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Toxicity of Chromic Acid in the Chromium Plating Industry(2)

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A population of chromium platers in the West Riding of Yorkshire, defined as described in a previous paper. together with a closely matched control group of manual workers in the same area, were subjected to morbidity screening for respiratory symptoms; the "plater" population was also screened for the ulcerative and dermatitic lesions commonly seen in chromate handlers. A standard questionnaire was used. but no physical examinations or physiological tests were performed: questionnaires relating to 997 platers and 1117 controls were successfully completed. In general, respiratory symptoms were experienced to a greater extent by the plater population. A higher proponion of platers had worked in dusty jobs, however, and, when the populations were divided into "dust-exposed" and "not-dust-exposed" groups. the disparity in symptomatology was seen to be more marked in the (larger) group of dust-exposed subjects. An exception appeared in the case of effort dyspnoea which. in its most severe form, affected practically the same proportion of each population. The prevalence of bronchial asthma was high in both platers (13.1%) and controls (9.8%), this increase being much more marked in the dust-exposed group. In the case of seasonal hay fever, 3.9% of platers and 5.5% of controls were affected. The risk of skin and intranasal ulceration is shown to increase progressively. the longer the period of chromic acid exposure. whereas allergic contact dermatitis occurs equally in platers with short and in those with longer exposure. An industrial hygiene survey. including air and dust analyses for chromic acid content. was carried out in 42 of the 54 plating plants from which the plater population was derived. in only two cases was the Threshold Limit Value (TLV) for atmospheric chromic acid exceeded. Analyses of many dust scrapings showed chromic acid content of from 0 to 298 mg/g. No comparison figures are available. but it is thought that these were high. and that the dislodgement of such dust could form an intermittent inhalant hazard in chromium plating.

In the first article (Royle, 1975), the mortality pattern in a population of subjects exposed for at least 3 months to chromic acid in 54 plating plants in the West Riding of Yorkshire was described. It was shown that there had been a significant increase in certified deaths from malignant neoplastic disease among these electroplaters, when compared with an individually matched control population in the same area: some increase in deaths from nonneoplastic pulmonary disease was also found, but there was little difference in the number of deaths from cardiovascular disease and other causes. This paper reports an industrial hygiene survey of the plating plants concerned, and a morbidity study of respiratory symptoms in the same populations.

INDUSTRIAL HYGIENE SURVEY

The plating plants were all visited personally. They showed substantial variation in size,. design, type of process, and general factory hygiene. Five of the plants had both manually operated and semiautomatic vats, two were semiauto-

matic only, and three were fully automated; the rest were solely manually operated, .open vat in type. Assessment of general factory hygiene was dependent upon impressions gained, and notes made, in the course of one or two visits only, so that detailed comparison was not possible; in some of the smaller plants, however, the standard was considered to be poor, and respirators were rarely used by the platers.

The plants were chosen because their principal industry was chromium plating, and chromic acid exposure was the hazard common to all the workers who were accepted as eligible for inclusion in the defined "plater" population. At the same time, most of these plants were plating other metals, although some of these were being processed only very occasionally. The other metals were nickel, cadmium, zinc, tin, copper, silver, gold, brass, and rhodium; lead was not being used at any of the plants, and nickel carbonyl did not develop in any of the nickel-processing operations. Of the 54 plants involved, 49 used nickel and 18 cadmium, nickel being deposited as an undercoating for other metals. Four plants used chromium only, the workers in these accounting for about one-sixth of the total plater population; persons who worked exclusively on vats plating metals other than chromium were excluded from the defined population.

Air and Dust Analyses for Chromic Acid

These were carried out by Manchester University's Occupational Hygiene Service between 1%9 and 1970. Twelve plants were not available for investigation in this way. either because they had ceased plating operations, or because permission for the tests was refused.

Air samples were taken at breathing zone height, and it was found that the results of the tests were overall very satisfactory. In all but two cases, the chromic acid air content was less than 0.03 mg/m³. The two exceptions were large plants, and in each case the Threshold Limit Value for chromic acid (0.1 mg/m³) was exceeded. No chromic acid was detected in the air samples from two of the automatic plants, and in the third the highest reading was only 0.009 mg/m³.

Dust samples from various sites at the 42 plants surveyed were examined for chromic acid content, and the amounts, expressed as milligrams per gram, showed very wide variation. Samples ftom the. three automatic plants had low content, varying from nil to 3.9 mg/g; whereas the two plants with high atmospheric content, both of which used the manually operated open vat type of process, had readings ranging from 46 to 251 mg/g. It was noted, however, that two of the other "open vat!' plants, both with low atmospheric CrO_3 readings (0.003 and 0.012 mg/m³, respectively) had dust samples of high degree (192.5 and 298 mg/g).

Apart from these specific examples, the range of chromic acid content in dust samples from the other 35 plants was from 0.3 to 97.0 mg/g.

DISCUSSION

There do not appear to be any published figures for chromic acid content in dust samples from chromium plating plants, so that the significance of the find-

ings in the West Riding is difficult to assess; the figures seem to be very high in some cases. 'Experienced platers have often commented, in personal discussions, that "windy days" were "bad days" so far as nasal irritative symptoms are concerned, and it appears likely that the build-up over the years of chromic acid in the dust in inaccessible sites. and its periodic disturbance by draughts or by the carrying out of repair work, may be an important intermittent factor in the production of harmful effects. even when the fumes from the vats are being adequately controlled.

The value of automation in this industry is emphasised by the very low air and dust chromic acid content in the three automatic plants surveyed.

Since the air and dust analyses were carried out, satisfactory improvements have been made at the two plants where the atmospheric chromic acid content exceeded the Threshold Limit Value. The new Chromium Plating (Amendment) Regulations, providing for the frequent recording of atmospheric chromic acid content in all plants, came into effect in February 1973, and it is hoped that these will lead to improved conditions in the industry. but the question of dust abatement, admittedly difficult, should be given serious consideration.

Atmospheric and dust samples were only examined for chromic acid content; nevertheless. the possibility of injurious effects being caused by the occasional inhalation of compounds of metals other than chromium cannot be ignored, but of those metals encountered in the plating shops only nickel and cadmium need to be taken into account. The characteristic skin lesion caused by exposure to nickel compounds is allergic contact dermatitis, and it is possible that some of the dermatitis cases seen among West Riding Platers were examples of "nickel itch"; but the deep chronic skin ulcers and nasal septal perforations, typical of chromic acid contact do not occur in nickel workers. A high incidence of lung and nasal cancers among nickel carbonyl workers at a South Wales refinery was described by Doll (1958, 1959), but there does not appear to be any convincing evidence to suggest that the solutions of nickel salts (sulfate, suiphamate, chloride) used in plating have any long-term adverse respiratory effects, assuming that adequate precautions are taken.

