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World Health Organisation
Collaborating Centre
For Occupational Health

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A Comparison of Two Different Methods for Assessment of Dermal Exposure to Non-agricultural Pesticides in Three Sectors

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By

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A COMPARISON OF TWO DIFFERENT METHODS FOR ASSESSMENT OF DERMAL EXPOSURE TO NON-AGRICULTURAL PESTICIDES IN THREE SECTORS

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SN Tannahill, A Robertson B Cherrie, PT Donnan, ELA MacConnell and GJ MacLeod.

SUMMARY

This report describes work carried out by the Institute of Occupational Medicine (IOM) on behalf of the Health and Safety Executive (HSE), to investigate dermal occupational exposures in the non-agricultural pesticides application industries and compare the efficacy of two of the most commonly used methods of exposure assessment.

The study involved field investigations of pesticide application techniques in three industry sectors, specifically pest control, timber treatment and erodible anti-fouling (EAF) paint application. Private and public sector organisations participated in the study. Efforts were made to ensure (within the scope of the study) that the selected organisations and application techniques were representative of the industry as a whole.

The participating organisations in the pest control area were predominantly local authorities (three out of four studies). All five timber preservation companies and all three users of EAF paints (shipyards) were in the private sector.

Operations surveyed in the pest control sector included spraying of water-based formulations of various active ingredients and powder application (primarily on wasps' nests). Spraying of water-based formulations was the method of application used in all of the timber treatment surveys, both sprayers and pump attendants being included. EAF paint was applied by spray guns in all cases, and both sprayers and "potmen" (who assisted the sprayers) were included.

The two methods of assessment of dermal exposure that were investigated were (i) "whole body sampling" wherein the operator wears an absorbent oversuit which is later sectioned, and extracted for analysis of material collected, and (ii) "patch sampling" where absorbent patches are attached to the outer clothing of the operator at various places, and similarly removed, extracted and analysed on completion of the task. Exposure information gathered by these methods was supplemented by visual observation of work practices by experienced occupational hygienists.

In addition, operators were issued with a questionnaire to determine the levels of hazard awareness in the various industry sectors, and attitudes to wearing of personal protective equipment (PPE).

The range of measured dermal exposures in the study as a whole (in terms of the total mass of pesticide deposited on the body) was large, covering some 5 orders of magnitude. The lowest levels were observed in the pest control sector followed by the timber and masonry preservation sector. Much higher levels were observed in the EAF paint sector. In general, dermal exposure for sprayers was greater than for their assistants (pump attendants and potmen).

Much of this work has been aimed at determining the comparison between the patch method and the whole suit method for measurement of potential dermal exposure. This has been assessed (a) for the study population as a whole, (b) for the individual industry sectors, (c) for individual workers, and (d) for individual sections of the oversuits (upper arm etc.).

For the study population as a whole, a generally linear relationship exists between the results obtained by the two methods.

In terms of individual sectors, in the pest control and timber treatment sectors the patch method overestimated the total potential dermal exposure (as assessed by the whole suit method) by, on average, a factor of two. In the EAF paint sector the patch method underestimated the potential dermal exposure by an average of approxiametely 40%.

For individual wearers, the ratios of the potential dermal exposure determined by the whole suit method to the patch method varied from less than to greater than one. As a general indication of variability, about 50% of the ratios were between 0.5 and 2, but several lay well outside this range.

For the individual sections of the oversuit, the patch method both underestimated and overestimated the suit method. The level of agreement between the two methods varied greatly for different sections, the best agreement being for the lower legs, and the worst for the front torso.

The overall indication is that the accuracy of the patch method as a means of assessing potential dermal exposure increases according to the number of patches included in the assessment. Its accuracy in assessing dermal exposure for a group of workers is better than for a single worker, and its accuracy in assessing whole body exposure is better than for assessment of regional exposure.

In general, the patch method has been shown to be an acceptable method for determining the order of magnitude of potential dermal exposure and can be used with confidence to identify operators who are most likely to be dermally exposed to pesticides. However, the results also suggest that there is considerable room for improvement of the patch method, particularly in terms of its accuracy in assessing whole body and regional exposure for individuals. In particular, it is recommended that further work should be be carried out to determine the optimal number and distribution of patches over the body of the worker.

Observation of work practices together with analysis of material collected on absorbent gloves indicated that potentially substantial dermal exposure can arise from contact with contaminated surfaces and from handling contaminated equipment in all industry sectors.

All operators surveyed had some level of hazard awareness. Most thought that skin contact with pesticides should be avoided. Beyond this, the levels of hazard awareness and of personal hygiene varied. Of those surveyed, pest control operators were most knowledgeable about potential health risks and generally took care to avoid skin exposure. EAF paint sprayers knew little of the associated health risks but made efforts to avoid contact because of difficulty of removal of paint from the skin and "burning sensations" in the area of deposition. Operators in all sectors tend to rely more on PPE than on good working practices for limitation of skin exposure.

1. BACKGROUND

Pesticides are widely used in non-agricultural applications including pest control, timber preservation and in erodible antifouling (EAF) paints. Several chemical types are employed as active ingredients. These include chemicals derived from inorganics such as tin, copper, boron and arsenic and organic chemicals such as synthetic pyrethroids, carbamates, organochlorines and the organophosphates.

By their nature pesticides are potentially hazardous to health. The nature of the hazard depends on several factors including its intrinsic biological properties (toxicity), the route (inhalation, ingestion or dermal exposure), and in the case of allergies to the individual sensitivities of those exposed to it. A total of 251 pesticide incidents were investigated by the Health and Safety Executive in 1994/95, compared with 196 in 1993/94 and 226 in 1992/93 (HSE, 1995). Of these incidents, 128 involved allegations of ill-health, the other 123 being complaints about pesticide use. The majority of reported incidents involve the general public.

In relation to pest control, some insects are carriers of disease and represent a potential danger to health. Their habits can lead to contamination of food and the transmission of disease such as dysentery, salmonella and typhoid. In addition, some insects may bite (e.g. fleas) or sting (e.g. wasps) and the human reaction to such bites or stings can be severe with swelling and irritation which can lead to infection. Insects may be suppressed by a range of compounds, usually synthetic pesticides (e.g. synthetic pyrethroids). Most pesticides are applied in the form of liquid sprays made by diluting concentrated liquids or solid formulations with water, but powders, granules and gaseous fumigants are also used.

Timber, a structural component of most buildings, can provide a niche for a number of damaging organisms including fungi and insects. The most common of these destructive organisms are *Serpulalacrymans* (dry rot), *Coniophora puteana* (wet rot), *Anobium punctatum* (common furniture beetle) and *Xestobium rufovillosum* (death watch beetle). Timbers in buildings are treated to eradicate or to protect against such organisms by spraying the surface of the timbers and associated masonry with water-based or solvent-based insecticidal and fungicidal solutions. These treatments commonly contain synthetic pyrethroids (e.g. permethrin, cypermethrin and alpha-cypermethrin), arsenates and boron compounds. The latter of these are considered to be less toxic. There is a trend towards the use of water-based solutions, which present a reduced health risk to operators with the added benefits of being more cost effective and virtually odourless.

Erodible antifouling paints are used to prevent the underwater fouling of ships which results in increased drag, leading to lower speed and higher fuel consumption. Antifouling paints typically contain components of toxic metallic compounds including tin, copper, lead and arsenic. Since the late 1980's, the use of copper-based antifouling paints has increased, replacing the formulations containing tin, normally as tributyl tin compounds (TBT). This trend has resulted mainly from the introduction of legislation prohibiting the use of TBT-based antifouling paints on vessels less than 25m in length.

In the United Kingdom, the statute which deals with pesticides is the Food and Environmental Protection Act 1985 (part III). The Act is implemented by the Control of Pesticides Regulations 1986, which establish a regulatory system for approval of pesticides, conditions for supply, storage and use, and competence training and certification for operators. In general terms the HSE deals with approvals for non-agricultural pesticides, while the Ministry of Agriculture, Fisheries and Food (MAFF) deals with those for agricultural pesticides. The list of pesticides approved for use under the Control of Pesticides Regulations 1986 is contained in the annual HMSO publication entitled "Pesticides 1994".

In addition, the general principles of the Control of Substances Hazardous to Health (COSHH) Regulations 1994 should be applied to the use of pesticides. Guidance on the use of non-agricultural pesticides in compliance with the COSHH Regulations 1994 and the Control of Pesticides Regulations 1986 is given in the Health and Safety Executive Approved Code of Practice entitled "The safe use of pesticides for non-agricultural purposes".

It is widely recognised that skin is a major route of systemic uptake for many pesticides, and dermal exposure assessments are therefore an essential component of the overall risk assessment for occupational exposure.

However, there is a lack of validated and standardised methods for assessing dermal exposure to pesticides and for assessing the associated risks to health. The legal duty of employers to carry out a risk assessment regarding health and safety is therefore difficult. In addition, without fully validated methods, the performance of personal protective equipment and other control measures is difficult to establish.

Several approaches have been taken for assessment of dermal exposure. These were reviewed by Fenske (1993) and can be divided into three broad categories:-

1. Surrogate skin monitoring (e.g. overalls, patches and gloves).

2. Visualisation techniques (e.g. fluorescent tracers).

3. Whole hand washing

The first draft protocols for assessing workers' dermal exposure to pesticides were prepared by the WHO in 1975. These two standard protocols were based on the work carried out by Durham and Wolfe (1962) and were subsequently published in 1982 (WHO, 1982). This work was prompted by the potential for acute poisoning amongst handlers of organophosphate pesticides. One method is based on analysing an entire suit of absorbent material worn by an operator while the other involves attachment of a number of absorbent patches to the operator's clothing. The patches are subsequently analysed for pesticide content. The concentration of pesticide on the patch is then extrapolated to the appropriate regional surface area of the body.

The use of patches is still widely accepted and used. However, the use of this method requires two major assumptions:-

1. exposure is uniform over each body region;

2. minimal exposure occurs beneath protective clothing.

Dermal exposure is often non-uniform and it has been suggested that patch sampling does not provide an accurate assessment (Fenske, 1990; Franklin *et al*, 1981; Chester and Ward, 1983). In addition, substantial discrepancies were observed during sheep dipping where gross contamination occurred (Niven *et al*, 1994). However, in spray or brush application, splashing or soaking of random areas of the body is less likely and it is suggested that dermal exposure to pesticides may be more uniformly distributed (Senior and Lavers, 1992).

This inherent limitation of the patch method can be overcome by the use of the whole-body method (WHO, 1982; Abbott *et al*, 1987; Bonsall, 1985) where the whole body area is sampled by means of lightweight coveralls. Unlike the patch method, it does not rely on uniform deposition of pesticide. It is, however, much less practicable as it is relatively intrusive and requires much larger quantities of solvents to extract the pesticides for analysis.

However, both methods tend to overestimate the potential for skin exposure since all contaminants which might have reached the skin are collected by the absorbent material, and are less likely to be wiped or drip off. The scope of these methods is inherently limited since the overall risk to health from exposure to pesticides depends on the mass absorbed by the skin which, in turn, depends on both the mass of the pesticide that is deposited and on its concentration. No indication of the amount of pesticide that is absorbed through the skin is given with these methods. In addition, they do not include any provision for assessing dermal exposure to the hands, which has been well documented as an important contribution to overall exposure (U.S. EPA. 1986). In reviews, it is generally accepted that hand exposure is important. Franklin (1985) has estimated that it is generally much higher than 50% of the total exposure.

This report describes an investigation on the use of whole body suits to measure potential dermal exposure to pesticides, and compares these results with simultaneous measurements made using absorbent patches attached to the surfaces of these body suits. Potential dermal exposure to other exposed areas, i.e. hands and head, has also been investigated. In addition, the effects of a number of factors on the level of dermal exposure were investigated, including activity, application method, working practices and the awareness of workers of the hazards associated with the use of pesticides.

2. AIMS OF STUDY

The specific research questions to be addressed in this study were:

(i) Are absorbent patches (WHO, 1982) a valid method of sampling for contamination during spray or brush application of pesticides during pest control, timber and masonry preservation and the application of anti-fouling paint?

(ii) How much pesticide accumulates on exposed skin and protective clothing during these operations?

(iii) Is attitude, custom and practice amongst workers important in determining potential skin exposure (as measured by contamination on the outer layer of protective clothing and on exposed skin)?

Answers to these questions may provide a basis for future studies on the effectiveness of protective clothing for reduction of skin exposure to these pesticides.

3. METHODS

3.1 Strategy of Surveys

This study was based on a total of twelve surveys in each of the following three sectors, (i) Pest control, (ii) Timber and masonry preservation, (iii) Application of erodible anti-fouling paint.

Before the field surveys, a pilot study was conducted in the timber preservation sector since it includes a large number of organisations. This made advance planning simpler than for other sectors. In addition, operators are generally based at one site throughout the day, and work in an enclosed area, enabling closer observations to be made by the hygienists.

Up to three operators were included in each survey and all tasks normally undertaken were covered, including:-

- preparation of pesticide for use (e.g. dilution, mixing)
- application
- cleaning of equipment
- removal of contaminated personal protective equipment

Operations where pesticides were applied by spraying were included in the study. Timber and masonry preservation was restricted to remedial work, and the amateur use of antifouling paint was excluded from the study.

3.2 Company Selection and Recruitment

The aim was to recruit a range of organisations in each of the three sectors, including small and large organisations, and private and public sectors (e.g. Local Authority, Government). This was to enable a comparison to be made of different working practices and associated levels of exposure to pesticides.

3.2.1 General selection strategy

The following matrix was drawn up as a guideline for the selection of organisations. The first figure in each of the sectors is the number of organisations in that category that we hoped to include in the survey. The figures in brackets are the actual numbers included in the study.

ORGANISATION	PEST CONTROL	TIMBER TREATMENT	EAF PAINT APPLICATION
PRIVATE - Large	2 (0)	2 (2)	2 (2)
PRIVATE - Small	1 (1)	2 (2)	1 (2)
LOCAL AUTHORITY	1 (3)	0 (0)	0 (0)
GOVERNMENT	0 (0)	0 (0)	1 (0)

Numerous trade associations in each of the three sectors were contacted by telephone to obtain information on the most commonly used pesticides. The aim was to include no more than four pesticides in the study.

3.2.2 Pest control and timber treatment organisations

The British Pest Control Association (BPCA) and British Wood Preserving and Damp Proofing Association (BWPDPA), the two main trade associations for these sectors, provided useful information including a list of their members in the Lothian and surrounding regions. In addition, the Principal Housing Officer of Midlothian District Council, and Senior Contracts Manager of Edinburgh District Council provided lists of companies who were undertaking remedial timber preservation work in their areas. Selected companies from these lists and some additional companies from the local Yellow Pages Directory were approached for participation in the study.

Company managers, occupational hygienists, health and safety advisors or paint supervisors were contacted by telephone and informed of the nature of the study. Those who expressed a willingness to participate were asked for information on the nature of work undertaken including details of pesticides used, normal work patterns, workload and seasonal variations. In the majority of cases, the initial contact was followed up with a letter giving a detailed explanation of the study and their anticipated involvement, with an invitation to meet to discuss the study in detail. Meetings were arranged at two shipyards to gain knowledge of typical working practices in this sector. In addition, a preliminary meeting was held with one of the large timber preservation companies, at their request, to discuss the scope of the study.

Several of the pest control companies and one timber preservation company were not willing to participate, and two companies withdrew from the study prior to the surveys. On the whole, there was a general willingness expressed by companies to participate in the study. However, it proved difficult to recruit pest control companies in the private sector. Reasons for this included the obligation of these companies to conduct their clients' work in confidence. In view of this, the local authority pest control sector was targeted first, until a sufficient number of organisations were successfully recruited.

In general the organisations who participated in this study are believed to represent a broad cross-section of their sector. In the pest control area, however, two out of three of the organisations were local authority, and only one in the private sector. It may be the case, therefore, that the public sector was over-represented, but the bulk of pest control in the UK is undertaken by local authorities.

The participating pest control organisations used either water based emulsions or dry powders containing either bendiocarb, alphacypermethrin or permethrin. The only occupational group surveyed were sprayers.

Five timber preservation companies were recruited. All of them were in the private sector, and used water based emulsions containing either permethrin, cypermethrin or carbamates. Two occupational groups were included in the surveys, sprayers and pump attendant/standby operators.

3.2.3 Organisations using EAF paints

The British Marine Industries Federation provided information on the major supplier of anti-fouling paint (International Paints Ltd., London) who were subsequently contacted. The regional marine coatings sales executive of International Paints Ltd. provided details of users of their EAF paints, including named individuals who were subsequently contacted. This proved to be an effective approach. As the project progressed, International Paints Ltd. provided a provisional timetable of dates when anti-fouling paint was likely to be applied at various shipyards. This proved to be extremely valuable since these companies were subsequently approached and surveys were arranged where possible.

Three shipyards were recruited where copper oxide based antifouling paints were used. These included two main occupations:- sprayers and potmen. All shipyards were in the private sector. Two separate surveys were conducted in one shipyard, however, separate dry docks were being used and the scale of the operation differed for each of the surveys.

3.3 Measurement Techniques

3.3.1 Sample collection procedures

Quantitative measurements of contamination were made simultaneously using the modified sampling suit and patch methods described by WHO (1982).

Each operator wore hooded overalls on top of his normal clothing (and personal protective equipment, where applicable). At the same time, eleven 10cm x 10cm absorbent patches were worn on top of the overalls. A suitable method of adhering the patches to the overalls was required. Initially, the patches were stapled onto Tenza self-adhesive packing list envelopes and attached to the overalls by means of the adhesive surface. In previous IOM this had been found to be an efficient method for attaching patches to suits (Sewell *et al*, 1995). However, as the study progressed, it became apparent that this method of attachment was unsuitable for certain types of work, e.g. crawling on top of floor joists in confined spaces, and the method of attachment was changed to sewing.

The WHO protocol (WHO, 1982) recommended six patches for each individual. In this study, eleven patches were placed strategically on the overalls and in the same position for each participant.

Patches were located on each participant in the following areas:

- lower legs (midway between ankle and knees, dosal surface)
- upper legs (mid thigh, dorsal surface)
- lower arms (midway between elbow and wrist, dorsal surface)
- upper arms (midway between elbow and shoulder seam, dorsal surface)
- front torso (right hand side)
- rear torso (between shoulder blades)
- hood (on back of head)

At the end of the survey the overalls were carefully removed with the assistance of the IOM hygienist and were then dissected using heavy duty dressmaking scissors. Each segment had an equivalent patch sample for comparative analysis.

The overalls were sectioned as follows:-

- lower legs (below knees)
- upper legs (above knees to groin)
- lower arms (below elbow)
- upper arms (above elbow to shoulder seam)
- front torso
- rear torso
- hood

These segments included the area that had been covered by the patch. This is allowed for in the analysis (Section 3.7.4).

Exposure to potentially uncovered areas of the body not covered by sampling overalls (i.e. hands) were assessed using absorbent gloves worn over protective gloves.

The segmented overalls, patches and gloves were placed in clean, uniquely labelled containers prior to transporting them back to the IOM laboratory for analysis.

3.3.2 Selection of overalls

Previous work carried out by the IOM showed that overalls made from 60% cotton and 40% polyester are suitable as whole body garment samplers (Niven *et al*, 1994). However, hooded overalls in this fabric were not readily available and therefore it was necessary to identify suitable overalls with hoods.

Hooded overalls made from 35% cotton and 65% polyester were identified. The most important features of the overalls which were assessed were:

- absorbency
- recovery efficiency of the active ingredients
- stability of the active ingredients
- wearability

In order to increase the absorbency of the overalls, they were pre-washed in an automatic washing machine using a biological washing powder.

Tests were carried out on both washed and unwashed fabrics to determine their retention and permeation capacities. The tests were carried out in accordance with ISO 6530 (International Standards Organisation, 1980), using ordinary tap water as the test liquid at room temperature. The equipment used was a standard system which was made up of a rigid transparent "gutter", of semi-cylindrical shape, which was used to hold a sheet of blotting paper and a sample of test fabric. A 10ml syringe with a hypodermic needle (bore size 0.8mm) was used to introduce the water onto the test material with a beaker to collect the run-off. Each test was timed with a stopwatch and the weights of fabric and liquid were determined using a balance accurate to 0.01g.

The wearability of the overalls was assessed during the pilot study. The sampling garments selected were ARCO white hooded overalls (35% cotton, 65% polyester).

3.3.3 Selection of gloves

Two glove types were identified (cotton knitted and cotton drill gloves). Their suitability was assessed using the same approach described in section 3.3.2.

The wearability of the cotton drill gloves was again assessed during the pilot study. The gloves selected were ARCO cotton drill gloves.

3.4 Questionnaire on Hazard Awareness and Attitude to PPE

A brief questionnaire was administered to all those who took part in the study to evaluate their awareness of the hazards of pesticides, and their attitude to personal protective equipment (Appendix 1). The questionnaire was administered during the course of the survey at a convenient time, e.g. meal breaks, or at the end of the survey.

