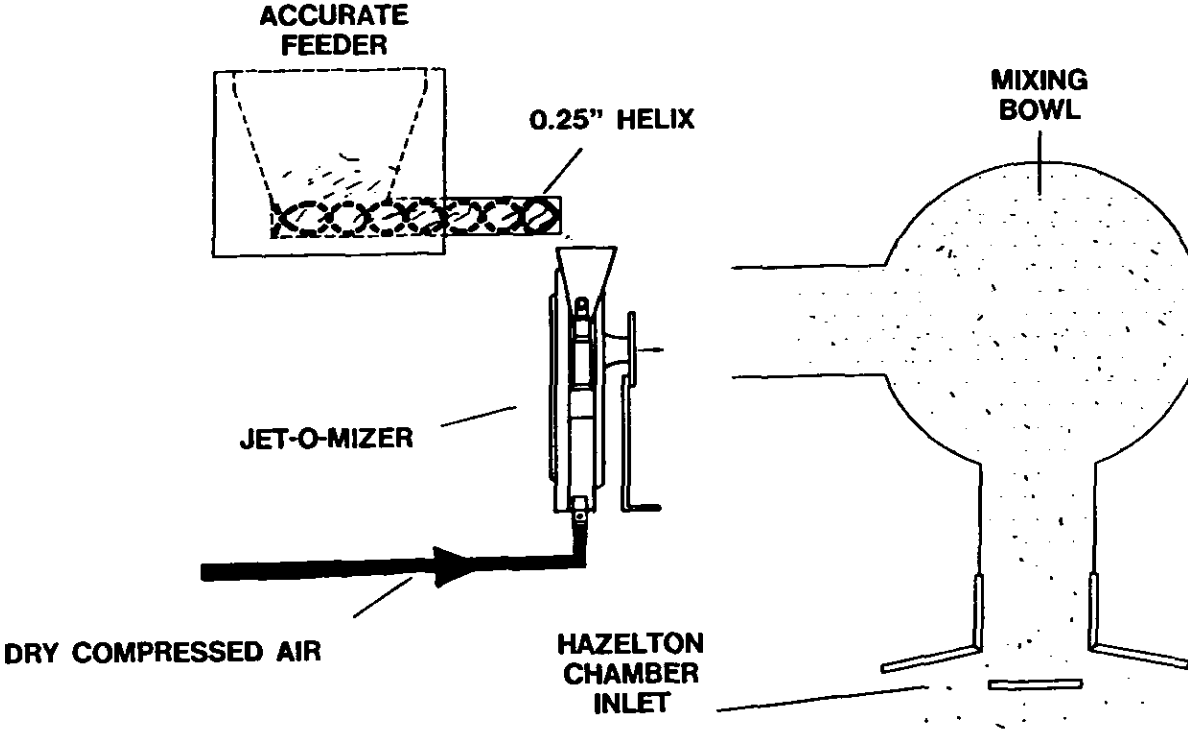


Figure 2. TiO_2 aerosol generation system.

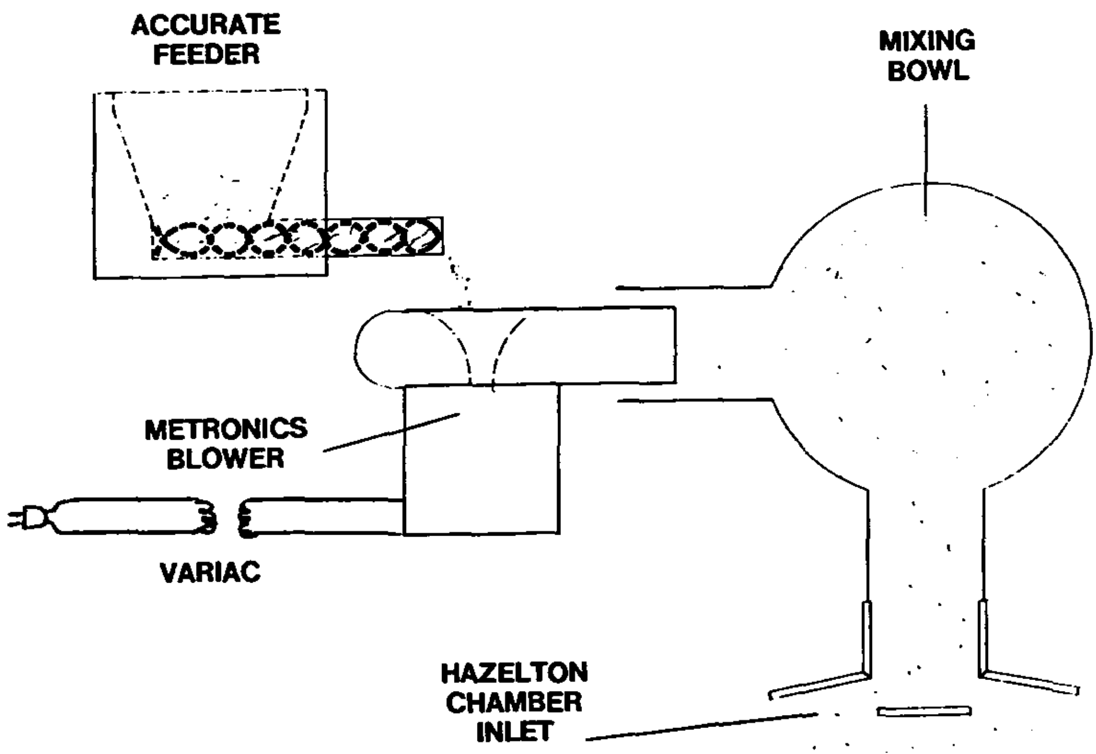


Figure 3. Graphite aerosol generation system.

showed an apparent statistically significant decrease in pulmonary resistance at 24 hours PE in the rats exposed to synthetic graphite and a significant increase in respirator rate at 14 days PE in the rats exposed to titanium dioxide. Neither of these apparent changes has any biological significance. Previous acute and repeated inhalation studies on synthetic graphite did not result in any consistent significant changes in pulmonary resistance.[21,22]

The enzymatic and protein analyses of the lavage fluid are summarized in Figure 4. There were significant increases in protein at 24 hours PE with all three dusts but at 14 days all values were within control levels. At 24 hours PE, there were significant increases in β-Glu and ALKP for both graphite dusts and an increase in LDH for the natural graphite. There was an unexplainable decrease in ALKP for titanium dioxide which may be caused by a material interference with the assay; this effect is being investigated. By 14 days PE, all enzymatic changes were resolved.

Cytological analyses of the lavage fluid are listed in Table I. All three dusts exhibited an influx of polymorphonuclear neutrophils (PMN) at 24 hours PE but the graphite dusts elicited a greater PMN response. Likewise, natural graphite exposure resulted in the largest increase in total cells. By 14 days PE, the PMN response had diminished to almost control levels. There was no decrease in macrophage viability from exposure to any of the test materials.

