RESPIRATORY FUNCTION AND DISEASE AMONG WORKERS IN ALKALINE DUSTS*

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Little is known of the possible effects of sodium carbonate dust on the lower respiratory passages. A large alkali industry, with a number of works, was used for an investigation of lime and soda ash dusts evolved during the process. The physical and chemical characteristics of these dusts and details of the type of work and environmental conditions are described. In 1954 and 1956 a survey was made of respiratory sickness absence, chest radiographic appearance, and respiratory function in workers employed in areas with exposure to soda ash, lime dust, and no dust. All were interrogated about their smoking habits. In 1954 there was found to be a significant reduction in expiratory flow rate of workers in dusty jobs in soda ash compared with the group not exposed to dust but this result was nullified in a random sample group in 1955 and in full groups in 1956. Respiratory sickness absence was found to be slightly greater in workers in dusty occupations, particularly in lime dust. No pneumoconiosis was detected on miniature films. The survey of smoking habits revealed that smoking was associated with a definite decrease in the expiratory flow rate, particularly after the age of 40 in heavy smokers. It was concluded that smoking habits played a more important part than alkaline dusts in the reduction of respiratory efficiency as measured by a study of sickness absence and performance of a simple spirometric test.

The irritant effect of sodium carbonate dust on the nasal mucous membrane was shown by Archibald (1954). Chronic inflammatory disease of the larynx from exposure to this dust was found by Profazio and Troisi (1953). However, no reports have been published on the possible effects of sodium carbonate dust or soda ash on the lower respiratory passages. Soda ash might be expected to produce a reaction on the mucous membranes of the lower respiratory tract. Despite the filtering action of the nasal cilia, small particles are likely to adhere to the walls of the bronchi, or indeed, enter the alveoli. Soda ash in aqueous solution is strongly alkaline (pH 11.6 to 12) and as the ciliated columnar-celled mucous membrane of the bronchi is identical with that of the larynx, a chemical inflammation might well result. Lime, being both alkaline and, when burnt, soluble, should produce a like effect. Doig (1955) found eight cases of pneumoconiosis in limestone workers who had been exposed to mixed dust containing silica. Although considered to be due to limestone these cases were primarily of silicosis.

Bridge Davis and Nagelschmidt (1956) carried out clinical and radiographic examinations of 14 men who had worked in pure limestone for periods varying from 12 to 35 years; no evidence of pneumoconiosis was found although the dust counts showed many thousands of particles between 0.5 and 5 μ in the atmosphere to which the men were exposed. Raymond *et al.* (1952) in 41 limestone quarrymen found no evidence of respiratory disability, though chronic bronchitis and emphysema were recorded. Cement, which is calcined limestone, was investigated by Gardner, Durkan, Brumfiel, and Sampson (1939) and no disability was found in workers exposed to dust in the grinding process. Sander (1958) surveyed again 195 cement workers who had been included in Gardner's original survey and who had had from 20 to 45 years of exposure to cement dust. There were minor changes ("linear exaggeration") in the chest radiographs of those exposed to raw or mixed cement dust, but in those exposed to finished cement dust alone there were no recognizable changes in the chest radiographs even after upwards of 30 years' exposure. Symptomless perforation of the nasal septum in cement workers was found by Marchand (1944). Hunter

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(1955) mentions harmless arborescent markings in chest radiographs of workers in limestone quarries.

The Registrar General's Decennial Supplement on Occupational Mortality (1931) gave the standardized mortality ratio (S.M.R.) for chemical workers as 80. In the 1951 Supplement the S.M.R. for chemical workers is given as 85. An analysis of the mean annual death rate from all causes per 100,000 and the ratio of death rate to that of all males taken as 100 indicates that chemical workers of all ages, except 70 to 75, have a relatively favourable mortality. No mortality data specific to the alkali industry are available. Respiratory mortality was lower in chemical workers than in other workers generally.

These studies on the two dusts which are most prevalent in the mid-Cheshire alkali industry suggested the need for an enquiry into the functioning of the lower respiratory tract of workers exposed to these dusts, and the possible existence of any unusual or excessive morbidity attributable to them.