3.5 Visual Observations and Record Keeping

Visual occupational hygiene assessments of working practices and exposures were undertaken by IOM hygienists who are experienced in the observation and evaluation of working practices, etc. An assessment proforma (adapted from that used by Niven *et al*, 1993, to assess sheep dipping practices) was used to record all relevant information on the applications and observations on working practices and exposures in a consistent, systematic manner for each survey (Appendix 2). This proforma provided for subjective estimates by the hygienist of the extent of contamination experienced by the operator. This information was used to complement the quantitative measurements.

Additional descriptive information was recorded in site note books by each member of the survey team.

The proforma records were supplemented by photographs.

3.6 Conduct of Surveys

Each survey was undertaken by two of four IOM occupational hygienists, with the exception of one survey which was undertaken by one hygienist. Consistency was maintained throughout the study with one hygienist being involved in all of the twelve field surveys and pilot study.

Surveys were normally arranged at least a week in advance. However, the hygienists were able to respond at very short notice to fit in with spraying schedules. These were often changed at the last minute as the application of antifouling paint was dependent on preparatory remedial metal work, and weather conditions.

At the start of each survey, the hygienist discussed the objectives of the study with the operators, and asked about normal working patterns and practices. This ensured full co-operation and allowed the work to be carried out with minimal disruption to their normal working practice.

Each operator was asked to wear a brand new pair of jeans and T-shirt which were provided to prevent potential cross-contamination from the operator's own clothing. On top, the operator wore white hooded overalls. In addition, cotton drill gloves were worn, either on their own, or on top of a new pair of nitrile gloves (which were provided in circumstances where the operator would normally have worn nitrile or PVC protective gloves).

Additional personal protective equipment (PPE), e.g. respiratory protective equipment, visors, helmets and beekeepers hats, supplied by the various organisations, was worn where required. All PPE was thoroughly cleaned to prevent cross-contamination and new PPE was worn wherever possible. Where practicable, PPE was worn underneath the sampling suits, however, certain items of PPE were worn on top of the overalls, e.g. beekeepers hats. In those circumstances, this information was recorded.

The hooded overalls and gloves were worn for the entire duration of the operators' shift which involved contact with pesticides, including formulation or mixing, application and cleaning of equipment. Overalls and gloves were changed at the discretion of the hygienist in cases where there was a risk of saturation. In cases where the operators undertook numerous assignments during the course of the survey, e.g. pest control, the overalls were worn throughout the day, in line with normal working practices. As a precaution, polythene sheeting was used to cover the seating in their transport vans to prevent cross-contamination.

The hygienist assisted with the removal of the overalls and gloves to ensure that cross-contamination was minimised. New pairs of disposable gloves were worn by the hygienist when handling each suit to avoid contamination. Operators gloves were carefully removed and placed in clean labelled jars. Thereafter, the patches were removed from the suits and placed in clean labelled jars. Finally, the suits were carefully dissected and placed in clean labelled jars.

3.7 Analyses

3.7.1 General procedures

Pesticide was extracted from segmented overalls and patch samples and analysed in accordance with analytical procedures developed in-house on the basis of previously documented and validated methods appropriate to the pesticides in the study.

3.7.2 Analysis of organic pesticides

Pesticide was extracted from sectioned suit samples, patches and gloves with acetone. A known volume of acetone was added to each sample container, which was placed in an ultrasonic bath for fifteen minutes. The volumes of solvent used ranged from 60ml to 1000ml for the larger suit segments (e.g. upper leg). A 1ml aliquot of each sample was transferred to a septum-sealed glass vial and a known volume of d^{10} phenanthrene or phenylanthracene was added as an internal standard. Calibration standards were prepared from known weights of the analyte in 1ml of acetone, containing the internal standard solution. Blank patches were prepared similarly. Samples were analysed by gas chromatography / mass spectrometry (GC/MS) using a Varian Saturn II system. Concentrations were calculated by comparing the ratio of the analyte and the internal standard peak areas with the calibration curve. This was performed by the GC/MS system software. An electronic copy of all data was stored on tape. The mass of analyte on each suit section / patch was calculated using the relevant solvent extraction volume.

The stability and recovery efficiency of the organic pesticides on the sampling media were investigated as part of the study. Sections of the fabric were loaded with known masses of each of the active ingredients (i.e. permethrin, cypermethrin, alphacypermethrin and bendiocarb). Details of the procedures adopted and the results are given in Appendix 4.

3.7.3 Analysis of copper

The extent of potential dermal contamination for EAF paint users was assessed by analysing for copper.

Sectioned suit samples, patches and gloves were extracted with 50% Analar grade nitric acid. A known volume of nitric acid was added to each sample contained in a heavy duty pyrex glass beaker, which was placed on a hot plate and heated to approximately 80C for 30 minutes.

About 25 cm^3 of each extraction solution was removed for each sample and aliquots of these were diluted (by factors of between 50-2000) with 5% nitric acid to bring their concentration within the range covered by the standard copper calibration solutions. The standards were prepared from a 100ppm standard copper solution in the range 0 - 4ppm (i.e. 0, 1ppm, 2ppm, 3ppm and 4ppm) in 5% nitric acid. Sample blanks were also made up by treating small patches of clean overalls in the same manner as described above.

The sample solutions were analysed within a day of extraction by flame atomic absorption spectroscopy using a Thermo Electron Video AA/AE spectrophotometer. (The solution became cloudy wih time and after 2 weeks a precipitate of copper complex was clearly visible). The instrument was calibrated using the standards described above. These standards also served as control samples, and were used to check the reliability and stability of the instrument. The concentration of copper was calculated by the instrument and displayed in ppm. The mass of copper on each suit section / patch was calculated using the relevant dilution rate and were blank corrected.

Sample solutions were prepared and analysed over a 3 week period. At the end of the three week period 10 per cent of the sample solutions were re-analysed.

The recovery efficiency of the copper on the sampling media were investigated as part of the study. Sections of the fabric were loaded with known masses of EAF paint with a predetermined copper content. Details of the procedures adopted and the results are given in Appendix 4.

3.7.4 Data analysis

The aim of the data analysis was to compare the total mass of pesticide estimated from the patch method with that derived from the total suit method. In addition, a comparison was made of the results for each section of the body. The mass of pesticide on the patch was added to that of the suit to give the total quantity on each section. This was compared with the estimate for that section based on the patch method where the mass of pesticide extracted from the patch alone. Each patch measured 10 by 10 cm, so the mass of pesticide on the corresponding area would be multiplied by the appropriate patch:area ratio. Table 1 shows the surface areas for large and extra large suits.

3.7.5 Agreement and systematic differences

In order to assess agreement and systematic differences Bland and Altman (1986) suggested plots of the differences between values (B - A) against the corresponding mean of the two values (A + B)/2. The measure of agreement is then the calculation of the range within which most of the disagreements occurred, or the limits of agreement (a mean difference close to zero would illustrate good agreement).

The mean difference (d) and standard deviation (s_{diff}) of the differences are calculated and the range is then:

$$d \pm t_{n-1} S_{diff}$$

where t is the value from the t-distribution with n-1 degrees of freedom, and s_{diff} is the standard deviation of the differences.

This is based on constant variance and so a transformation may be necessary if the data are not approximately normally distributed. In this case a logarithmic transformation was used and so the back transformation of the mean of the differences gives the ratio of the geometric means of the suit method to the patch method and hence a comparison of the methods in terms of the percentage overestimation or underestimation of one method by another. As the value from the patch method was subtracted from the value for the suit method negative differences indicate overestimation by the patch method, as do ratios of less than one.

The mass of pesticide from the suit method and patch method were compared by direct plotting of one against the other on the logarithmic scale. Close agreement would be shown if the points were close to the line y = x through zero in this plot. In addition the differences in log mass (suit) - log mass (patch) were also plotted against the mean of the log values from the two methods for the complete suit. As already described three sectors of use of pesticides were considered and these are presented separately. The logarithmic transformation also facilitates presentation of the data together, as the mass of pesticide differs greatly between the three sectors. All plots were produced using the graphic computer software Sigmaplot (Kuo and Fox, 1993).

Analyses were carried out using the statistical computer package Genstat 5 (Genstat 5 Committee, 1987).

4. DESCRIPTION OF FIELD STUDIES

4.1 Overview of Field Surveys

The details included in the following sections are intended to give a general overview of the nature of the activities included in this study.

Appendix 5 describes the conditions for each survey and includes information on reasons for treatment, application details, active ingredient, quantity of formulation used, spraying duration and personal protective equipment worn.

4.1.1 Pilot field study

A pilot field study (Survey 01) was undertaken to assess and refine the practicability of the site sampling protocol. The pilot field study was also used to identify any changes required to the proforma and questionnaire.

The pilot study was undertaken in the timber preservation sector during the spray treatment of attic timbers and wooden flooring within a derelict tenement building to eradicate dry rot. Two operators participated in the pilot study, one sprayer (01/1) and one pump attendant (01/2). The concentrated pesticide was supplied as an aqueous solution containing cypermethrin (0.46% w/w) in a 5 litre plastic container. The entire contents were poured into a 25 litre capacity plastic drum which was subsequently diluted with approximately 20 litres of water (supplied from a nearby tap). The working strength emulsion was decanted by the pump attendant via a plastic funnel into a 7 litre "Super Seven" hand operated compression type sprayer. The pump attendant then pressurised the sprayer tank with an integral hand pump. Application of the working strength emulsion was carried out by the sprayer for approximately 10 minutes in total. During the pilot study 15 litres of working strength emulsion was used.

During the pilot study, the "wearability" of the sampling gloves was assessed. It was difficult to fit the cotton sampling gloves over the operators' own protective gloves. There was also some concern over the potential for cross-contamination from the operators' gloves onto the sampling gloves. These problems were overcome in subsequent surveys by providing the operators with unused nitrile protective gloves which could be worn comfortably under the cotton sampling gloves. These were worn in circumstances where the operator would normally wear an equivalent protective glove type.

The method of attaching the absorbent patches on the whole body sampling suit was evaluated. It was important that the patches remained in place for the duration of the survey. The patches were stapled onto Tenza self-adhesive packing list envelopes which were attached to the overalls by means of the adhesive surface. As the study progressed, it became clear that this method of attachment was unsuitable for certain types of work and the patches were thereafter sewn onto the overalls with cotton thread. This ensured that they were not dislodged.

Minor amendments were made to the assessment proforma following the pilot study. The revised version of the assessment proforma which is given in Appendix 2 was used throughout the remainder of the study.

The questionnaire was administered to both operators during the pilot study without any difficulties. Therefore, no changes were made to the original version of the questionnaire which was used throughout the study (Appendix 1).

4.1.2 Pest control

Three organisations in the pest control sector (two local authorities and one small company in the private sector) participated in this study. Four surveys (02, 03, 06 & 09) were conducted involving four participants. One operator participated in two surveys (02 & 03), however, the scope and working conditions differed in each survey.

A wide range of pesticides are used in this sector; the choice of pesticide largely depends on how efficacious it is against the particular target insect and the habits of the insect. Pesticide formulations containing either bendiocarb, alphacypermethrin or permethrin were used, in the form of either water-based formulations or dry powders. In this study, numerous insects were targeted including beetles, ants, cockroaches, fleas, mites, spiders and wasps.

The liquid insecticides were applied by compression type sprayers (Gloria (02 & 03) and Hozelock (06)). The compression type sprayers have tanks which are partially filled with working strength solution leaving an air space. Spray is forced out of the tank through a spray nozzle attached to a spray lance by pressurising the tank with air using an integral hand pump. Decompression can occur when the lid is opened, however, both sprayers were fitted with a decompression valve to allow controlled decompression prior to opening the lid.

Two types of spraying were carried out in Surveys 02, 03 and 06 using liquid insecticides, namely "band" spraying and "high" spraying. Band spraying involves the application of a band of residual insecticide to flooring and skirting boards, etc., and is commonly used to treat cockroaches. High spraying involves generating a fine aerosol mist in mid-air and is commonly used to treat fleas where large surface areas (carpets etc.) require to be covered.

In Survey 06 powder based insecticide was applied by a compression type sprayer (Birchmeier DR5), similar to the liquid sprayers described above. In Survey 09 the powder was applied with a 2 litre capacity bellows type dust applicator. The bellows produces a flow of air and the powder in the half-filled tank is forced through the delivery tube onto its target. In both surveys (06 & 09), the powder formulation was used to treat wasps' nests where the powder was simply directed onto the entire structure of the nest.

Application times, i.e. the total time spent applying pesticide formulations in the course of the survey, ranged from 15 to 75 minutes.

4.1.3 Timber preservation

Three large companies (07, 010 & 012) and one small company (08) participated in this study (08), all in the private sector. Nine operators participated in the surveys, seven sprayers and two pump attendants.

Pesticide formulations containing either cypermethrin, permethrin or 3-iodo-2-propyl-n-butyl carbamate were used in the form of water-based emulsions. In this study, surveys were undertaken during remedial work to treat either dry rot or woodworm infestations.

Surveys were predominantly carried out during the treatment of attic timbers in domestic dwellings (07, 010, 012). Survey 08 was carried out during the treatment of masonry in a derelict tenement building undergoing refurbishment.

In each survey the water-based emulsions were prepared from liquid concentrates. The concentrates were supplied in a range of container types. In each survey the concentrate was poured from its original container into a larger container into which water was added to dilute the concentrate to the required working strength.

The method of application was substantially the same in each of the surveys. The formulation was supplied under pressure by a mechanical pump driven by an electrical compressor through a spray lance (Eclipse) fitted with an adjustable nozzle and operated by a trigger valve.

In Surveys 07 & 012, the pump attendant prepared the working strength solution and the sprayer applied it. The pump attendant also ensured that there was a sufficient quantity of working strength solution available in the supply vessel. In Survey 012 the sprayer (012/1) also handled the concentrate. In each of these surveys the pump attendant was not in the vicinity of the spraying operation since spraying was typically carried out in attics. In Survey 010 both operators treated the timbers although only one operator (10/1) was involved in the preparation of working strength solution and setting up the compressor, including priming the pump, etc. In Survey 08, all three operators were involved in the treatment of masonry, the team comprising one main sprayer (08/1), one standby sprayer (08/3), and a pump attendant (08/2) who prepared the working strength solution.

The total application time ranged from 15 to 60 minutes with one exception where the standby sprayer spent around 3 minutes spraying. In each survey spraying was carried out more or less continuously until the day's treatment was completed.

4.1.4 Application of EAF paint

One large shipyard and two small private shipyards participated in this study. Two separate surveys were conducted at the large shipyard (04 & 013) involving seven participants. However, each survey was carried out at a different dry dock or slipway, and the scope and working conditions differed in each survey. The surveys carried out at small yards (05 & 011) involved four participants.

A range of erodible anti-fouling (EAF) paints manufactured by International Paints Ltd. were used at each yard, including base coats and finishing or sealer coats. These paints were xylene based with copper oxide as the active ingredient. The paints typically contained 25-50% cuprous oxide, except the paint used in Survey 011 which contained 5-10% cuprous oxide supplemented with organotin compounds. The copper content in the corresponding dry paint, as determined by the IOM, was approximately 41-51% and 6%, respectively. The tin free paints contained additional biocides, e.g. diuron, to boost the effectiveness of copper.

In each survey the paint was applied by a Graco air-powered spray gun driven by an airless spray unit. The pistol type spray guns were fitted with a reversible self-cleaning tip and butterfly guard.

In each survey operators worked in pairs; the sprayer applied the EAF paint whilst the "potman" mixed the paint and ensured that there was a continuous supply of paint to the spray unit (to prevent an airlock), which was fed via a hose directly from the paint drum. The potman also assisted the sprayer during spraying, e.g. hose handling, driving fork lift truck.

The total application time ranged from 40 to 170 minutes. Spraying was interrupted with regular coffee/meal breaks in each survey except in Survey 013 where spraying was carried out continuously for 40 minutes.

4.1.5 Cleaning facilities and personal hygiene

Cleaning facilities and standards of personal hygiene were variable. Washing facilities were available at each of the shipyards and at local authority pest control headquarters. Pest control operators relied primarily on washing facilities available on site which generally consisted of hot and cold water. However, due to the nature of the work, timber treatment operators had access to limited washing facilities since their work was generally carried out in derelict buildings with only cold running water. Several pest control operators and timber treatment operators carried a supply of clean water and hand cleaner in their vans, in addition to cleaning wipes in some cases.

All operators at shipyards washed before meal breaks and at the end of the shift, although some smoked during the shift without washing their hands. In comparison, only a few timber treatment and pest control operators washed before meal breaks, and smokers in these sectors did not wash their hand before smoking. However, in each of these sectors, although the operators did not generally wash during the shift, they washed after all the work had been completed.

5. RESULTS

5.1 Pilot Work

5.1.1 Measurement of absorbency of overalls

Hooded overalls made from 35% cotton and 65% polyester (ARCO Safety Products, Livingston, Scotland) were identified as potentially suitable for use as whole body sampling overalls.

The overalls were washed in an automatic washing machine using a biological washing powder in order to increase their absorbency.

Tests were carried out on both washed and unwashed overalls in accordance with ISO 6530 (International Standards Organisation, 1980) to determine their retention and permeation capacities. Three features of the fabrics were assessed; the percentage of test liquid (tap water) that penetrated the fabric, the percentage retained on the fabric and the percentage not retained (run-off). The results of these laboratory tests are given in Table 2.

The washed overalls had a significantly higher retention and lower run-off than the unwashed overalls. Liquid penetration was also higher for the washed overalls, but this disadvantage was outweighed by their high retention and negligible run-off.

Washed ARCO white hooded overalls were therefore selected as whole body sampling overalls for this study.

5.1.2 Measurement of absorbency of gloves

Two glove types, cotton knitted and cotton drill (ARCO Safety Products, Livingston, Scotland), were identified as potentially suitable sampling gloves to assess dermal exposure on the hands.

Tests were again carried out on both glove types using the procedure described previously (International Standards Organisation, 1980) to determine their retention and permeation capacities. The results of these laboratory tests are given in Table 3.

The cotton drill gloves had a higher retention, and lower run-off than the cotton knitted glove. The liquid penetration was similar for both glove types.

ARCO cotton drill gloves were therefore selected as the sampling gloves for this study. Their "wearability" was assessed during the pilot study.

5.1.3 Measurement of stability and recovery efficiency of the active ingredients

The stability and recovery efficiency of the active ingredients on the whole body sampling overalls were investigated. The results are given in Appendix 4.

5.2 Potential Dermal Exposure

5.2.1 General overview

Five pest control operators participated in the study, and five corresponding sets of results are reported. In the timber and masonry preservation sector, eleven subjects participated, but only eight sets of results are reported, the results from Survey 08 having been discarded due to problems described in Section 5.2.4. Nine shipyard operators participated in the study. One operator wore two sets of overalls / patches to prevent saturation, and these results are reported as 05/1a and 05/1b. The rear torso patch was lost for another of the shipyard operators (04/2) and it was not possible, therefore, to compare the extrapolated results for this subject. In total, therefore, nine completed sets of results are reported for shipyard operators.

The total mass of pesticide extracted from the suit sections / patches ranged from around 1 mg to 19.2 g. The lowest levels were found in the pest control sector (Table 9) followed by the timber treatment sector (Table 10). Much higher levels were found in the EAF paint sector (Table 11).

The mass of pesticide extracted from the gloves was also greatest in the EAF paint sector, followed by the timber treatment sector and pest control sector, respectively. These results are reported in Tables 9-11. Where an operator wore more than one pair of gloves, the results were summed to give the total mass.

The mass of pesticide extracted from the suit sections and patches have been extrapolated to give an estimation of total potential dermal exposure derived from both methods, using the procedure described in Chapter 3. The extrapolated results are summarised in Tables 9 to 11. Where the mass of pesticide was below the limit of detection its extrapolated value (shown in itallics) has been derived from a value of one half of the detection limit to enable subsequent statistical analysis.

5.2.2 Differences between the suit method and patch method for individual whole body exposures for the survey as a whole

In Figure 1, the results shown in Tables 9 to 11 for the whole suit method are plotted against the corresponding estimate of whole body exposure obtained using the patch method. This shows a generally linear relationship between the results obtained by the two methods, indicating the usefulness of the patch method as a general indicator of whole body exposure.

For more detailed scrutiny, the results derived from the patch method and whole suit method are also summarised in Table 4. The differences between the results obtained by the two different methods are expressed as a percentage of the values derived from the whole suit method. The results show generally negative differences indicating that there is a systemic overestimation by the patch method.

The differences between the log transformed values from the suit method and those derived from the patch method have been plotted against the mean of these two values in Figure 2. This plot relates to the estimated total potential dermal exposure derived from both methods.

On average, differences between the log transformed results were close to zero for the EAF paint sector, with larger differences in the other two sectors. However, for interpretation purposes, it should be noted that these results are plotted on a logarithmic scale. In general, the pest control and timber preservation sectors show negative differences indicating overestimation by the patch method. In the EAF paint sector, most of the differences are greater than zero indicating underestimation by the patch method for this sector.