Pathological Evaluations

The gross observations noted at the time of necropsy indicated that several of the graphite exposed rats had discolored or mottled lungs. There were no apparent differences in body or organ weights. Treatment related changes were present in the lungs of all exposed rats consisting of brown to black, isotropic pigment. At 24 hours PE in all cases, the pigment was present either free or within macrophages in terminal airways and alveoli. Microscopically, the three types of pigment were indistinguishable from each other. There was no pigment in the peribronchial lymph nodes and no adverse tissue reaction to it. By 14 days PE, there was no free pigment (extracellular) in the lungs of the exposed rats. Again, the three types of pigment were indistinguishable; however, in the graphite exposed rats, the pigment-laden macrophages tended to be aggregated in small groups more than in the titanium dioxide exposed rats. The only other changes were two minimal foci of epithelial hyperplasia in the alveoli and/or the terminal bronchioles of three rats exposed to synthetic graphite and one rat exposed to titanium dioxide. The pigmented macrophages were not associated with the hyperplasia. It was concluded that the degree of pigmentation was mild in all exposed rats and nearly identical within and between groups.

DISCUSSION

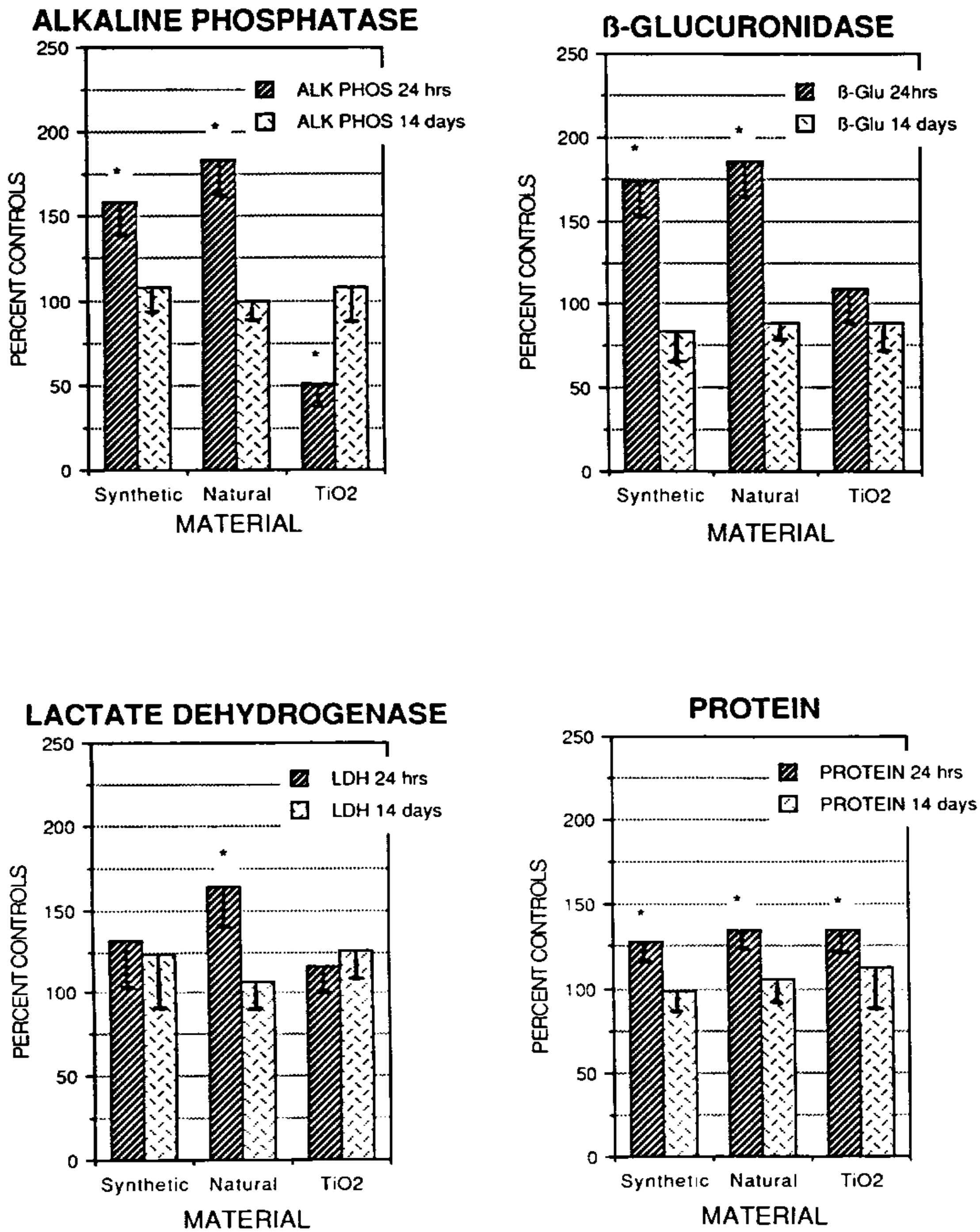
Inhalation exposure of Fischer 344 male rats to 100 mg/m^3 of titanium dioxide, natural and synthetic graphite dusts for 4 hrs/day for four days resulted in minimal adverse effects. There were no adverse toxic signs following exposure, no mortality and no consistent pulmonary function changes. All the rats gained weight at the same rate as the controls. BAL analyses resulted in increases in protein for all three materials; increases in β-Glu and ALKP for both graphites; and increases in LDH for natural graphite at 24 hours PE. The increase in LDH is reported to be indicative of damage to the pulmonary Type 1 cells while ALKP increases may be correlated with Type II cell hyperplasia.[8] Type II cell hyperplasia was only observed in three rats at 14 day PE, two from the synthetic graphite exposed group and one from the titanium dioxide exposed group. This effect was observed in a previous study where rats were exposed to 100 mg/m^3, 2 hours/day, 5 days/wk for two weeks.[22] Perhaps a longer repeated exposure would have resulted in more Type II cell hyperplasia in this study. Since Type II cells are the progenitors of Type I cells,[4] this would be an indicator that the damaged alveolar epithelium is undergoing repair and replacement. The graphite exposed rats also had increases in β-Glu which is a lysosomal enzyme released by phagocytic cells in response to inflammation.[8] These enzymatic changes correlate with the BAL cytological profile (i.e., increases in PMN and total nucleated cells), which are indicative of an inflammator response. By 14 days PE, all BAL alterations were resolved.

The histopathological evaluation revealed mild lung pigmentation in all the exposed rats with more aggregates of pigment in the graphite exposed rats at 14 days PE. The macrophages seen in the alveoli appear to be actively phagocytizing all three materials. There was no decrement in macrophage viability which is in agreement with previous studies with synthetic graphite and titanium dioxide.[1] No pigment was observed in the peribronchial lymph nodes; this was expected since in prior inhalation studies with graphite, pigmentation in the lymph nodes was not evident until 3 months PE. Clearance of these dusts may be a slow, protracted process.

The BAL changes seen after repeated exposure to graphite were more severe than the changes following a single exposure. Previous acute inhalation exposure to graphite resulted in minimal cytological changes reversible by 14 days PE and no enzymatic BAL changes.[21] However, the BAL response in this study is mild compared to the dramatic inflammatory reactions observed in acute studies with brass powder,[18] and is not as persistent as the effects seen with aluminum

single 100 mg/m^3 inhalation exposure to quartz, BAL enzymes were elevated two to five hundred percent over controls at 3 days and 3 months PE. The changes with graphite were minimal and reversible.

The repeated inhalation studies in this report and the previous acute inhalation exposure to synthetic graphite even at very high concentrations (500 mg/m^3 does not result in any permanent effects. This is in agreement with the OSHA[14] and Documentation of TLVs[3] guidelines which regard synthetic graphite as a nuisance dust. The higher quartz content (>1%) of natural graphite supposedly accounts for the greater risk of developing fibrosis; thus, natural graphite is assigned a TLV of 2.5 mg/m^3. However, this hypothesis is not conclusive; a survey of the literature on the etiology of coalworkers' pneumoconiosis (CWP) reveals uncertainty as to what part quartz plays in pathogenesis.[15] Several studies in animals have implicated quartz as the causative factor in



*SIGNIFICANT IN DUNNETT'S TEST @ P ≤ .05

Figure 4. BAL results for graphite and TiO_2 exposed rats.