Type of Works

The mid-Cheshire alkali industry is largely carried on in four works: one large (A); two medium-sized (B) and (C); and one small (D). Works A, B, and C are within one mile of a town of 35,000 inhabitants which has no other major industry. Works D is in open country three miles from the town. The approximate total numbers employed are:

Works	Approximate No. of Pay Roll Workers	Dusts Involved in Process
A	2,500	Lime
B	1,000	Ash and lime
C	700	Ash and lime
D	200	Nil

These numbers include all employees on the pay roll. Thus the men under consideration, namely those continually exposed to the dust in certain areas in the works A, B, and C, were only a small proportion of the total (Table 1).

At works A caustic soda and its by-products and at works B and C sodium carbonate and its by-products are made. The three alkali works (A, B, and C) produced lime dust, either as limestone or burnt lime, and sodium carbonate dust as a result of part of the process. At works D where brine is won through holes in the earth, there is no dust and the workers here therefore served as controls.

Type of Work

Soda ash manufacture has been carried out for over 75 years and caustic soda manufacture for over 40 years in this district. The three raw materials (brine, limestone, and coke) are used in a chemical reaction with ammonia (derived from gas works

crude liquor) to produce sodium bicarbonate. This is calcined to produce sodium carbonate (soda ash) or reacted with lime to produce caustic soda. No fundamental alterations in this industry have occurred since it started and the only changes in the exposure of men to the dusts under consideration have been a gradual reduction in the evolution of dust and a better extraction of the dust which found its way into the atmosphere.

The process is continuous and therefore all workers on it have to work on a shift rota, whereas those handling the finished product or raw materials need only work by day. The workmen in the lime areas at works A, B, and C work three shifts and their job is to despatch from stock quantities of limestone (calcium carbonate) to the kilns where it is burned with coke to form burnt lime (calcium oxide) and to dissolve the burnt lime to form milk of lime (calcium hydroxide). At the times during the shift when lime and limestone are conveyed on bands, the atmosphere in the kilns where the men are working is noticeably dusty. The lime bands run during all the shift except for half an hour, and the limestone band runs for two to three hours per shift. Little, if any, dust comes from the coke which is added in small quantities to the limestone at an early stage.

Workers in soda ash may be divided into two groups. One deals with the packing and loading of 1 to 2 cwt. bags of soda ash. The second reclaims jute bags which have been soiled and caked with soda ash. Physical demands are greater in both these groups than in those on process work and dust exposure is both heavy and prolonged. Many of the men employed in the soda ash areas, the bag packers, bag stitchers, and handlers of contaminated bags, do not move about much during their work; the concentration of dust inhaled is thus greater and more constant than in the lime area.

Works D is mainly concerned with the erection, maintenance, and working of brine boreholes. The erection and maintenance is done by day workers, but approximately 20 shiftmen are needed to look after the bore holes at night. Physical fitness is needed, as much of the work involves the use of weighty tackle and there is very little protection from weather.

Dusts Produced

The dusts are chemically of two groups: lime (calcium carbonate and oxide) and soda ash (sodium carbonate). All of them are white, flocculent and anhydrous. The alkalinities of the dusts are:

Lime { calcium carbonate (limestone) pH 8.5
 calcium oxide (burnt lime) pH 12.5
 Soda ash (sodium carbonate) pH 11.6 to 12.0

The varieties of soda ash (light, dense, and granular) are chemically identical but vary in structure. The dusts at the various sampling places are microscopically similar.

Chemical analysis revealed that the silica content of limestone varied from 0.35 to 0.42% at the different works and was approximately 2.8% when the limestone was burned to produce calcium oxide. Soda ash contained no silica.

Method of Survey

Selection of Test Method.—Simple tests of respiratory function have been used in the assessment of disability in pneumoconiosis for a number of years. Garrad (1949) using the vital capacity, investigated Cornish tin-miners. More modern tests, including the maximum breathing capacity test and gas distribution and transfer estimations, have been utilized by Motley, Lang, and Gordon (1949) and Gilson, Hugh-Jones, Oldham, and Meade (1955) on miners with varying degrees of disability. Kazantzis and Buxton (1956) used the maximum breathing capacity test (M.B.C.) and both the conventional vital capacity and the expiratory fast vital capacity tests in a survey of the respiratory function of men casting cadmium alloys.

The test described by Kennedy (1953), using a graphic method of recording a tracing on a moving drum, is short and simple and needs little effort or cooperation on the part of the subject. The expiratory flow rate at 40 breaths/min., *i.e.*, "the timed vital capacity" or "expiratory fast vital capacity" (E.F.R.) showed a correlation of +0.927 with the maximum breathing capacity. The standard error of 5.95 l./min. on single tracings, compared with a mean of 2.43 l./min. averaged over six tracings, indicated a high degree of reproducibility. This test was therefore adopted.