The results (expressed logarithmically) are also presented in Table 5. Back transformation of the log differences between the results derived by the suit method and patch method represent the ratio between these methods. A ratio of one would indicate perfect agreement between the methods. In the pest control sector and timber treatment sector the ratios were generally less than one, indicating a comparative overestimation by the patch method. In the EAF paint sector the ratios were more evenly spread, with the exception of two extreme ratios of 6.67 and 31.09 in Survey 011, indicating substantial underestimation by the patch method.

The mean and median differences between the suit method and patch method, calculated using log transformed data, are given in Table 6. The median is presented along with the mean since the mean is sensitive to extrememe values (e.g. Survey 011), and because it is difficult to check normality with sparse data. Table 6 shows that, on average, the total potential dermal exposure derived from the suit method is 12% lower than that derived by the patch method (based on a ratio of geometric means of suit to patch of 0.88). The 95% limits of agreement between the two methods gives a range of values for the suit method from 91% lower to 835% greater than those for the patch method.

Detailed consideration of the implications of these results should be approached with caution, due to the small number of participants in the study. However, the results in Table 6 suggest that (i) for the pest control sector and timber treatment sector there were similar differences between the suit method and patch method, with the patch method generally overestimating potential dermal exposure and (ii), the results obtained in the EAF paint sector showed the greatest variation in differences between the two methods, but when averaged over all participants, agreement between the two test methods was slightly better here than for the other two sectors with the patch method generally underestimating total potential dermal exposure.

5.2.3 Comparison of the results obtained using the suit and patch methods for individual suit sections over the whole survey

Figures 3 to 13 show the relationship between the estimates of regional dermal exposure obtained using the patch and the whole suit methods. These show a generally linear relationship between the results obtained by the two methods, indicating the usefulness of the patch method as a general indicator of regional dermal exposure. However, the comparisons for individual segments showed considerable variability as described below.

For more detailed statistical comparison, Table 7 presents the ratios of the geometric mean value derived by the suit method to that derived by the patch method and is based on the mean and median differences for each suit segment and its corresponding patch. For total potential dermal exposure, the ratio of the value derived by the suit method to that derived by the patch method was estimated to be 0.88 based on the mean difference, and 0.66 based on the median difference. The ratios vary from a ratio of 2:1 to 1:2 for the patch method to suit method, across the different suit sections.

The 95% limits of agreement are wide and include both underestimation and overestimation by the patch method for all suit sections.

The lower leg (Table 7) shows best overall agreement between the two methods, on average the patch method overestimating potential dermal exposure by between 1 and 4%. Figure 6 and 7 illustrate the good agreement between both methods for the lower legs. There is also a suggestion (Table 7) that agreement between the two methods was better for the lower arms than for the upper arms.

The poorest agreement between the two sampling methods was for the front torso, where, on average, the patch method underestimated potential dermal exposure by a factor of two.

Detailed comparison of the patch and suit section results for the three separate industry sectors are presented in the following sub-section.

5.2.4 Comparison of the results obtained using the suit and patch methods for individual suit sections for each of the three industry sectors surveyed

In the pest control sector and the timber treatment sector the patch method overestimated the total dermal exposure by a factor of two, whereas in the EAF paint sector the patch method underestimated total dermal exposure by about 42%. However, it must be stressed that the limits of agreement were large and they included results where the patch method underestimated and overestimated potential dermal exposure in each sector.

Pest control. The total potential dermal exposure of pest control operators to pesticides as assessed by the whole suit method ranged from 1.22 mg to 12.40 mg. The results of simultaneous measurements by the patch method ranged from 1.04 mg to 36.99 mg.

Potential dermal exposure to the hands ranged from 0.24 mg to 6.05 mg.

In this sector there were large differences in agreement between the patch method and whole suit method for individual suit sections (see Table 8). Best agreement was for the lower left leg, and hood. The small sample size in this sector meant it was difficult to tell whether the data were normally distributed, and therefore any interpretation of the results should be treated with caution.

The highest exposure was received by the operator in Survey 06. However, this is likely to be attributable to the total application time and amount of pesticide formulation used which was greater than in the other surveys.

In Surveys 02 & 03, where liquid formulations were used, exposure was predominantely to the legs. In both surveys band spraying was mainly used. Visual observations made during the surveys indicated that during band spraying, contamination of the lower legs is most probable since the operator sprays downwards. However, during high spraying, when the operator may work within the aerosol mist, exposure is more evenly distributed over the whole body.

In Surveys 06 & 09 where powder formulations were used, agreement between the suit method and patch method is slightly better. This may be attributable to the absence of random splashing. In addition, the dust is likely to be more evenly distributed on the body. However, in Survey 06 the operator also used a liquid formulation.

Operators in Survey 09 wore a beekeeper's hat over their hooded overalls so the results reported for both the hood section of the suit and the corresponding patch are likely to be underestimates of potential exposure.

Timber preservation. The total potential dermal exposure of timber treatment operators to pesticides as assessed by the whole suit method ranged from 0.67 mg to 49.21 mg. The results of corresponding simultaneous measurements by the patch method ranged from 1.05 mg to 106.10 mg.

Potential dermal exposure to the hands ranged from 0.19 mg to 39.43 mg.

No results are reported for Survey 08 since the active ingredient, 0.5% w/w 3-iodo-2-propyl-n-butyl carbamate, could not be readily separated from the other components in the product to enable quantification. In addition, it was not possible to obtain a certified standard of 3-iodo-2-propyl-n-butyl carbamate.

Based on the median difference, the level of agreement between the suit method and patch method was similar to that in the pest control sector. The lower legs showed reasonably good agreement, but, the best agreement was shown by the front torso and lower left arm. As for the pest control sector, the power of any statistical analysis of the level of agreement between the two sampling methods is severely restricted by the small sample size.

The highest exposure was received by one of the sprayers in Survey 010. This was clearly attributable to a leaking spray lance. The highest levels were measured for the operator's right arm and leg, and right glove, indicative of splashes/drips from the leaking lance held in the operator's right hand. However, the pump attendant in Survey 012 had high exposure to his hands attributable to handling contaminated hoses. The levels of exposure for the pump attendants were generally lower than those measured for sprayers.

In Survey 010 the operators wore a helmet fitted with a visor over their hooded overalls so the reported results for both the hood section of the suit and corresponding patch are likely to be underestimates of potential exposure.

Application of EAF paint. The total potential dermal exposure of shipyard operators to copper, as measured by the suit method, ranged from 1019 mg to 9582 mg. The results of simultaneous measurements by the patch method ranged from 45 mg to 19245 mg.

Potential dermal exposure to the hands ranged from 6 mg to 2150 mg.

Reasonably good agreement was found for the lower legs and lower arm suit sections, with poorest agreement for the front torso. Potential dermal exposure was generally lower for potmen than for sprayers.

In general, sprayers were mainly contaminated by overspray which was relatively uniformly deposited on their sampling suits. Those operators who sat or lay on the ground (05/1 & 013/1) were also contaminated by overspray from the ground. In addition, sprayers were occasionally splashed with paint from the spray nozzle, and often brushed against newly painted surfaces. Hand exposure resulted almost entirely from reversing the tip of the spray gun to unblock the nozzle. For potmen, exposure of the legs and hand was most common, resulting from handling paint drums and lids, and brushing against paint drums. In Survey 05, where a mechanical agitator was used to mix the paint, the potman was splashed on his front torso and right upper leg, resulting in elevated levels for each of those sections.

5.3 Consideration of the Relationship between the Measured Contamination and the Activities in each of the three Industry Sectors.

5.3.1 Pest control sector

During the application of liquid pesticides, the degree of dermal exposure was observed to depend on the application technique.

During band spraying the operator sprayed downwards with the spray nozzle below knee level. Contamination was negligible and restricted to the lower legs (and shoes).

During high spraying, however, the operator was frequently exposed to the aerosol mist, resulting in substantial but fairly uniform deposition over the surface of the body. Operators generally attempted to avoid working in the aerosol during high spraying, but this was not always practicable, eg. in Survey 03 where access was restricted and lighting was poor.

Operators often adjusted the nozzle of the spray lance during spraying, thereby contaminating their hands.

During the application of powder formulations (used in this study solely to treat wasps' nests) operators were exposed mainly on their arms, front torso, upper legs and hood (although the hoods were covered by beekeepers hats in Survey 09). The majority of powder treatments were carried out in restricted spaces, e.g. attics using a bellows type pump. The operators' exposures were higher when they destroyed the nest with a stick once the powder had been applied. In Survey 06, exposure to powder was negligible. Here spray was applied with a compression type sprayer outdoors, often with an extended lance, and the nests were not destroyed.

Exposure was negligible during the preparation of the liquid formulations. Working strength solutions were prepared by diluting emulsifiable concentrates with water. Either liquid concentrate or powdered concentrate supplied in water soluble sachets were used in the study. There was a greater likelihood of exposure to the hands during the dilution of liquid concentrate. However, in each case, care was taken to minimise contact with the concentrate. Nevertheless, preparation of the working strength solutions from concentrate supplied in water soluble sachets is likely to result in less dermal exposure than for liquid concentrate.

Dermal exposure during preparation was observed to be most likely when the lid of the compression type sprayers were removed. The sprayers were fitted with a decompression valve to allow controlled decompression prior to opening the lid. However, there was some degree of positive pressure in the sprayer when its lid was opened and this resulted in working strength pesticide being released under pressure.

The likelihood of dermal exposure during the preparation of powder-based formulations appeared greatest when the powder was scooped into the applicator. Contact was restricted to the hands, but on a windy day, more widespread exposure is possible.

At the end of the day, the left-over working strength solution and powder were left in their sprayers / bellows pump for use on the following day.

5.3.2 Timber and masonry preservation sector

There were several potential routes of dermal exposure during timber treatment.

While spraying, operators generally worked in the aerosol mist resulting in a relatively uniform deposition of the aerosol onto the body and hands. The aerosol also deposited on the hoses and spray lances, and then transferred onto the hands and body of the operator by surface contact. Surface contact with treated timbers was another significant source of exposure, predominately of the operators' hands but, in addition, operators often kneeled on treated floor joists and brushed against treated rafters and sarking. Hands contact occurred when operators adjusted the spray nozzle, which was done frequently. In Survey 010, an operator who used a leaking spray lance had a relatively high exposure. The greatest contamination was measured on the operator's right arm and leg and right glove which was consistant with a leaking lance held in the right hand.

Exposure from operators' hands was transferred to their sampling suits and patches. This source of cross-contamination was accentuated when operators were working in confined spaces, often on their knees or in a stooped position.

The main source of exposure by surface contact was considered to be contaminated hoses.

Exposure was low during the preparation of the liquid formulations, although there was some potential for splashing. Sometimes the floor was soaked with working strength solution due to leaking pumps, etc. In most cases, however, there was a metal drip tray under the pump to contain any spills.

At the end of the treatment session, the main source of exposure was again from surface contact with contaminated hoses and spray lances. Hoses were rolled up and lances were usually wiped with a paper towel or rag. The empty drums were transferred into the operators' van or left on site for use the following day.

5.3.3 Application of EAF paint

The measured potential dermal exposures in this sector were much higher than in pest control and timber treatment.

During spraying, operators were exposed to a fine aerosol of paint (overspray) which was uniformly distributed on their sampling suits / patches. Since the paint was coloured (red/pink or blue) visual assessments were straightforward. These revealed that the closer the operator stood to the surface being sprayed, the less likely he was to be exposed to overspray. Operators who sprayed from fork lift trucks or scissor lifts generally stood much closer to the boat while spraying than did those operators who sprayed from ground level. In addition, overspray which had reached the ground was transferred onto operators' hands and sampling suits when they sat or lay on the ground to spray.

Surface contact with newly painted surfaces was another source of exposure. This was non-uniform and mainly restricted to the legs and hands. Operators were occasionally splashed with paint from the spray gun, but the main source of exposure to their hands was undoubtedly when they reversed the tip of the spray gun to unblock the nozzle.

Higher levels of exposure were measured for sprayers than for potmen. Visual observations revealed that potmen were rarely exposed to overspray unless they were working close to the sprayer, e.g. operating the fork lift truck. Surface contact with paint on paint drums and lids was the main route of dermal exposure and was mainly restricted to the hands and legs.

During mixing of the paint, dermal exposure arose from surface contact with paint drum lids, but exposure levels were low and restricted mainly to the hands. Occasional random splashing occurred during mixing. Splashing occurred where a mechanical agitator was used to mix the paint as the result of an air lock. No splashing occurred when the paint was mixed with a wooden stick or when it was "boxed". However, dermal exposure is potentially high if paint spills during mixing, particularly where the paint was "boxed".

Once spraying was completed, cleaning of the spray gun nozzle was generally carried out by the sprayer who simply purged the spray gun with thinners containing a mixture of xylene and butan-1-ol. Dermal exposure to EAF paint was generally negligible during cleaning and restricted to surface contact with paint on paint drums and lids

5.4 Questionnaire on Hazard Awareness and Attitude to PPE

All twenty-four subjects who participated in this study were questioned on their awareness of the hazards of pesticides, and their attitude to personal protective equipment.

5.4.1 Hazard awareness

Nearly everyone questioned thought that skin contact with pesticides should be avoided. Only one operator (in the timber preservation sector) thought that skin contact should be avoided only if the skin is cut.

All four pest control operators thought that inhalation was the most likely route of exposure, compared with about half of the subjects in each of the timber and masonry preservation sector and about a third in the EAF paint sector. Only three operators in total thought that intact unbroken skin was the most likely route of exposure for pesticides, including two in the EAF paint sector. None of the operators in the EAF paint sector knew what the active ingredient was. There was general confusion over whether the paint was tin-free. In one survey, operators using tin-free paint thought that it contained tin; conversely, operators at another shipyard who were using paint containing both copper and tin compounds thought that it was tin-free.

When questioned on the health hazards associated with pesticides, the majority of subjects thought that pesticides affected health over a long period of time. Two of the operators at shipyards thought that pesticides had both long term and immediate effects. Pest control operators were, by far, the most knowledgeable on the health risks associated with the use of pesticides. All operators in this sector had attended in-house or external training courses on the safe handling of pesticides. For operators at the shipyards (who did not know what the active ingredient of the EAF paint was), it is suspected that responses relate to the health effects arising from the xylene-based EAF paint which may cause immediate central nervous system symptoms such as headache and drowsiness. Operators also said that they experienced burning sensations on their skin associated with the use of EAF paint.

Operators were asked about the extent of skin or clothing contamination with pesticides during various activities including:- the preparation of formulation, application of pesticide, cleaning of equipment and removal of personal protective equipment. Operators were asked to class the level of contamination as:- "high exposure" where gross contamination of hands/exposed body or clothing was likely, "medium exposure" where there was some contamination mainly restricted to overalls or "negligible/no exposure" where there was seldom or no contamination of hands/exposed body or clothing.

All pest control operators and the majority of operators in the timber and masonry preservation sector thought that there was negligible or no exposure to pesticides during the preparation of pesticide formulations. However, one pest control operator commented that significant exposure may occur when filling the bellows type applicator on a windy day. At shipyards, there was a range of responses to this question; most of the operators thought that medium exposure is likely whilst preparing paint for spraying.

During the application of pesticides the majority of subjects thought that exposure is high or medium, though two of the operators in the timber and masonry preservation sector and one pest control operator thought that exposure was generally negligible.

Very few operators in this study maintained or repaired the application equipment themselves. Those who did thought that resultant exposure to pesticides was generally negligible or medium. However, there was a varied response on exposure during the cleaning of equipment. Pest control operators thought that exposure was likely to be negligible, whereas operators at shipyards and in the timber and masonry preservation sector gave varied responses. Half of the operators at the shipyards thought that exposure was high during cleaning. Only two timber treatment operators thought that exposure was high during cleaning of equipment, the remainder of responses being divided between medium and negligible/no exposure.

The majority of operators thought that exposure was negligible or medium when removing their personal protective equipment such as gloves and overalls. However, three of the shipyard operators thought that exposure is generally high when removing protective equipment.

5.4.2 PPE

During the application of EAF paint, all sprayers took precautions to minimise skin contact. Several sprayers wore cotton rags around their wrists and forehead, or a Tyvek cape hood. In addition, sprayers at each of the small yards applied either vaseline or castor oil to exposed areas of their face. However, in their material safety data sheets, International Paints Ltd. advise against using petroleum based products on exposed skin. Operators normally wear riggers gloves and cotton and/or disposable overalls. Riggers gloves are worn in preference to chemically resistant gloves since a good grip is required to operate the spay gun.

Operators normally wear PVC or nitrile gauntlets, during the treatment of timber and masonry, and cotton overalls. In addition, one operator regularly used barrier cream on his hands.

Some operators in the pest control sector always wear gloves and the rest only wore them for some of the time. A range of protective gloves including nitrile gloves, riggers gloves, PVC gauntlets and disposable latex gloves were provided. Operators normally wear cotton overalls, and PVC overalls are worn in cases where ULV mist is applied. One operator sometimes used a face shield.

All subjects in the study wore respiratory protective equipment (RPE) at some stage during spraying operations, and some wore it during the preparation of the formulation. Details on types of RPE worn are given in Appendix 5. In the timber and masonry preservation sector, the North ori-nasal mask was the most commonly used respirator. Other RPE included the 3M 4251 disposable respirator and the Racal Airlite airfed visor. In the pest control sector, operators wore either full facepiece respirators or the North ori-nasal mask. At shipyards, operators wore either full facepiece respirators or nuisance dust masks.

However, based on observations, it is thought that some operators, particularly those working in the pest control sector (and timber preservation sector to a lesser extent) wore respiratory protection because they were being watched. Several respirators were clearly unused prior to the study. In addition, most of operators wore their RPE incorrectly, for example, straps were generally not tightened sufficiently, one operator forgot to fit a filter to a full facepiece respirator, operators wore cotton rags underneath the faceseal of negative pressure full facepiece respirators, and one operator who wore a disposable dust mask was bearded.

6. DISCUSSION

6.1 Measurement of Dermal Exposure

The skin is a major route of systemic uptake for many pesticides. Over the years, various methods have been used to estimate dermal exposure to pesticides, the most common of which has been the patch method. However, non-uniform deposition across the body has been reported suggesting that patch sampling may not be able to provide accurate assessment of dermal exposure.

The degree of uniformity of dermal deposition will, however, depend on work activity and type of application. In spray or brush applications of pesticides, for example, splashing or soaking of random areas of the body is unlikely, and it has been suggested that dermal exposure may be more uniform. The principal aim of this study has been, therefore, to evaluate the validity of patch sampling during the spray application of pesticides for three industrial sectors, specifically, pest control, timber and masonry preservation and the application of anti-fouling paint.

The study was based on a total of twelve surveys in these sectors and a pilot study in the timber and masonry preservation sector. The findings are considered to be representative of spray application of pesticides in each sector, across a range of organisations.

The total mass of pesticide extracted from the suit sections and patches ranged from around 1mg to 19.2g.

The lowest levels of dermal exposure (in terms of absolute mass) were observed in the pest control sector followed by the timber and masonry preservation sector. Much higher levels were observed in the EAF paint sector where sprayers generally had a higher exposure than potmen. Observations of working practices revealed that dermal exposure occurred via a number of routes, and was influenced by incidental factors such as leaking spray lances. However, the most relevant factors are considered to be application technique, type of formulation, working method and working conditions.

Dermal exposure during the study resulted via the following routes:-

Deposition of aerosol - aerosol deposition, which typically results in a fairly uniform exposure, was observed whilst operators were positioned within the aerosol / powder cloud during spraying, e.g. in spraying of timbers, and "high" spraying and powder application in pest control. During the application of EAF paint, sprayers were exposed to significant "overspray".

Splashing - splashing was non-uniform. Splashing was observed during the mixing of EAF paint, and directly from applicator nozzles in each sector. In the pest control sector some splashing occurred during the preparation of working strength solution when the compression sprayer was opened.

Direct contact - direct contact with pesticides resulted mainly in exposure to the operators' hands. In the EAF sector, direct contact with paint on drums and lids was the main route of dermal exposure for potmen. Pest control operators were exposed to powder formulations during filling of the bellows type applicator. Operators in all sectors were exposed when they adjusted the nozzle of their spray applicator, or reversed the tip of the spray gun. The highest measurement in the timber and masonry sector arose from a leaking spray gun, which resulted in high exposures to the hands and body.

Surface contact - contact with newly treated surfaces or contaminated equipment, such as lances and hoses, was non-uniform affecting the hands and other parts of the body which may have brushed against a contaminated surface. Visual observations indicated that surface contact was a significant route of exposure during timber treatment, and, to a lesser extent, at shipyards.

Cross-contamination - cross-contamination was observed in the timber treatment sector where operators touched their sampling suits with their contaminated gloves. By its nature, exposure via this route is non-uniform.

The likelihood and extent of dermal exposure by the above routes will affect the distribution and uniformity of pesticide over the body. This consideration alone is likely to have a strong influence in determining whether the patch method is an acceptable means of assessing dermal exposure in these applications.

