CONCENTRATION AND GRIST SIZE SPECTRUM OF AIRBORNE DUST DURING OPERATION OF EARTH MOVING MACHINERIES ON ALLUVIAL SOIL

S. C. Ganguli, B. K. Datta Gupta, and R. D. Gupte,

Explosives Research and Development Laboratory, Kirkee.

ABSTRACT

Concentration and grist size spectrum of airborne dust generated by heavy earth moving machinery while operating on alluvial soil on the Indogangetic plain at Roorkee (29.52°N, 77·53°E N) has been determined.

INTRODUCTION

Workers in atmosphere heavily laden with dust are liable to be attacked by various types of occupational pneumoconiasis of which silicosis is best known. Susceptibility to such attack increases with environmental temperature and humidity [1] and is therefore of special importance in tropical countries. No systematic work appears to have been done in India regarding the dust hazard under various occupational conditions except those on the Kolar Gold Fields by the Rege Committee [2] and Barenberg [3].

Operators of earthmoving machineries are also liable to prolonged exposure of heavy dust concentration under operational conditions specially in summer and thus become susceptible to occupational pneumoconiasis. The present report describes the results of field trials carried out for the sampling and determination of concentration and grist size spectrum of airborne dust under normal service conditions when earthmoving machines operate in an alluvial plain.

EXPERIMENTAL

(*a*) *Layout and environmental conditions*

The trials were carried out at Roorkee (29·52°*N*, 77·53°*E*) on the Indogangetic plain in the last week of March under the following environmental conditions :—

(*i*)	Duration	0730 hrs. to 1530 hrs. (8 hrs.)
(*ii*)	Temperature	20°C to 30°C
(*iii*)	Relative Humidity	41—46%
(*iv*)	Wind velocity	9—11 Km./hr.
(*v*)	Wind direction	Variable

The lay out of the machines is shown in Fig. 1. Four earthmoving machines were employed. Three of them moved in a circle 90—100 m dia. and the fourth one moved along the perimeter of an equilateral triangle as shown in the figure. This arrangement was found to give the maximum uniformty of dust concentration in the air in the area under the operational conditions.

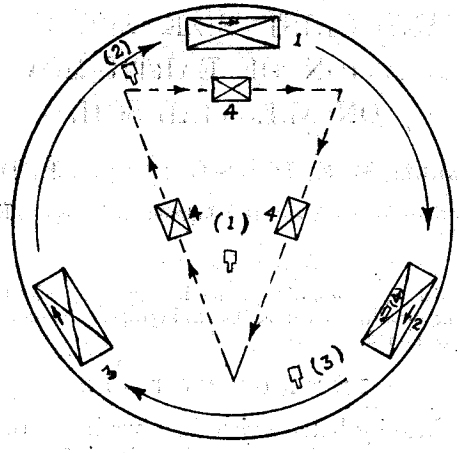

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Fig 1. Lay out for Creating Artificial Airborne Dust and its Sampling by Sugar Tubes

NOTES

A :— 1, 2, 3, 4 indicates No. and way of operation of earth-moving machines.

B :— (1), (2,) (3), (4) indicates the position of Sugar tubes used for sampling of airborne dust.

(*b*) *Sampling of airborne dust*

The airborne dust was sampled by the sugar-tube method of US Bureau of Mines [4] which consists essentially of passing a known volume of the airborne dust, through a column of moistened sugar in a tube. The dust is arrested by the moistened sugar which is dissolved out and the insoluble dust filtered off and examined. The original method works with a a high rate of aspiration of air (32 litres/min.) which requires powerful mechanical pumps which it was not possible to use in the present series of field experiments and whose efficiency also does not exceed 95% by wt. The method was modified by Ganguli, Dattagupta and Ganguli [5] so as to utilise a lower rate of aspiration that could be created in the field with a water filled drum aspirator and having a dust collecting efficiency of 99—100% by weight. The modifications consist of :—

(*i*) Using a lower quantity of sugar—50 gms. against 100 gms. specified in the original method.

(*ii*) Control of the grist size spectrum of the sugar used as in Table I below :—

TABLE I

GRIST SIZE SPECTRUM OF SUGAR USED IN THE MODIFIED SUGAR TUBE METHOD

I. S. Sieve No.		% by weight
Passing through	Retained on	
170	120	3
120	85	15
85	40	60
40	25	15
25	20	7

(*iii*) The sugar in the sugar-tube was divided into three beds with air gap in between. The efficiency of the sugar tube for arresting airborne dust is shown by the results in table II in control experiments[4].