Chronic poisoning by exposure to cadmium has been reported by Princi (1947), Princi and Geever (1950). Friberg (1950), Bonnell (1955), Bonnell *et al.*, (1959), Smith, Smith, and McCall (1960). The manifestations of ill-health among the cases described were many and varied (fatigue, loss of weight, impairment of renal and Liver function, anosmia, watery rhinorrhoea, dyspnoea, anaemia, etc.), but the main disability was emphysema, which differed from the usual type in not being preceded by cough and attacks of bronchitis. These effects have occurred chiefly in persons employed in casting cadmium alloys and in the manufacture of storage batteries; Fairhall (1945) states that cadmium poisoning is unlikely to be caused by the electroplating process.

Every effort was made to exclude from the plater population all those who were, or had been, closely involved in nickel or cadmium plating, but to have limited the study to the four plants using chromic acid only would have reduced the available population to about *200,* and it was not thought that the possible occasional contact with the salts of the other two metals would make any important impact on the results.

MORBIDITY STUDY

The method adopted is described in the first article (Royle, 1975). It was based on the successful completion of the Medical Research Council's Questionnaire on Respiratory Symptoms (1966), with additional questions regarding bronchia] asthma and hay fever and the occurrence of the skin and nasal lesions which commonly affect chromium platers and others handling chromium compounds,

It was, unfortunately, impracticable to undertake the clinical part of the Questionnaire, which provides for respiratory function tests and the measurement of sputum volume.

Results

The Questionnaire was satisfactorily completed by 997 "platers" and 1117 "controls," the larger control population being accounted for by the fact that more control subjects than platers were domiciled in York and district, where tracing and establishing contact was easier than in the widespread West Riding. However, no significant differences were evident in the age and sex distribution (Table 1); the mean age of platers was *42.9* years, of controls 43.6 years. Males comprised 84.5% of the plater population, and 85.3% of control subjects.

No important differences were found in the tobacco smoking history, inhaling habits, type of smoking, and the average amount of tobacco smoked per diem, when the available populations were compared (Table 2).

Some difference was found between the two populations in respect of dust exposure in specific and nonspecific dusty jobs. More platers (651, with a total of *5568* years of exposure) than controls (550, with a total 5136 *years* of exposure) had worked in such jobs, the difference being largely due to the greater number of platers who had also worked at a coal mine [I 14 (11.4%) platers and 54 (4.8%) controls], at a foundry [231 (23.2%) platers and 83 (7.4%) controls], and at a cotton, flax, or hemp mill [95 *(9.5%)* platers and 32 (2.9%) controls]; more control subjects had worked in asbestos processing [36 (3.6%) platers and 93 (8.3%) controls]. All four differences are 0.1% significant (Table 3).

TABLE 1
AGE AND SEX DISTRIBUTION IN "MORBIDITY" POPULATIONS

	Males				Females			
	Platers		Controls		Platen		Controls	
Age	No.	%	No.	%	No.	%	No.	%
0-20	17	2.0	15	1.6	8	5.2	4	2.4
-30	134	15.9	132	13.9	34	21.9	29	17.7
-40	212	25.2	229	24.0	36	23.2	26	15.9
-50	244	29.0	338	35.4	41	26.5	57	34.7
-60	147	17.5	157	16.5	24	15.5	26	15.9
-70	70	8.3	64	6.7	11	7.1	18	11.0
>70	18	21	18	19	1	0.6	4	2.4
Total	842	100	953	100	155	100	164	100

TABLE 2
TOBACCO SMOKING

(a) Smoking history

		Never smoked	Exsmoken	Current smokers	Total smokers
Platers	Number	134	107	7%	863
	%	13.4	10.7	75.8	86.6
Controls	Number	165	175	777	952
	%	14.8	15.7	69.6	85.2

(b) Type of smoker. Numbers in each category and percentage of total smokers

		Total smokers	Cigarettes only	Pipe only	Cigarettes and pipe/cigars	Cigars and pipe	Cigars only
Platers	Number	863	752	28	69	9	5
	%		87.1	3.2	8.0	I.0	0.6
Controls	Number	952	794	45	94	I0	9
	%		113.4	4.7	9.8	1.0	0.9

(c) Inhaling habits in current smokers (756 platers and 777 controls)

		Noninhaler	Slightly	Moderately or deeply
Platers	Number	65	117	574
	%	8.6	15.5	75.9
Controls	Number	81	137	559
	%	10.4	17.6	71.9

(d) Amount of cigarette tobacco consumed per diem (including weekends) per person in total "Morbidity" populations

		Nil	1–4 grams	5–14 grams	IS–24 grams	25 grams or more	Total
Platers	Number	177	39	303	327	1s1	997
	%	17.8	3.9	30.4	32.8	15.1	100
Controls	Number	231	36	307	37s	168	1117
	%	20.7	3.2	27.5	33.6	15.0	100

Mean daily consumption of cigarette tobacco per person in total "Morbidity" populations: *Platers:* 14.6 g; *Controls:* 13.7 g

Mean daily consumption of cigarette tobacco per person in smokers: *Platers:* 16.1 g; *Controls:* 16.1 g

(e) Amount of pipe and cigar tobacco consumed per diem (including weekends) per person in total "Morbidity" populations

		Nil	1–4 grams	5–14 grams	15–24 grams	25 grams or more	Total
Platers	Number	8%	40	46	11	4	997
	%	89.9	4.0	4.6	11	0.4	100
Controls	Number	9%	76	66	11	8	1117
	%	85.6	6.8	5.9	I.0	0.7	100

Mean daily consumption of pipe and agar tobacco per person in total "Morbidity" populations: *Platers:* 0.9 g; *Controls:* 2.0 g

Mean daily consumption of all forms of tobacco per person in total "Morbidity" populations: *Platers:* 14.8 g; *Controls:* 14.9 g

Mean daily consumption of all forms of tobacco per person in smokers: *Platers:* 17.1 g; *Controls:* 17.4 g

TABLE 3
DUST EXPOSURE

A. Proportions of "Morbidity" populations who have worked at various dusty jobs

	Platers	Controls	Significance
Coal mine	114 (11.4%)	54 (4.8%)	0.1%
Mine other than coal	7 (0.7%)	5 (0.4%)	Not sign.
Quarry	29 (2.9%)	20 (1.8%)	Not sign.
Foundry	231 (23.2%)	83 (7.4%)	0.1%
Pottery	12 (1.2%)	3 (0.3%)	2.5%
Asbestos processing	36 (3.6%)	93 (8.3%)	0.1%
Cotton, flax, or hemp mill	95 (9.5%)	32 (2.9%)	0.1%
Any dusty job other than above	404 (40.3%)	404 (36.2%)	Not sign.