For the survey as a whole, the results indicated that the patch method overestimated the potential whole body dermal exposure. The evidence from this study alone is insufficient to confidently define why this should be the case, but the most likely reason is the positioning of the patches in relation to the distribution of exposure over the body. For example a patch positioned (as it was) on the outer sleeve is likely to give a higher estimate of exposure of the arm than one placed on the inner sleeve. However, it should be noted that the limits of agreement between the two methods were large and the patch method also underestimated potential dermal exposure for some individuals in each of the sectors, particularly in the EAF paint sector.

Individually, the relationship between the assessments of whole body exposure by the two methods varied between the three sectors. For both the pest control and timber treatment sector, the average estimation of whole body exposure by the patch method is twice that for the suit method. In the EAF paint sector, however, the patch method underestimated the potential dermal exposure by on average, around 40%.

Within each of the industry sectors, there was considerable individual variability between the ratios of the estimates of whole body dermal exposure by the suit and patch method. As a general indication of variability, more than half of the ratios were between 0.5 and 2, but several lay well outside of this range. For all three industry sectors individual values of this ratio greater than and less than one occurred.

In terms of the results for individual suit segments, the best agreement between the two methods was observed for the lower legs (Figures 6 and 7). Reasonably good agreement was observed for the majority of other suit sections (Figures 3, 5, 8-13). The poorest agreement was observed for the front torso (Figure 4) where the patch method indicated exposures that were lower than those determined by the suit method by a factor of greater than two.

The general impression, therefore, is that the relationship between the estimate of regional exposure derived from the suit and the patch method depends critically upon the position of the patch relative to the distribution of pesticide deposited on that section of the suit. Because of this, the assessment of individual regional deposition obtained using the patch method will be less reliable than the corresponding assessment of whole body exposure where the results for several patches are averaged. Where this assessment of whole body exposure is extended to an average over a given population carrying out similar work activities, the additional averaging involved will improve the reliability of the estimates of whole body exposures further.

However, the range of potential dermal expsoures measured in the study was enormous, from about 1mg to nearly 20g. In the light of this range, the discrepancies generally do not appear to be important. In general, therefore, the patch method has proved to be an acceptable means of determining the order of magnitude of whole body dermal exposure to pesticides and can be used to reliably identify those operators whose jobs or work practices give risk to particularly high dermal exposure levels. The practical advantages of patches over suits, in our opinion, outweigh the additional measurement errors.

The data arising from either the suit or patch methods should be interpretated with a degree of caution. Both methods can be used to provide an estimate of potential dermal exposure, but neither provides information on the mass of pesticide that reaches the skin, nor on the mass absorbed through the skin. Therefore, the scope of each of these methods is inherently limited since the overall risk to health from exposure to pesticides depends upon the mass *absorbed* by the skin, which, in turn, depends on both the mass of the pesticide that is deposited on the skin and on its concentration.

In summary, the patch method is an acceptable means of *estimating* potential dermal exposure to pesticides, and may be used as a tool to identify operators most at risk. Clearly, however, where a more accurate estimate of actual dermal exposure is required, e.g. assessment of the effectiveness of personal protective overalls, a change of approach is necessary.

Experience gained in this study suggests that, the degree to which the material collected on the patch accurately represents regional exposure may be strongly dependent on the position of the patch. For example, in this study the "front torso" patch was placed on the right-hand side of the operators' torso. However, better agreement between the two sampling methods for the front torso may have been achieved if the patch had been either (i) placed in the centre of the torso, (ii) supplemented by a second patch, or (iii) increased in size (eg. a long thin patch running vertically down the middle of the torso).

We recommend, therefore, that some further work be carried out to investigate means of improving the overall accuracy of the patch method, for determining individual regional and whole body dermal exposure. In particular, further studies should include an assessment of whether modified patch shapes and locations would improve agreement between the whole suit section and patch methods for assessment of regional dermal exposure. This, in turn, will greatly improve the reliability of the patch method as a means of estimating whole body dermal exposures for individals and for groups of workers.

6.2 Hazard Awareness and Attitude to Personal Protective Equipment

The pesticides included in this study (synthetic pyrethroids, carbamates and copper) have relatively low toxicity compared with pesticides commonly used in the past, e.g. lindane and tributyl tin compounds. Any health effects experienced with the use of copper-based EAF paints are likely to be attributed to other compounds in the paint such as xylene and biocide boosters. However, one of the EAF paints included in this study also contained tributyl tin compounds, which may present additional health effects. Copper poisoning due to occupational exposure is very rare. Similarly, with reasonable precautions, the organic pesticides in this study represent a low risk. Nevertheless exposure should be reduced to as low a level as practicable. Furthermore, there is increasing concern in Germany over the chronic health effects of synthetic pyrethroids which may lead to a ban on their use there.

Almost everyone questioned in this study thought that skin contact with pesticides should be avoided. Evidence of operators taking precautions to avoid skin contact was demonstrated at shipyards and by pest control operators.

Pest control operators were the most knowledgeable on the health risks associated with the use of pesticides and handled the pesticides, particularly the liquid forms, with care to avoid skin contact because of the potential skin uptake. Those who used powder formulations relied on personal protective equipment since the nature of the task led to unavoidable exposure.

Shipyard operators were likely to minimise skin contact with EAF paint because it was difficult to remove and was said to cause a burning sensation. Paint sprayers wore either cotton rags around their wrists and forehead or a Tyvek cape hood, in addition, vaseline or castor oil was used on their face.

Timber treatment operators were generally less knowledgeable on the associated health hazards compared with the pest control operators. Visual observations revealed that fewer precautions were taken by operators in this sector to minimise dermal exposure. This is highlighted by the operator who used a leaking lance, who did so without showing any concern. Operators also worked within the aerosol mist during spraying, although this was often unavoidable due to the working conditions. They generally relied on personal protective equipment such as PVC or nitrile gauntlets for protection.

The total mass of pesticide on the sampling suits and gloves varied from very low levels in the pest control sector, through to much higher levels in the EAF paint sector.

The highest of the exposures in the timber treatment sector were most likely related to the application technique and working conditions, such as spraying attic timbers in confined spaces.

The highest levels were measured in the EAF paint sector. However, direct contact with the paint and exposure to the overspray is generally unavoidable. Operators in this sector also relied on personal protective equipment to minimise their exposure.

Working practices adopted by pest control operators and timber treatment operators, which are generally influenced by perception of risk, will undoubtedly have contributed to their overall exposure.

7. CONCLUSIONS

The range of measured potential dermal exposures in the study was very wide. The total mass of pesticide extracted from the suits and patches ranged from around 1mg to 20g.

The lowest levels of dermal exposure were observed in the pest control sector followed by the timber preservation sector. Much higher levels were observed in the EAF paint sector where contact with EAF paint during spraying was generally unavoidable.

In the pest control sector and timber preservation sector the patch method overestimated the total dermal exposure by a factor of two, whereas in the EAF paint sector the patch method underestimated total dermal by approximately 40%. However, in each sector they included results where the patch method both underestimated and overestimated potential dermal exposure.

The differences between methods are small compared with the range of exposures measured. The patch method has proved to be an acceptable means for reliably identifying those operators whose jobs or work practices give rise to particularly high dermal exposure levels.

Some further work should be carried out to investigate means of improving the overall accuracy of the patch method, particularly for the determination of individual regional and whole body dermal exposure.

Almost everyone questioned in this study thought that skin contact with pesticides should be avoided.

Pest control operators were the most knowledgeable on the health risks associated with the use of pesticides and took care to avoid contact with them because of the potential skin uptake. Timber treatment operators were generally less knowledgeable and took fewer precautions to minimise dermal exposure. Shipyard operators took precautions to minimise skin contact with EAF paint, because it was difficult to remove and was said to cause a burning sensation.

The extent to which good working practices are adopted by operators in the pest control and timber treatment sectors, in response to their perception of risk, will undoubtedly have influenced their overall exposure.

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Table 1. Surface area of large and extra large suits

	Large (cm^2)	Extra large (cm^2)
Hood	1248	1288
Torso - front	2975	3480
Torso - back	2838	3132
Lower leg L	1868	2247
Lower leg R	1868	2247
Upper leg L	4008	4213
Upper leg R	4008	4213
Lower arm L	850	1027
Lower arm R	850	1027
Upper arm L	1104	1329
Upper arm R	1104	1329
Total	22721	25532

Table 2. Measurement of absorbency of washed and unwashed overalls

FABRIC	Pre-treatment	Penetration (%)	Retention (%)	Run-off (%)
ARCO white hooded overalls (35% cotton, 65% polyester)	Unwashed	18	8	74
ARCO white hooded overalls (35% cotton, 65% polyester)	Washed	58	42	0.1

Table 3. Measurement of absorbency of sampling gloves

GLOVE TYPE	Penetration (%)	Retention (%)	Run-off (%)
ARCO cotton knitted glove	13	3	84
ARCO cotton drill glove	14	6	80

Table 4. Differences in mass of pesticide for the whole suit estimated by the suit and patch methods.

Survey	Sector	Sprayer/ Pot man	Suit Method (mg)	Patch Method (mg)	Difference = Suit - Patch (mg)	Difference/ Suit x 100 (%)
2/01	Pest	S	1.4	1.0	0.4	28
3/01	Control	S	9.6	13.3	-3.7	-38
6/01		S	12.4	37.0	-24.6	-198
9/01		S	1.2	3.7	-2.5	-207
9/02		S	2.9	5.9	-3.0	-105
1/01	Timber	S	4.9	7.2	-2.3	-46
1/02	Pres.	P	0.7	1.1	0.4	57
7/01		S	9.2	7.1	2.3	23
7/02		S	20.3	51.6	-31.3	-153
10/01		S	49.2	106.1	-56.9	-116
10/02		S	25.4	52.3	-26.9	-106
12/01		S	39.6	103.1	-63.5	-160
12/02		P	4.0	14.1	-10.1	-256
4/01	EAF	S	1418	1206	212	15
4/03		P	2078	1138	940	45
5/01		S	2569	4363	-1794	-70
5/02		P	1019	636	383	38
5/03		S	9582	19245	-9663	-101
11/01		S	3668	550	3118	85
11/02		P	1402	45	1357	97
13/01		S	7628	11299	-3671	-48
13/02		P	1085	765	319	29

Table 5. Logarithmic transformed values of pesticide for the suit and patch methods and Differences between the two for the whole suit.

Survey	Sector	Sprayer/ Pot man	Log(Suit Method)	Log(Patch Method)	Difference = Suit/Patch	Exp(Difference) = Suit/Patch
2/01	Pest	S	0.348	0.037	0.311	1.36
3/01	Control	S	2.263	2.585	-0.322	0.72
6/01		S	2.517	3.611	-1.094	0.33
9/01		S	0.195	1.318	-1.123	0.32
9/02		S	1.050	1.769	-0.719	0.49
1/01	Timber	S	1.589	1.967	-0.378	0.69
1/02	Pres.	P	-0.403	0.048	-0.451	0.64
7/01		S	2.221	1.963	0.258	1.29
7/02		S	3.013	3.944	-0.931	0.39
10/01		S	3.896	4.664	-0.768	0.46
10/02		S	3.235	3.958	-0.723	0.49
12/01		S	3.679	4.635	-0.956	0.38
12/02		P	1.372	2.643	-1.271	0.28
4/01	EAF	S	7.257	7.095	0.162	1.18
4/03		P	7.639	7.037	0.602	1.83
5/01		S	7.851	8.381	-0.530	0.59
5/02		P	6.926	6.456	0.470	1.60
5/03		S	9.168	9.865	-0.697	0.50
11/01		S	8.207	6.310	1.897	6.67
11/02		P	7.246	3.809	3.437	31.09
13/01		S	8.940	9.332	-0.392	0.68
13/02		P	6.989	6.640	0.349	1.42

Table 6. Mean difference between log transformed mass from suit and patch methods in three sectors.

	All Sectors (n = 22)	Pest Control (n = 5)	Timber Preservation (n = 8)	Erodible anti-fouling Paint (n = 9)
Mean difference	-0.130	-0.589	-0.653	0.589
Standard dev.	1.086	0.600	0.465	1.320
Ratio G.M. Suit/Patch	0.88	0.55	0.52	1.80
95% Limits of agreement	0.09, 8.35	0.10, 2.93	0.17, 1.56	0.09, 35.7
Median Difference	-0.422	-0.719	-0.746	0.348
Ratio G.M. Suit/Patch	0.66	0.49	0.47	1.42

G.M. - Geometric Mean

Table 7. Ratio of geometric means from the suit method divided by the patch method based on the mean and median differences in log transformed values and the limits of agreement for the individual sections of suit.

Section	Ratio based on Mean difference	95% Limits of agreement	Ratio based on Median difference
Hood	1.41	0.07, 27.9	1.16
Torso - Front	2.05	0.04, 98.1	1.19
Torso - Back	0.97	0.06, 15.5	0.78
Lower leg L	0.96	0.15, 4.5	0.92
Lower leg R	0.99	0.22, 4.4	0.96
Upper leg L	0.56	0.06, 5.2	0.46
Upper leg R	0.54	0.09, 3.3	0.53
Lower arm L	1.18	0.28, 5.0	1.22
Lower arm R	0.84	0.11, 6.3	0.56
Upper arm L	0.52	0.14, 2.0	0.47
Upper arm R	0.67	0.15, 2.9	0.59
Whole suit	0.88	0.09, 8.35	0.66

Table 8. Ratio of geometric means for the suit method divided by the patch method based on the mean and median of the log transformed values for the pest control, timber preservation and erodible anti-fouling paint sectors, for the whole suit and each section of suit.

Section	Pest control		Timber Pres.		EAF	
	Ratio based on Mean difference	**Ratio based on Median difference**	Ratio based on Mean difference	**Ratio based on Median difference**	Ratio based on Mean difference	**Ratio based on Median difference**
Hood	3.44	**1.16**	0.85	**0.67**	1.35	**1.43**
Torso - Front	1.60	**0.76**	0.76	**0.93**	5.16	**2.71**
Torso - Back	2.00	**1.80**	0.96	**0.82**	0.66	**0.54**
Lower leg L	0.72	**0.89**	1.16	**1.28**	0.96	**0.95**
Lower leg R	0.66	**0.59**	1.16	**1.27**	1.07	**1.20**
Upper leg L	0.38	**0.28**	0.37	**0.31**	0.96	**0.67**
Upper leg R	0.50	**0.31**	0.41	**0.36**	0.71	**0.62**
Lower arm L	1.85	**1.81**	1.11	**1.14**	0.99	**0.85**
Lower arm R	0.76	**0.56**	0.92	**0.51**	0.81	**0.63**
Upper arm L	0.47	**0.50**	0.46	**0.41**	0.61	**0.51**
Upper arm R	0.67	**0.49**	0.83	**0.87**	0.56	**0.54**
Whole suit	0.55	**0.49**	0.52	**0.47**	1.80	**1.42**

Table 9. Pest Control Sector - Mass of Pesticide (in mg) for Suit Sections and Extrapolated Patches

Survey/Participant:	02/1	03/1	06/1	09/1	09/2
Job:	Sprayer	Sprayer	Sprayer	Sprayer	Sprayer
Hood	0.023	0.10	*0.94*	0.019	0.13
Patch - Hood	*0.004*	0.10	0.04	0.09	0.11
Torso F	0.12	0.16	2.0	0.21	0.56
Patch - Torso F	*0.009*	0.79	0.15	0.52	0.74
Torso B	0.16	0.75	0.48	0.07	0.17
Patch - Torso B	0.09	0.32	*0.008*	0.29	0.30
Lower Leg L	0.30	1.83	0.34	0.11	0.12
Patch - Lower Leg L	0.22	1.99	0.38	0.35	0.23
Lower Leg R	0.21	2.71	0.16	0.10	0.16
Patch - Lower Leg R	0.11	4.81	0.26	0.32	0.25
Upper Leg L	0.20	2.74	4.06	0.22	0.47
Patch - Upper Leg L	0.44	1.78	26.42	0.78	1.74
Upper Leg R	0.36	0.78	0.86	0.24	0.47
Patch - Upper Leg R	0.15	2.66	1.62	0.84	1.54
Lower Arm L	0.008	0.12	0.89	0.08	0.19
Patch - Lower Arm L	*0.003*	0.07	0.27	0.07	0.21
Lower Arm R	0.01	0.22	0.84	0.07	0.30
Patch - Lower Arm R	*0.003*	0.39	3.38	0.14	0.33
Upper Arm L	*0.001*	0.07	0.63	0.05	0.12
Patch - Upper Arm L	*0.003*	0.15	1.25	0.18	0.15
Upper Arm R	0.012	0.11	1.21	0.05	0.17
Patch - Upper Arm R	*0.003*	0.22	2.24	0.15	0.27
Suit Total	1.42	9.61	12.40	1.22	2.86
Patch Total	1.04	13.26	36.99	3.74	5.87
Glove L	0.24	3.49	4.76	0.34	2.10
Glove R	1.13	0.58	6.05	1.11	1.67

*** - Patch lost**

Figures in italics have been derived from one half of the detection limit

Table 10. Timber and Masonry Preservation Sector - Mass of Pesticide (in mg) for Suit Sections and Extrapolated Patches

Survey/Participant:	01/1	01/2	07/1	07/2	010/1	010/2	012/1	012/2
Job:	Sprayer	Pump Attendant	Sprayer	Sprayer	Sprayer	Sprayer	Sprayer	Pump Attendant
Hood	0.34	0.09	0.07	0.78	0.97	0.20	2.64	0.15
Patch - Hood	0.48	0.20	0.20	0.57	0.24	0.46	4.14	0.10
Torso F	0.62	*0.07*	0.77	2.11	3.72	3.19	4.02	0.80
Patch - Torso F	0.69	0.48	0.46	2.19	7.91	3.12	6.58	0.43
Torso B	0.88	*0.05*	1.27	1.14	2.09	2.30	2.38	0.38
Patch - Torso B	0.46	*0.06*	0.68	1.57	3.63	1.14	6.10	0.58
Lower Leg L	0.30	0.08	0.90	2.17	8.21	2.34	5.19	0.35
Patch - Lower Leg L	0.42	*0.04*	0.46	1.23	8.90	3.48	21.11	0.15
Lower Leg R	0.35	0.10	0.53	2.56	10.10	3.58	3.34	0.21
Patch - Lower Leg R	0.46	*0.04*	0.33	1.58	26.46	3.49	5.35	0.08
Upper Leg L	0.89	0.10	1.60	2.48	4.41	2.19	5.34	0.41
Patch - Upper Leg L	1.92	*0.08*	1.70	13.40	27.41	10.05	25.26	0.92
Upper Leg R	0.62	0.12	2.63	5.34	10.13	1.41	6.06	0.58
Patch - Upper Leg R	0.83	*0.08*	1.56	24.56	29.64	5.23	15.93	11.03
Lower Arm L	0.21	0.02	0.60	1.49	0.84	1.54	3.65	0.28
Patch - Lower Arm L	0.70	*0.02*	0.57	0.85	0.24	1.69	7.03	0.13
Lower Arm R	0.19	*0.01*	0.41	1.02	2.42	5.50	4.16	0.31
Patch - Lower Arm R	0.39	*0.02*	0.20	2.51	0.76	19.09	9.04	0.17
Upper Arm L	0.20	*0.01*	0.29	0.59	0.74	0.74	1.26	0.16
Patch - Upper Arm L	0.59	*0.02*	0.81	1.42	0.58	1.56	5.16	0.24
Upper Arm R	0.30	0.02	0.14	0.67	0.58	2.40	1.54	0.32
Patch - Upper Arm R	0.20	*0.02*	0.16	1.80	0.33	3.02	6.34	0.22
Suit Total	4.90	0.67	9.22	20.34	49.21	25.40	39.59	3.95
Patch Total	7.15	1.05	7.12	51.64	106.10	52.34	103.05	14.05
Glove L	1.71	0.23	2.45	7.41	10.31	1.11	1.73	3.44
Glove R	0.80	0.41	3.53	6.39	39.06	12.27	0.19	39.43

*** - Patch lost**

Figures in italics have been derived from one half of the detection limit

Table 11. Application of EAF Paint - Mass of Copper (in mg) for Suit Sections and Extrapolated Patches