Every effort was made to obtain as many volunteers as possible for the respiratory tests but nevertheless the lapse rate was regrettably high. The morbidity and radiographic findings were not obtained directly from the men, though their cooperation was required in filling

up the questionnaire on smoking. The men who were on incentive bonus were given the assurance of the management that no loss of pay would result from time spent away from work while undergoing tests. The tests were undertaken at the most convenient time of day and at a site near the work. As only a very small number of employees working in soda ash and lime are women (approximately 20) only men were included in the investigation. All volunteers, between 20 and 70 years of age, were allowed to undergo the test, though some of them were known to have respiratory disabilities of long standing.

Many of the volunteers for the respiratory function test also volunteered for a routine mass miniature radiograph (M.M.R.) at works A. No pneumoconiosis was found, but simple pneumoconiosis cannot, of course, be detected with reliability on small films.

Lapsed Volunteers

Table 1 shows the number of volunteers and lapsed employees in 1954 together with the total possible in each exposure group. Certain results were inconsistent and in 1956 all employees in the designated areas were therefore again encouraged to volunteer. Table 2 shows the distribution of the 1956 group; the lapse rate was unfortunately high.

The average age in both volunteers and lapsed groups (Table 3) shows slight variability except in the 1954 "no-dust lapsed group", which is markedly high because of the inclusion of nine men over the age of 60*.

* (1) The differences shown in numbers of attacks per man are not large enough to prove any systematic difference between the lapsed and volunteer groups.

(2) There is no evidence that the number of weeks' absence per attack differs amongst the groups, though there is a significant fall between 1954 and 1956. This taken in conjunction with (1) above, makes it unlikely that the changes in weeks of absence per man shown in Table 4 represent a genuine effect.

TABLE 1
DISTRIBUTION OF VOLUNTEERS AND LAPSED EMPLOYEES IN 1954

Exposure Group	No. Possible	Volunteers	% Volunteered	No. Lapsed	% Lapsed
No dust	218	188	86.24	30	13.76
Lime	197	134	68.03	63	31.97
Soda ash	305	243	79.68	62	20.32
Total	720	565	78.47	155	21.53

TABLE 2
DISTRIBUTION OF VOLUNTEERS AND LAPSED EMPLOYEES IN 1956

Exposure Group	No. Possible (1954 Volunteers)	Volunteers 1956 (from 1954 Volunteers)	% Volunteered	No. Lapsed	% Lapsed	1956 New Volunteers	Total Volunteers
No dust	188	89	47.34	99	52.66	37	126
Lime	134	83	61.95	51	38.05	25	108
Soda ash	243	167	68.72	76	31.28	62	229
Total	565	339	60.00	226	40.67	124	463

TABLE 3
COMPARISON OF AVERAGE AGES OF VOLUNTEER AND LAPSED GROUPS IN 1954 AND 1956

Exposure Group	1954				1956			
	No. of Volunteers	Average Age	No. Lapsed	Average Age	No. of Volunteers	Average Age	No. Lapsed	Average Age
No dust	188	43.8	30	50.8	89	42.6	69	45.9
Lime	134	43.5	63	45.0	83	44.3	49	41.6
Soda ash	243	41.2	62	43.8	167	41.2	52	42.3

Examination of the sickness absence of the 1954 and 1956 groups shows that the "no-dust lapsed" subjects had a higher attack and sickness duration rate than other groups. The nine men aged 60 and over in the no-dust lapsed group contributed 17 attacks and 90 weeks lost. This will have materially affected the results. However, there appears from Table 4 to be no significant difference between the lapsed and volunteer groups in lime and soda ash works.

TABLE 4
TOTAL RESPIRATORY SICKNESS ABSENCE AS WEEKS LOST AND ATTACK RATE PER MAN OF VOLUNTEER AND LAPSED GROUPS IN 1954

Exposure Group	Lapsed Group		Volunteer Group	
	Attacks per Man	Weeks Lost per Man	Attacks per Man	Weeks Lost per Man
No dust	1.07	4.73	0.505	1.65
Lime	0.73	2.55	0.619	1.55
Soda ash	0.5	1.43	0.531	1.38

In 1956 examination of the sickness absence of the lapsed group shows that this is very similar both for attack and sickness duration rate compared with the volunteer group, though the volunteer lime group was higher than the others (Table 5).