B. Exposure to all forms of dust

(1) Number of years' exposure per person in "Morbidity" populations

	Ted subjects not exposed	Number of years exposed					Total subjects exposed	Total exposure (years)
		1–4	5–9	10–14	15–19	20+		
Platers	346	299	149	75	44	85	651	5568
Controls	567	237	120	65	37	91	550	5136
Total	913	536	269	140	81	175	1201	10704

(2) Mean number of years' dust exposure per person in each total "Morbidity" population and in each exposed group

	Mean exposure in total population (years)	Mean exposure in exposed group (years)
Platers	5.6	8.6
Controls	4.6	9.3

The length of time of dust exposure is thought by some to have an important bearing on respiratory disorder (Lowe, 1969; Rogan *et al.*, *1973*). No significant difference was found in the mean time of exposure per person, either in the total population under review (5.6 years for platers, 4.6 years for controls) or in the exposed group (8.6 years for platers, 9.3 years for controls).

Past History of Specific Chest Illnesses

Subjects were questioned about broadly defined chest illnesses (including "heart trouble") from which they might have suffered in the past, and which might have been relevant to the development of chronic respiratory disease. No significant differences were found in the case of chest operation or injury, "heart trouble," pneumonia, pleurisy, tuberculosis, or "other chest trouble." In the case of attacks of bronchitis, a higher proportion of platers (28.2%) than of controls (23.7%) asserted that they had had one or more attacks (2.5% significance). The questions relating to bronchial asthma are considered below.'

RESPIRATORY SYMPTONS

Haemoptysis

A significantly larger number of platers [79 (7.9%)] than controls [57 (5.1%)] claimed to have coughed up blood. This had occurred during the previous year in 25 (2.5%) platers and 23 (2.1%) controls.

Breathlessness

Degrees of effort dyspnoea were divided into four grades, from (1) "No abnormal breathlessness" to (4) "Forced to stop for breath when walking at own (slow) pace on level ground." However grouped, no significant difference was found on comparing the two populations: the proportions in the two most severe grades combined (3 and 4) were: Platers 7.4%. Controls 7.6%. Subjects who were handicapped by musculoskeletal or neurological disorders were not questioned (Table 4).

Nasal Catarrh

This is defined, for the purpose of the Questionnaire. as "a stuffy nose or catarrh at the back of the nose." and an incidence for at least 3 months in each year is posed as-a test of chronicity. It will be seen from Table 5 that a high proportion of subjects in both populations claimed to be affected (28.9% platers, 26.8% controls). When the seasonal incidence of these symptoms is examined, it

TABLE 4
BREATHLESSNESS

(I) **Degree of Dyspnoea Graded 1–4**

		Grade					
		1	2	3	4	Total	"Disabled"
Platers	Number	691	168	47	22	928	69
	%	74.5	18.1	5.0	2.4	100.0	
Controls	Number	762	245	52	31	1090	27
	%	69.9	22.5	4.8	2.8	100.0	
Total subjects		1453	413	99	53	2018	96

No significance

(2) **Proportion of *each* population, with dyspnoea graded 3 and 4**

		Grade			Proportion in grades
		1 and 2	3 and 4	Total	3 and 4
Platers	Number	859	69	928	7.4%
Controls	Number	1007	83	1090	7.6%
Total		1866	152	2018	

No significance

TABLE 5
NASAL CATARRH FOR AT LEAST THREE MONTHS

		Winter only	Summer only	Perennial	Total
Platers	Number	77	6	205	288
	% Total "Morbidity" population	7.7	0.6	20.6	28.9
Controls	Number	114	10	175	299
	% Total "Morbidity" population	10.2	0.9	15.7	26.8
Significance		Not sign.	Not sign.	0.5%	

is shown that perennial cases account for the large majority and that there is a significant increase among platers in this category. "Summer only" cases were few in number, but there was a slight preponderance of "winter only" cases in the control population.

Cough and Phlegm

There is still considerable difference of opinion as to the definition of "chronic bronchitis,,, from the point of view of symptomatology (Higgins, 1957; Higgins *et al.*, 1959; Fletcher *et al.*, 1959; College of General Practitioners, 1961; World Health Organization, 1961; Deane *et al.*, 1965; Holland *et al.*, 1966); Stuart-Harris (1972) has suggested that, when prolonged symptoms occur for more than one winter, a diagnosis of chronic bronchitis must be considered.

The procedure adopted in assessing the replies to questions bearing on chronic bronchitis was to place the subject in one of three grades in respect of cough, and similarly in respect of phlegm production. Grade 0 denoted those Without respiratory symptoms: those with "productive" cough lasting for at least 3 consecutive months each year were placed in Grades 1 and 2, according to whether the symptoms occurred first thing in the morning only, or continued throughout the day. It is considered that a large proportion of Grade 2 subjects would in fact be chronic bronchitics.

Table 6 shows the proportions of persons in each population, graded as above, and it will be seen that there is a significantly increased number of platers in Grade 2, both as regards cough and production of phlegm.