Survey/Participant:	04/1	04/2	04/3	05/1a	05/2	05/1b	011/1	011/2	013/1	013/2
Job:	Sprayer	Sprayer	Potman	Sprayer	Potman	Sprayer	Sprayer	Potman	Sprayer	Potman
Hood	110	176	19	347	48	586	23	1	276	6
Patch - Hood	65	74	3	246	33	764	13	1	316	15
Torso F	258	751	1764	515	281	669	3402	1360	1507	61
Patch - Torso F	126	1776	684	434	29	582	86	2	216	22
Torso B	92	*	17	269	46	1621	25	2	994	181
Patch - Torso B	86	*	32	973	95	6838	30	2	7841	16
Lower Leg L	155	153	94	179	105	1358	18	11	141	172
Patch - Lower Leg L	142	501	84	191	110	2626	42	3	300	36
Lower Leg R	240	97	62	128	81	1675	26	7	374	236
Patch - Lower Leg R	122	21	26	181	54	1752	104	3	410	538
Upper Leg L	141	258	36	417	85	1619	48	5	2549	356
Patch - Upper Leg L	35	754	179	698	112	2906	58	13	778	41
Upper Leg R	129	157	30	172	296	1009	42	6	411	36
Patch - Upper Leg R	141	228	67	403	131	1802	54	16	746	26
Lower Arm L	69	298	22	158	26	329	20	2	370	11
Patch - Lower Arm L	84	591	15	301	9	521	23	1	297	21
Lower Arm R	60	119	18	158	13	351	31	2	548	6
Patch - Lower Arm R	129	452	15	306	21	446	48	2	106	11
Upper Arm L	78	268	6	87	25	219	14	3	292	8
Patch - Upper Arm L	123	578	10	391	25	455	48	1	205	27
Upper Arm R	85	129	8	140	10	148	19	1	165	12
Patch - Upper Arm R	157	431	16	238	18	552	46	2	84	13
Suit Total	1418	*	2078	2569	1019	9582	3668	1402	7628	1085
Patch Total	2106	*	1138	4363	636	19245	550	45	11299	765
Glove L	2150	260	390	1061	867	2109	143	83	323	70
Glove R	975	390	485	646	1074	1817	110	54	385	6

* - Patch lost

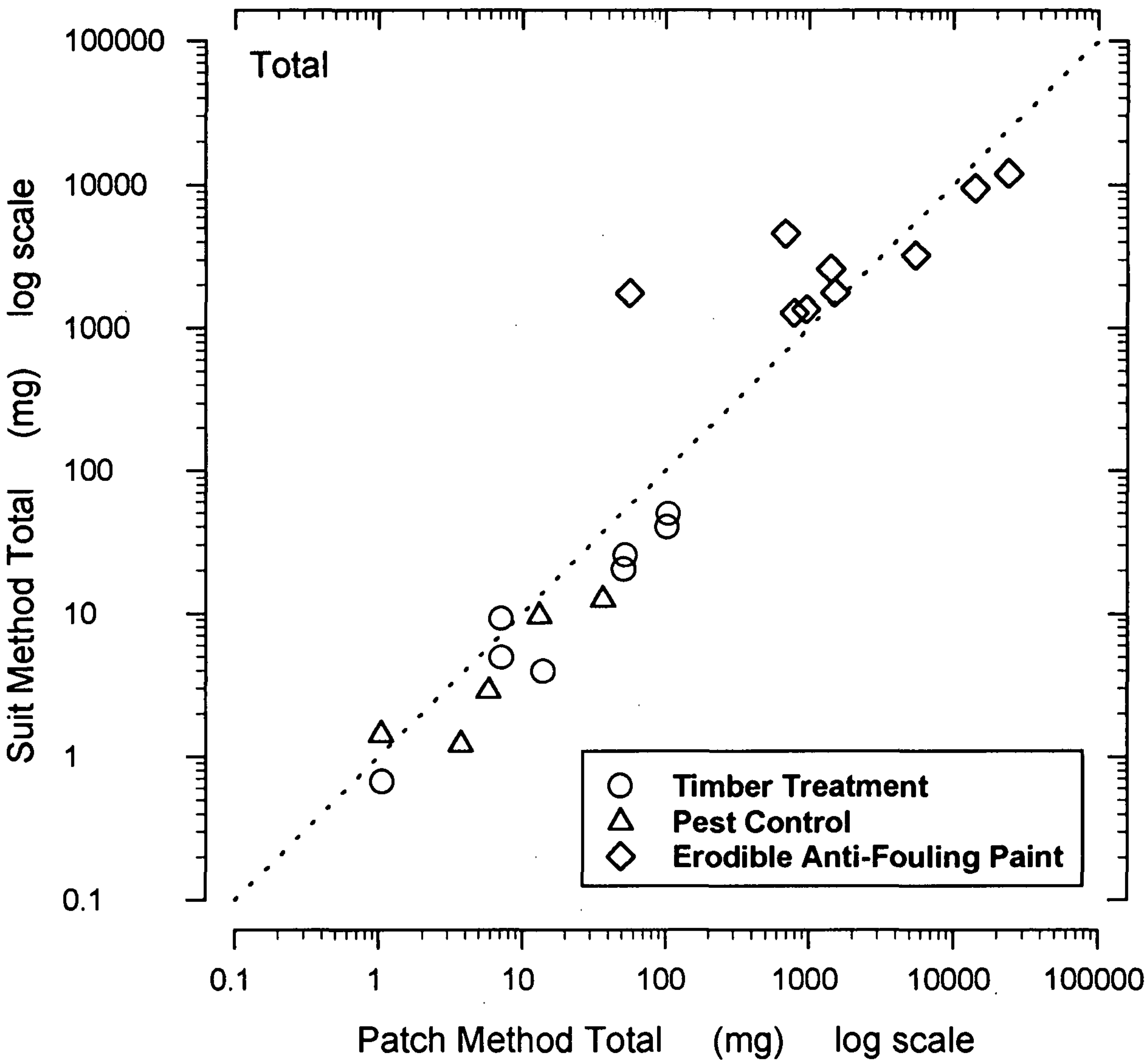


Figure 1. Plot of Mass of Pesticide from Suit Method Total and Patch Method Total in three sectors of use.

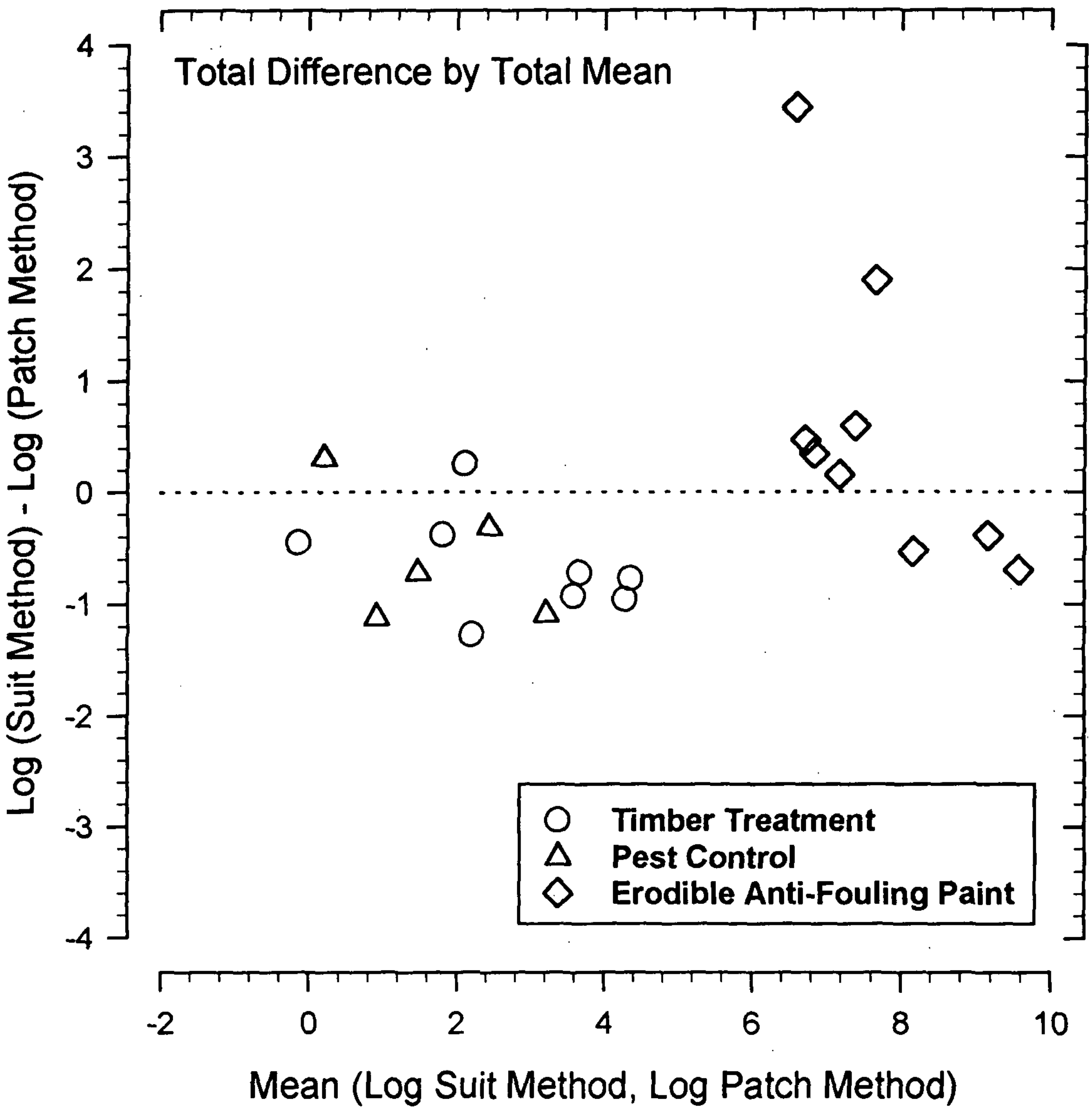


Figure 2. Plot of log Mass of Pesticide (in mg) from the difference between Suit Method Method Total and Patch Method Total and their Mean in three sectors of use.

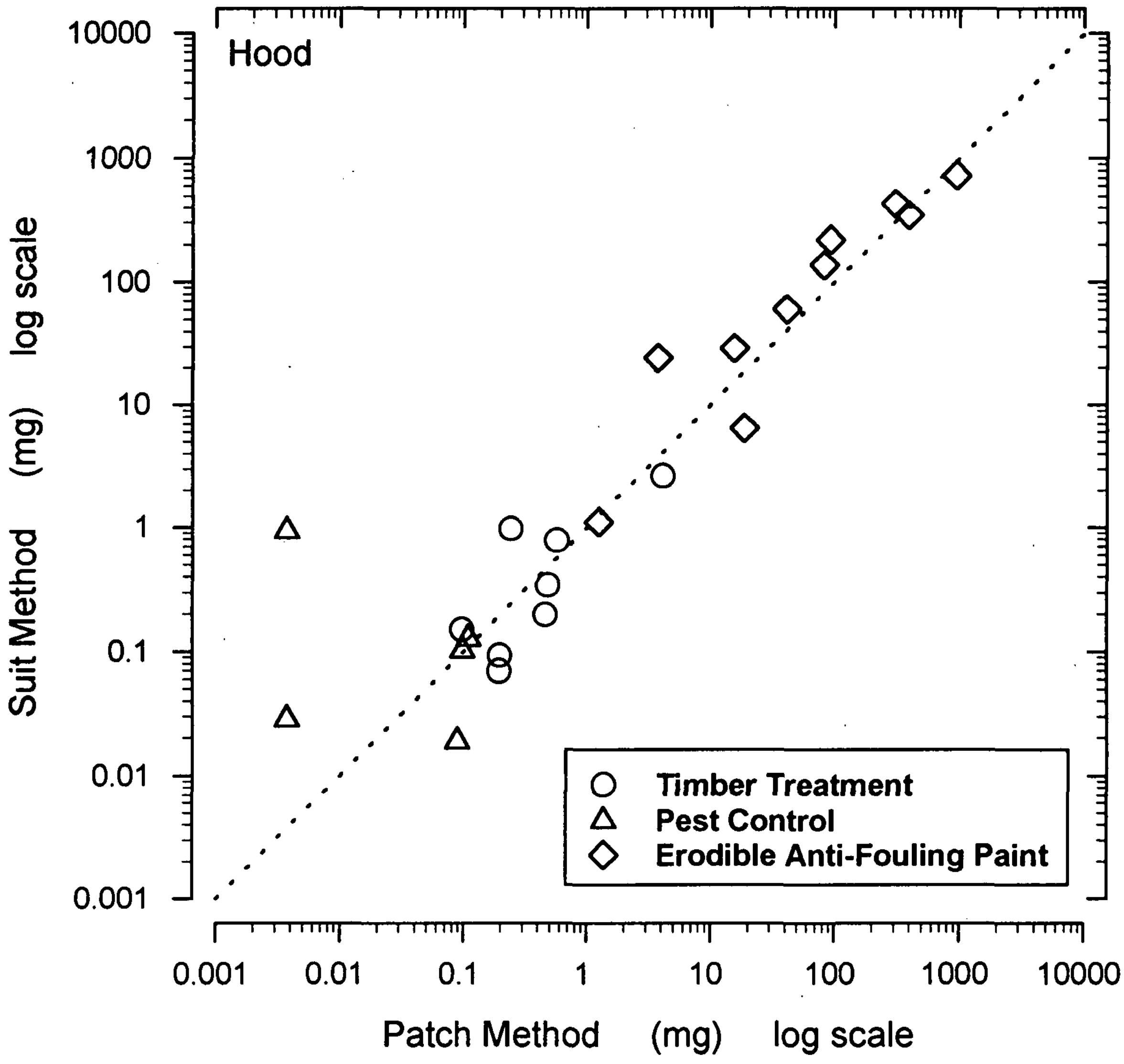


Figure 3. Plot of Mass of Pesticide from Suit Method and Patch Method for Hood in three sectors of use.

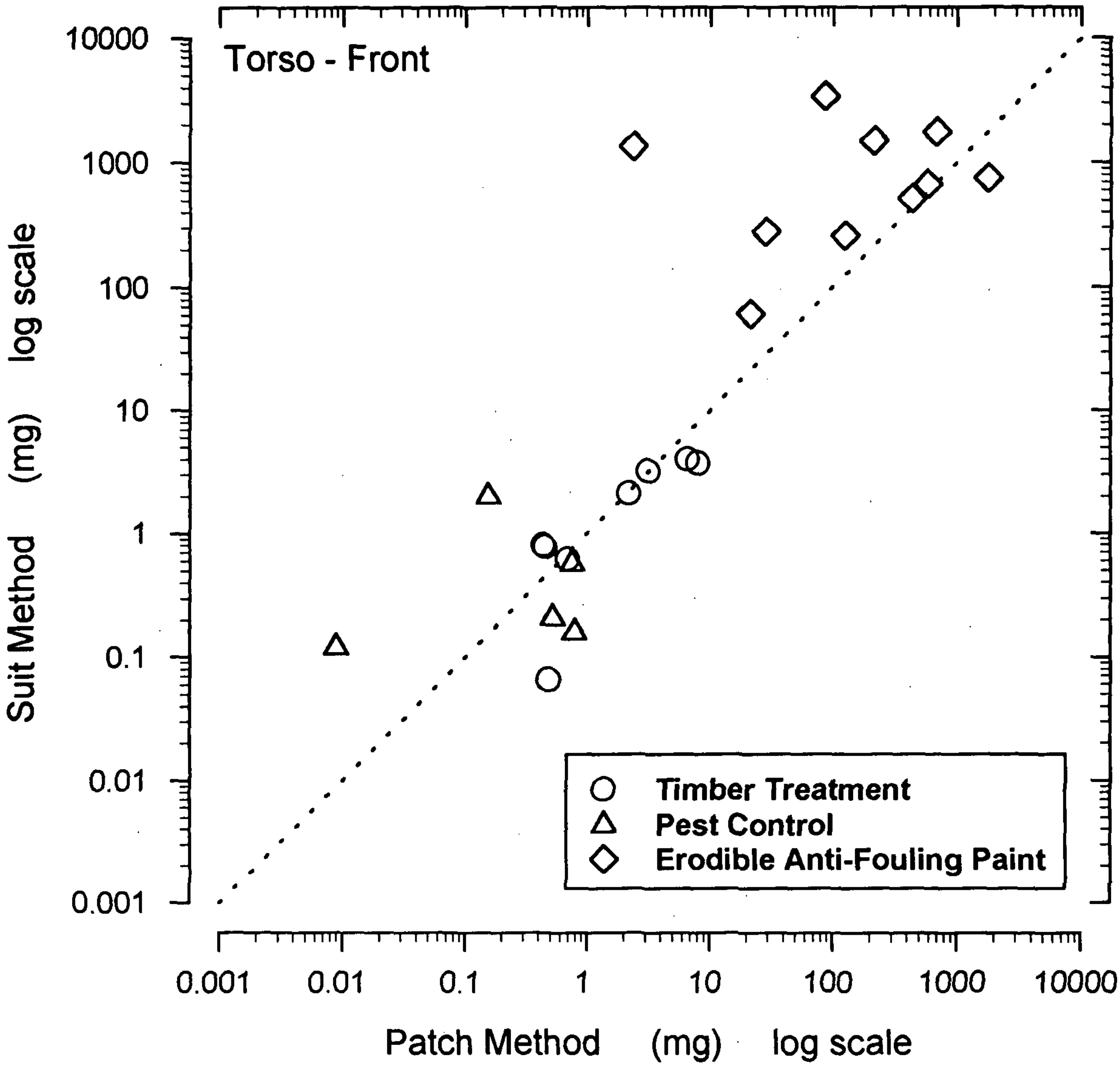


Figure 4. Plot of Mass of Pesticide from Suit Method and Patch Method for Torso Front in three sectors of use.

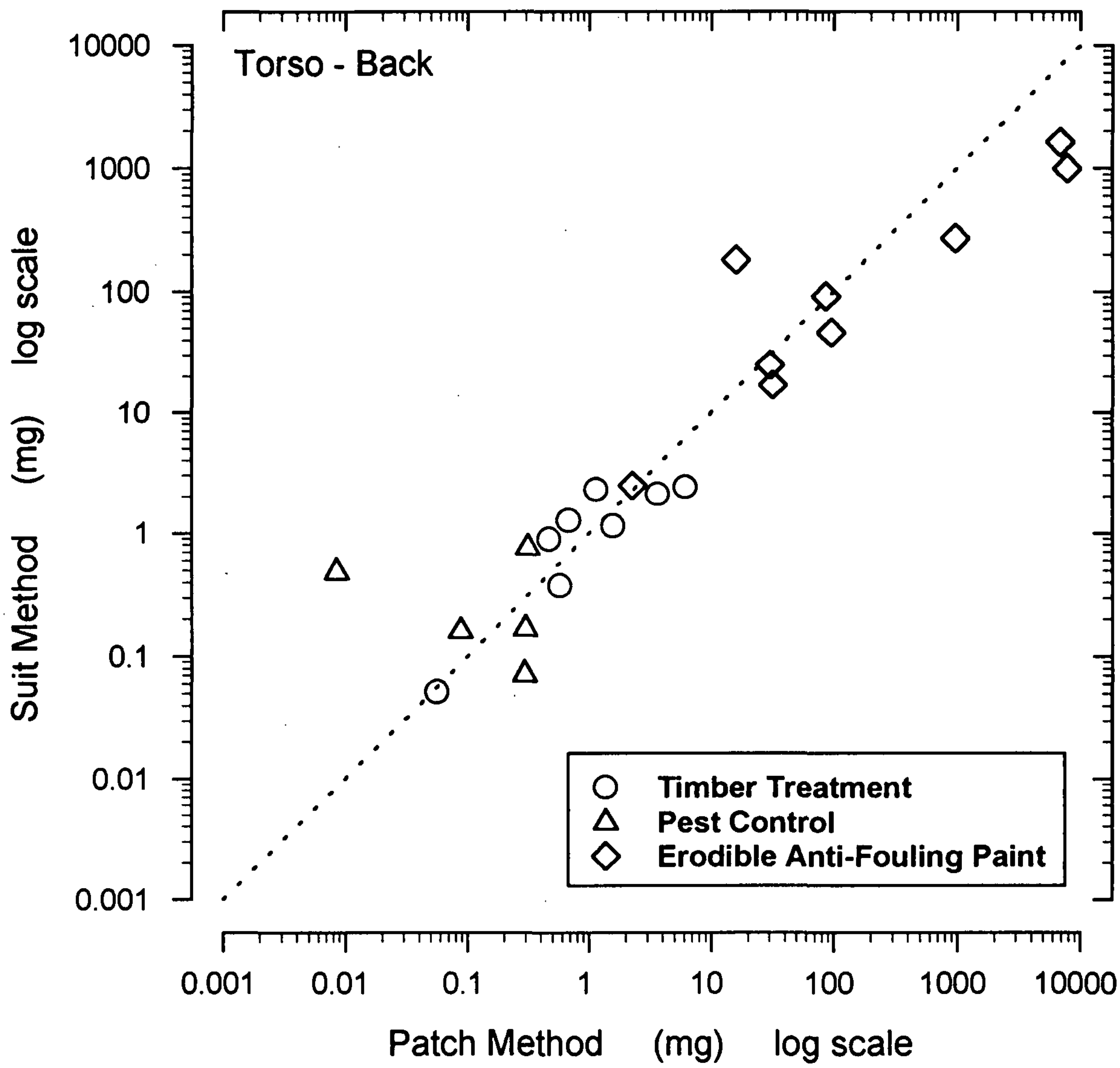


Figure 5. Plot of Mass of Pesticide from Suit Method and Patch Method for Torso Back in three sectors of use.

