

An Occupational Hygiene Team*

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with the assistance of

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Occupational hygiene is the measurement and control of the working environment with the object of safeguarding the health of people at work. Traditionally in Great Britain the two ways of approaching industrial health problems which have developed are those of the industrial medical officer from within the factory and the factory inspector through the medium of legislation.

The approach of the industrial medical officer includes treatment of accidents and illness occurring at work, provision of first aid services, supervision of general factory hygiene, and advice to management on any question involving medical policy. He is not able, however, accurately to assess and control dust, fume, radiation, noise, and other hazards without the help of engineers and chemists trained in this work. Such help is at present almost impossible to obtain, unless the particular hazard is so spectacular or has such national importance or research interest as to engage the attention of the Medical Research Council or a special university department.

The approach of the factory inspector is, in the main, that of a safety engineer, and it is to his credit that our industry is so well supervised from this standpoint. But the factory inspector is also charged with the prevention of occupational disease, for example in Section 47 of the Factories Act 1937, which deals with the control of dust and fume "likely to be injurious or offensive". For this task he is not well equipped, since he has no means of estimating whether a dangerous amount of air pollution is present and must depend on making an intelligent guess. He may seek the help of the engineering and chemical branch or call in one of the 16 medical inspectors. The latter are experienced in industrial hygiene but are expected to cover all factories in England, Scotland, and Wales. The medical inspectors have facilities for clinical examination and haematology but are limited in the number of radiographs which may be taken. Samples of the substance in use or of the air contaminant itself can be sent to the Government Laboratory but, because only occasional samples can be analyzed, few, if any, complete and repeated factory surveys can be made.

A situation exists, therefore, in which many health hazards, particularly in small factories, remain undetected and, if known, cannot be controlled with certainty. We believe, in fact, that much occupational disease is never diagnosed or notified, and that discomfort due to working conditions, as distinct from actual

illness, is common. These must, in the aggregate, be responsible for considerable loss of efficiency or working time. A few large factories with particular hazards, such as the lead battery manufacturers and the chemical industries, have realized this deficiency and have organized a limited form of occupational hygiene in which engineers, chemists and medical officers work together to assess and control hazards. But most factories remain without any such service.

Other countries, notably the U.S.A., have long had such occupational hygiene services organized by the States. These have been described elsewhere (Nash, 1952), and the capabilities of a fully trained industrial hygiene engineer have been stressed by Herford (1951).

The need for industrial hygiene control in the small factories on the Slough Trading Estate was realized by the Nuffield Foundation and the staff of the Slough Industrial Health Service. One of us (R.J.S., an engineer) was therefore sent to the Harvard School of Public Health for training in occupational hygiene techniques under Professor Philip Drinker. On his return in October, 1950, the occupational hygiene team was formed by the collaboration of the present two writers, the first of whom (P.H.N., a physician) had already been trained at Harvard. Later the team was completed by the addition of a chemist, Miss Joan Bedford. No laboratory was available until January, 1952, when, again through help from the Nuffield Foundation, one was made available to us at the London School of Hygiene and Tropical Medicine. The Occupational Health Sub-Unit, so formed, was linked with the departments of public health and applied physiology of the University of London.

In planning and equipping the laboratory we had to rely largely on our own experience since there was no other unit in the country equipped to investigate any type of health hazard on request. The principle we try to follow is one of service to industry rather than long-term research, and problems are not rejected because they seem either trivial or unlikely to lead to a promising line of research. If a health risk is thought to exist, either by management, employees or ourselves, it is investigated. In this way we are often able to say that no hazard is present, but frequently unsuspected hazards have been uncovered and eradicated.

When such an investigation is completed a detailed report is sent to the firm concerned, dealing with medical and engineering aspects, figures for air concentrations of toxic materials, photographs if helpful, and suggestions for appropriate action. It has been found by experience that advice given in this form is far more effective than verbal arguments in producing a positive response from managements.