Chronic Nasal Catarrh with Chronic Bronchitis

The two populations were compared in respect of the coincidence of chronic nasal catarrh and "chronic bronchitis,, in the same subject. In this case, the definition of chronic bronchitis as "persistent cough and phlegm in the winter" was adopted, and therefore all Grades 1 and 2 Subjects were placed in this category. Table 7 shows that, of the 288 platers and 299 controls who suffered from "chronic nasal catarrh," 104 platers and 90 controls respectively also suffered from "chronic bronchitis," if the 'above empirical definition of the term is adopted. Looked at from the point of view of seasonal incidence, the figures in

TABLE 6

LOWER RESPIRATORY SYMPTOMS

(1) Habitual winter cough for at least 3 consecutive months graded 0–2

		Grade 0	Grade 1	Grade 2	Total
Platers	Number	732	100	165	997
	%	73.4	10.0	16.6	100
Controls	Number	845	136	136	1117
	%	75.6	12.2	12.2	100
Significance		Not sign.	Not sign.	1.0%	

(2) Habitual production of phlegm from the chest in the winter. for at least 3 consecutive months graded 0–2

		Grade 0	Grade 1	Grade 2	Total
Platers	Number	775	73	149	997
	%	77.7	7.3	15.0	100
Controls	Number	877	122	118	1117
	%	78.5	10.9	10.6	100
Significance		Not sign.	Not sign.	0.1%	

both populations show a fair degree of consistency, suggesting that about one-third of the cases of "chronic nasal catarrh" whether of perennial or "winter' only'' type, have a coexisting prolonged winter bronchitis. The small number of "summer only" cases would .probably be pollen or mould spore allergy sufferers.

Respiratory *Allergy*

"Hay fever" and "bronchial asthma" are, in the public mind, the two terms which *are* commonly associated with respiratory allergic disease.

TABLE 7.

CHRONIC NASAL CATARRH WITH "CHRONIC BRONCHITIS"

Proportions of subjects in "Morbidity" populations with co-existing symptoms

	Platers		Controls		
	Chronic nasal *catarrh*	Chronic nasal catarrh + "chronic bronchitis"	Chronic nasal catarrh	Chronic nasal catarrh + "chronic bronchitis"	Significance
Winter only	77 (7.7%)	26 (2.6%)	114 (16.2%)	39 (3.5%)	Not sign.
Summer only	6 (0.6%)	2 (0.2%)	10 (0.9%)	3 (0.3%)	Not sign.
Perennial	205 (20.6%)	760.6%)	175 (15.7%)	48 (4.3%)	0.5%

Hay Fever

According to the replies to the question "Have you ever suffered from hay fever?" 52 (5.2%) platers and 72 (6.4%) controls had been troubled in this way; of these, only 4 platers and 7 control subjects had attended hospital for their condition; 9 platers and 8 controls said that they had suffered from both hay fever and asthma; 33 of the hay fever platers and 52 controls had summer symptoms only. If these are added to the 6 platers and 10 controls who suffered from seasonal (summer) nasal catarrh and can be taken as putative hay fever subjects (Table 5), we find a total population of 39 (3.9%) platers and 62 (5.5%) controls who suffered from summer hay fever.

The age at onset, in decades, is set out in Fig. 1, where it is apparent that the pattern is similar in the two populations, most hay fever subjects in each experiencing symptoms for the first time in the second decade.

Bronchial Asthma

In reply to the question "Have you ever had bronchial asthma?" affirmative replies were given by 34 (3.4%) platers and 29 (2.6%) controls. A second question ("Have you ever had attacks of shortness of breath with wheezing?" together with a subsidiary "Is/was your breathing absolutely normal between attacks?") was designed to detect, by indirect means, bronchial asthma in subjects who may not have been aware that they suffered from this disorder. An approximate comparison of the incidence of asthma in the two populations could be expected to be shown by tabulating the number of subjects who gave affirmative answers to either of these questions alone, or to both. On this basis, 131 (13.1%) platers and 110 (9.8%) controls could be considered as putative asthmatics, showing an increase among platers of 2.5% significance.

All those who answered "yes" to the first question were further asked about their medication, and it was found that out of the total of 63 subjects, 20 used the

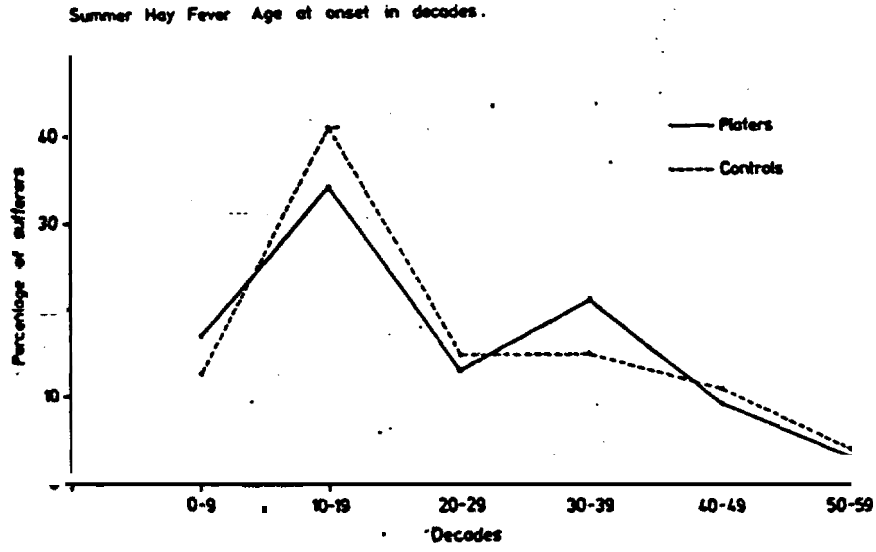

FIG. 1. Summer hay fever. *Age* of onset in decades.

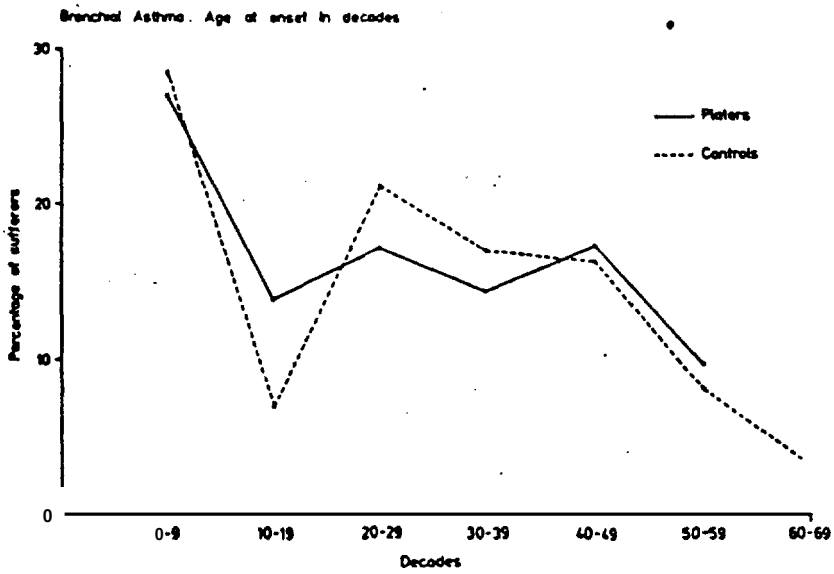

FIG. 2. Bronchial asthma. Age of onset in decades.

common bronchodilating remedies occasionally and 14 used them habitually; 5 used corticosteroid drugs for emergencies only, and 5 used them for long-term treatment; 19 had received no medical treatment for their asthma, and only 7 subjects in each population had had a full hospital investigation.