Table I
Cytological Analysis of Bronchoalveolar Lavage Fluid

		WBC x10³	TOTAL x104	VIABILITY %	MACROPHAGE %	LYMPH %	PMNS %
24 Hours Post Exposure							
CONTROL	x	2.22	4.34	97	98	2	0
	s	0.50	1.51		2	1	0
SYNTHETIC	x	2.40	5.18	95	56	1	43
	s	0.46	0.89		7	0	7
NATURAL	x	3.37*	6.10	94	46	2	52
	s	0.73	1.26		10	1	10
TITANIUM OXIDE	x	1.45	6.22	96	85	4	11
	s	1.20	2.07		15	5	11
14 Days Post Exposure							
CONTROL	x	2.00	4.41	98	97	2	1
	s	0.66	1.11		2	1	1
SYNTHETIC	x	2.13	5.29	98	92	3	5
	s	0.43	1.01		7	3	4
NATURAL	x	2.58	6.12*	99	92	2	6
	s	0.57	0.61		4	1	4
TITANIUM OXIDE	x	1.88	3.67	98	94	2	4
	s	0.42	0.53		3	2	3

* significant p=0.05 (t-test)

mixed dust fibrogenesis. Martin et al.[11] found collagen formation after 18 months in the lungs of rats that had inhaled a coal mixture with 5% quartz for 80 days. At concentrations above 10% quartz, the formation of fibrotic nodules and collagen occurred at a rate five times higher than coal alone. Further confirmation of this theory was demonstrated by Schlipkoter et al.[18] in experiments where quartz, coal and titanium dioxide, alone and in mixtures, were administered to rats intraperitoneally. Fibrosis was induced when quartz was added to the mixtures and the authors concluded that whenever quartz is present in a particular mine dust producing CWP, it should be considered the dangerous agent. This interpretation according to Parkes[15] is contradicted by a number of observations in human beings. Both simple pneumoconiosis (benign dusty lung) and progressive massive fibrosis have occurred in men exposed to artificial or quartz-free graphite.[6,16,17] In each caae, quartz was absent or less than 1% in the lungs; therefore, such instances imply quartz is not the pathogenic factor. The controversy is more than an academic debate since occupational exposure standards are based upon the quartz content of the dust in question (eg. graphite). Recent epidemiological studies in British mines showed that an apparent increase in the prevalence of pneumoconiosis with increasing quartz exposure is reversed in the presence of high clay mineral exposure (aluminum silicate clays are known to inhibit silicosis) and that mass concentration of respirable dust is the best exposure index when the quartz content does not exceed 7.5%.[15] This "mass" effect of dust exposure has been recently demonstrated by the results of chronic inhalation studies conducted with titanium dioxide. Lee et al.[10] found fibrosis and bronchoalveolar adenomas in the lungs of rats exposed to 250 mg/m^3 of titanium dioxide for 6 hrs/day, 5 days/wk, for 2 years. The pulmonary lesions were the result of overwhelming the lung clearance mechanisms.

CONCLUSIONS

Repeated inhalation exposure of Fischer 344 rats to 100 mg/m^3 of titanium dioxide, natural graphite, and synthetic graphite for 4 hours/day for four days resulted in a mild inflammatory response 24 hours PE. BAL changes were the most sensitive indicator of damage; although the enzymatic and cytological alterations were evident with all three materials, there were greater increases with the graphite dusts. Even though the graphite dusts and titanium dioxide were still present in the alveolar macrophages of each respective group of rats, by 14 days PE, all BAL changes were resolved. This seems to indicate that the initial period of inflammation had ceased and a slow clearance was in process. There appears to be no deleterious tissue reaction to any of the materials at the levels tested in this study.

In this experiment, synthetic graphite, natural graphite, and titanium dioxide meet the criteria of the ACGIH for a nuisance dust: (1) the architecture of the air spaces remained intact; (2) collagen (scar tissue) was not formed; and (3) the tissue reaction was potentially reversible. Repeated exposure to graphite dust results in more pulmonary damage than single exposures. If the nuisance dust TLV (10 mg/m^3) is exceeded, respirator protection should be utilized.

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THE STUDY ON THE RELATIONSHIP BETWEEN BREATH DUST VALUE (BDV) AND PNEUMOCONIOSIS

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INTRODUCTION

How to determine the exposed-dust volume is the key index in the study on the relationship between dust and pneumoconiosis. Hatch once used the product of dust concentration (mg/m^3) by labour age as exposed-dust volume. Authors, after long kinematic observation, discovered that the incidence rate of pneumoconiosis had significant difference in labour strength, under the same mg. Yes, its cause was related to breath volume. It is verified that the difference in breath volume is greater and it is extremely reached 1:2:3 in the labour strength medium and heavy.

Therefore, the author proposed the breath dust value obtained by multiplying dust concentration exposed time by labour breath value as the index of exposed-dust volume. The following is the studied results on the relationship between BDV and pneumoconiosis.

METHOD OF STUDY

Two plants were chosen as observation targets where the conditions of dust prevention and production were stable and the workers were exposed to silica dust and had little mobility.

1. Established strict regulations of environment supervision (to measure dust concentration once a month), and health guardianships (to make health examinations once a year). The occupational history and examination results were recorded on "health cards," while the results of measured dust were recorded on "labour hygiene cards."

2. Measured exposed time labour breath volume, oxide exhausted and energy exhausted in a shift in different types of work, and determined the breath volume and labour strength in different types of work according to the measured results.

3. Computed the BDV for all exposed workers and pneumoconiosis cases, and then analyzed the relationships between BDV and pneumoconiosis.

RESULTS

According to the studied results, specified a table of breath volume under various labour strengths as shown in Table I, and then determined breath volume in light, medium, and heavy. According to formula (1), calculate BDV.

$$X = \sum_{i=1}^{n} (K(CHT))i \qquad (1)$$

where:

X—BDV accumulate value;
C—average dust concentration (mg/m^3);
H—labour breath volume (l/min);
T—exposed years of standing (year × shift × min);
K—adjusted index of time unit (0.144).

When dealing with the data of retrospective study, use the average dust concentration of year and month as the basis for calculating BDV. But in prospective study, it is best to use the average dust concentration in a shift as a basis of calculating BDV. Labour time (min), labour breath volume (l/min) and personal exposed concentration (mg/m^3) must be practically measured data.

First, calculate BDV in a shift, then, according to number of worker's shifts determine accumulated value of BDV.

Figure 1 shows the statistical results of the relationship between BDV and accumulated incidence rate of pneumoconiosis from 706 exposed workers in plants A, B.

Table II shows the statistical results of BDV in 42 pneumoconiosis cases in different phases in plant A. The BDV from pneumoconiosis in different phases has significant difference by T test. The greater the difference of BDV is, the more serious the phase of pneumoconiosis.

Figure 2 shows the results of relationship between BDV and fatality rate through 20 years of observation. The greater the BDV is, the higher the fatality rate. When analyzing the relationship between "exposure standing up to diagnosis" and BDV in average years, it was found that there is a straight correlation of BDV in average years with "exposure standing up to diagnosis" as shown in Figure 3. The smaller the BDV average is, the longer "exposure standing up to diagnosis" of pneumoconiosis is.