TABLE II

Expt. No.	Quantity of airborne dust passed through the tube	Quantity of airborne dust arrested by the sugar tube.	Efficiency % by wt.
1	1·773	1·767	99·7
2	1·665	1·665	100·0
3	1·727	1·729	100·2
4	1·455	1·450	99·4

Table III represents a typical grist size spectrum of the dust arrested by the modified sugar tube as obtained in the control experiments with siliceous dust (passing through I.S. 8 mesh)

TABLE III

Particle size (microns)	Weight %
<1	9·04
1—2	2·22
2—5	3·10
5—10	3·94
10—20	5·93
20—50	7·31
50—250	67·64
250—420	0·72
Total ..	100·00

From these results it will be seen that the modified sugar tube method gives 99·9 to 100% efficiency for dust with particle of size below 1 μ which is an improvement over the original sugar tube which works with 95% efficiency for dust upto size 1μ. The final set up of the sugar tube with the aspirator drum is shown in Fig. 2. Three sets each of these assemblies were placed at positions (1), (2) and (3) shown in Fig. 1 on the ground at 1 meter height and a fourth set marked (4) in Fig. 1 was placed on an earth moving machine at a height of two meters from the ground. The earth moving machines moved at a rate of 6·5 Km./hr. Sampling was commenced about 2 hrs. after the machines started working when the dust concentration in the atmosphere became stable. The outlet of the aspirator was adjusted to discharge 4—5 litres/min. When 32 litres of water was discharged all the sugar tubes were plugged simultaneously and then dismantled and taken to the laboratory for examination. In the course of the trial, 6 such sets were examined.

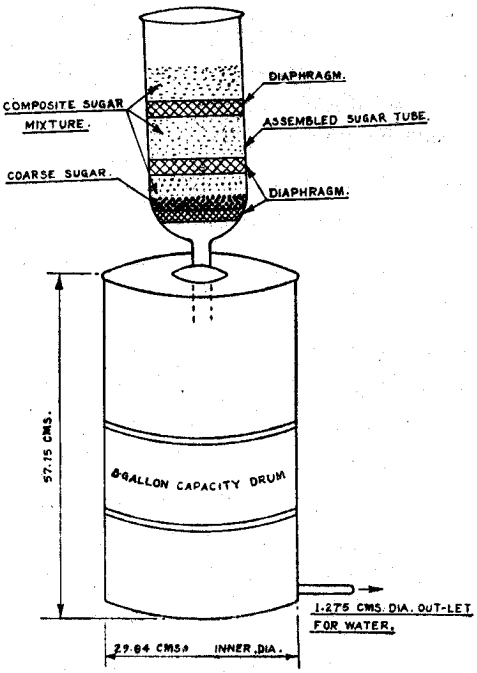

Fig. 2

(c) Determination of Grist Size Spectrum.

The sugar from the three tubes of each set was dissolved in water and filtered. The residue was collected, dried at 110°C and weighed. This gave the dust concentration in the atmosphere in mg./cu. meter. The dust was then tranferred to a 500 ml. beaker moistened thoroughly with water and treated with excess of water (150—200 ml.) 10 ml. of 10% sodium metaphosphate solution was then added and the mixture boiled for 30 mins replacing any water lost by evaporation. The solution was then cooled to room temperature and filtered through a 1 : S : 8 mesh. The residue on the sieve washed and dried gave the percentage of airborne particles of size above 50 μ. This was further analysed by sieves of different sizes. The filtrate from the IS 8 mesh was collected in a measuring cylinder, made upto 50 ml. and analysed for grist size spectrum by the Andreasen Pipette method[6].

Table V

Grist size spectrum of soil dust and airborne dust as collected by Sugar tube

Particle Size (μ)	% by Weight					
	Top layer of soil	Airborne Dust				
		Stations (1)	(2)	(3)	Average	Station (4) (Av.)
420 ..	2·3	0·4	0·2	0·3	0·3	Nil
420—200 ..	34·7	5·2	3·0	4·7	4·3	Nil
200—149 ..	20·1		4·0	4·3	4·1	Nil
149—74 ..	15·6	9·1	6·8	7·2	7·7	1·14
74—50 ..	5·1	13·2	12·1	9·8	11·7	0·43
50—20 ..	4·8	20·7	28·3	25·1	24·7	12·44
0—10 ..	3·6	11·8	13·6	14·8	13·4	21·42
10—5 ..	2·4	6·9	7·1	7·9	7·3	12·08
5—2 ..	1·9	7·3	6·1	5·8	6·4	13.99
2—1 ..	2·1	8·0	7·5	6·7	7·4	16·01
<1 ..	7·4	12·8	12·1	13·5	12·8	21·89

The results have been plotted graphically in Fig. 3 to show the weight percentage below each size for Top layer of soil and airborne dust in station (3) above.