Figure 2 shows that, unlike hay fever. symptoms of asthma begin most commonly in the first decade, followed by a sharp fall in the incidence of new cases. during the second decade; the same general pattern is seen in both platers and controls.

Special Exposure Symptoms

In order to minimise bias, those who carried out the questioning were kept in ignorance as to whether each individual was a "plater" or a control. When the questionnaire had been completed, however. they were instructed to enquire as to whether the subject had worked in a chrome plating plant, and if so to question him or her about the various skin and nasal effects which could have been caused by chromic acid exposure, as follows:

(1) Have you ever suffered from nose bleeding? (Accept two or more nose bleeds per annum.)
(2) Have you ever had nasal ulceration?
(3) Have you ever had nasal perforation?
(4) Have you ever had ulcers on the hands or forearms?
(5) Have you ever had dermatitis of the hands or forearms?
(6) Have you ever had an imtable rash, lasting more than 3 weeks, on the hands or forearms?

The last question was included in an attempt to detect those subjects who had probably been affected by dermatitis but were unaware of it, although it was

TABLE 8
SPECIAL EXPOSURE SYMPTOMS
Incidence in total "Morbidity" plater population and in groups with short, medium, and long exposures

		Total plater population (997)	CrO_3 exposure less than 1 year (234)	CrO_3 exposure 1–5 years (394)	CrO_3 exposure over 5 years (369)	Significance of trend over exposure period
Nose bleeding	Number	168	34	75	59	
	%	16.9	14.5	19.0	16.0	Not sign.
Nasal ulcers	Number	128	14	52	62	
	%	12.8	6.0	13.1	16.8	0.1%
Nasal perforations	Number	47	1	14	32	
	%	4.7	0.5	3.6	8.7	0.1%
Skin ulcers	Number	217	15	84	118	
	%	21.8	6.4	21.3	32.0	0.1%
Dermatitis	Number	245	56	102	87	Not sign.
	%	24.6	23.9	26.0	23.6	

realised that in a small number of cases the disorder may have been caused by scabies or some other imtable nondermatitic skin lesion.

Comparison was made between the length of exposure to chromic acid and the incidence of each symptom. Of the 997 platers:

234 were exposed for less than 1 year;
394 were exposed for one to 5 years;
369 were exposed for over 5 years.

Table 8 shows how common these effects have been among platers and how, in the case of nasal ulceration, nasal perforation and skin ulcers, the incidence becomes progressively higher the longer the exposure; as between short and long exposure, the increase is nearly 3-fold for nasal ulcers, 17-fold for nasal perforation, and 5-fold for skin ulceration. The figures show that the incidence of dermatitis, which is surprisingly high at 24.6% of the total available plater population, bears no relationship to the length of time exposed.

Since nose bleeding may be caused by many agents other than chrome exposure, it was not expected to show any important variation in the exposure groups, and this proved to be the case.

Dust Exposure

It has been pointed out above that a higher proportion of the plater population had worked in designated and nondesignated "dusty jobs" (651 = 65.3%) compared with controls (550 = 49.2%). This difference was largely due to the greater number of platers who had worked at a coal mine, at a foundry, or at a cotton, flax, or hemp mill, but at the same time it was found that a significantly larger number of controls had worked in the processing of asbestos. With the exception of effort dyspnoea and winter nasal catarrh, where no difference was seen, the

TABLE 9

RESPIRATORY SYMPTOMS, COMPARING THEIR INCIDENCE IN SUBJECTS WHO HAVE WORKED IN "DUSTY JOBS" AND IN SUBJECTS NOT SPECIFICALLY DUST EXPOSED, IN "MORBIDITY" POPULATIONS

Whether dust exposed or not			Cough Grade 2	Phlegm Grade 2	"Chronic bronchitis"	Chronic nasal catarrh			Nasal catarrh + "chronic bronchitis"			Asthma	Total number of subjects
						Winter only	Summer only	Perennial	Winter only	Summer only	Perennial		
Dust exposed	Platers	Number	127	114	132	54	4	149	21	1	56	102	651
		%	19.5	17.5	20.3	8.3	0.1	22.9	3.2	0.2	8.6	15.7	
	Controls	Number	80	78	109	58	6	100	21	3	34	61	550
		%	14.5	14.2	19.8	10.5	1.1	18.2	3.8	0.5	6.2	11.1	
Significance			5.0%	2.5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	5.0%	
Not dust exposed	Platers	Number	38	35	39	23	2	56	5	1	20	29	346
		%	11.0	10.1	11.3	6.6	0.6	16.2	1.4	0.3	5.8	8.4	
	Controls	Number	56	40	69	56	4	75	18	0	14	49	567
		%	9.9	7.1	12.2	9.9	0.7	13.2	3.2		2.5	8.6	
Significance			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	2.5%	N.S.	
Total sample	Platers	Number	165	149	171	77	6	205	26	2	76	131	997
		%	16.5	14.9	17.1	7.7	0.6	20.6	2.6	0.2	7.6	13.1	
	Controls	Number	136	118	178	114	10	175	39	3	48	110	1117
		%	12.2	10.6	16.0	10.2	0.9	15.7	3.5	0.3	4.3	9.8	
Significance			0.5%	0.5%	N.S.	N.S.	N.S.	0.5%	N.S.	N.S.	0.5%	2.5%	

replies to the questionnaire indicated that there was a general prevalence of respiratory symptoms in the plater population over the controls, When the populations were divided into two groups, one with heavy dust exposure ("dust-exposed") and one less heavily exposed ("not-dust-exposed"), it was shown that there was an increase in respiratory symptoms among both platters and controls in the heavily exposed group, as would be expected: yet even in the "not-dust-exposed" group the platers tended to be more subject to chronic respiratory symptoms (Table 9).

Further light on the question of the relative importance of chromic acid exposure on the one hand and residence in a heavily industrialised area and heavy overall dust exposure on the other, as causes of the increase in respiratory symptoms in the plater population, was sought by comparing two chromium plating plants.