The BDV of average years in 1 phase pneumoconiosis was obtained by accumulated BDV in 1 phase pneumoconiosis divided by "exposure standing up to diagnosis," which provided the proof for searching the limit value of BDV in pneumoconiosis

Table I
Strength versus Breath Volume

Strength	Energy exhausted (l/min)	Breath volume (l/min)
light		10 - 20
medium		21 - 35
heavy		36 - 50

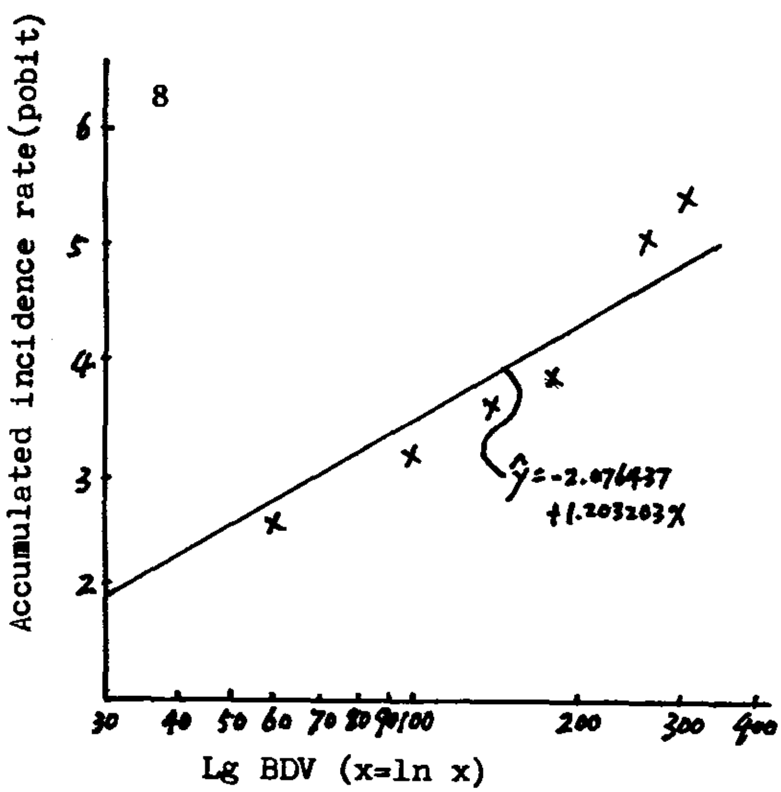

Figure 1. The relationship between BDV and the incidence rate of pneumoconiosis.

According to the closed relationship between the occurrence and development of pneumoconiosis and BDV, from the correlation of BDV in average years with "exposure standing up to diagnosis," the author provided the formula of calculating dust allowable concentration.

(2)

where:

D — dust allowable concentration;
g — logarithmically geometric mean of BDV in I pneumoconiosis;
Sg — logarithmically standard error of geometric mean of BDV in 1 phase of pneumoconiosis;
$t_{0.05}(n')$ — one-sided value obtained by the statistical number of cases N and degrees of freedom N-1 in table.
T — the specified breath volume under the certain labour strength;
T — the longest labour age of exposed workers;
K — factor 0.144 adjusted by time unit.

Table II
BDV in 42 Pneumoconiosis Cases

Phases of pneumoconiosis	Statistical cases	Average of BDV
0 – 1	7	846.09
1	12	1890.39
2	10	8185.50
3	13	15636.48

See the following example from the original data of BDV of 27 cases in 1 phase pneumoconiosis in plant B as shown in Table III.

where:

1. logarithmically geometric mean g=2.4119;
2. logarithmically standard deviation Sg=0.3488;
3. $t_{.05}(26) = 1.706$;
4. labour breath volume, 20 l/min;
5. the longest exposed labour ages, 30 Yrs.
6. K = 0.144

$$D = lg^{1} ((2/411.9\text{-}1.706\ 0.3488\text{-}1g(30 \times 0.144 \times 20))$$
$$= 0.76\ (mg/m^3)$$

DISCUSSION

The key problem in the survey is how to determine the relationship of dose-response between dust and pneumoconiosis. Dutoid, Risner, Bedlle, etc. have studied the above problem and proposed various indexes after Hatch. Among these indexes are dust concentration and the most basic parameters. But they all do not involve the labour strength.

The author considered that labour strength shouldn't be ignored according to studied results. Because of various labour strength effects on labour breath, which effects the dust deposit rate in the respiratory tract, it is related to inhaled dust volume. Therefore, the important factor of labour breath volume should be induced into the calculation of three factors of dust concentration (c), exposed time (T) and breath value (H). But, because it has a difference from practically inhaled dust volume, it should be called exposed volume named as BDV. The parameters of BDV are strong according to the different data. In the data treatment of retrospective study, although no method to recollect historic date, it is possible to calculate the BDV's factors according to the table of dust concentration in different years obtained by collected monitored data. But in introspective study, it is based on personal exposed concentration while labour breath volume and labour time should be measured practically. Still, a lot of problems about how to obtain the exact data of dust concentration need to be researched.

The Relationship Between BDV and Pneumoconiosis

Studied results, proved further that there is a dose-response relationship between dust and pneumoconiosis

Objective of investigation is these workers who were exposed to silica dust and their pneumoconiosis is the typical silicosis. In the long statiistical survey of 20 years, dust monitoring and workers' health examinations were carried out by study groups, themselves under the unified planning. Most data about measured dust is measured by themselves, and diagnosed by a special diagnosis group which is composed of experts of X-ray, lungs, tuberculosis, and hygiene. So, the first-hand data is reliable, and based on that, we have confidence to search the limit value of BDV in pneumoconiosis by the relation of both of them and proposed assessment formula of dust allowable concentration. The formula's property is that data treatment is based on BDV of 1 phase pneumoconiosis. It is not easy to set data on an exposed population in an investigation of pneumoconiosis for a long time, therefore, treating the data on dynamic incidence rate is difficult. But for each record of pneumoconiosis, such as occupational dust concentration, diagnosis is actual. Most cases of pneumoconiosis occurred in major, exposed types of work. There were detailed records of occupational history, and data of dust concentration in the workplace. Other workers who were not affected by pneumoconiosis worked in unimportant, exposed type of work, where there was little detailed data of measured dust. And hence, it was very difficult to calculate exposed-dust volume. Sometimes to resolve the above mentioned problem, the method must be adopted of assession or multiplication of the data of major exposed type of work by a certain factor. Hence, the calculation of exposed-dust volume in health population is not certain. From the practical conditions, there is an actual significance to search a method with reliable data of cases of pneumoconiosis. Of course, its science and reality must be tested and proved in practice

SUMMARY

According to long studied results in a field survey, it is considered that breath volume should be introduced to reflect the difference of labour strength while calculating exposed-dust volumes and proposed calculation method of exposed-

Table III
The Example from the Original Data of BDV of 27 Cases in 1 Phase Pneumoconiosis in Plant B

27 cases in 1 phase pneumoconiosis in plant B				
175.19	246.76	261.29	310.68	259.30
92.07	252.66	1019.91	931.54	225.50
271.27	956.45	138.60	935.57	1675.58
262.11	206.66	264.96	113.68	101.11
153.34	159.47	265.20	231.82	148.28
57.11	264.35			