TABLE 5
TOTAL RESPIRATORY SICKNESS ABSENCE AND ATTACK RATE PER MAN OF VOLUNTEER AND LAPSED GROUPS IN 1956

Exposure Group	Lapsed Group		Volunteer Group	
	Attacks per Man	Weeks Lost per Man	Attacks per Man	Weeks Lost per Man
No dust	0.56	1.71	0.507	1.56
Lime	0.53	1.43	1.10	2.21
Soda ash	0.69	2.13	0.611	1.39

Evaluation of Sample

The workers in soda ash from works B and C and workers in lime from works A, B, and C were the two dust groups which were to be compared with those from control works D, which had no dust. Table 6 shows that these groups were similar in age and physique.

In 1956 the sample was obtained as before and the same volunteers and any others were asked to attend.

TABLE 6
MEAN AGE, HEIGHT, AND WEIGHT OF THE THREE GROUPS IN 1954

Exposure Group	No.	Mean Age (yr.)	Height (in.)	Weight (lb.)
No dust	188	43.89	68.02	155.2
Lime	134	43.46	67.99	149.5
Soda ash	243	41.19	68.17	150.5

The numbers and mean ages of those who volunteered in 1956 are shown in Table 7.

TABLE 7
MEAN AGE OF THREE GROUPS IN 1956

Exposure Group	No.	Mean Age (yr.)
No dust	126	42.5
Lime	108	45.5
Soda ash	229	42.8

Test Methods

Industrial History.—Note was made of a number of characteristics, *e.g.*, age, height, weight, and smoking habits, of each volunteer at the time of the test.

The type of exposure, whether to soda ash, lime, or no dust was also noted. The duration of years of exposure to each dusty or non-dusty atmosphere was recorded. As all men were coded for these works the exposure can be considered pure.

Physiological Test.—A minimum rest period of two to three minutes was allowed. Where any obvious dyspnoea or cough was present before the test, the subject waited until the breathing had returned to normal or the cough ceased.

The apparatus used was a simple spirometer with a constant speed kymograph. The subject was seated facing the spirometer but unable to see the tracings on the drum. After the subject had taken a deep breath he blew strongly through the mouthpiece. Using a protractor and carriage, the vital capacity and the expiratory flow rate were calculated. The average of the best three and the best result were recorded for both the vital capacity and the expiratory flow rate. The volumes were corrected to standard temperature and pressure.

Sickness Absence.—The names of employees certified sick by their own doctors were sent via the labour departments to the health visitors. The health visitors' records were used whenever possible in order to obtain a precise diagnosis; when not available the labour department records were used. In this way all employees'

TABLE 8
AGE AND DURATION OF EXPOSURE OF THE EMPLOYEES IN THE THREE GROUPS IN 1954

Exposure (Years)	No Dust					Lime					Soda Ash				
	Age Groups					Age Groups					Age Groups				
	20—	30—	40—	50—	60—	20—	30—	40—	50—	60—	20—	30—	40—	50—	60—
6—	40	31	36	20	3	11	49	28	11	1	40	71	38	13	1
11—	—	—	12	25	8	—	1	7	7	1	6	6	14	12	2
21—	—	—	—	2	5	—	—	2	2	2	—	1	9	15	4
31—	—	—	1	3	—	—	—	—	2	3	—	—	1	5	2
41—	—	—	—	1	1	—	—	—	1	1	—	—	—	1	2

TABLE 9
AGE AND DURATION OF EXPOSURE OF THE EMPLOYEES IN THE THREE GROUPS IN 1956

Exposure (Years)	No Dust					Lime					Soda Ash				
	Age Groups					Age Groups					Age Groups				
	20—	30—	40—	50—	60—	20—	30—	40—	50—	60—	20—	30—	40—	50—	60—
6—	23	29	22	24	—	3	31	30	6	2	17	73	33	15	4
11—	1	—	2	11	2	—	—	5	10	2	2	17	16	10	3
21—	—	—	2	3	4	—	—	1	7	4	—	1	6	16	5
31—	—	—	—	1	2	—	—	—	1	4	—	—	1	6	—
41—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	3

health records were obtained. The diagnoses were coded in accordance with the International Statistical Classification of Diseases. Hughes (1952) used this classification to indicate subgroups and two of his subgroups (upper and lower respiratory illness) were used for differentiation. Thus, the number of attacks and total weeks lost for each employee were ascertained.

