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OCCUPATIONAL EXPOSURE TO TRICHLOROETHYLENE IN METAL CLEANING PROCESSES AND TO TETRACHLOROETHYLENE IN THE DRYCLEANING INDUSTRY IN THE U.K.

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Abstract—Personal monitoring surveys are being carried out to measure time weighted average concentrations to which operators may be exposed when using trichloroethylene for metal cleaning and perchloroethylene for professional drycleaning. The technique is based upon the Sipin personal sampler which continuously draws from the vicinity of the operator's face, a sample of air, which is passed over activated carbon to adsorb the solvent vapour. Subsequently the solvent determination is carried out by GLC (gas–liquid chromatography). Preliminary results are given for levels of exposure to each solvent which indicate that the large majority of installations operate well below the Threshold Limit Values (TLVs). The value of this technique in diagnosing the causes of high solvent levels is exemplified. The present generally satisfactory levels of solvent in working places result from years of persevering effort to promote safety. Still higher levels of safety will be promoted in new guidelines for drycleaning and for metal cleaning which will be available early in 1979.

INTRODUCTION

THE CHOICE of solvents for industrial cleaning applications in engineering, electronics and textiles is heavily predisposed towards the family of halogenated hydrocarbons [of which trichloroethylene and perchloroethylene (tetrachloroethylene) are members], because of their good solvent properties and their non-flammability. They are stable, of low reactivity and eminently suitable for repeated recovery and reuse; they are readily available and the scale of manufacture is such as to result in prices which make solvent based cleaning processes competitive with alternative systems.

Trichloroethylene has been the major solvent used in the engineering industry since the mid-1930s and it is currently used in around 10,000 locations throughout the U.K. Nearly all manufacturing operations using metals involve, at some stage, the need to clean in order to allow inspection or measurement, to enable further finishing processes such as plating or painting to be carried out, or in order to give a good finish prior to sale.

Along with white spirit, trichloroethylene was used as a major solvent for drycleaning up to the mid-1960s around which time, because of certain dye bleeding problems caused by this solvent, there was an almost complete change to perchloroethylene, which is now by far the major solvent for factory, unit shop and coin-operated drycleaning establishments.

The toxicologies of trichloroethylene and perchloroethylene have been extensively studied, and have resulted in the setting of standards for occupational exposure which vary from country to country depending upon interpretation of the published data and upon the philosophy of regulations. In the U.K. the Threshold Limit Value

(TLV) for both solvents is 100 ppm (HEALTH AND SAFETY EXECUTIVE, 1978). The most recent comprehensive toxicity reviews are those published by NIOSH in the respective criteria documents (NIOSH, 1973, 1976). The effects on the central nervous system causing anaesthesia/narcosis are well known and are relevant to working conditions if a fault or accident occurs where solvent concentrations are substantially in excess of the TLV. The results of recent work by the U.S. National Cancer Institute and others on the carcinogenicity of these two solvents are inconclusive about the risk to humans and firmer evidence is required before this can be regarded as a major cause for concern.

The development of appropriate plants and machines, with their associated work practices, has resulted in generally satisfactory levels of exposure of operators to solvent vapours in the work place. So far as we are aware, there is no evidence that the health records of personnel using solvents differ significantly from the norm for industry as a whole.

Over the years, continuing efforts have been made to minimize operator exposure to volatile solvents and in this connection the dry cleaning industry has recently published guidelines for safety in professional drycleaning and ICI Ltd has in preparation metal cleaning safety guidelines.

APPARATUS AND METHODS

The most commonly used technique for measuring solvent vapour concentrations in air has been the colorimetric method employing proprietary equipment such as that of Draeger, Kitagawa etc. and this sort of technique will continue to be used for spot checks because of its convenience and reliability. In skilled hands it is useful, but the result obtained relates only to the concentration of solvent vapour in the air at the point sampled at that precise moment.