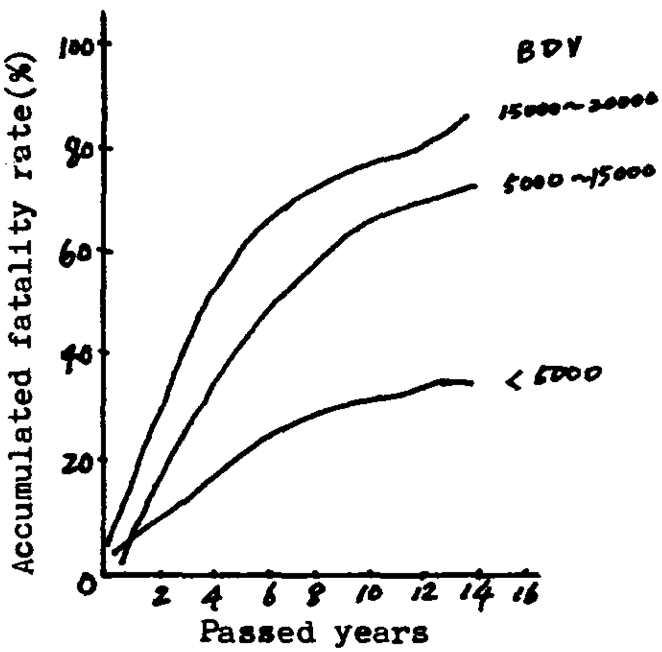

Figure 2. The relationship between BDV and the fatality rate of pneumoconiosis.

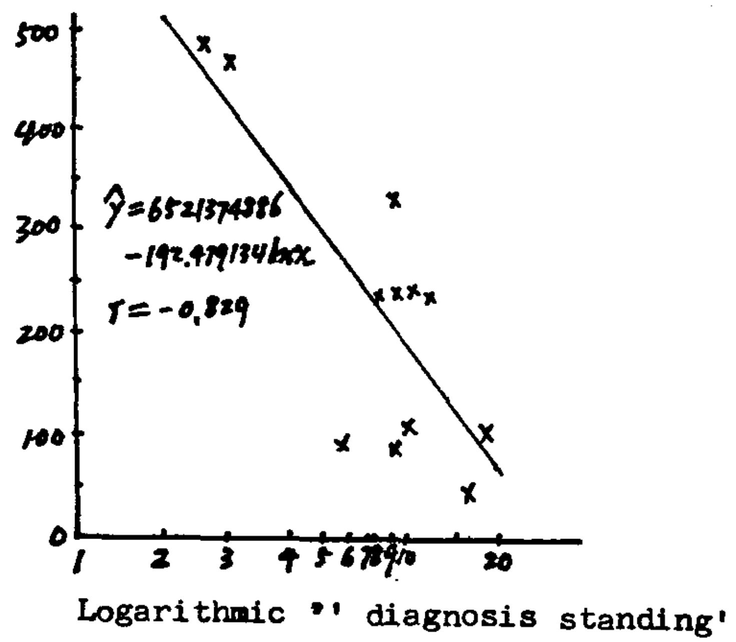

Figure 3. The relationship between BDV average years and "exposure standing upon diagnosis" in 1 phase pneumoconiosis.

dust volumes; i.e., BDV and the studied relationship between BDV and pneumoconiosis. From the closed relationship between pneumoconiosis and BDV, the author has expounded the linear correlation of BDV in average years with "exposure standing upon diagnosis" in 1 phase pneumoconiosis, searched the limit value of BDV in 1 phase pneumoconiosis, and proposed the method of calculating dust allowable concentration, based on BDV in 1 phase pneumoconiosis.

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PROBLEMS OF LABOUR HEALTH ON PREVENTING DUST HAZARD IN TOWNSHIP INDUSTRIES

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Along with the changes in the rural economic structure, small township factories are on the rise and have rapidly developed. These industries, however, face some serious health protection problems. Because production techniques in many factories are often backward and, in addition, their equipment is poor, economic standards in rural areas is lower, and administration regulation is not good, these factories create environmental pollution and endanger the health of workers and local residents. So how to resolve these problems are imminent. Through making investigations in township factories of Liaoning Province for more than ten years, we expound some views about labour health problems of preventing dust hazards in township factories.

INVESTIGATION

The investigation we refer to is of dust hazards in key township factories which create dust and seriously endanger the occupational workers' health. Its purpose is know the degree of dust hazard, the cause and the consequence so that we can provide the necessary basis for finding suitable preventing measures. Through our investigation in Sueizhong and Janpin County, the west part of Liaoning Province, we found that there have been 10 crushing mills of silica and feldspar in Sueizhong and in Janpin, the township-runned mining factories all over the County. Above all, there are more than 10 mining stops to process perlite. In view of representative perlite in our province, we illustrate an example of investigation in it. The results are following:

1. Dust concentration is very high.
2. Among 225 workers clear irregular shadows and some speck shadows on lung X-rays were seen. There is notable relation between FEV_1 or mmEF, and the changes of lung X-rays. The more the volume of dust exposure is, the lower the aeration functions mentioned above are.
3. We injected intra-tracheally 50mg of perlite dust into rat lungs. For 12–18 months, we observed that perlite dust caused fibrosis in rat lungs. These results proved the hazard of perlite dust, and emphasized and proved that it is necessary to take preventive dust measures.

PREVENTIVE MEASURES

We have investigated and experimented in preventive dust measures of township factories in Liaoning Province for several years. Considering the difficulty of funds and low level of techniques in these industries, we propose that the following two types of preventive dust measures can be taken.

Hydraulic Production

It is appropriate for highly hydrophobic and possible wet operating mineral production and has advantages of equipment, convenient simple administration and reliable effectiveness. It is very useful for township factories. To date, there are two sets of hydraulic production equipment spread in our province.

Closed Dry-Production

It is suitable for the mineral production which doesn't fit hydraulic operation and suitable in the areas where the water sources are poor. In this situation closed and ventilated dust-proof measures can be carried out.

This small closed-ventilated dustproof system reduced the dust concentration from 289.0 mg/m^3 to 9.9 mg/m^3. The measure has the advantage of less cost and obvious effectiveness. It is also appropriate to expend the measure in town enterprise

TECHNICAL GUIDANCE

At present, in township industries there are generally no specific technologists who know ventilation. So it is extremely necessary to provide concrete technical guidance and to teach some labour hygiene professionals and technicians for these township factories

Also, today's young doctors engaged in this field lack the knowledge of industrial ventilation and the experience of work, therefore for them to have some studies in industrial ventilation is very useful and necessary for their directing and supervising dust prevention situations. In our province the study class of "ventilation removing dust" or of "evaluating effectiveness of dust-proof equipments" is held every two or three years. Its effect is very obvious.

STRENGTHEN MANAGEMENT

We think that the management system of township industries is quite different from that of state industries. Therefore we should supervise and manage the township industries in labour hygiene in a different way. Much attention should be paid to the following items:

1. The departments responsible in health, in labour job and in environmental protection should match with each

other well. The cooperation among them is the necessary condition for pushing labour hygiene, safety, and environmental protection of township industries forward. The problems existing in these areas need to be planned and unified with due consideration for all concerned and tackled in a comprehensive way. It is supported by the facts that the situation is getting better wherever cooperation is better

2. The key for us to develop the labour hygiene work in township industries is relying on all stages of the government and the departments responsible for it. For example, we can supervise and urge the work, give directions, run study classes, and make programms, together with the concerned departments.