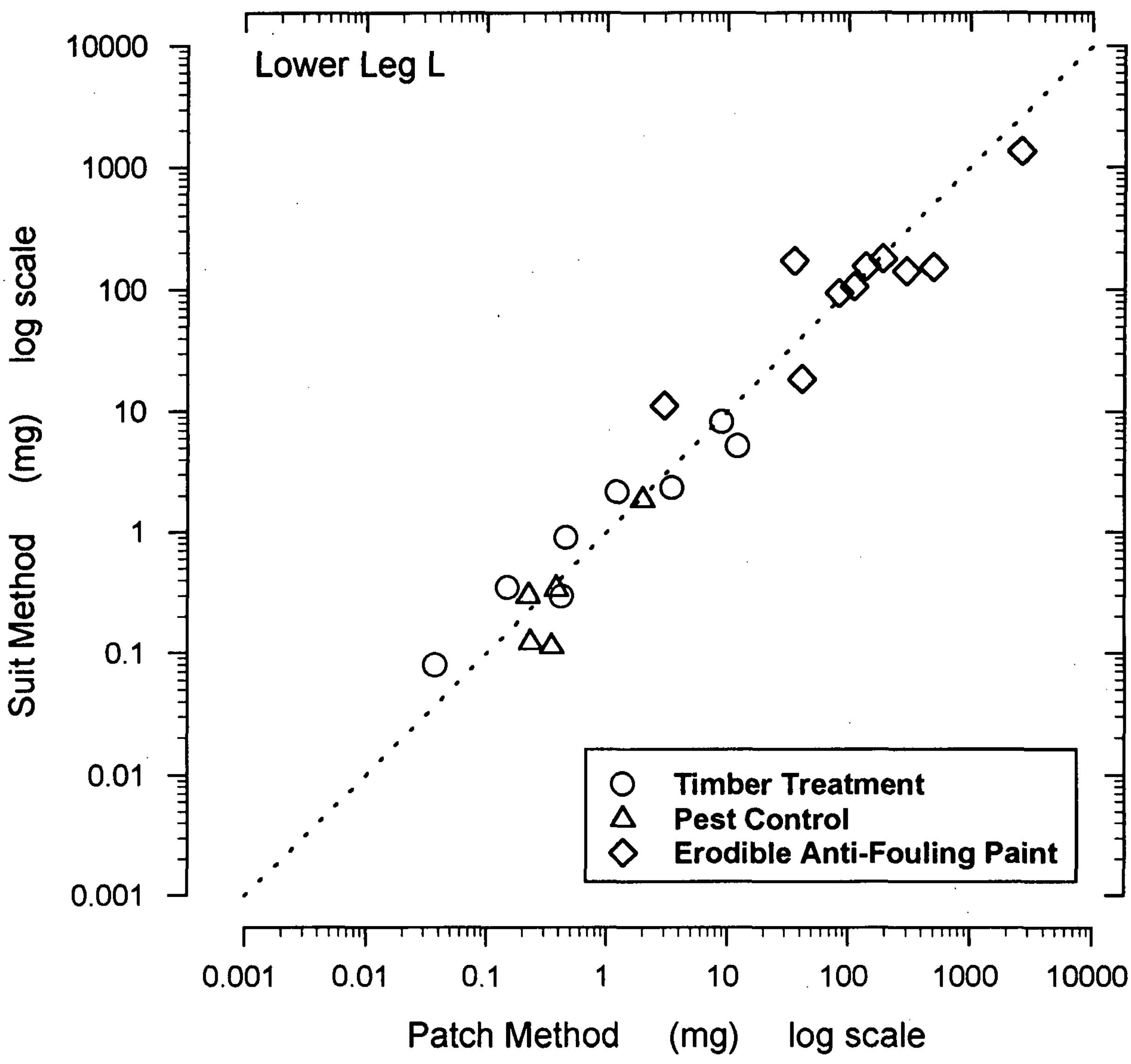


Figure 6. Plot of Mass of Pesticide from Suit Method and Patch Method for Lower Left Leg in three sectors of use.

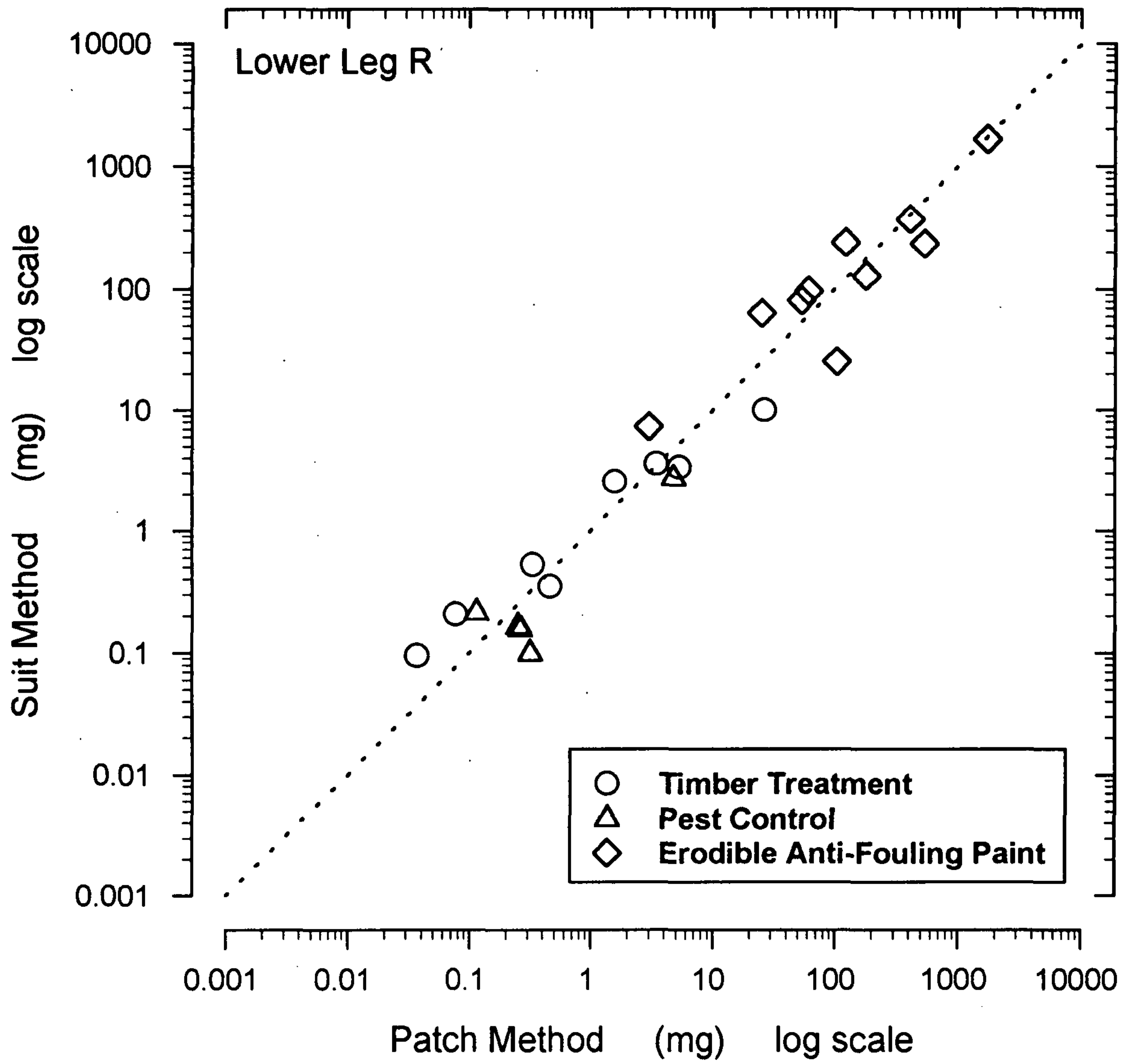


Figure 7. Plot of Mass of Pesticide from Suit Method and Patch Method for Lower Right Leg in three sectors of use.

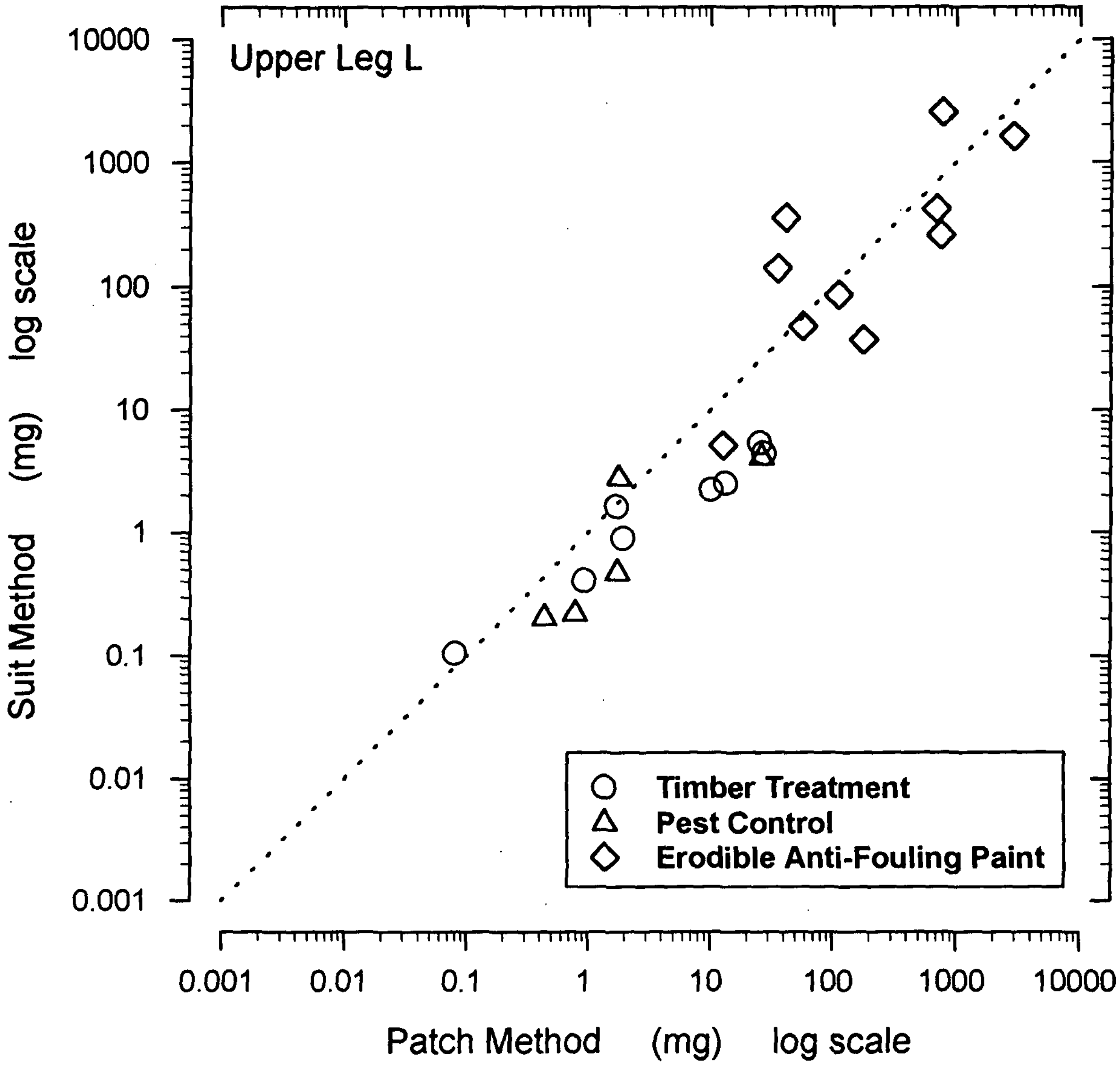


Figure 8. Plot of Mass of Pesticide from Suit Method and Patch Method for Upper Left Leg in three sectors of use.

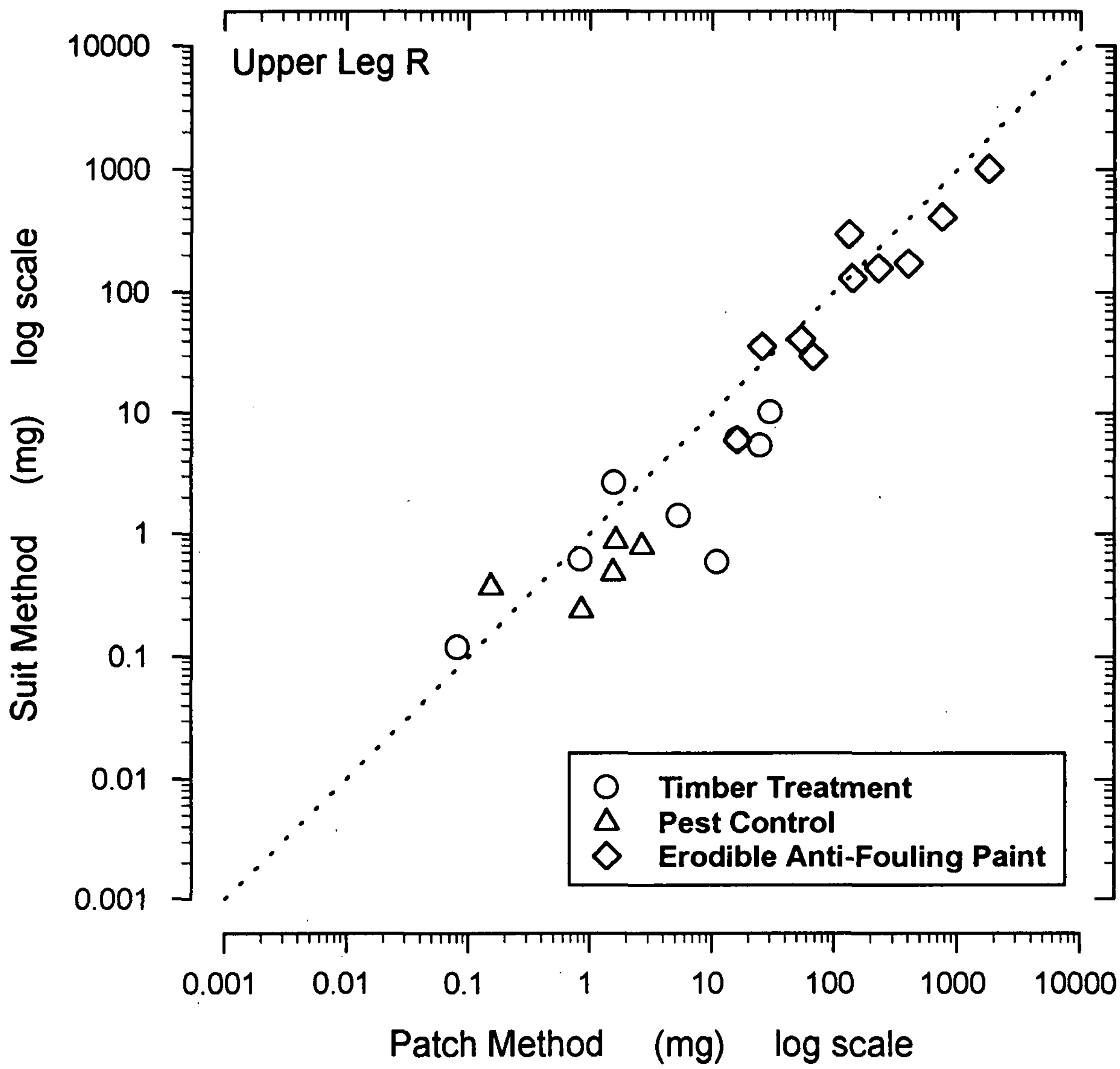


Figure 9. Plot of Mass of Pesticide from Suit Method and Patch Method for Upper Right Leg in three sectors of use.

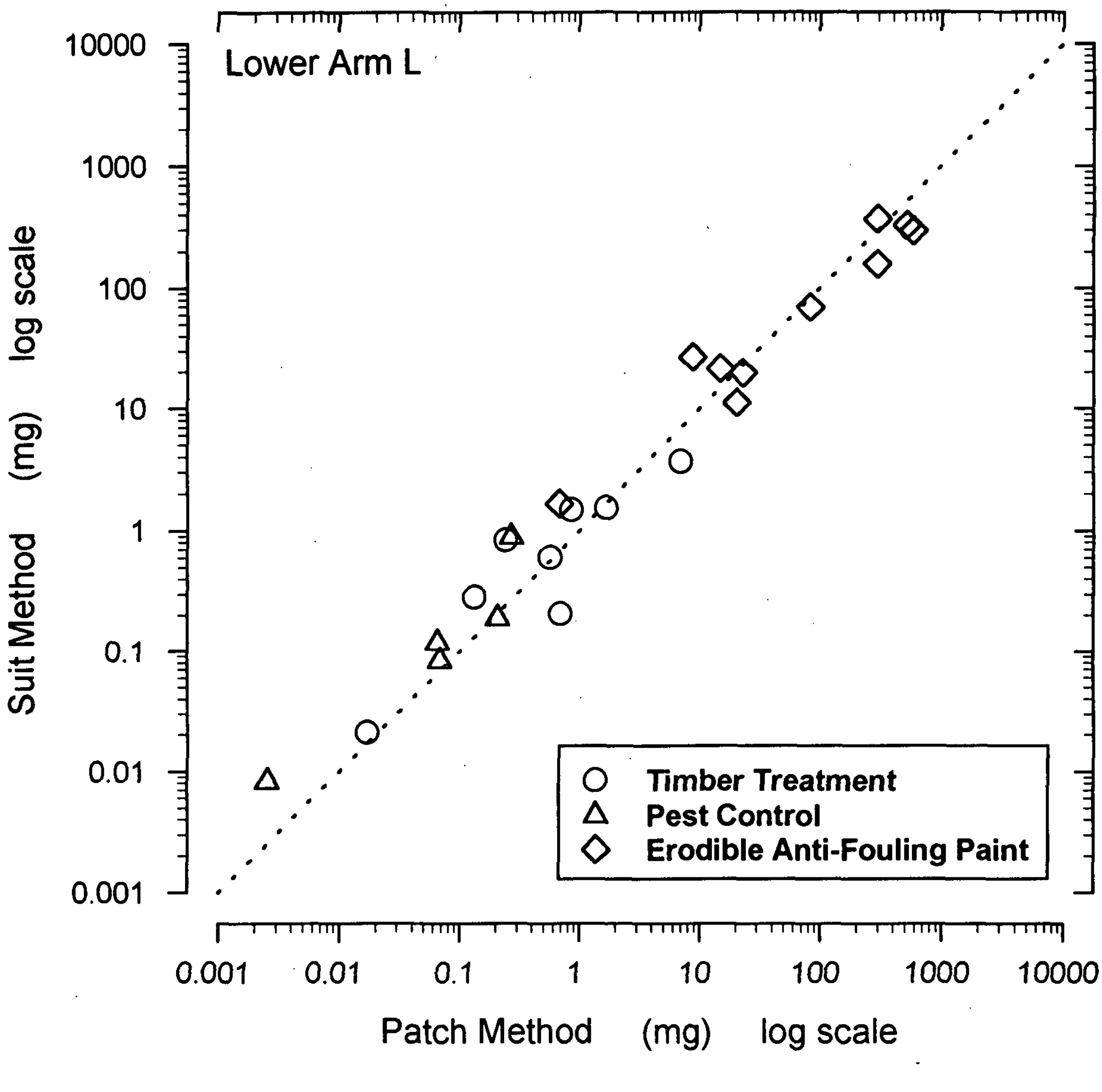


Figure 10. Plot of Mass of Pesticide from Suit Method and Patch Method for Lower Left Arm in three sectors of use.