Since the principal concern in the use of solvents is the amount breathed by an operator, it seemed that some form of continuous monitoring, preferably of the air being breathed by the operator, would provide a better guide to the suitability or otherwise of the working atmosphere. Furthermore, since the TLV is defined as the time weighted average concentration of vapour which may be breathed by a person over an 8 h working day or 40 h working week, continuous monitoring over such times provides the right basis for comparison of a working atmosphere against the TLV.

At the time when this investigation was being considered there were two general sampling methods which suggested themselves: (1) the passive sampler, such as a 'button', consisting of activated carbon behind a permeable membrane; and (2) the personal sampler pump, whereby air containing solvent vapour is drawn through an adsorbent bed of carbon for subsequent analysis. Up to that time we had been unable to produce a 'button' which was capable of giving reliable results. It was found that the amount of solvent vapour adsorbed, for both trichloroethylene and perchloroethylene, was affected by the velocity of air stream in relation to the 'button' and on the relative humidity of the air. The personal sampler pump, on the other hand, was demonstrated to be reliable and accurate.

The method samples the air being breathed by the operator continuously over the period of the working day, say 8 h, adsorbing the solvent for subsequent analysis to give the time weighted average concentration. However, such a determination reveals

nothing about the variation of solvent concentration with time during the 8 h period. That there are such variations is certain during the variety of tasks performed. However, whilst this is acknowledged to be a shortcoming of the method, there is at present no convenient portable method available for continuous recording of solvent vapour concentrations; the MIRAN Infra-Red spectrophotometric analyser has been used for static continuous recording of solvent concentrations, but it is not convenient for personal sampling. The main justification for the emphasis which has been placed upon health and safety over the years has been: (1) to so influence machine design, installation and ventilation, maintenance and operation as to minimize the concentration of solvent vapour to which an operator is exposed; and (2) to reduce the possibility of an accident and to protect the operator and others in the event of an accident. With reference to the first of these it seems logical to use the results of personal monitoring as the prime criterion against which to judge the standard of a work place from an occupational health point of view.

To this end the techniques have been developed for personal monitoring for trichloroethylene and perchloroethylene and surveys embarked upon in the engineering and drycleaning industries. The surveys have not yet been completed, but the purpose of what follows is to describe the method used, the results obtained so far and to draw preliminary conclusions.

Analytical method for personal monitoring

The method consists of drawing a continuous sample of air, from the vicinity of the operator's face, at the rate of 10 ml min^{-1} using a Sipin Personal Sampler. The air passes through activated carbon, Sutcliffe Speakman 207C (20–45 mesh), contained in two copper tubes 6 × ¼ in. o.d. in series, the second of which is to guard against breakthrough from the first. Any trichloroethylene or perchloroethylene in the air is adsorbed on to the charcoal. The two tubes are connected by means of a copper U-tube and one end is connected by means of ¼ in. Tygon tubing to the inlet of the 'Sipin' pump. The open end of the sampling system is fastened by a clip to the operator's lapel. The volume of air passing through the adsorber tubes is known from the number of pump cycles on the pump counter recorded during the experiment. The flow rate is set at the start of the experiment at 10 ml min^{-1} using a bubble flow meter and checked at the end of the experiment. In a normal 8 h experiment the total volume sampled is 4.8 l.

At the end of the day each of the tubes is sealed with rubber caps. To analyse for the adsorbed solvent, the carbon from each of the copper tubes is transferred into a vial containing 5 ml of cooled (0°C) carbon disulphide and sealed with a Suba seal. The contents are shaken and allowed to stand for 1 h. Then 1 ml of supernatant carbon disulphide is injected into a Perkin Elmer F33 FID isothermal gas chromatograph using a 5 ft × ⅛ in. o.d. stainless steel column packed with 30% Apiezon L on 80/100 mesh Chromasorb BH–T100 column packing. The chromatograph is calibrated by sampling known mixtures of trichloroethylene or perchloroethylene in air.