3. The legal systems must be strengthened. Suel Zhong County has more than 10 crushing mills. Thee county government has made three decisions for the production of crushing mills. They are:

- Hydro-production is required;
- The closed production is required where hydro-production meets big problems;
- Factories could be allowed to go into production only if they have been checked and accepted by epidemic prevention station in county and labour bureau.

Due to these decisions the dust concentration has been kept on a lower level for many users. The government in Janpin County also promulgated "Mine administration regulations." Two of them are emphasized.

As a result, the county government has spread simple and effective preventive dust facilities within one year in 12 perlite mines. These "decisions" and "regulations" are promulgated by the county governments local legality. The only way to guarantee the cardinal interests of the people is to strengthen the legal system and administer strictly.

STUDY OF FIBROGENIC EFFECT OF VERMICULITE DUST ON RAT LUNG

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INTRODUCTION

Vermiculite is a water-bearing aluminum silicate with iron and magnesium. Its size expands after it is heated. Expansive vermiculite can be used for heat preservation insulation, sound insulation, fire-proofing, antibiosis, acid-proofing, etc. The reports are few on whether vermiculite dust can cause the fibrose of the lung.[1-3] In order to search into the fibrogenic effect of vermiculite dust, the study of vermiculite dust on animals has been made as follows.

MATERIALS AND METHODS

Dust used for experiment is obtained from vermiculite mine of Qingyuan, and quartz dust used for control is obtained from sandstone mine of Haicheng. The dust was baked and ground into powder in which the dust size of ≤ 5 µm is more than 95%. The content of free silica is 1.96% in the vermiculite dust and 93.8% in the quartz dust.

54 male rats which were of age were divided randomly into three groups. In one of these groups 50 mg of the vermiculite dust was injected intratracheally into each rat and the other two groups were given injection of normal saline or quartz dust in the same way. 1, 3, 6, 9 and 12 months after the injection these rats were killed in batches. The tissue sections of the rats lungs were dyed in HE, foot or VG. The classified criteria of pathology referred to those of experimental silicosis.[4]

RESULTS

Naked Eye Observation

Quartz Group. One month after injecting the dust the lymph nodes of hilus of the lung are the same size as small peas; the surface of the lung is smooth and the quality of the lung is soft. After 12 months the lymph nodes of hilus of the lung are the same size as broad beans, their quality are hard, and the spread, or piecewise spots, were found in the surface of the lung as well as the quality of the spots was hard.

Saline Group. 9 months after the injection, the confined emphysema appeared in some lungs.

Vermiculite Group. One month after injecting the dust the lymph nodes of hilus of the lung are also the same size as small peas and are ochreous; the ochreous spots were seen in the surface of the lung and the lung tissue is soft and sprung. After 9 months the confined emphysema appeared in the lung

Microscopy

Quartz Group. One month after injecting the dust the cell nodes were found in the lymph nodes of hilus of the lung and the lung tissue; after 9 months the cell and fiber nodes appeared; after 12 months the fiber nodes were seen.

Saline Group. The dust response was not shown in the lung throughout the experiment.

Vermiculite Group. One month after injecting the dust, the cell nodes which were of all sizes appeared in the lung tissue. In these nodes there were a lot of the dust particles and epithelium-like cells (23 HE). The proliferation of reticular fiber was found in the nodes and a little collagenous fibers appeared in some nodes (12 VG). Around the nodes there was increased volume widened interval and thickened wall of the alveoli. The proliferation of the epithelium cells was seen in some bronchi and there was a great deal of secretion in their cavities. After 3 months the collagenous fibers were found in the nodes (19 VG) and the confined emphysema appeared around the nodes. After 6(37VG) ~ 12(6HE,VG) months the node-like changes were still seen in the lung. There are a little collagenous fibers, a lot of reticular fibers and spread dust particles in the nodes. The confined emphysema were shown round the nodes. The proliferation of collagenous fiber appeared in the intervals of the alveoli and around various bronchi as well as small blood vessels after 12 months

Biochemical Analyses

The collagen content of the whole lung in each group is shown in Table I and Figure 1.

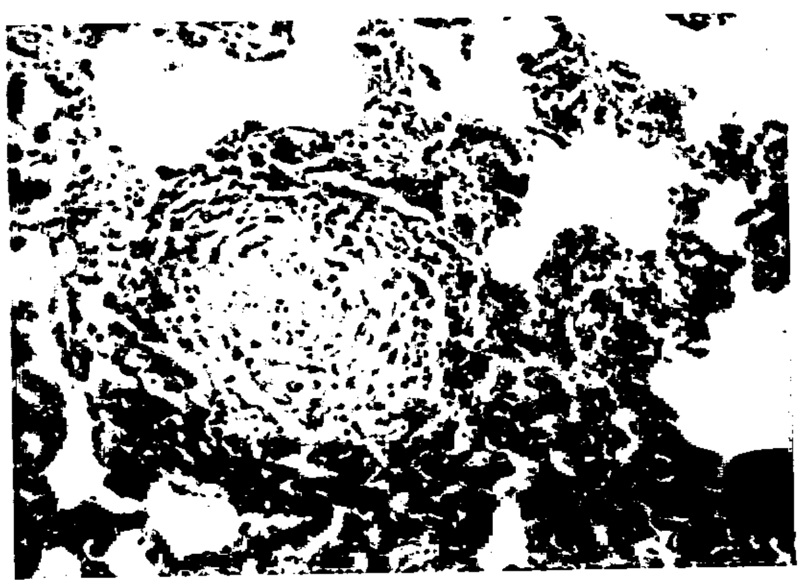
DISCUSSION

The fibrogenic effect of various silicate dust on the lung is quite complex, and it is a wide field in the study of pneumoconiosis etiology. In the group of vermiculite dust of this experiment one month after injecting the dust, the thinner fibers which were dyed in red were found in the cell modes; after 3 months little recognizable fibers of collagen were seen in the nodes and the intervals of the alveoli which were dyed in VG. These changes are rare in other silicate dusts. After 6 ~ 12 months the collagen fibers were still shown but they differ from the typical silicosis-like changes in amount and distributive scope of the nidus and component change in the node. The results of pathologic observation is in agreement with the result of collagen content of

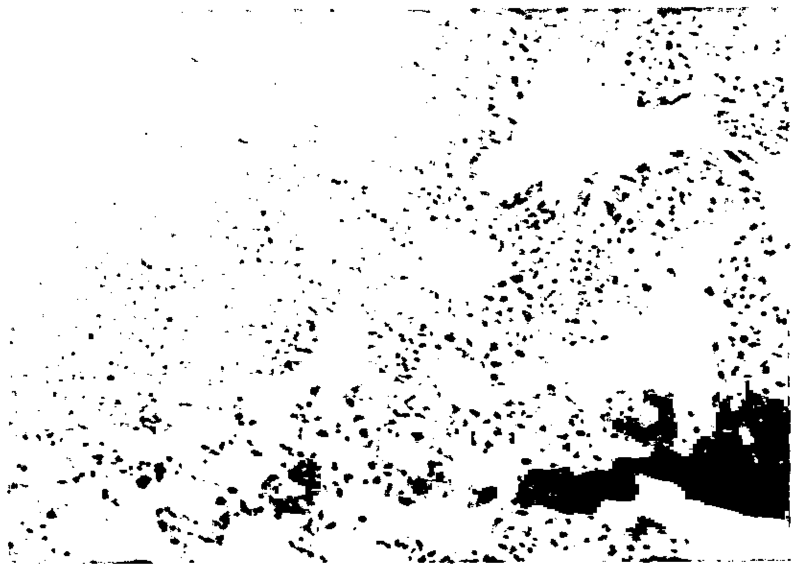
Table I
Collagen Content of Whole Lung in Each Group (mg/whole lung)