Twenty such reports on the use of toxic substances have now been sent to firms, each involving an investigation with only a small number of men at risk. These necessitated the use of many techniques, chemical, physical, and pathological. Sometimes it happened that after much work had been done on a method for estimating a toxic substance the factory would abandon the process before the investigation could be made. Usually

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this was due to a setback in trade ; on one occasion the reason was the employees' objection to the process. The investigations illustrate hazards found in a group of small, modern factories, all of which already had the benefit of an efficient industrial medical service. In older factories, or those with less efficient or no medical arrangements, conditions would certainly be worse.

Some examples of these investigations are given below, not so much for their intrinsic interest as to illustrate the type of work done by a small occupational hygiene team, working only part time.

Asbestos

There are various methods for collecting and counting asbestos fibres. In the U.S.A. the impinger is used as a standard sampling device, whereas in England the thermal precipitator is preferred.

We collect samples in sedimentation cells to give an absolute standard, a method only suitable for high concentrations, and by thermal precipitator to give working standards. The Watson konimeter is used as a guide to the collection of thermal precipitator samples and to demonstrate rapidly to managements the degree of dustiness of the air. It also gives an indication of variations in the concentration of dust and its source.

Sedimentation cell and thermal precipitator samples are counted on a Beck microprojector using a 3.75 mm. objective and a 25x eyepiece at a magnification of 2,500 diameters. Samples are incinerated before mounting and only fibrous particles are counted. We usually compare our counts with the following suggested limits, based on a 40-hour working week :—

(1) Five million particles per cubic foot (equivalent to 175 particles per cc.) of fibrous dust down to 0.9 microns long (American Conference of Governmental Industrial Hygienists, 1952) ; (2) 30 particles per cc. of fibrous dust down to 10 microns long (Vorwald, 1952).

In an operation involving the cutting of asbestos board with a bandsaw, a considerable amount of dust was seen to be produced, even though the saw was fitted with a standard type of exhaust system. Counts showed the operator's average exposure to be 170 particles per cc. of all fibrous dust and 20 particles per cc. of fibrous dust over 10 microns long. Regular medical examinations and chest radiographs of this man, who has been on the job for eight years, have so far shown no evidence of asbestosis. A special type of external local exhaust, in conjunction with a transparent guard, is being developed in the hope that it will both control the dust and reduce the risk of accident. As the dust concentration is so near the accepted maximum limit the continued wearing of a suitable mask has been recommended as a temporary measure.

In another factory asbestos was sieved by hand and added to a solution of bitumen in a tank. Counts in the operators' breathing zones ranged from 3,600 to 11,000 particles, larger than 0.5 microns, per cc. The work was, however, intermittent, and the average concentration for a 40-hour week was in the region of 800 particles per cc.

Medical examinations, including vital capacity readings and chest radiographs of the four men concerned, revealed nothing abnormal apart from the presence of a few single asbestos bodies in sputum samples. Two of the men had been on the process for four years, one for three, and one for two years.

A large measure of control was achieved by using a different grade of asbestos packed in multi-wall paper bags instead of cloth bags. This reduced the aggregation of the material due to moisture, and sieving became unnecessary. Although the tanks were fitted with an exhaust system to remove solvent vapours, this was evidently inadequate for the control of asbestos dust. An external local exhaust system was therefore added and, as a result, dust concentrations fell to the region of 740 particles, larger than 0.5 microns, per cc. The duration of the operation had now been shortened by the elimination of sieving so that the average concentration of dust in this size range was estimated to be 30 particles per cc. for a 40-hour week. Alterations were then made in the design of the exhaust hoods which resulted in an increase of air velocity over the operation up to 150 feet per minute. Average concentrations fell to less than 10 particles per cc. and the process was considered entirely safe.

Exhaust systems in factories are often installed without preliminary measurements of the quantities of solvent or dust which they will have to remove, and no subsequent check on their effectiveness is made. For this reason they are frequently over-elaborate or almost useless. In one factory where many workers were potentially exposed to asbestos dust, conditions were found to be safe whether the very extensive exhaust system was in use or not. In practice it reduced the dust count by only 10%.

In another process eight girls were engaged in dusting down an asbestos product with hand brushes. The amount of dust produced was very small, but no less than 12,500 cubic feet of air were withdrawn from the building by the exhaust system every minute. No provision was made for heating the incoming air and for this reason the operators complained of cold draughts in the winter. The air removed by the exhaust system was passed through bag filters before discharge and this filtered air was found to contain a negligible amount of asbestos dust (less than 20 particles of all sizes per cc.). It was therefore recommended that 100% recirculation of air be permitted in cold weather.