Test protocol

After the preliminary experiments in the laboratory and first field trials in local drycleaners, it was decided that the selection of establishments for testing should be

made randomly. In the geographical areas covered by each Sales Office, the name of every fifth professional drycleaning customer from the computer sales print-out was written on a slip of paper and the required number of sites for random testing was drawn from the collection of slips. In almost every case, through the good offices of the local representative, the collaboration of the drycleaner was obtained.

There are probably around 4500 professional drycleaning establishments in the U.K. The majority of these are High Street shops where the full drycleaning service can be carried out, using a drycleaning machine usually of 25 or 40 lb dry weight loading. Such a shop would also be equipped with facilities for spotting and pressing garments. Standards of ventilation vary widely from highly efficient mechanical exhaust systems to those which rely solely upon natural ventilation. Likewise, inevitably, there are wide variations in attitude towards machine maintenance and housekeeping.

There are significant numbers of factory installations, some drycleaning domestic work from receiving shops or in association with a laundry and others processing workwear. Generally larger machines are used in factories, up to perhaps multiple installations of 150 lb dry weight loading machines. General ventilation perforce is usually to a good standard and carbon recovery units are standard on machines in excess of 60 lb loading.

Personal monitoring tests for perchloroethylene have been carried out in 90 unit shops and 41 factories so far.

For metal cleaning plants the results so far are from a preliminary study based upon 30 factory sites chosen by ICI convenient to Mond Division headquarters at Runcorn and upon customers who were judged likely to be willing to co-operate in the study. Most of the plants in this first part of the study relate to open-topped machines, since these should give higher levels of exposure than enclosed or automated machines.

The next phase of the metal cleaning study has already begun, based upon a random selection of proposed test sites.

The majority (90%) of metal cleaning plants are open-topped and for these the operator stands within 1 m of the plant top to manipulate the work in the plant. Otherwise the component to be cleaned may be handled with a hoist mechanism, manually in baskets or by the use of a semi-automatic lift with manual transfer between compartments.

In most cases measurements were made on four or five separate days in the working week on each machine operator. Before carrying out the experiments the management and operators involved were instructed in the procedures to be adopted. A member of ICI staff started the experiments on the first day and thereafter the personnel involved at each site checked the flow rate, the number of pump cycles and sealed the carbon tubes after each day's tests. The carbon tubes were then analysed in ICI laboratories and the results made available to the customer concerned together with any recommendations for modifications in practices or equipment. To this end, at the time of the test, information was recorded relating to the installation, such as the type of work undertaken, machine, ventilation, layout and size of work area etc. to facilitate drawing conclusions from the results. One important pre-requisite for co-operation has been that the individual result shall be confidential to the participating company.

RESULTS

1. *Drycleaning*

Because of the major differences which exist between unit shops and factories it is appropriate to consider the results separately for these two types of installations. The results of 333 one-day tests in 90 unit shops are shown in Fig. 1 and of 160 tests in 41 factories in Fig. 2; the latter include both domestic and overall cleaning.

For the unit shops 97% of the results were below 100 ppm, 88% below 50 ppm and 74% below 30 ppm.

For the factories 93% of the results were below 100 ppm, 76% below 50 ppm and 53% below 30 ppm.

These results indicate that the large majority of operators in each area are working in concentrations of perchloroethylene well below the TLV. Where the results are in excess of 100 ppm, personal monitoring has been a useful diagnostic technique to draw attention of management and operators to shortcomings in working practices or installations.

For example, two unit drycleaners replaced aged machines more quickly than had been intended because of high levels caused by leaks on the machines. At two factories,

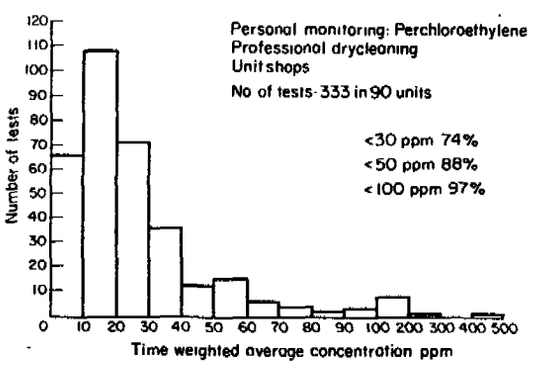

FIG. 1. Personal monitoring of perchloroethylene. Professional drycleaning in unit shops.