Observation Term (month)	1		3		6		9		12	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
Saline Group	2	32.4	2	28.8	2	39.2	2	34.4	2	63.0
Quartz Group	2	35.7	2	38.5	2	75.7	2	116.5	2	239.8
Vermiculite Group	2	44.4	2	55.1	2	94.1	2	88.0	2	106.5

Vermiculite (One month) 23 HE 6.7×10



Vermiculite (Three months) 19 VG 6.7×10



Vermiculate (Nine months) 35 HE 6.7×10

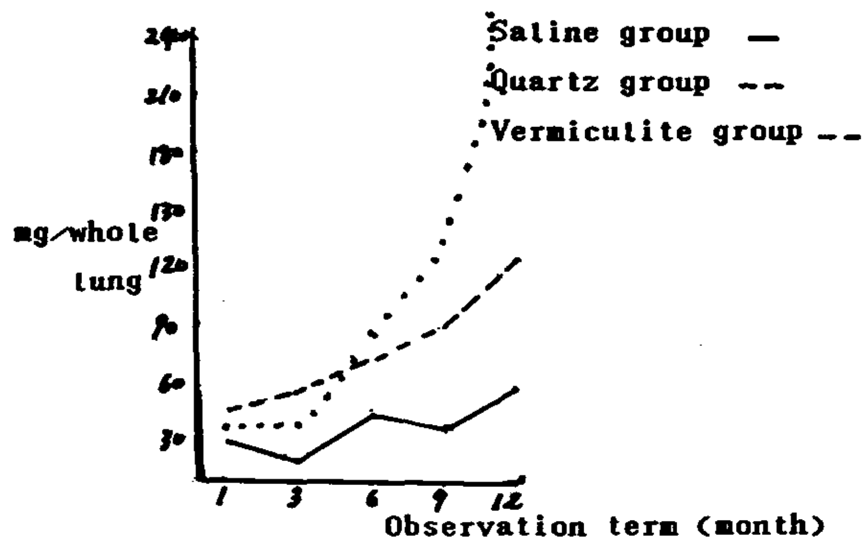


Figure 1. The change of the collagen content of the whole lung in each group.

whole lung. It is indicated that the slight fibrogenic effect on the rat lung is caused by the vermiculite dust.

CONCLUSION

50 mg of the vermiculite dust was injected intratracheally into each rat and after 1 ~ 12 months the pathologic observation and the analysis of collagen content of whole lung were made. The author indicated that the slight fibrogenic effect on the rat lung was caused by the vermiculite dust. The progress of the effect was slower and milder than that of the quartz group and the typical silicosis-like change was not seen.

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STUDY ON DUST HAZARDS AND PREVENTIVE MEASURES IN MODERN LARGE SCALE PETROCHEMICAL ENTERPRISES

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Presently, it is reported at home and abroad, whether there is harm of dusts in modern large petrochemical industries. Our country's petrochemical industries will develop greatly with the vigorous development of our country's oil resources. We had found the problem of dust pollution in processes when testing in a chemical synthetic fibre company before it went into operation. In order to look into dust hazards and preventive measures, we had made investigations and experiments on the dust hazards of this company's polythene, polypropylene and nylon-66-salt, etc., three workshops, from 1983 through 1986.

LABOUR HYGIENIC INVESTIGATION

That company is a new large petrochemical synthetic fibre cooperation company. Major productive equipment was all introduced from abroad. Polythene, polypropylene and nylon-66-salt were put into production in 1981. Dust concentration is relatively high in the air of polluted spot by dust, when adding auxiliary dosage in stable post of polythene 3.4–619.3 mg/m^3, adding auxiliary dosage in stable post of polypropylene 0.7–67.5 mg/m^3, putting them in mother feed jar 3.4–13.3 mg/m^3, at the head of a continuously mixing machine, 2.6–78.8 mg/m^3; in front of the packer of nylon-66-salt 48.7–157.3 mg/m^3.

The free silica content in three dusts have not been detected by mini-X-ray diffractometer. Those (their dispersities are less then 5 μm) are up to 84.5%–99% by using Glyn's subsidence.

A HEALTH CHECKUP OF DUST EXPOSED WORKERS

We checked about 600 workers for dust exposure in three workshops. Other workers had been found with special changes; besides, these workers of nylon-66-salt had been found to have symptoms of conjunctive stimulate.

ANIMAL EXPERIMENTS

We divided randomly wistar 250 rats with weight 170–210 mg into polythene, polypropylene, nylon-66-salt, quartz control and physiological salt water control etc., into five groups. 50 mg/ml dust mixed-liquid made by polythene, polypropylene was poured into trachea one time. Nylon-66-salt with simulations scene condition through trachea was spouted to lungs 50 mg, observed a year and half. We observed pathological change and measured content of collagen protein of total lungs. Result of polythene, polypropylene has a light fibering effect; fibering of polypropylenes is more than one of polythene; fibering affect of nylon-96-salt dust is not evident.

POISON TEST OF MACROPHAGUS

We chose New Zealand rabbits with weight of 2–3 kg and killed them by bloodletting on abdomen aorta, collected macrophagus of pulmonary alveolus for training by Myrivk's method. We classified polythene, polypropylene nylon-66-salt, quartz and control into five groups by observing colouration rate of macrophagus and vitality of lactate dehydrogenase. Result is that all of three dusts have some effect

DISCUSSION

Through investigations of three workshops, it is denoted that there are problems of dust pollution in modern large petrochemical industries. Major cause is irrational productive technology and defects in equipment. Stable post of productive route of polythene, polypropylene, due to man handwork, adding auxilliary dosage, brought about an opening operation in continual production. Productive route of polypropylene is conveyed by mother feed jar after adding auxiliary dosage. Nylon-66-salt after water comes off dried by air flow in carrying pipe, due to shortage of heat preservation on separate equipment; it easily coagulates in it. Workers were compelled to heat equipment frequently or to add vibration installation on equipment, having to put original air tight tie into soft tie, which resulted in destruction of air tightness of equipment. Next is short of necessary ventilator protective equipment

Results of experiments show that polythene, polypropylene dusts all have tight fibering effect on lungs of rats and Nylon-66-salt dusts have certain injury to trachea of rats. Therefore it is considered that long-term exposure of workers to the above mentioned dusts of high-concentration have affected workers' health.

According to results of spot investigations, it is considered that to solve dust hazards in the above-mentioned production process, one needs to eliminate opening productive links and to realize through air tightness products, not to ignore needful ventilation dust-proof equipment at the same time.