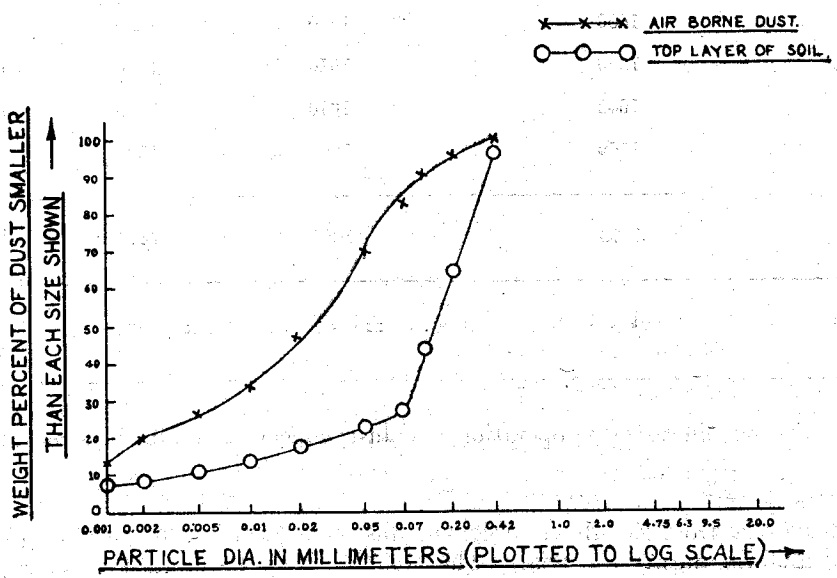

Fig. 3

TABLE VI

INSOLUBLE SILLICA CONTENT AND ITS GRIST SIZE SPECTRUM

Insoluble silica in soil .. .. 87·8 % by weight

Insoluble silica in airborne dust .. .. 75·5 % by weight

Particle size (μ)	Insoluble silica in soil % by weight	Insoluble silica in airborne dust % by weight
410	4·9	..
410—210	38·9	4·8
210—152	18·0	2·9
152—104	15·1	4·8
104—76	5·5	5·2
76—64	1·1	0·6
<64	16·5	81·7

DISCUSSIONS

The toxic effect of dust depends on the number concentration, free silica content and size distribution of the dust particles. The UK Ministry of Labour Regulations allow a maximum rock dust content of 450 particles per cc of air within the range of particle size 0·5μ to 5μ for operation without protection. The US Regulations (7) do not give the size limits, but allow a threshold limit for mineral dust as per Table 7 :—

TABLE VII

THRESHOLD LIMIT FOR MINERAL DUST

	(Number of particles per cc)
Alundum	1,600
Asbestos	160
Carborundum	1,600
Cement	1,600
Dust (Nuisance, no free silica)	1,600
Mica	695
Talc	695
Silica—	
(*i*) High, above 50% free SiO_2	160
(*ii*) Medium 5—50% free SiO_2	695
(*iii*) Low, below 5% free SiO_2	1,600
State (below 5% free SiO_2)	1,600
Total dust (below 5% free SiO_2)	1,600

Though the number of particles in the airborne dust have not been determined in the present trials a rough estimate of the number present within 1μ and 5μ range (average size of 3μ) shows that it will be order of $7 \cdot 55 \times 10^5$. A still larger number is expected to be present below 1μ suze. It will be seen from Table VI that the insoluble silica content is also very high and they come under the category of high silica particles of Table VII. The threshold limit is 160 particles per cc. according to the American regulations which is about 1/2000 of the particles in the size range 1μ—5μ present in the air in the present trials. The dust is therefore highly pathogenic and the maximum possible protection should be given to the workers under these conditions.

A remark regarding the protection afforded by various dust respirators available in trade will not be out of place here. B. S. Specification No. 2577: 1952 specifies that a respirator for protection against dust should not have a methylene blue penetration exceeding 10 per cent when tested as laid down in the specification. This is considered adequate for protection against silicosis producing dust. Out of 7 different types of imported respirators anti-dust examined only one passed this requirement whereas out of 6 different types of indigenous dust respirators none passed this requirement. What is more disturbing is that whereas the imported respirators did afford some protection against methylene blue cloud (the penetration of the six remaining cases varying from 38 per cent to 67 per cent), the indigenous respirators afforded practically no protection except one type which gave a penetration of about 38 per cent. As considerable health hazard is involved specially in a country where unfavourable environmental conditions *e.g.*, high temperature and humidity and low nutritional level of the population make the people highly susceptible to pulmonary diseases, the importance of studying the dust characteristics of the atmosphere during quarrying, mining and similar operations and the control of the quality of dust respirators to be issued to workers cannot be over emphasized.

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