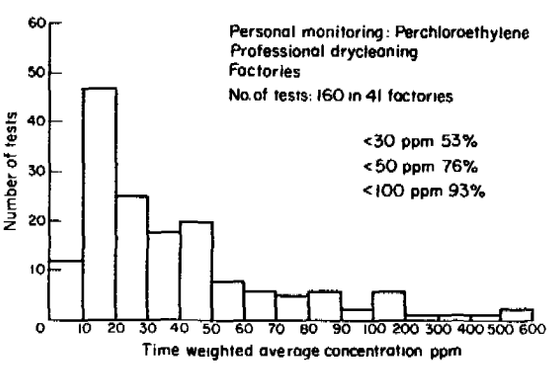

FIG. 2. Personal monitoring of perchloroethylene. Professional drycleaning in factories.

managers found that isolated high results were due to spillages of which they were previously unaware and procedures have since been changed to remove this risk. Not infrequently it has been possible to suggest improvements to the ventilation arrangements where high results have been found.

The fact that the exposure levels in factories generally are higher than in unit shops is probably caused primarily by the differences in the machines used, 25–40 lb in unit shops and 100–150 lb in factories. Also, with the larger machines the volume of work processed per shift is very much higher and the larger cage requires the operator to approach closer to the machine to remove the garments after cleaning. In addition, one operator may be using up to three machines continuously.

The encouraging aspects of both sets of results are:

(1) that the general levels of exposure are significantly below the TLV;
(2) that, if the best current practice is implemented, then resultant exposure levels may be very low;
(3) that poorly operated units can be identified by this technique.

Where high results have been found, it is usually possible to identify one or more of the following causes:

(1) old and worn machines;
(2) poorly maintained or faulty machines;
(3) inadequate or faulty ventilation;
(4) lack of concern or supervision, resulting in unsafe work practices.

2. *Metal cleaning*

The results obtained from this preliminary study at 25 locations with a total of 32 installations are shown in Fig. 3. In total, 212 measurements were taken over 8 h work periods and the results indicate clearly that the exposure levels are well below the TLV. Only in one case did the level exceed 100 ppm and this was caused by too rapid removal of work from the plant. Most of the measurements were below 50 ppm (97%) and 91% were below 30 ppm.

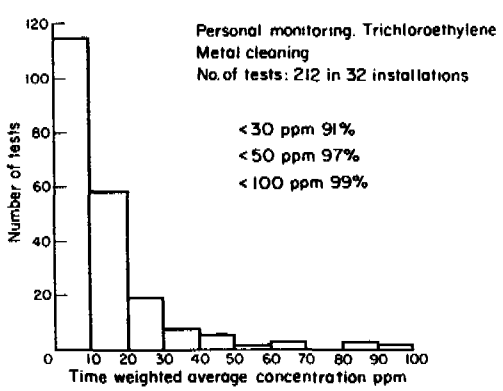

FIG. 3. Personal monitoring of trichloroethylene. Metal cleaning.

In most cases the variation for one operator from day to day was small, but in a few instances considerable variation was observed; this was attributed to a number of factors, such as increased work throughput, incorrect operation, plant cleanout, etc.

There were no unusual features about the plants studied which would make them uniquely able to operate at these low levels of exposure.

It is concluded, therefore, that for metal cleaning plants of current design, operated in accordance with good working practices well known and publicized to the users of trichloroethylene, the exposure of operators to this solvent can be very low and well within the U.K. TLV of 100 ppm.

Those practices which lead to high exposures, and, incidentally, poor solvent economy are well known:

(1) incorrect siting of plant;
(2) excessive drag out due to incorrect operation;
(3) inadequate plant maintenance;
(4) overloading of equipment and incorrect jigging of work leading to solvent trapping.