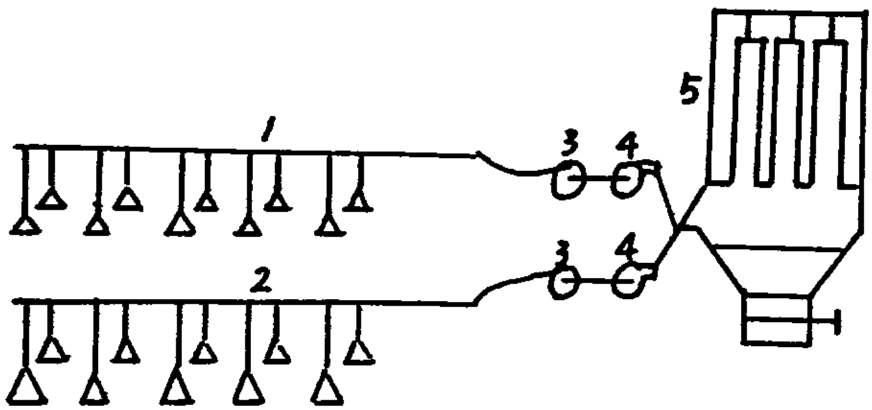

Figure 1. A ventilated dust-proof and dust-removing system in the perlite mine.
1-2. ventilating pipes
3. cyclone dust remover
4. ventilator
5. simple cloth pocket dust chamger

DUST ARRESTER (DA)

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ABSTRACT

DUST ARRESTER—It is a device, designed and developed by CMRS to collect fine dust generated during large diameter deep hole drilling in open cast coal and metal mines. The device does not use any extra energy apart from the energy associated with the dust particles which are coming out from the drill hole. The dust Arrester is placed at the drilling point and the drill rod with the drill bit passes through it. It has no exhaust fan, no motor or any moving parts. The dust collection efficiency of the DA varies from 95% to over 99%.

A summary of the results of the tests carried out in various rocks in open cast mines is given below (Midget Impinger was used).

Rock type	Drill Dia.	Airborne Dust Concentrations in ppcc.		
		without DA	with DA	Dust arrested by DA
Coal—I	100mm	11,212	240	97.8%
Coal—II	100mm	2,385	109	95.4%
Stone OB-I	100mm	17,745	333	98.1%
Stone OB-II	150mm	4,653	198	95.7%
Iron Ore-I	150mm	71,327	188	99.7%
Iron Ore-II	150mm	9,482	183	98.1%

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HANDLING OF MINERAL WOOL WITHIN THE CONSTRUCTION INDUSTRY

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The results of earlier fibre measurements show that the concentration of fibres (respirable fibres) in the air during the normal handling of mineral wool is relatively low compared with the current Swedish hygienic limit value (1 f/ml).[1,2] Symptoms in the form of skin irritation are well known to occur in connection with the handling of mineral wool products.

Medical studies have shown that there is a high likelihood that "coarse fibres", cause skin irritation through mechanical action.

The project "Handling of mineral wool within the construction industry" has examined the possibilities of improving handling in such a manner that coarse fibres are emitted as little as possible and of reducing exposure by finding handling methods where the time of direct contact with mineral wool products is sharply reduced.

The project has also included attempts to measure coarse fibres using new methods in order to improve the possibilities of evaluating the effectiveness of adopted changes in methods and products.

The project has had two main components:

1. Studies of handling
2. Product development—measurement method development

Studies of Handling

The studies have been carried out at factories, warehouses and during transports. Furthermore, studies have been conducted at wholesalers and on building sites. The studies conducted during the different handling phases have endeavoured to concentrate on the most common mineral wool products.

The results of the studies show that manual handling is considerably reduced when the products are delivered in crates or on pallets. The manufacturers are currently working on developing rational delivery systems for reducing manual handling. Studies have been made of special cutting stations and cutting table for mineral wool.

The study has shown that large quantities of fibre dust are stirred up during cleanup and collection of mineral wool waste. During insulating work with mineral wool, special containers, sacks or the like should be available for collecting mineral wool waste.

The report gives examples of hints and ideas to limit the spread of dust from mineral wool products and to obtain more rational mineral wool handling out on the building sites.

Measurement Method Development

Experiments with better methods for measuring coarse fibres have been carried out within the framework of the project. "The surface limitation method," where fibre dust was vacuumed up from ten areas, about 50 mm in diameter, on the floor immediately after the end of the insulation work on the test premises, can probably be developed with a slightly modified sampling system. The experimental series must also be large enough to obtain a statistically useful body of data for processing. Studies of the behaviour of fibres in the air have been documented using a video camera and strong lighting. The method, which originally comes from the U.K., has attracted the interest of the National Board of Occupational Safety and Health and may in the long run be an interesting aid in assessing fibre emissions during insulation work.

Product Development

In cooperation with the manufacturers, experiments have been conducted involving "preparation" of products aimed at binding loose fibres. The results have been interesting, although many problems remain to be solved. In the experiments, vacuumed mineral wool products have emitted lower concentrations of airborne fibres than non-vacuumed products. The values of vacuuming should be evaluated in relation to other handling of the different products.

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MECHANISM OF THE DAMAGE TO AM BY SILICA AND ANTI-CYTOTOXIC EFFECTS OF ALUMINUM CITRATE: ULTRASTRUCTURAL STUDY

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ABSTRACT

The mechanism of the damage induced by silica to alveolar macrophages (AM) was investigated at the ultrastructural level. The experimental results with TEM and SEM show that apparently injurious alterations occur for AM exposed to a higher dose of silica in a short time, such as the swelling of mitochondria, the dilating of endoplasmic reticulums and the changes on the surfaces of cells. Further, plasma membrane Mg^{2+}-ATPase and freeze-fracture observation indicates that the decrease of the reaction products of the enzyme on the cell membranes and aggregation of intramembranous particles on two halves of the membrane of AM can be seen in those cells without evident morphological changes, suggesting that the damage induced by silica to the plasma membrane of AM may be an important key in the initiating of the cytotoxic process. In addition, the evidences from the phagocytosis-inhibited experiment with cytochalasin B (CB) proves that the inhibition of phagocytosis with CB cannot prevent AM against being damaged by silica, indicating that the cytotoxicity by silica may be independent of the phagocytosizing of the silica particles into the cells and the plasma membrane may be primary foci of the damage. And, on the other hand, ACPase cytochemistry shows that the reaction products of the enzyme have a similar diffusing distribution throughout the cytoplasm within both of cells with and without CB, demonstrating that the leaking of lysosome enzymes into the cytoplasm may be, at least under some of conditions, a secondary event with the disturbance of metabolism of cells following the injury to the plasma membrane. Finally, the protective effects of aluminum citrate on AM are also proved at the ultrastructural level. A possible mechanism of the protection is that silica particle combined with aluminum element on its surface has lower affinity to the cell membrane and therefore lessens the cytotoxicity of silica.

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MINI-CYCLONES "TCR" IN NYLON AND IN ALUMINUM: THE INFLUENCE OF ELECTROSTATIC CHARGES ON THE EFFICIENCY OF THE COLLECTING OF RESPIRABLE DUST

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ABSTRACT

For evaluation of the existence of risk to professionals (workers) exposed to fiber dust, it is necessary to resort to the collecting of the respirable fraction of the dust in suspension at the work posts of a variety of occupations.

A mini-cyclone, investigated at the Italian establishment TCR TECORA S.r.I., has been realized in dual fashion, in nylon and in aluminum, to examine the influence of electrostatic charges on the effectiveness of collecting dust.

Like the well-known cyclone in nylon at ten millimeters in diameter of ACGIH, the cyclone "TCR" also works at weak intensity (1.5–2.0 l/l'): it is distinguished by the dimension of the opening for the air, by the assembly of the group cyclone filter portal, and by the connection (of the rigid type) between the two principal elements of the cyclone.

We will collate and discuss the results of the measures effectuated, in parallel, by the two TCR examples and the the 10mm, nylon cyclone (DORR-OLIVER Model).

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