Plant No. 1 had a "morbidity" population of 115, all male. Only hard chrome plating was performed there and, for part of the time that this plant was under review, factory hygiene was unsatisfactory with, at times, abnormally high readings both for atmospheric chromic acid and for chromic acid in the dust. This factory is situated in a suburban area and all the plater population resided either in the surrounding rural areas or in the adjacent city, which is only lightly industrialised. Plant No. 35, by contrast, was situated in the heart of the industrial part of Leeds (it has subsequently ceased operations), where the large majority of its plater population resided; as in the case of Plant No. 1, factory hygiene was unsatisfactory to a similar extent.

Table 10 (1) shows that the amount of dust exposure in jobs other than chromium plating was considerably in excess among the platers at the Leeds plant (No. 35), 95 (75.4%) being "dust-exposed" in Plant No. 35 compared with 71 (61.7%) in Plant No. 1, but an even more striking difference appears when the length of time of dust exposure is examined. The total years of exposure for Plant No. 35 platers was 1204 (mean = 12.67 among the 95 "dust-exposed"); in the case of Plant No. 1, the comparable figures were 391 (mean = 5.50 among the 71 "dust-exposed").

A comparison was made between the platers in these two plants in respect of the incidence of the same range of respiratory symptoms as were considered above. The available numbers are too small for valid significance-testing to be undertaken, but it will be noted that, in spite of the higher dust exposure among Plant No. 35 platers, a higher proportion of Plant No. 1 platers suffered from Grade 2 Cough, "Chronic bronchitis" and Perennial Nasal Catarrh, and it was only in the case of "Asthma" that a considerably higher incidence was encountered among the Leeds platers [Table 10 (2)].

DISCUSSION

According to the answers to a standard questionnaire, respiratory symptoms in general were experienced by the platers to a greater extent than the controls, with the remarkable exception of effort dyspnoea. This would seem to suggest that irreversible structural bronchial and lung changes occur to a similar extent

TABLE 10

COMPARISON OF DUST EXPOSURE AND RESPIRATORY SYMPTOMS IN TWO PLATING PLANTS

(1) Comparison between years of dust exposure among Platers in plant no. 1 and plant no. 35

		"Not dust exposed"	Number of "dust exposed" subjects	Length of exposure		Total years of dust exposure	Mean exposure years per exposed subject	Total subjects
				<10 years	>10 years			
Plant no. 1	Number	44	71	61	10	391	5.50	115
	%	38.3	61.7	53.0	8.6			
Plant no. 35	Number	31	95	49	46	1204	12.67	126
	%	24.6	75.4	39.7	36.5			

(2) Respiratory symptoms among platers in plant no. 1 and plant no. 35

		Cough Grade 2	Phlegm Grade 2	Chronic bronchitis	Chronic nasal catarrh			Nasal catarrh + chronic bronchitis			Asthma	Total number of subjects
					Winter	Summer	Perennial	Winter	Summer	Perennial		
Plant no. 1	Number	29	23	27	8	1	35	3	0	16	12	115
	%	25.2	20.0	23.5	7.0	1.0	30.4	2.6		13.9	10.5	
Plant no. 35	Number	23	26	28	12	1	33	5	0	11	23	126
	%	18.3	20.6	22.2	9.5	1.0	26.2	4.0		8.7	18.3	

in the two populations, since no significant differences were found in any of the four grades of dyspnoea. Without the help of a clinical examination, sputum tests and measurement, respiratory function tests and radiography, a certain diagnosis of emphysema or bronchiectasis is often not possible, and unfortunately these procedures were beyond the scope of the investigation. However, this limitation weighed equally on the two populations, and as effort dyspnoea is a prominent feature of the symptomatology of both these conditions, it seems reasonable to assume that neither population was the more affected in this way.. This finding is interesting in view of the comprehensive investigation carried out by Brinton et *al.* (1952) for the United States Public Health Service, into the health of 897 workers in the chromate-producing industry, where radiography showed no evidence of excessive pulmonary fibrosis, and the mean vital capacity was actually higher in the chromate workers than in the controls.

A possible explanation of this finding would be that a majority of those in both populations with prolonged cough and sputum production are mildly affected, without being subjectively dyspnoeic, but tests of ventilatory capacity might well have helped to clarify this point.

A large number of subjects claimed to be sufferers from "nasal catarrh," with a duration of 3 months or more each year; The imprecise character of this term throws doubt upon the actual numbers, but a comparison between the positive replies in each population and a division into the seasonal incidence of symptoms is thought to give a rough guide as *to* the relative importance of the major causative factors. It is widely believed that the majority of "Winter only" cases are the result of chronic bacterial infection, and that most "Summer only" cases are caused by seasonal allergy due to pollen and mould spore sensitivity, whereas in perennial cases either chronic infection, allergy, irritation by occupational dust or fume, or tobacco smoking, may be a predominant aetiological factor.

This study shows that "Summer only" cases are few, but in the "Winter only" group there were more controls than platers (10.3% and 7.7% of their respective populations). Numbers were considerably higher in the perennial group, where the position is reversed (20.6% platers, 15.7% controls, with a significance level of 0.5%). Consideration of these latter two *groups* suggests that, as platers seem to be no more subject to chronic upper respiratory infection than the controls, and since the two populations are closely matched for tobacco smoking, this prevalence of perennial "nasal catarrh" among platers was due to occupational causes or allergy. or a combination of the two.

It is beyond the scope of this study to discuss the merits of the different combinations of chest symptoms which would indicate the "chronic bronchitis syndrome," and it was thought best to record the prevalence of symptoms separately. Effort dyspnoea has been discussed above. The significantly higher proportion of platers who suffered from Grade 2 cough and Grade 2 phlegm production is shown in Table 6, where it can also be seen that the less severe Grade 1 symptoms (occurring first thing in the morning only), affects more controls than platers, but this is within chance *limits.*

RESPIRATORY ALLERGY

The graphs (Figs. 1 and 2), showing the age at onset of symptoms among subjects with respiratory allergy, indicate clearly the different patterns of seasonal (Summer) hay fever and asthma. It should be noted that these subjects all lived in England, and therefore the question of ragweed pollen allergy does not arise. 80.7% of platers and 83.9% of controls were over the age of 30 years at the time of questioning, so the graphs give a reasonable picture of the first three decades, but it is possible that some of those in the middle age groups would develop symptoms later in life.