DISCUSSION

The results of measurements of time weighted average concentrations of trichloroethylene vapour in engineering degreasing operations and of perchloroethylene vapour in drycleaning applications indicate clearly that current practices can result in worker exposure well below the current TLVs. These generally satisfactory conditions have resulted from much sensible attention over the years to minimizing solvent emission from the respective plants and machines used, backed by appropriate ventilation arrangements to cope with unavoidable minimal losses from the process.

In any industry there are likely to be variations in operating standards and practices, but it remains the duty of management and operators to recognize these factors and to aim for minimum exposure which can be and is being achieved in typical U.K. installations.

What has been achieved so far has been as the result of encouragement and example by all concerned operating within a framework of commercial viability with an added spur from the Health and Safety at Work Act and the growing social conscience regarding the well-being of workers. It is believed that a better understanding of the consequences of work practices which are below the standard of the best average achievable with present technology will result in further improvement. It is hoped that the results of the work described above will provide an original and important contribution to development in these areas.

The implications to be drawn from these results in relation to current TLVs is worthy of comment. It is clear that the large majority of the establishments where measurements have been made are maintaining operator exposure levels well below the TLV as a result of following the principle of minimizing exposure rather than working to the TLV. On this basis the TLVs should continue to be 'based on the best available information from industrial experience, from experimental human and animal studies, and where possible, from a combination of the three' (HEALTH AND SAFETY EXECUTIVE, 1978). The TLV then remains as a meaningful datum against

which to compare an actual operator exposure and there is not necessarily any conflict between a TLV of 100 ppm for trichloroethylene and perchloroethylene and the establishments of an operating standard or code at a lower level of, say, 50 or 30 ppm.

Acknowledgements—We thank our colleagues within Mond Division who were responsible for developing the appropriate techniques and carrying out the experimental work and also our customers upon whose co-operation this study depended.

REFERENCES

HEALTH AND SAFETY EXECUTIVE (1978) *Threshold Limit Values for* 1977. Guidance Note EH 15/77. HMSO, London.

ICI LTD (1980) *Metal Cleaning Safety Guidelines*. In press.

NIOSH (1973) *Criteria for a recommended standard for occupational exposure to Trichloroethylene*. U.S. Dept of Health Educational and Welfare.

NIOSH (1976) *Criteria for a recommended standard for occupational exposure to Tetrachloroethylene (Perchloroethylene)*. U.S. Dept of Commerce.

Safety in Drycleaning. Guidelines on professional drycleaning machines, their design, installation and use. Obtainable from the Association of British Launderers & Cleaners and the Fabric Care Research Association.

U.S. DEPT OF HEALTH EDUCATION AND WELFARE (1978) *Special Occupational Hazard Review with Control Recommendations. Trichloroethylene*. Cincinnati, Ohio.

DISCUSSION

J. R. GLOVER (Welsh National School of Medicine, Cardiff): Did you carry out any trichloracetic acid in urine measurements to confirm by biological monitoring that the individual monitoring was really measuring the weight of trichlorethylene absorbed by each individual?

A. J. SHIPMAN: No, but there is an approximate correlation between the concentration of trichloracetic acid vapour in the working atmosphere and the subsequent concentration of TCA in urine.

W. MUDD (Commercial Union Assurance Co. Ltd, Croydon): 'No Smoking' is one of the precautions ICI recommend for use and handling of chlorinated solvents. What is the basis for this recommendation?

A. J. SHIPMAN: In the hot region of the cigarette the halogenated solvents are converted to oxygenated chloro-organics and hydrogen chloride which are likely to be offensive to the taste and harmful to the respiratory system.

A. M. RICKMANN (written question): Do the results presented on exposure to trichloroethylene in metal cleaning processes refer also to liquid/vapour degreasing plant or simply to single phase vapour degreasing plant?

A. J. SHIPMAN: The measurements of workers' exposures for metal cleaning plants cover a wide range of installations including both simple vapour plants and plants with vapour and boiling liquid compartments.