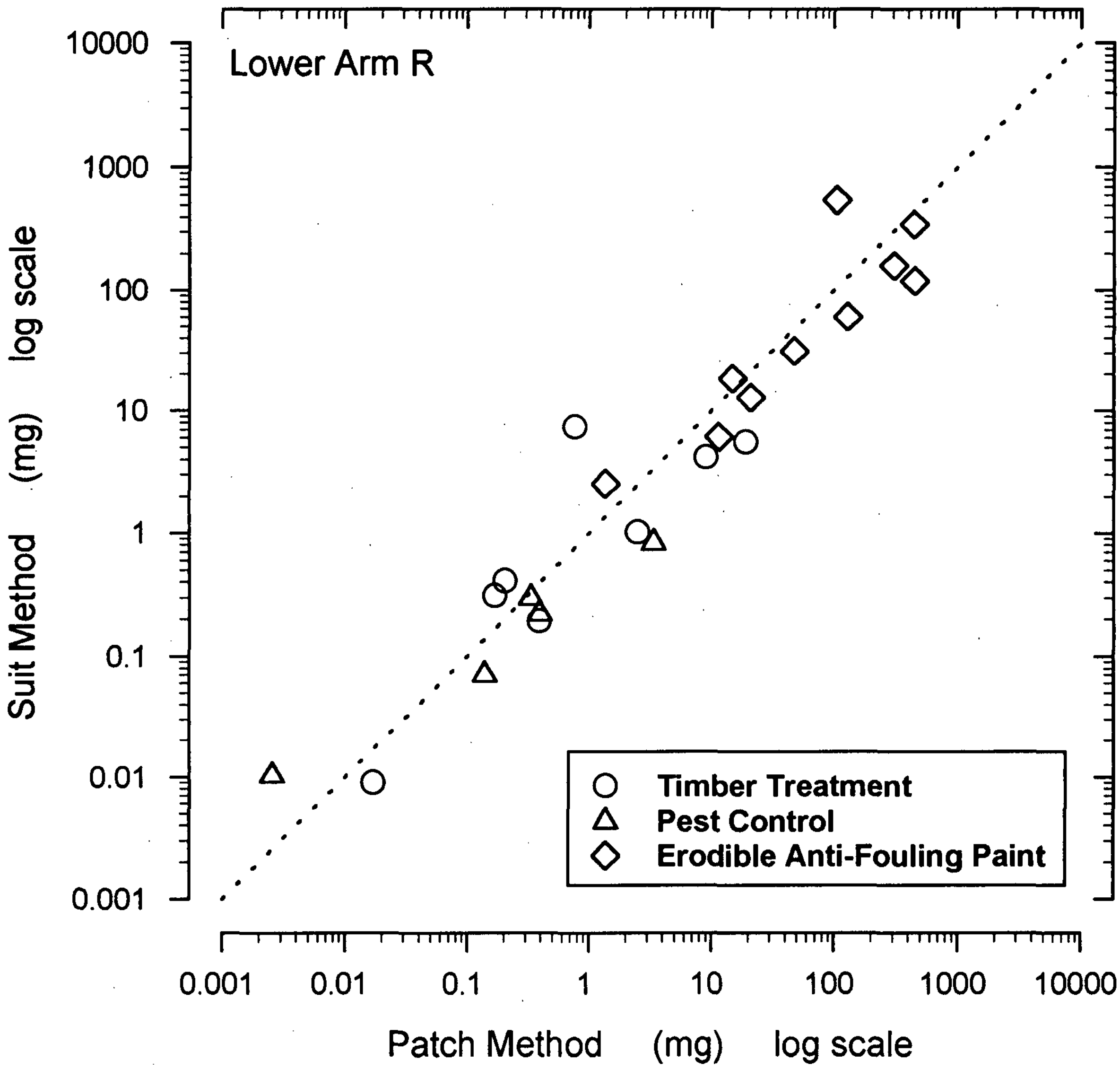


Figure 11. Plot of Mass of Pesticide from Suit Method and Patch Method for Lower Right Arm in three sectors of use.

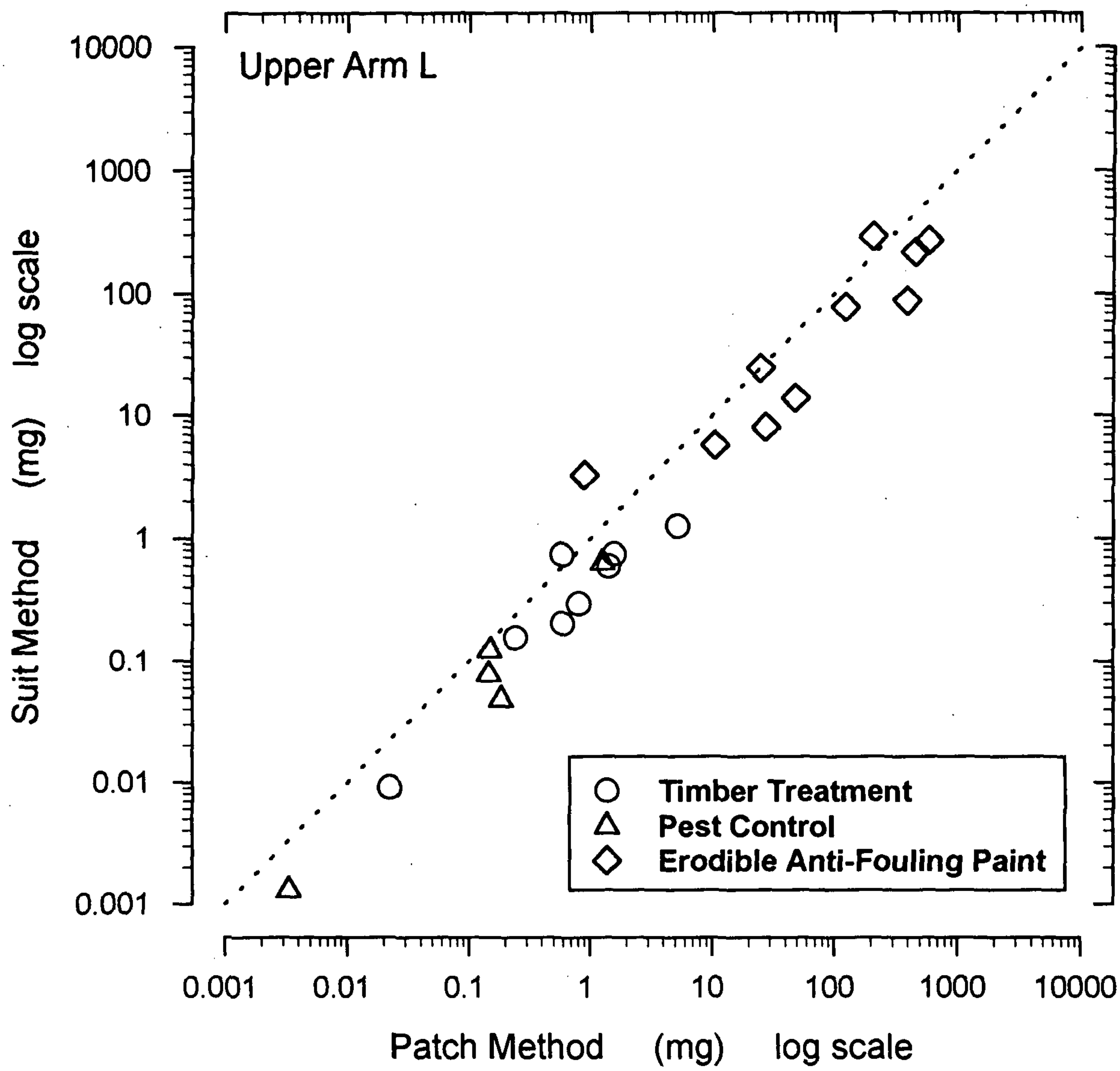


Figure 12. Plot of Mass of Pesticide from Suit Method and Patch Method for Upper Left Arm in three sectors of use.

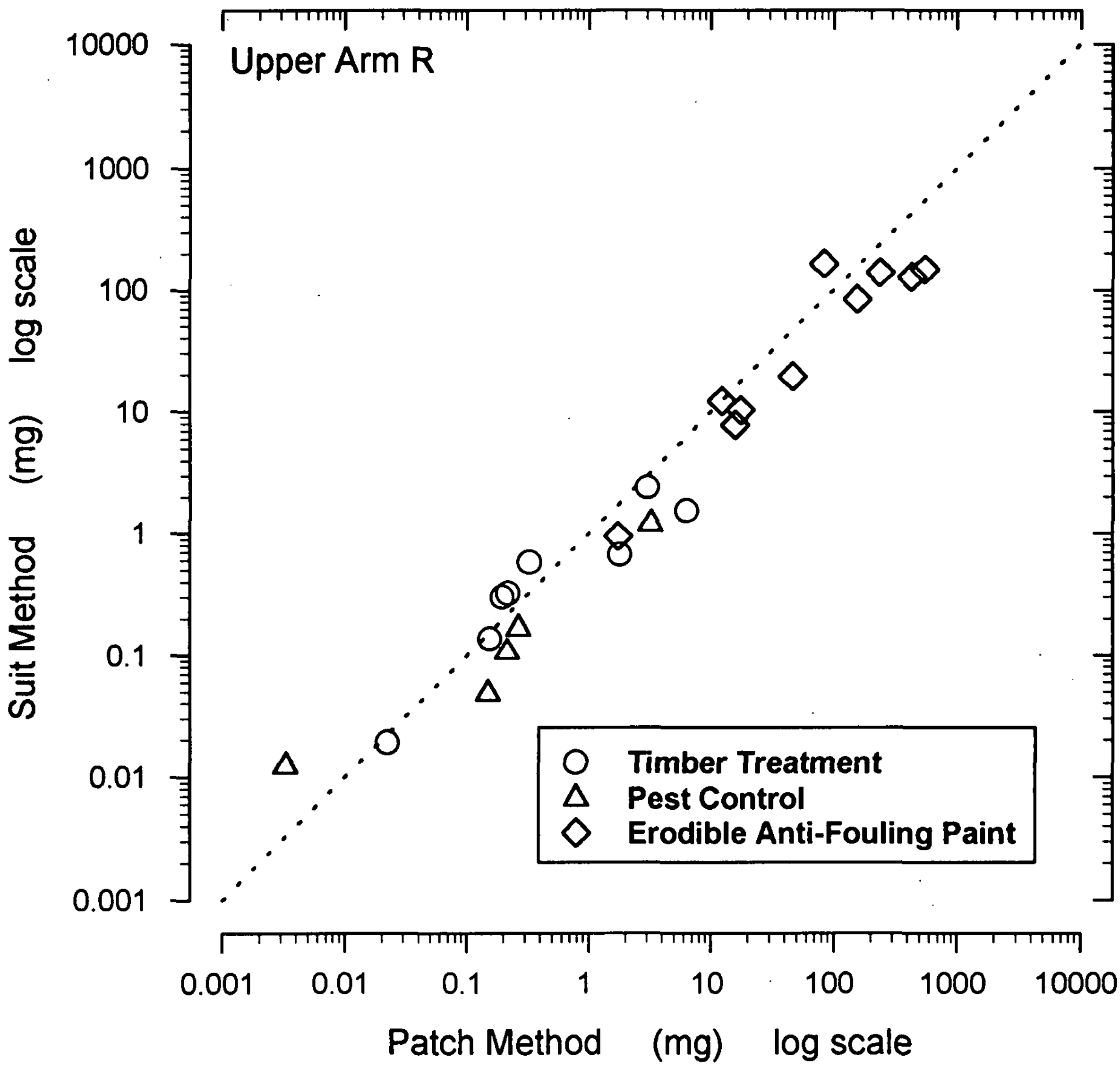


Figure 13. Plot of Mass of Pesticide from Suit Method and Patch Method for Upper Right Arm in three sectors of use.

APPENDIX 1

Questionnaire on Hazard Awareness and Attitude to PPE

INSTITUTE OF OCCUPATIONAL MEDICINE
8 Roxburgh Place, Edinburgh EH8 9SU

Occupational Hygiene Assessment of Non-agricultural Exposure to Pesticides

Risk Perception Questionnaire

Activity:

Name:	**Date:**
Company:	
Site(s)	

REFERENCE	668/

For each question place a **tick** in the box that most closely matches your answer. Use only **one** tick for each question unless otherwise instructed.

Definition

"Pesticide" is a general term to describe any chemical that kills or controls pests, or affects plant or animal life. Pesticides contain the pure chemical "active ingredient" mixed with other chemicals for practical use.

1. What pesticide(s) do you normally use? ____

2. What pesticide(s) did you use during this survey? ____

3. What special protective clothing do you normally wear?
   (*please specify*)

	a	s
Gloves	☐	☐
Overalls (cotton/poly-cotton or disposable)	☐	☐
Special overalls	☐	☐
Leggings	☐	☐
Hat/hood	☐	☐
Respiratory protection	☐	☐
Face-shield	☐	☐

a : always s : sometimes

4. Pesticides can enter your body via which of the following routes?
   (*you may tick more than one box*)

Breathing in	☐
Through the skin	☐
Swallowing	☐

5. Which is the most likely route for pesticides to enter your body?

- Breathing in ☐
- Through cuts in the skin ☐
- Through intact unbroken skin ☐
- Swallowing ☐
- Don't know ☐

6. Should skin contact with pesticides be avoided?

- Yes, always ☐
- Yes, only if the skin is cut ☐
- No ☐
- Don't know ☐

7. Does using pesticides without special protective clothing affect your health?

- Yes, immediately ☐
- Yes, over a period of time ☐
- No ☐
- Don't know ☐

8. How much skin contact or contamination of your clothing by pesticides is likely to occur for each of the following activities? (Tick only one box for each activity)

Activity	High Exposure	Medium Exposure	Negligible/No Exposure
Preparation of pesticides (eg dilution)			
Application of pesticide			
Cleaning of tools and equipment			
Maintenance and repair of equipment			
Removal of personal protective equipment (eg gloves, overalls)			
Others			

High exposure : **gross contamination of hands/ exposed body or clothing**

Medium exposure: **some contamination, mainly restricted to overalls**

Negligible/ No exposure: **seldom or no contamination of hand/ exposed body or clothing**

APPENDIX 2

Assessment Proforma

Institute of Occupational Medicine
8 Roxburgh Place, Edinburgh EH8 9SU

Occupational Hygiene Assessment of Non-Agricultural Exposure of Pesticides

Section 1 - Initial Information

Date of assessment : dd mm yy [| | | | |]   Assessor : [ ]

1. Sector
   1 = Pest control
   2 = Timber treatment
   3 = Application of erodible anti-fouling paint [ ]

1.1 Survey Number : [|]

1.2 Participant Number (leave blank) : [|]

1.3

Company name :	Contact :
Address :	
Post Code :	☎ :

2.0 Survey Details :

2.1

Application Address :
Site of Application :
Areas to which applied :

2.2 Location of site of application :

1 = Outside
2 = Inside building
3 = Tented enclosure
4 = Other

If *other,* please specify :

2.3 For indoor or tented facilities only :

1 = Natural ventilation
2 = Forced extraction
3 = Both
4 = None

3.0 Plan of application site :

Dimensions of treated area :

Dimensions of enclosed area :

4. Environmental Conditions :

4.1 Wet bulb (sling) temperature [°C]

4.2 Dry bulb temperature [°C]

4.3 Relative humidity [%]

For Outdoor Applications Only :

4.4 Air Speed (m/s) :

4.5 Wind direction :

4.6 Precipitation :

1 = Dry
2 = Drizzle
3 = Rain

Section 2 : Pesticide Application

1. Site Details :

1.1 Reason for treatment/infestation :

2. Product Used :

2.1 Manufacture :

2.2 Trade Name :

2.3 Active Ingredients :

1 = Permethrin

2 = Bendiocarb

3 = Cypermethrin

4 = Cuprous oxide

2.4 Batch Number :

2.5 Diluent :

1 = Solvent

2 = Water

3 = Other

2.6 Dilution rate :

2.7 Quantity used :

2.8 (i) Application method

1 = Spraying

2 = Brushing (Go to 2.9)

3 = Spraying and brushing

4 = Other (Go to 2.9)

If *other*, please specify :

2.8 (ii) (If 2.8(i)= 1 or 3) Applicator used for spraying (where applicable)

0 = Non-applicable

1 = Airless gun

2 = Nap sack sprayer

3 = Gas propellent

4 = Other

If *other*, please specify :

2.8 (iii) (If 2.8(i)=1 or 3) Spraying Method (where applicable)

0 = Non-applicable

1 = Entire area

2 = Band spraying

3 = Blanket spraying

4 = Other

If *other*, please specify :

2.9 Describe procedure for application :

3. Participant Details :

3.1 Individuals taking part in treatment application :

	Name :	Task :
3.2	1:	
3.3	2:	
3.4	3:	

3.5 Individuals responsible for preparation of pesticide formulation :

1:

2:

3:

3.7 Description of PPE :

Participant 1 - Name :

0 = Not worn

1 = Worn correctly

2 = Worn incorrectly

	Worn?	Removed at any time ? Y/N	Comments :
(a) Gloves			
(b) Face protection			
(c) Waterproof trousers			
(d) Waterproof jacket			
(e) Overalls			
(f) Wellingtons			
(g) Respiratory protection			
(h) Other			

Participant 2 - Name : ____________

(Code as for participant 1)

	Worn?	Removed at any time ? Y/N	Comments :
(a) Gloves	☐	☐	
(b) Face protection	☐	☐	
(c) Waterproof trousers	☐	☐	
(d) Waterproof jacket	☐	☐	
(e) Overalls	☐	☐	
(f) Wellingtons	☐	☐	
(g) Respiratory protection	☐	☐	
(h) Other	☐	☐	

Participant 3 - Name : ____________

(Code as for participant 1)

	Worn?	Removed at any time ? Y/N	Comments :
(a) Gloves	☐	☐	
(b) Face protection	☐	☐	
(c) Waterproof trousers	☐	☐	
(d) Waterproof jacket	☐	☐	
(e) Overalls	☐	☐	
(f) Wellingtons	☐	☐	
(g) Respiratory protection	☐	☐	
(h) Other	☐	☐	

4. Contamination: Participant 1

Main route of contamination:

0 = None

1 = Spills/splash at formulation

2 = Leakage of spray nozzle during application

3 = Leakage of container during application

4 = Accidental direct spray

5 = Spray back

6 = Spills/splash at shift end clean-up

7 = Other

4.1 Participant 1 - Name : ☐

(a) Main route of contamination: ☐

If *other,* please specify : ☐

(b) Subjective assessment of contamination:

0 = Dry

1 = Some wetness

2 = Soaked

3 = Not applicable

	Following formulation	At end of treatment	At end of clean-up
(i) Head/face	☐	☐	☐
(ii) Hands/gloves	☐	☐	☐
(iii) Arms	☐	☐	☐
(iv) Legs (lower)	☐	☐	☐
(v) Legs (upper)	☐	☐	☐
(vi) Groin	☐	☐	☐
(vii) Torso (front)	☐	☐	☐
(viii) Torso (back)	☐	☐	☐

Comments: ☐

Applicator held in left or right hand: 1 = Left, 2 = Right ☐

4. Contamination: Participant 2

Main route of contamination :

0 = None

1 = Spills/splash at formulation

2 = Leakage of spray nozzle during application

3 = Leakage of container during application

4 = Accidental direct spray

5 = Spray back

6 = Spills/splash at shift end clean-up

7 = Other

4.2 Participant 2 - Name : [ ]

(a) Main route of contamination : [ ]

If *other*, please specify : [ ]

(b) Subjective assessment of contamination :

0 = Dry

1 = Some wetness

2 = Soaked

3 = Not applicable

	Following formulation	At end of treatment	At end of clean-up
(i) Head/face	[ ]	[ ]	[ ]
(ii) Hands/gloves	[ ]	[ ]	[ ]
(iii) Arms	[ ]	[ ]	[ ]
(iv) Legs (lower)	[ ]	[ ]	[ ]
(v) Legs (upper)	[ ]	[ ]	[ ]
(vi) Groin	[ ]	[ ]	[ ]
(vii) Torso (front)	[ ]	[ ]	[ ]
(viii) Torso (back)	[ ]	[ ]	[ ]

Comments : [ ]

Applicator held in left or right hand: [ ]

1 = Left
2 = Right

4. Contamination: Participant 3

Main route of contamination :

0 = None

1 = *Spills/splash at formulation*

2 = Leakage of spray nozzle during application

3 = Leakage of container during application

4 = Accidental direct spray

5 = Spray back

6 = Spills/splash at shift end clean-up

7 = Other

4.3 Participant 3 - Name : [ ]

(a) Main route of contamination : [ ]

If *other,* please specify : [ ]

(b) Subjective assessment of *contamination* :

0 = Dry

1 = Some wetness

2 = Soaked

3 = Not applicable

	Following formulation	At end of treatment	At end of clean-up
(i) Head/face	[ ]	[ ]	[ ]
(ii) Hands/gloves	[ ]	[ ]	[ ]
(iii) Arms	[ ]	[ ]	[ ]
(iv) Legs (lower)	[ ]	[ ]	[ ]
(v) Legs (upper)	[ ]	[ ]	[ ]
(vi) Groin	[ ]	[ ]	[ ]
(vii) Torso (front)	[ ]	[ ]	[ ]
(viii) Torso (back)	[ ]	[ ]	[ ]

Comments : [ ]

Applicator held in left or right hand : 1 = Left 2 = Right [ ]

4.4 Was personal washing water available during treatment session?

0 = None
1 = Cold water
2 = Hot and cold running water
3 = Shower facilities
4 = Other

If *other*, please specify :

4.5 Frequency of washing :
1 = Always
2 = Occasionally
3 = Never
4 = Not applicable

Participant 1 : Name

After contamination with pesticide :

Before meal breaks :

Before smoking :

At end of treatment session(s) :

Participant 2 : Name

After contamination with pesticide :

Before meal breaks :

Before smoking :

At end of treatment session(s) :

Participant 3 : Name

After contamination with pesticide :

Before meal breaks :

Before smoking :

At end of treatment session(s) :

4.6 Approximate quantity of pesticide formulation used (litres) :

Participant 1 :

Participant 2 :

Participant 3 :

5. Post Treatment

Y/N

5.1 Was there any surplus pesticide formulation ? ☐

If ***YES,*** describe how it was disposed/stored and by whom :

5.2 Was the applicator cleaned after treatment was completed ?

	Y/N
Participant 1 :	☐
Participant 2 :	☐
Participant 3 :	☐

6. Additional Information

Complete this section only if necessary to clarify answers already given (include any unusual events and note the time of occurrence).