This particular system was unnecessarily elaborate and a far cheaper installation would have sufficed.

Benzol

In a factory producing steam glands, oil seals, and other packings, four men were engaged on a process involving the use of benzol (90% benzene C_6H_6). They had been observed by Dr. M. E. M. Herford (appointed factory doctor) and one was found to be suffering from chronic benzene poisoning. He had no symptoms but a blood count showed total white cells to be 4,800, of which 29% were polymorphs. Although he has been

removed from contact with benzol for two years, his polymorph count is still low.

Two other men showed transitory depression of the polymorphs in one count only.

As soon as this hazard was discovered, an environmental survey was carried out and the concentration of benzol in the air measured at the various operations in the department. The principal method used was that of Siegel and Burke (1939), but the D.S.I.R. method (1939) and a Poole explosimeter were also used for comparison.

General room concentrations of benzol ranged from 45 to 460 p.p.m. and breathing zone concentrations varied at different stages of the process from 60 to 600 p.p.m. (The threshold limit for benzol accepted by the American Conference of Governmental Industrial Hygienists, 1952, is 35 p.p.m.)

An exhaust system was then installed and, as a result, the air concentrations of benzol, both in the general atmosphere and breathing zones, fell to the region of 15 p.p.m. Occasional brief exposures to concentrations as high as 300 p.p.m. still occurred. Urinary sulphate ratios (conjugated sulphates : total sulphates), determined on urine specimens from the operators, have not been above 2 in 10. This shows that some absorption of benzol is possibly still occurring (Goldblatt, 1951) but conditions are undoubtedly very much improved.

In another factory, where dry batteries were made, certain components were dipped in benzol and allowed to dry in a brick chamber. About 150 gallons of benzol were evaporated daily into this chamber which was exhausted and the fumes passed to a recovery plant. It was necessary for the operator to enter the chamber every few minutes to move the components along so that the chamber could be completely filled. This appeared to us to be a very dangerous exposure. Air measurements confirmed this, the concentration of benzol in the chamber being over 1,000 p.p.m. and probably of the order of 4,000 p.p.m.

Blood counts carried out on the seven men concerned revealed the presence of hypochromic anaemia with some macrocytosis in one of them. As he gave a history of past anaemia it was difficult to assess the role which benzol played in this, but he was given a job away from the process. Three of the operators have at some time shown transitory low polymorph counts (i.e. less than 2,500 polymorphs per c.mm.).

Detailed suggestions were made to the management as to how the process could be arranged so that the operator need never enter the chamber. These were carried out and the process is now safe.

Trichlorethylene

In a factory where paper was laminated on Dickson machines the adhesive was changed to one containing polyvinylacetate with trichlorethylene as a solvent. After a few days we had an urgent call from the firm saying that employees were being affected by the fumes and that one had "passed out".

A visit to the factory on the next day showed that the adhesive was spread by the machine on a roll of plastic which was pressed on to a sheet of card between two rollers.

To ensure rapid drying, one of these rollers was gas heated and this resulted in the evaporation of a large amount of trichlorethylene. The air smelled strongly of this substance.

Six operators were interviewed and urine samples were taken from four. At the same time air samples were taken for the measurement of trichlorethylene. The chief complaint was of difficulty in keeping the eyes open and of falling asleep during the lunch break and on reaching home. Examples were a man who had sat down to watch television and promptly fallen asleep until wakened by his wife at bed time, and the young girl who was reported to have "passed out". She had arranged to spend the evening at home with her boy friend and, though he was present, she slept solidly for four hours and had to be wakened at midnight to say goodnight.

Evidently a considerable hazard was present and the air samples and urinary trichloroacetic acid values confirmed this (Table 1).