Figure 1 demonstrates that most seasonal hay fever sufferers commence symptoms in the second decade. and this appears to be in line with general clinical experience. Bray (1937) found that the age-incidence of hay fever was greatest from 15 to 40 years, only 5% of cases developing before the age of 5 years. By contrast. the onset of asthma is shown to have its peak in the first decade, which confirms the findings of Ogilvie (1962). who described a follow-up of 1000 asthmatics of all types over a period of more than 25 years; 62.4% of these subjects first had asthmatic symptoms before the age of 16 years. In a survey of 388 asthmatic boys up to the age of 15 years, Morrison Smith (1961) found that in 83.25% the onset was before the age of 6 years.

There have been many attempts to estimate the prevalence of hay fever and asthma in the general population. In the United States, Blanton *et al.* (1953) screened 37497 persons over the age of 15 years for respiratory allergy history; of these, 3.2% of the total whites had summer seasonal hay fever, and 2.8% bronchial asthma. Standard text books give a prevalence ranging from 1.5 to 5.3% for seasonal hay fever, and 0.5 to 3.3% for asthma. There do not appear to be any published figures relating to a population of industrial manual workers in England, but the figures for the study under discussion (3.9% for platers and 5.5% for controls) is not far out of line so far as seasonal hay fever is concerned; those for bronchial asthma (13.1% for platers and 9.8% for controls) on the other hand seem very high, even when allowance is made for the exceptional dust and fume hazards to which the plater population was exposed, and also for the probability that some of the subjects, who answered positively to the question about attacks of shortness of breath with wheezing, were in fact chronic bronchitics.

Table 9 shows conclusively that the higher incidence of asthmatic symptoms among platers occurs predominantly in the heavily dust-exposed group.

Industrial environment would not have been likely to have any relevance to the prevalence of seasonal hay fever, which is presumed to be caused by grass pollen and mould spore allergy, but it might be expected to play a part in the case of asthma. If an affirmative reply to the question "Have you ever had branchial asthma?" were to be taken as the sole criterion, the figures for asthma would have been 3.4% platers and 2.6% controls, but these would almost certainly have been too low, and it is reasonable to assume that a considerable proportion of those with attacks of shortness of breath with wheezing were, in fact, asthmatic.

It was impracticable to attempt an aetiological classification of asthmatics in this study, but chromates are well known to be potent skin sensitisers, producing Type IV allergic reactions, and it is possible that they are also capable of inducing, in some cases, the reagin-mediated Type I sensitivity typified by respiratory allergy. Indirect support for this concept comes from the well-documented reports, where modern immunology laboratory techniques have been employed. showing that other inhaled chemical agents (tolylene di-isocyanate, piperazine di-hydrochloride, amino-ethyl ethanolamine, platinum salts) can be directly responsible for this type of reaction in the industries in which they are used (Fuchs and Valade. 1951: Bruckner *et* al., 1968; Taylor, 1970; Pickering *et al.*, 1972; Pepys *et al.*, 1972).

Reggiani et *al.* (1973) studied a group of 101 workers who were exposed to chromic acid inhalation in a galvanising department. Of the large number (60%) of persons with subjective symptoms of chronic bronchitis. spirographic changes were detectable only in a small number of cases, whereas investigation of bronchospastic activity showed significant increase in almost 25% of subjects, and steady state CO transfer values were significantly decreased in over 60% of cases. The authors conclude that these tests are much more sensitive than the traditional spirographic method. as far as chromic acid exposure is concerned.

This work has opened up a line of research which might profitably be taken up in the case of both chromium and other chemical substances.

CHROME ULCERATION AND DERMATITIS

Without clinical examination, the value of posing to platers questions about skin and nasal ulceration is limited. Affirmative replies suggested a much lower incidence than that found among chromate handlers by various investigators. The American Public Health Service report by Brinton *et al.* (1952), for instance, found nasal septal perforation in 56.7% of their subjects, and an examination by the author of 41 chromium platers at a plant where the hygienic conditions were unacceptably bad (1964, unpublished), revealed 34.1% with septal perforation and a total of 61.0% with nasal ulceration, including those with perforations. Since skin ulceration and its scars are visible, the figure of 21.8% is probably a close approximation to its incidence in the plater population, but many platers have nasal ulceration and even septal perforation without being aware of it, and therefore the figures shown in Table 8 are almost certainly too low. A comparison of the incidence of symptoms with the duration of exposure shows highly significant increases in the two long exposure groups in each case, which suggests that these injuries were, in the large majority of platers, caused by chromic acid.

The prevalence figure of 24.6% for dermatitis cannot be taken as representing dermatitis due' to chromic acid only, since an unknown number of these cases would be caused by nondermatitic skin lesions, or dermatitis due to other agents some of which could be nonoccupational. Fregert (1969) and his co-workers at skin clinics in several European countries, undertook an extensive patch-testing exercise on dermatitis cases, in which it was found that dichromate gave the highest number of positive reactions (almost 11%) among a number of known skin-sensitising chemicals; the prevalence varied from one district to another,

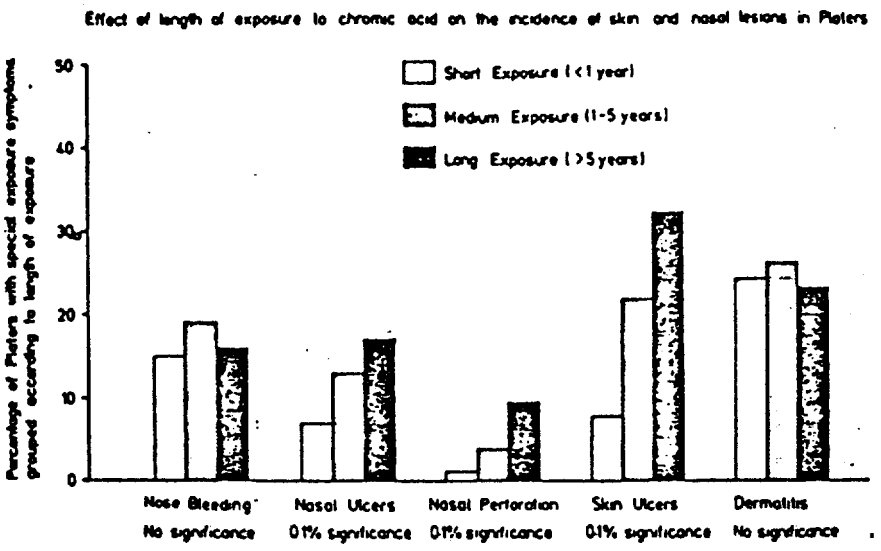

FIG. 3. Effect of length of exposure to chromic acid on the incidence of skin and nasal lesions in platers.