Results

Industrial Dust Conditions.—The duration of exposure of the three exposure groups is shown in Tables 8 and 9. The concentrations of dust were determined by collecting the dust from a measured volume of air on a filter paper. The gradings of the dusts were measured by microscope counts on samples collected, on an electrostatic precipitator (Table 10). Representative points for dust collection were chosen. Most of the workers were placed in constant concentrations of lime dust and a central point was therefore chosen. Ash workers may be exposed to high or low concentrations depending on their work, and therefore both figures were noted. The advantageous effect of a good exhaust system

is shown by the figures which do not indicate a high percentage of small particles.

TABLE 10
REPRESENTATIVE DUST PARTICLE CONCENTRATIONS
IN COMPARABLE WORKING PLACES

Works	Average Dust Concentration ($\frac{\text{mg.}}{\text{m}^3}$)	Number of Particles Less than 4.5 μ per cu. ft./air	Particles Less than 4.5 μ (% by weight)
Lime: A	8.82*	2,780	0.018
C	2.1	662	
Soda Ash: B	184.5 max.* 4.9 min.	745,000 19,800	0.215
C	50.3 max. 2.1 min.	203,000 8,500	
No Dust: D	0.3	89	0.017

* The concentration was much reduced later by dust extraction equipment already present at works C.

Sickness Absence.—Table 11 shows the sickness experience in contrasted dust exposure groups.

There were no significant differences between exposure groups in the mean frequency and time

TABLE 11
MEAN FREQUENCY AND TIME LOSS IN 1954

	No Dust Group			Lime			Soda Ash		
	Total No. in Groups	Attacks per Man	Weeks Lost/Man	Total No. in Groups	Attacks per Man	Weeks Lost/Man	Total No. in Groups	Attacks per Man	Weeks Lost/Man
Upper respiratory illness	188	0.505	1.65	134	0.619	1.552	243	0.531	1.38
Lower respiratory illness	188	0.181	0.856	134	0.164	0.604	243	0.152	0.514

TABLE 12
MEAN FREQUENCY AND TIME LOSS IN 1954
(95% CONFIDENCE LIMITS)

Between Groups	Weeks Lost per Man			Attacks per Man		
	Upper Respiratory	Lower Respiratory	Significance	Upper Respiratory	Lower Respiratory	Significance
No dust and lime	-0.83 to 1.78	-1.06 to 1.73	NS	-0.34 to 0.41	-0.25 to 0.26	NS
No dust and soda ash	-0.91 to 1.72	-0.99 to 1.85	NS	-0.31 to 0.36	-0.22 to 0.31	NS

NS = not statistically significant

TABLE 13
MEAN FREQUENCY AND TIME LOSS IN 1956

	No Dust Group			Lime			Soda Ash		
	Total No. in Groups	Attacks per Man	Weeks Lost/Man	Total No. in Groups	Attacks per Man	Weeks Lost/Man	Total No. in Groups	Attacks per Man	Weeks Lost/Man
Upper respiratory illness	126	0.508	1.56	108	0.805	2.20	229	0.611	1.39
Lower respiratory illness	126	0.182	0.849	108	0.296	1.41	229	0.170	0.620

TABLE 14
MEAN FREQUENCY AND TIME LOSS IN 1956
(95% CONFIDENCE LIMITS)

Between Groups	Weeks Lost per Man			Attacks per Man		
	Upper Respiratory	Lower Respiratory	Significance	Upper Respiratory	Lower Respiratory	Significance
No dust and lime	-0.85 to 1.99	-0.87 to 2.08	NS	-0.12 to 0.53	-0.14 to 0.36	NS
No dust and soda ash	1.10 to 1.20	-1.16 to 1.62	NS	-0.18 to 0.46	-0.18 to 0.26	NS

NS = not statistically significant

lost because of respiratory sickness absence (Table 12).

Two years later the same exposure groups' sickness absence (Table 13) showed that there was still no significant difference between the groups (Table 14).

In both instances a detailed study of the age-specific attack rates showed no important divergence between dusty and non-dusty groups.

Results of Chest Radiography.—Chest radiographs of 20 workers with long service and exposure to dust showed no abnormality and no evidence of pneumoconiosis on miniature films.