TABLE 1
ANALYSIS OF TRICHLORETHYLENE IN AIR AND TRICHLOROACETIC ACID IN URINE

Operator	CHCl=CCl ₂ in Breathing Zone (p.p.m.)	Trichloroacetic Acid in Urine (mg./l.)	
		Time of Exposure	One Week after Exposure Ceased
A	390	486	12
B	250	334	24
C	—	153	29
D	—	39	24

General atmosphere 10 ft. from machine 200 p.p.m. CHCl=CCl₂
 Concentration close to roller 1,460
 Threshold limit 70

The threshold limit accepted by the American Conference of Governmental Industrial Hygienists (1952) is 100 p.p.m. for a 40-hour week. The average working hours in this instance were 60, so that it was advisable to take 70 p.p.m. as a maximum allowable concentration. By this standard air concentrations were many times the safe limit. The urinary trichloroacetic acid level was also very high. A figure of 70 mg. per litre has been mentioned as the level at which signs of intoxication are likely to appear and the desirable limit is probably about 6 mg. per litre (Ahlmark and Forssman, 1949). There were appreciable quantities of trichloroacetic acid still present in the urine samples one week after the process had been stopped. Normal urine, measured as a control, contained none.

As soon as the measurements had been made the use of the particular adhesive was discontinued and another which did not contain trichlorethylene temporarily substituted. Plans for a suitable exhaust system, with suggestions for the recovery of the solvent, have been submitted to the firm and are being put into effect. As soon as the exhaust system is installed, further air concentration readings will be taken to check its effectiveness. Since one roller is gas heated there is a theoretical possibility that phosgene might be formed. Measurements will therefore be made for this also.

Lead and Antimony

A small study was made of an operation in which a man was working up to 12 hours daily casting a lead-antimony alloy (95% lead, 5% antimony). He had made no complaints but it was felt that a health hazard might be present.

Medical examination revealed nothing abnormal. The red cells showed no stippling. The urine contained 0.13 and 0.08 mg. of lead per litre on two occasions, values which are below the acceptable limit of 0.2 mg. per litre for lead workers. No coproporphyrin was detected.

Air sampling was carried out by a number of small sampling units, drawing air through filter paper at 1 litre per minute throughout most of the working day. Ten-minute samples were also collected by a larger unit at 3 cubic feet per minute. By this means variations in concentration could be detected and integrated to find an average value. The mean concentration of lead was found to be 0.08 mg. per cubic metre and that of antimony 0.87 mg. per cubic metre. The threshold limit for lead in the air is generally taken to be 0.15 mg. per cubic metre and the operation therefore appeared safe from this point of view. The probability of the safe limit being exceeded was calculated to be less than 0.1%. The concentration of antimony was, however, higher than the threshold limit now accepted in the United States of America of 0.5 mg. per cubic metre, although no ill effects could be detected in the operator who had been employed on the process for 18 months.

Recommendations were made for a simple improvement in the ventilation system, which has now been carried out. It is interesting to note that although lead was the main hazard suspected, since it formed 95% of the alloy, it was the antimony which was found to be present in undesirable amounts.

Air Pollution Outside the Factory

A complaint was received from a factory about fumes which emanated from the exhaust system of a nearby magnesium foundry. It was said that these were irritating to the nose and throat, and caused corrosion of bright metal parts.

The air was sampled for aldehydes, carbon monoxide, fluorine, fluorides, sulphur dioxide, sulphates, and total acidity. With the exception of sulphur dioxide, measurable amounts of all these pollutants were found in the air immediately outside the factory. In only one case, that of sulphates, was the concentration above the threshold limit. The total acidity of the air was, however, fairly high, 5.1 mg. per cubic metre calculated as H_2SO_4 . Spot tests carried out for nitrates, nitrites, phosphates, chromates, and esters were negative.

It was thought that the acidity of the air certainly explained the corrosion of tools and other metal parts in the factory but we were unable to say definitely if any risk to health were present. As in the case of fog, too little is known about the possible synergistic effects of small quantities of many irritants in the air, and the chemical changes which may occur in them through the

effect of atmospheric conditions or sunlight, to give an opinion with any certainty.

Chromium Plating

It is well known that in chromium plating there is a risk of ulceration and eventual perforation of the nasal septum for which a special nose ointment is prescribed in the regulations as a preventive. This ulceration can only occur, of course, if there is a sufficient quantity of chromic acid mist in the air breathed. In order to reduce this, exhaust ventilation is applied to the plating bath, and foaming agents are occasionally used to minimize generation of mist.