21% of those tested at Bari (Southern Italy) being positive. while the figures for London and Copenhagen were 6 and 3%, respectively. The high proportion of positive reactors at Bari was thought to be due to the large numbers of cement handlers among the building workers in that area. A similar study by Magnusson *et al.* (1968). found that. of 5558 dermatitis cases tested at six of the main Scandinavian centres. 7.4% gave positive dichromate patch-test reactions.

Comparison of the exposure groups.in the present study suggests that .the chance of developing allergic contact dermatitis does not increase with the length of exposure (Fig; 3).

DUST AND CHROMIC ACID EXPOSURE

When Fig. 4 is studied it will be seen that there is a higher incidence of respiratory symptoms in platers. compared with the control population. whether the subjects had high or low dust exposure; but the percentage of persons affected, whether platers or controls, was in almost all cases lower in the "not dust-exposed" group. This strongly suggests that both dust and chromic acid exposure played a part in causing this increase in symptoms among platers, but it is doubtful whether it would be possible to quantify this. The comparison between the workers at two plating plants (Table 10) does, however, tend to confirm this concept, and to suggest that chromic acid exposure was probably the more important factor.

Of recent years, there has been considerable discussion about the relative importance of 'industrial dust exposure, tobacco smoking, urbanisation, etc., as factors in the development of chronic respiratory disorder (Higgins *et* al., 1959; Suis-Cremer et *al.*, 1967; Lowe *et al.*, 1970; Ashford *et al.*, 1970; Lloyd Davies, 1971; Rogan et *al.*, 1973; Morgan *et al.*, *1973).* There appears to be little doubt that coal miners, foundrymen, and workers in cotton, flax, and hemp mills, of whom there are more among platers than among controls in the populations

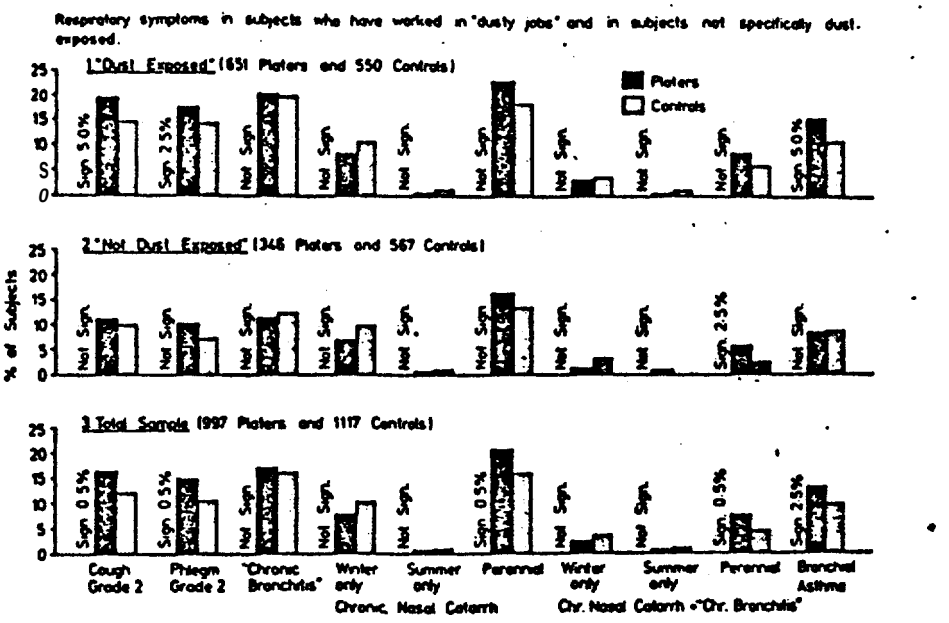

FIG. 4. Respiratory symptoms in subjects who have worked in "dusty jobs" and in subjects not specifically dust exposed.

under review, are particularly liable to develop respiratory symptoms. National statistics do not suggest that workers in the chemical industry are unduly subject to respiratory symptoms (quoted by Higgins et *al.*, 1959), but there are no published reports of the situation in chromium plating. An example of the difficulties surrounding this subject is the report by Fregart (1963) of cases of chrome dermatitis among foundry workers, caused by working with foundry sand containing ground chromium magnesite bricks which had been used as a refractory material—a common admixture according to Fregert. It seems possible that such workers could have been exposed to an inhalent chromium hazard.

A significantly greater number of controls than platers had been employed at a British Rail Carriage Works where asbestos is used for insulation and fire prevention purposes in the building of railway coaches: crocidolite was the most usual form. The symptoms of early asbestosis are marked dyspnoea and, frequently, nonproductive cough. As there was no difference in the prevalence of dyspnoea in the two populations, it does not appear likely that the disparity of numbers of asbestos workers would significantly affect the figures for other respiratory symptoms in controls. The increased cancer risk among asbestos-exposed workers has been confirmed by many authors, and its possible effect on the prospective mortality study, described in the first article, has been noted.

CONCLUSIONS

As a whole, respiratory symptoms were experienced to a greater extent by the plater population than by controls, with the exception of effort dyspnoea which, in the most important Grades 3 and 4, was practically the same in the two populations.

The disparity was seen more markedly in those who had worked in dusty jobs (the larger group), but even in the "not dust-exposed" the same trend is seen, although to a somewhat lesser extent. A more precise evaluation of the relative importance of dust exposure and exposure to chromic acid fume might have been attained had the populations been larger and if the resources of the study had allowed for simple respiratory function tests and chest radiography to be performed.

Bronchial asthma had a high incidence in both these populations of factory workers, compared with what we know about asthma in the general population. It was in the dust-exposed subjects, however, that a significant increase among platers was seen. and this leads to speculation as to whether bronchial irritation from dust inhalation could pave the way for a Type I allergic sensitisation to occur in some cases; a full investigation of a group of asthmatic chromium platers might yield valuable information.

The risk of skin and intranasal ulceration is shown to increase progressively, the longer the period of chromic acid exposure. whereas this does not apply in the case of contact dermatitis. The prevalence figures found by simple questioning without physical examination are thought to be approximately correct for skin ulceration, but too low for nasal mucosal ulceration and septal perforation; for the reasons stated, the figures for dermatitis may be misleadingly high.

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