Physiological Tests

Vital Capacity in 1954.—In 1954 the statistical analyses related vital capacity to age in years, height

TABLE 15
CHARACTERISTICS OF GROUPS AND MEAN VITAL CAPACITY IN 1954

Exposure Groups	No. Examined	Age (yr.)	Height (in.)	Weight (lb.)	V.C. (litres)
No dust	188	43.89	68.02	155.2	3.96
Lime	134	43.46	67.99	149.5	3.93
Soda ash	243	41.19	68.17	150.5	4.01

in inches, and weight in pounds, for the three exposure groups.

The regression coefficients (b) in the equation, $V = b_1A + b_2H + b_3W + \text{constant}$ are shown in Table 16.

TABLE 16
REGRESSION COEFFICIENTS

Exposure Groups	b_1	b_2	b_3
No dust	-0.0442	0.119	-0.00188
Lime	-0.0392	0.111	-0.00117
Soda ash	-0.0455	0.127	-0.00073

The regression coefficients for any group did not differ significantly from those of any other group, and they were, therefore, combined to give an overall estimate of the regression relationship, viz:—

$$V = -0.0420A + 0.132H + \text{constant}$$

The weight term is omitted since no coefficient differed significantly from zero.

The figures were further examined to see if a difference in vital capacity would appear in older men between the ages of 50 and 60. The results from 17 men from each group are shown in Table 17.

TABLE 17
CHARACTERISTICS OF GROUPS (OLDER MEN) AND
MEAN VITAL CAPACITY

Exposure Groups	Age (yr.)	Height (in.)	Vital Capacity (litres)
No dust	53.6	68.0	3.33
Lime	54.1	67.53	3.61
Soda ash	54.0	67.65	3.32

The *t* test again showed that the most extreme difference, *i.e.*, that between the soda ash and lime areas, is not significant. It can, therefore, be concluded that there is no evidence that the vital capacity of men in these groups is affected by their environment.

Expiratory Flow Rate, 1954.—A regression analysis was done for expiratory flow rate similar to the analysis studying the dependence of vital capacity on age, height, and weight. The groups were the same. The regression coefficients (*b*) in the equation $M = b_1A + b_2H + b_3W + \text{constant}$ are shown in Table 18.

TABLE 18
REGRESSION COEFFICIENTS

Exposure Groups	<i>b</i> ₁	<i>b</i> ₂	<i>b</i> ₃
No dust	-1.25	2.38	0.20
Lime	-1.34	2.52	0.09
Soda ash	-1.23	1.63	0.11

As before, weight did not appear to be a factor affecting E.F.R. nor did the regression coefficients differ significantly between groups either for age or height. The overall relationship was:

$$M = -1.19A + 2.34H + \text{constant}$$

The average figures are shown in Table 19.

TABLE 19
CHARACTERISTICS OF GROUPS AND MEAN EXPIRATORY
FLOW RATE IN 1954

Exposure Groups	No. Examined	Age (yr.)	Height (in.)	Weight (lb.)	E.F.R. (litres/min.)
No dust	188	43.89	68.02	155.2	104.06
Lime	134	43.46	67.99	149.5	97.44
Soda ash	243	41.19	68.17	150.5	98.23

If the expiratory flow rates are adjusted for age 42 years and height 68 in., common to all groups, they become:—No dust, 106.4; lime, 99.4; soda ash, 96.9.

The application of *t* tests showed that the differences between soda ash and lime groups and the no-dust group were highly significant (1.0%). This result was considered in relation to the radiographic and sickness-absence records of the exposure groups; it was felt that it should be confirmed in

view of the negative findings in these two aspects of evidence of respiratory disability.

Thus, during the following year preparations were made to repeat the E.F.R. test on sample groups of 50 men from each of two works (B and C) and the control works D, drawn strictly at random from those tested in 1954. All aspects of the test, except the weight and height recording, but including the scene and time of year, were the same as in 1954.

The 1955 results (Table 20) were consistent with the linear regression relationship between E.F.R., age and height (*M*, *A*, and *H*) obtained in 1954.