The generally accepted safe limit is 0.1 mg. of CrO_3 per cubic metre of air for a 40-hour week. We have measured the concentration of chromic acid mist over several plating baths in small factories and have usually found it to be below this limit. In such cases the use of a nose ointment is probably unnecessary.

The chromic acid is collected in distilled water by the midget impinger and estimated by a colorimetric reaction. This technique is so simple that it could easily be carried out by laboratory technicians, safety officers, or other responsible people, and would give a definite indication of the safety or otherwise of a particular bath.

General Factory Hygiene

Minor hygienic improvements in factories often bring about a considerable increase in the comfort and well-being of employees. Under this heading we include such things as improvements in lighting, heating, ventilation, canteens, toilets, and first-aid facilities. Recommendations are best made in writing and, if they are extensive, a full report is sent in the same way as for a health hazard. The following example may be of interest.

Conditions in a plant for the manufacture of "ice lollies" were considered poor by the District Inspector of Factories who referred the firm to us for specific advice. The factory was centred round a large brine (calcium chloride) freezing bath. At one end was a defrosting tank which gave off large quantities of steam. Everything was dripping wet from condensation, the floor slippery and covered with waste material, and the employees, clad in street clothes, worked in a haze of steam. There had been dermatitis among those working at the bath; cloakroom and first-aid facilities were poor, and the toilets needed many improvements. The management were, however, anxious to improve conditions and asked for advice as to the best procedure.

A survey was carried out which included records of air temperature, humidity, air movement and radiation in many parts of the factory, and photographs of situations needing improvement. The relative humidity was found to be 84% (air temperature 65° F.). The report to the management recommended installation of a polished canopy with an exhaust system over the two baths to reduce condensation, improvements in heating, seating, floor drainage, and salvage of waste material. Also suggested were the provision of a cloakroom, improvements to toilets, the wearing of white work

clothing, protective clothing and barrier cream for the brine workers, and detailed advice on first-aid services and equipment.

Most of these recommendations have now been put into practice and conditions are very considerably improved.

Conclusions

This paper describes some of the investigations which we have carried out in a group of small factories. Besides this work a very large number of smaller problems have been dealt with. These involved giving advice on such things as general and local ventilation, lighting, heating, eye protection, skin protection, respirators, protective clothing, handling of radioactive substances, first-aid for special purposes such as bitumen and hydrofluoric acid burns, and accident prevention. In addition considerable work has been done outside the Slough area, sometimes for large concerns such as British Railways and London Transport. Some requests for help have had to be refused owing to pressure of work. This has been done with great regret since it is a principle of the team to tackle any problem which appears to constitute a health risk in any particular factory, unless it is too extensive for a unit of our size.

Two conclusions may perhaps be drawn. The first is that since this amount of work was necessary in a group of comparatively modern small factories comprising less than 15,000 workers in all, there must be many thousands of dangerous, or at least uncomfortable, situations in other parts of the country which could be put right by the application of known industrial hygiene techniques. Some investigations have admittedly been done in which no hazard was revealed. Such enquiries help to promote good relations in industry by removing from the minds of employees suspicions that their work may be unhealthy. Scientific evidence is acceptable to both sides where verbal reassurance, even from a factory inspector, may fail to convince. Some situations, however, have proved to be dangerous, perhaps even to life, such as the benzol and asbestos exposures reported above. Others, like the

trichlorethylene exposure, were at least very uncomfortable.

The second conclusion is that to deal adequately with these hazards very close cooperation between physicians, engineers, and chemists trained in this work is needed. We have been particularly fortunate in starting as a small team, since closer personal cooperation has been possible than might have been in the case in a larger unit. We prefer to visit factories together so that an immediate appraisal of the problem can be made from all points of view. When separate surveys have been conducted we have invariably agreed regarding the presence or absence of a hazard and the form which any investigation should take. Such teamwork between different specialities has long been practised in medical research; it is just as necessary in occupational health.

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The first conference of the recently formed British Occupational Hygiene Society will be held at the London School of Hygiene and Tropical Medicine on Monday, November 2, 1953.