TABLE 20
COMPARISON OF MEAN E.F.R. (1954-55)

Exposure Groups (50 in each)	Average E.F.R. (litres/min.)		Increase (litres/min.)
	1954	1955	
No dust	103.6	105.8	2.2
Soda ash: works C	103.3	115.0	11.7
Soda ash: works B	94.04	101.0	7.0

The marked increase in the E.F.R. in both groups exposed to soda ash compared with the non-dust group nullified any statistical difference found in 1954. This result was also remarkable as a slight fall in the E.F.R. should theoretically have been expected in all groups because of increase in age. It was, therefore, imperative to repeat the entire test in 1956 in order to confirm the 1955 findings. Thus, at the same time of year (July) and at the same site, the E.F.R. test was performed in exactly the same way as before. The 1954 volunteers were encouraged to repeat the test. The numbers obtained are shown in Table 21, together with the average E.F.R.

TABLE 21
COMPARISON OF MEAN E.F.R. (1954-56)

Exposure Groups	1954		1956	
	No. in Group	Average E.F.R. (l./min.)	No. in Group	Average E.F.R. (l./min.)
No dust	188	104.06	89	106
Lime	134	97.44	83	100
Soda ash	243	98.23	167	104

The results were on the average higher than those for 1954. For the means of these the average increase was 4.50 litres/min. (95% confidence limits, 3.22 to 5.78), which suggests that there are no systematic differences between the groups. This conclusion was confirmed by an analysis of variance in which the variation in the group average for 1956 was compared with the variation within the groups. The variation between group averages was not significantly greater than would have been expected if the groups had been identical.

Smoking Habits and Sickness Absence due to Respiratory Illness.—Oswald and Medvei (1955) in their investigation of London civil servants indicated the importance of smoking in respiratory disorders, particularly bronchitis. This has been confirmed by Doll and Bradford Hill (1956).

TABLE 22
MEAN CIGARETTES PER DAY OF EXPOSURE GROUPS IN 1956

Exposure Group	Number in Group	Cigarettes per Day
No dust	126	12.7
Lime	108	12.3
Soda ash	229	13.1

A comparison of the smoking habits of the three occupational groups in 1956 showed no difference (Table 22). The respiratory sickness absence attack rate for the three groups provides an indication of the effect of smoking (Table 23), based on one year's experience.

TABLE 23
SMOKING RELATED TO TOTAL RESPIRATORY SICKNESS (UPPER AND LOWER RESPIRATORY ILLNESS) ABSENCE IN 1956 (ATTACK RATE)

Exposure Group	Attacks per Man		
	0 to 5 Cigarettes per Day	6 to 20 Cigarettes per Day	Over 20 Cigarettes per Day
No dust	0.548	0.847	0.682
Lime	1.52	1.00	0.875
Soda ash	0.692	0.806	0.823

Table 24 shows the 95% confidence limits between the three smoking groups.

As there appeared to be a slight possibility of some significance in the no dust and lime groups, the analysis was repeated for the two groups 0 to 5 and over 21 cigarettes per day. The result is shown in Table 25.

There does not appear to be any significant difference in the total respiratory sickness absence between the three exposure groups attributable to smoking.

TABLE 24
95% CONFIDENCE LIMITS BETWEEN SMOKING AND TOTAL RESPIRATORY SICKNESS ABSENCES (MEAN FREQUENCY)

Exposure Group	1956			
	Cigarettes per Day		Cigarettes per Day	
	Between 0 to 5 and 6 to 20	Significance	Between 6 to 20 and over 21	Significance
No dust	-0.07 to +1.09	Possible S	-0.53 to +1.23	NS
Lime	-1.01 to +2.16	NS	-0.09 to +1.31	Possible S
Soda ash	-0.18 to +0.92	NS	-0.028 to +1.22	NS
All areas	-0.26 to +0.27	NS	-0.14 to +1.05	NS

S = statistically significant

NS = not statistically significant

TABLE 25
95% CONFIDENCE LIMITS BETWEEN SMOKING AND TOTAL RESPIRATORY SICKNESS ABSENCES (MEAN FREQUENCY)

Exposure Group	Between 0 to 5 and over 21 Cigarettes per Day	Significance
No dust	-0.593 to +0.909	NS
Lime	-0.432 to +2.801	NS
Soda ash	-0.526 to +0.720	NS
All areas	-0.539 to +0.805	NS

S = statistically significant. NS = not statistically significant

Smoking Habits and Respiratory Tests.—A combined regression of expiratory flow rate on age and height (disregarding smoking) was worked out. This gave an average E.F.R. of 109.6 litres per minute; average age, 43.7 years; average height, 68.2 inches. The regression equation of E.F.R. (M) on age (X) and height (X₂) becomes:

$$M = -1.27(X) + 3.86(X_2) - 98.1.$$

The 95% confidence limits for the two constants are:

$$b = -1.20 \text{ to } -1.35. \quad c = +3.44 \text{ to } +4.28.$$

These slopes do not differ significantly from the 1955 random sample.

Tables 26 and 27 (Figs. 1 and 2) give the mean E.F.R. for the three smoking groups according to age and height.

Separate regressions were fitted to each smoking group.

The differences are significant, and indicate that moderate smoking (six to 20 cigarettes/day) increases the effect of both age and height. The effect of smoking in reducing E.F.R. is greatest for older and shorter men (Figs. 1 and 2). The group of men who smoke more than 20 cigarettes a day showed even steeper regressions, but as the number of men in the group was small and the results found were more variable than in the other groups, the differences in the regression constants are not statistically significant.

Discussion

Respiratory function tests have rarely been used on men exposed to alkaline dusts. However, Kadlec

TABLE 26
MEAN E.F.R. IN LITRES PER MINUTE BY AGE IN THREE SMOKING GROUPS

Age Group (Years)	0 to 5 Cigarettes per Day		6 to 20 Cigarettes per Day		Over 20 Cigarettes per Day	
	Number in Group	Mean E.F.R.	Number in Group	Mean E.F.R.	Number in Group	Mean E.F.R.
20—	11	118	33	122	2	117
30—	32	110	111	108	8	100
40—	32	102	68	98	18	98
50—	28	86	79	84	4	78
60—	12	80	21	71	4	56

TABLE 27
MEAN E.F.R. IN LITRES PER MINUTE BY HEIGHT IN THREE SMOKING GROUPS

Height (Inches)	0 to 5 Cigarettes per Day		6 to 20 Cigarettes per Day		Over 20 Cigarettes per Day	
	Number in Group	Mean E.F.R.	Number in Group	Mean E.F.R.	Number in Group	Mean E.F.R.
64—	28	97	50	89	6	63
66—	35	91	75	88	9	88.5
68—	31	108	112	101	9	92.5
70—	21	101	75	109	12	113

FIG. 1.

FIGS. 1 and 2.—The mean E.F.R. for the three smoking groups according to age and height.

FIG. 2

and Vyskocil (1950) employed the fast expiratory vital capacity method for evaluation of the differences between three groups of workers in lime-containing cement. They had previously been graded by other functional tests and clinical and radiographic examinations into the three groups: slight bronchitis, advanced bronchitis, and doubtful emphysema. In 97 men who had been exposed to the dust for more than seven years, Kadlec and Vyskocil found statistically significant differences between the groups. Kazantzis and Buxton (1956) using the same test found no difference between control groups and groups exposed to cadmium fume. Gilson *et al.* (1955) considered that this type of test might be useful in assessing disability in pneumoconiosis particularly when compensation issues were at stake.

In the present paper the respiratory function of workers in alkaline dusts was compared with a control group using the expiratory flow rate test and, in contradistinction to Kadlec and Vyskocil's work, the affected groups were not previously subdivided according to respiratory disability. The findings in 1954 of a real difference in E.F.R. and no difference in vital capacity between the groups with a similar E.F.R. in the succeeding two years emphasized the importance of both the lack of morbidity and radiological evidence of effects from the dust. The E.F.R. test was chosen for its simplicity and had been used many times before the survey, but the stimulating effect of a group of men on each volunteer's efforts had not been appreciated. The uniform results obtained from the control group (works D) confirmed this view.

Sickness absence studies indicated that dust, particularly lime, does slightly increase the respiratory morbidity, a view which is in accord with that of Oswald and Medvei (1955).

Smoking habits coupled with respiratory morbidity and function tests indicated that heavy

smoking combined with age and height in being significantly correlated with the E.F.R. This finding is similar to that of Whitfield, Melville Arnott, and Waterhouse (1951) who found a reduction in lung volume in heavy smokers. The older and shorter men had a greater impairment of the E.F.R. due to smoking. Respiratory sickness absence was also increased in heavy smokers. The implication from these findings was that, although the dusts concerned in the working environment do cause some increase in respiratory illness, their significance in the production of respiratory disability, either functional or pathological, is not as important as the number of cigarettes smoked daily.

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