Time	Event

APPENDIX 3

Analytical Instrument Conditions

Analytical Instrument Conditions

1. Organic pesticides

Instrument:	Varian Saturn II, ion trap mass spectrometer interfaced to a Varian 3400 gas chromatograph fitted with septum equipped programmable injector (SPI) and Varian 8200 autosampler.	
Column:	30m x 0.25mm id 0.25μm film thickness, DM5-MS capillary column.	
Injection Volume:	1μl.	
Temperature Programme:	Column:	100°C for 1 minute 15°C/minute to 280°C 280°C for 8 minutes
	Injector:	60°C for 0.1 minute 180°C/minute to 300°C
Ions Monitored:	Cypermethrin + alphacypermethrin : 181 amu Permethrin : 183 amu Bendiocarb : 151 + 166 amu d^{10} Phenanthrene : 188 amu Phenylanthracene : 254 amu	

2. Copper

Instrument:	Thermo Electron Video 22 AA/AE Spectrophotometer
Wavelength:	324.7nm
Bandwidth:	1.0nm
Copper Lamp Current:	4.5mA
Flame Conditions:	Air/acetylene, fuel lean, blue flame

No background correction is required when analysing elements at wavelengths above 300nm.

APPENDIX 4

Stability and Recovery Trials

The stability and recovery of the pesticides on the sampling suits/patches were investigated as part of the study.

1. ORGANIC PESTICIDES

Sections of the suit fabric used for sampling were loaded with known masses of active ingredient and extracted after 1 hour and an extended period (see Tables below). Samples were analysed following the method detailed in section 3.7.1.1.

The suit sections and patches were extracted over a period of between 1 hour - 5 months. An attempt was made to test the stability and recovery of the active ingredients over this period. However, due to practical problems, including difficulty in obtaining certified grade standards for alphacypermethrin, it was not possible to do so within the timescale of the project. The recovery and stability of the active ingredients are given below.

TABLE A4.1a Bendiocarb Stability and Recovery Trials

Suit/Patch Samples

Extraction After 1 hour

Sample Number	File Name	Bendiocarb		
		μg/sample Recovered	Loading (μg)	Recovery (%)
B1	230108	36.02	36.96	97.4
B2	230109	34.86	36.96	94.3
B3	230110	36.28	36.96	98.2
B4	230111	6.86	7.39	92.8
B5	230112	6.75	7.39	91.3
B6	230113	7.21	7.39	97.3
MEAN				95.3

TABLE A4.1b Bendiocarb Long Term Stability and Recovery Trials

Suit/Patch Samples

Extraction After 4 weeks

Sample Number	File Name	Bendiocarb		
		μg/sample Recovered	Loading (μg)	Recovery (%)
BD2	141210	5.51	5.88	93.7
BD5	141211	26.94	19.6	137.4(R)
BD8	141212	72.40	78.4	92.3
MEAN				93.0

R - Rejected

TABLE A4.2a Permethrin Stability and Recovery Trials

Suit/Patch Samples

Extraction After 1 hour

Sample Number	File Name	Permethrin		
		μg/sample Recovered	Loading (μg)	Recovery (%)
P1	19019	35.21	37.75	93.3
P2	19020	33.11	37.75	87.7
P3	19021	32.85	37.75	87.0
P4	19022	7.38	7.55	97.7
P5	19023	7.23	7.55	95.8
P6	19024	7.06	7.55	93.5
MEAN				92.5

TABLE 4.2b Permethrin Long Term Stability and Recovery Trials

Suit/Patch Samples

Extraction After 29 weeks

Sample Number	File Name	Permethrin		
		μg/sample Recovered	Loading (μg)	Recovery (%)
PE8	121244	30.92	37.80	81.8
PE9	121245	33.49	37.80	88.6
PE10	121246	28.76	37.80	76.1
MEAN				82.2

TABLE A4.3a Alphacypermethrin Stability and Recovery Trials

Suit/Patch Samples

Extraction After 1 hour

Sample Number	File Name	Alphacypermethrin		
		μg/sample Recovered	Loading (μg)	Recovery (%)
AC1	190133	31.12	36.18	86.0
AC2	190134	33.59	36.18	92.8
AC3	190135	30.33	36.18	83.8
AC4	190136	8.03	7.24	110.9(R)
AC5	190137	6.52	7.24	90.0
AC6	190138	6.73	7.24	93.0
MEAN				98.1

R - Rejected

TABLE A4.3b Alphacypermethrin Long Term Stability and Recovery Trials

Suit/Patch Samples

Extraction After 6 weeks

Sample Number	File Name	Alphacypermethrin		
		μg/sample Recovered	Loading (μg)	Recovery (%)
ACP3	141220	5.45	5.43	100.4
ACP4	141221	21.75	21.71	100.2
ACP9	141222	117.66	108.56	108.4
MEAN				103.0

TABLE 4.4a Cypermethrin Stability and Recovery Trials

Suit/Patch Samples

Extraction After 1 hour

Sample Number	File Name	Cypermethrin		
		μg/sample Recovered	Loading (μg)	Recovery (%)
C1	190146	30.84	34.30	89.9
C2	190147	32.58	34.30	95.0
C3	190148	32.74	34.30	95.4
C4	190149	7.69	6.86	112.1(R)
C5	190150	6.75	6.86	98.4
C6	190151	6.83	6.86	99.6
MEAN				95.7

R - Rejected

TABLE A4.4b Cypermethrin Long Term Stability and Recovery Trials

Suit/Patch Samples

Extraction After 22 weeks

Sample Number	File Name	Cypermethrin		
		μg/sample Recovered	Loading (μg)	Recovery (%)
CPS1	250113	6.06	4.38	138.0
CPS6	250115	22.57	17.50	129.0
CPS9	250117	100.83	87.50	115.0
MEAN				127.3

2. COPPER

2.1 Determination of Copper Content in EAF Paint

A sample of EAF paint, provided by International Paints Ltd, was spread onto a glass slide and allowed to dry. The dried paint was weighed into a 25cm^3 beaker then treated with 5cm^3 50% nitric acid, heated at 80°C for 20 minutes, and made up to 25cm^3 with distilled water. A blank solution of 10% nitric acid was similarly prepared. The results are given below:-

Weight of paint (mg)	122.29
Concentration of copper (ppm)	1.71
Dilution factor	500
Correction factor	0
Corrected concentration of copper (ppm)	855
Solvent volume (cm^3)	25
Weight of copper in sample (mg)	21.38
Percentage of copper in paint (%)	**17.5**

In addition, the copper content was determined for each of the EAF paints used in the study. The results are given in Appendix 5.

2.2 Recovery and Stability of Copper

The sample of paint, provided by International Paints Ltd, containing 17.5% copper was used in the laboratory studies to determine the recovery of copper from the patches / suits and stability.

Sampling suits

Two sleeves from unused sampling suits were each halved. Two sections were retained as blanks. A small section was cut from each of the remaining sections of sleeve and coated with a known amount of paint. The samples and blanks were treated with $300cm^3$ 50% nitric acid and heated for 45 minutes. An aliquot of the extract solution ($25cm^3$) was taken and diluted accordingly.

SAMPLE	SLEEVE 1	SLEEVE 2
Weight of sampling material (mg)	461.31	401.64
Weight of sampling material + dried paint (mg)	530.85	557.05
Weight of dried paint (mg)	69.54	155.41
Concentration of copper in diluted sample solution (ppm)	1.72	3.79
Dilution factor	25	25
Correction factor	+0.03	+0.03
Corrected copper concentration (ppm)	43.0	94.8
Original sample volume (cm^3)	300	300
Weight of copper in sample (mg)	12.91	28.43
Percentage of copper recovered from paint (%)	**18.6**	**18.3**

Patches

Two samples were prepared by coating 5cm squares of suit material with a small amount of paint. After drying, the samples were treated with $10cm^3$ 50% nitric acid, and heated for 20 minutes at 80°C. The samples were then made up to $50cm^3$ with distilled water. A sample blank was prepared by treating a clean patch in a similar manner.

Two spiked samples were also prepared by diluting known amounts of standard copper solution to give 1ppm and 3ppm solutions.

SAMPLE	PATCH 1	PATCH 2
Weight of sampling material (mg)	676.3	669.0
Weight of sampling material + dried paint (mg)	766.3	803.5
Weight of dried paint (mg)	90.0	134.5
Concentration of copper in diluted sample solution (ppm)	3.19	3.78
Dilution factor	100	125
Correction factor	-0.03	-0.03
Corrected copper concentration (ppm)	319	472
Original sample volume (cm^3)	50	50
Weight of copper in sample (mg)	15.95	23.62
Percentage of copper recovered from paint (%)	**17.7**	**17.6**

SPIKED SAMPLES	Spike 1	Spike 2
Calculated concentration (ppm)	1	3
Measured concentration (ppm)	1.03	2.99

The results indicate a similar recovery of copper from both the pure paint painted onto the patches / suits indicating that the procedure was suitable for the extraction of copper from patches / suits.

APPENDIX 5

Survey Details

TABLE A5.1 Survey Details

Pilot Study (Timber and Masonry Preservation)

Organisation	Reason for Treatment	Application Details	Temperance (°C)	(%) Active Ingredient (dilution rate)	Survey/ Participant	Job Category	Quantity Formulation Used (litres)	Spraying Duration (mins)	Personal Protective Equipment
Private - small	Dry rot	•Indoors •All attic timbers and bedroom floor sprayed •"Super seven" *compression* sprayer	15	0.46% w/w cypermethrin (1:5)	01/1	Sprayer	15	10	North ori-nasal facemask (EN 141) fitted with A1 filters
					01/2	Pump attendant	N/A	N/A	

TABLE A5.2 Survey Details

Pest Control Sector

Organisation	Reason for Treatment	Application Details	Temperance (°C)	(%) Active Ingredient (dilution rate)	Survey/ Participant	Job Category	Quantity Formulation Used (litres)	Spraying Duration (mins)	Personal Protective Equipment
Local Authority	Hide beetle Ants Carpet beetle	•Outdoors and indoors •"High" spraying and "band" spraying •Gloria compression sprayer		5.8% w/w alphacy-permethrin (1:200)	02/1	Sprayer	7.5	50	CK 4002 full facepiece respirator (EN 149) fitted with FFP2 filter
Local Authority	Cock-roaches Fleas	•Indoors •"High spraying and "band" spraying •Gloria compression sprayer	28	5.8% w/w alphacy-permethrin (1:200)	03/1	Sprayer	10	75	CK 400 full facepiece respirator (EN 149) fitted with FFP2 filter
Private - small	Mites Spiders Cock-roaches Wasps	•Outdoors and indoors •"Band" spraying and "dusting" •Hozelock compression sprayer (liquid) •Birchmeier DR5 compression sprayer (powder)		1% w/w bendiocarb (powder	06/1	Sprayer	10.5	80	3M full facepiece respirator fitted with A2 filters
				80% w/w bendiocarb (15g in sachets)			60ml	10	
Local Authority	Wasps	•Indoors and Outdoors •"Dusting" •Bellows type dust applicator		0.5% w/w permethrin (powder)	09/1	Sprayer	0.75kg	15	North ori-nasal respirator (EN 141) fitted with A1-P3 filters Beekeepers hat
					09/2	Sprayer	0.75kg	24	North ori-nasal respirator (EN 141) fitted with A1-P3 filters Beekeepers hat

TABLE A5.3 Survey Details
Timber and Masonry Preservation Sector

Organisation	Reason for Treatment	Application Details	Temperance (°C)	(%) Active Ingredient (dilution rate)	Survey/ Participant	Job Category	Quantity Formulation Used (litres)	Spraying Duration (mins)	Personal Protective Equipment
Private - Large	Woodworm	•Indoors •All attic timbers sprayed •Electrical compression pump	23	0.1% w/w cypermethrin (1:100)	07/1	Sprayer	20	40	North ori-nasal facemask (EN 141) fitted with A1 filters
					07/2	Sprayer	18	20	North ori-nasal facemask (NE 141) fitted with A1 filters
Private - Small	Dry rot	•Outdoors •Masonry •Electric compression pump	14 Dry	0.5 w/w 3-iodo-2-propyl-n-butyl carbamate (1:4)	08/1	Sprayer	20	15	North ori-nasal facemask (EN 141) fitted with A1 filters
					08/2	Pump attendant	N/A	N/A	
					08/3	Sprayer/ Stand by operator	5	3	North ori-nasal facemask (EN 141) fitted with A1 filters
Private - Large	Woodworm	•Indoors •All attic timbers sprayed •Electrical compression pump	12	4.4 w/w permethrin (1:4)	010/1	Sprayer	6	30	3M 4251 respirator Visor attached to safety helmet
					010/2	Sprayer	6	30	3M 4251 respirator Visor attached to safety helmet
Private - Large	Woodworm	•Indoors •All attic timbers sprayed •Electrical compression pump	16.5	2.38 w/w permethrin (1:11.5)	012/1	Sprayer	30	60	Racal airlite (EM 46) respirator (THP2) with visor
					012/2	Pump attendant	N/A	N/A	Racal airlite (EN 146) respirator (THP2) with visor

TABLE A5.4 Survey Details

Application of EAF Paint

Organisation	Application Details	Weather Conditions	Mean (%) Copper Content in Paint (dry wt.)	Cu(I)O (%) * Content in Paint (wet wt.)	Survey/ Participant	Job Category	Quantity of EAF Paint Applied (litres)	Spraying Duration (mins)	Personal Protective Equipment
Private - large	•Dry dock - partial enclosure •MOD naval ship •Airless spray gun	Dry Temp 15-16°C Still	45 51	25-50 25-50	04/1	Sprayer	60	105	Sabre full facepiece respirator fitted with A-P3 filter Cotton rags around head and wrists
					04/2	Sprayer	60	120	Sabre full facepiece respirator fitted with A-P3 filter Cotton rags around head and wrists
					04/3	Potman	N/A	N/A	Sabre full facepiece respirator fitted with A-P3 filter
Private - small	•Dry dock - open •Nuclear waste carrier •Airless spray gun	Dry Temp 12.5°C V. Still	46	25-50	05/1a+	Sprayer	120	85	3M 4151 disposable respirator Caster oil applied to face
					05/1b+	Sprayer	240	170	
					05/2	Potman	N/A	N/A	
Private - large	•Slipway - open •Tug boat •Airless spray gun	Dry Temp 12.5°C Windy	6	5-10	011/1	Sprayer	80	120	Nuisance dust mask Tyvek cape hood Vaseline applied to face
					011/2	Potman	N/A	N/A	
Private - small	•Dry dock - open •Tug boat •Airless spray gun	Dry Temp 10.5°C Still	41	25-50	013/1	Sprayer	30	40	Racal full facepiece respirator fitted with A-P3 filter

*** - Information taken from manufacturer's health and safety data sheets**
+ - Overalls changed

APPENDIX 6

Evaluation of Potential Dermal Exposure and Significant Incidents

TABLE A6.1 Evaluation of Potential Exposure to Pesticides

Pilot Study (Timber and Masonry Preservation)

Survey/Participant	Job Category	Main Route(s) of Exposure/Significant Incidents
01/1	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle
01/2	Pump Attendant	- preparation of formulation (handled concentrate)

TABLE A6.2 Evaluation of Potential Exposure to Pesticides

Pest Control Sector

Survey/Participant	Job Category	Main Route(s) of Exposure/Significant Incidents
02/1	Sprayer	- preparation of formulation (handled concentrate) - depressurisation of compression sprayer - working in aerosol mist during "high" spraying
03/1	Sprayer	- preparation of formulation (handled concentrate) - depressurisation of compression sprayer - working in aerosol mist during "high" spraying
06/1	Sprayer	- spray back whilst spraying above head height - adjustment of spray nozzle - contamination of overalls during application of powder
09/1	Sprayer	- working in dust cloud during application of powder to wasps' nests - working in dust cloud during destruction of treated wasps' nests
09/2	Sprayer	- direct contact with powder during filling of bellows pump - working in dust cloud during application of powder to wasps' nests - working in dust cloud during destruction of treated wasps' nests

TABLE A6.3 Evaluation of Potential Dermal Exposure to Pesticides

Timber and Masonry Preservation Sector

Survey/Participant	Job Category	Main Route(s) of Exposure/Significant Incidents
07/1	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle - handling contaminated lance and hoses
07/2	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle - handling contaminated lance and hoses
08/1	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle - dripping nozzle during spraying
08/2	Pump Attendant	- preparation of formulation (handled concentrate) - handling contaminated hoses
08/3	Sprayer/Standby Operator	- working in aerosol mist - adjustment of spray nozzle
010/1	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle - handling contaminated lance and hoses - preparation of formulation (handled concentrate) - leaking lance
010/2	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle - handling contaminated lance and hoses
012/1	Sprayer	- working in aerosol mist - direct contact with treated timbers - adjustment of spray nozzle - handling contaminated lance and hoses - preparation of formulation (handled concentrate) - handling contaminated hoses
-12/2	Pump Attendant	- preparation of formulation - handling spray nozzle during preparation - handling contaminated hoses at end of shift

TABLE A6.4 Evaluation of Potential Exposure to Pesticides
Application of EAF Paint

Survey/Participant	Job Category	Main Route(s) of Exposure/Significant Incidents
04/1	Sprayer	- over spray - reversing tip on spray gun - direct contact with sprayed surfaces
04/02	Sprayer	- over spray - reversing tip on spray gun - direct contact with sprayed surfaces
04/3	Potman	- handling paint drums - mixing paint with wooden stick - splashing whilst disconnecting spray gun from paint line
05/1(a+b)	Sprayer	- over spray - reversing tip on spray gun - direct contact with sprayed surfaces - contamination from over spray on ground underneath treated surfaces
05/2	Potman	- handling paint drums - splashing during mixing of paint with "wet end" attached to compressor
011/1	Sprayer	- over spray - reversing tip on spray gun - splashes during spraying
011/2	Potman	- handling paint drums - over spray - handling paint drums and hoses
013/1	Sprayer	- over spray - reversing tip on spray gun - direct contact with sprayed surfaces - contamination from over spray on ground underneath treated surfaces
013/2	Potman	- handling paint drums - over spray

APPENDIX 7

Health and Safety Executive Protocol to Estimate Dermal Exposure using Amended WHO Patch Method

A protocol to estimate dermal exposure has been developed by the Health and Safety Executive. The method is based on the WHO protocol for the patch method (WHO, 1982) and has been modified to take into account the difference in physical build of the subjects in the initial WHO study from a typical operator in the UK.

The body has been divided into rectangular areas, based on the measurement of a typical boiler suit worn by operatives. The head is treated as a cylinder with a percentage of the area subtracted to allow for curvature of the skull. To allow for uneveness of deposition in areas where direct exposure is less likely, ie. inside of legs and underarms, the final total was halved.

The whole body exposure is estimated as the mass of pesticide found on each patch, multiplied by a correction factor based on its corresponding regional surface area of the body, divided by two, plus the amount of pesticide found on the gloves (Figure A7.1).

In this study, the whole body exposure was calculated by extrapolating the mass of pesticide found on each patch to the appropriate regional surface area of the body. In Table A7.1, the measured whole body exposures are compared with the whole body exposures calculated from the patch loadings using the HSE method and the IOM procedure (which is based on the WHO protocol [WHO, 1982]). All results include glove contamination.

The patch locations used in this study differed slightly to those described in the HSE method (Figure A1). However, patches corresponding to those shown were used to enable an estimate of dermal exposure to be made using the HSE method.

In the pest control sector and timber preservation sector, estimates of dermal exposure derived using the HSE method showed better agreement with the whole suit method than the estimates based on the IOM protocol. On average, the HSE method gave similar body exposures to those measured using the sampling suit method. The IOM procedures used in this study, on average, overestimated exposure in comparison with the suit method by about 50%

In the EAF paint sector, estimates of dermal exposure using the HSE method and IOM procedure both underestimated the suit method. The results derived using the HSE method were considerably lower than those derived by the patch method.

Overall, the HSE method provides a lower estimate of dermal exposure than the IOM's patch method. However, the levels of agreement between both the HSE method and the IOM patch method, and the whole suit method varied greatly between individuals. For the HSE method, more than 75% of the ratios were between 0.7 and 1.3. Less than 50% of the ratios calculated using the IOM method lay between 0.7 and 1.3.

In summary, the HSE method is an acceptable means of estimating potential dermal exposure to pesticides in the pest control sector and timber treatment sector. In general, the agreement with the sampling suit method appears better than when exposure is calculated using the IOM procedure. However, in some applications, as illustrated by EAF paint spraying, additional patches may be desirable to minimise the likelihood of splashing being missed. Also, in this application, there was considerable deposition on the operators' back and on the backs of their legs. This could affect assumptions made in the HSE method to allow for uneven contamination.

TABLE A7.1 Estimates of Whole Body Dermal Exposure

a) Pest control sector

Survey/ Participant	Mass of Pesticides (in mg)		
	Whole Suit Method	IOM Patch Method	HSE Method
02/1	2.8	2.4	1.9
03/1	13.7	17.3	25.3
06/1	23.2	47.8	27.3
09/1	2.7	5.2	2.8
09/2	6.6	9.6	5.6

b) Timber treatment sector

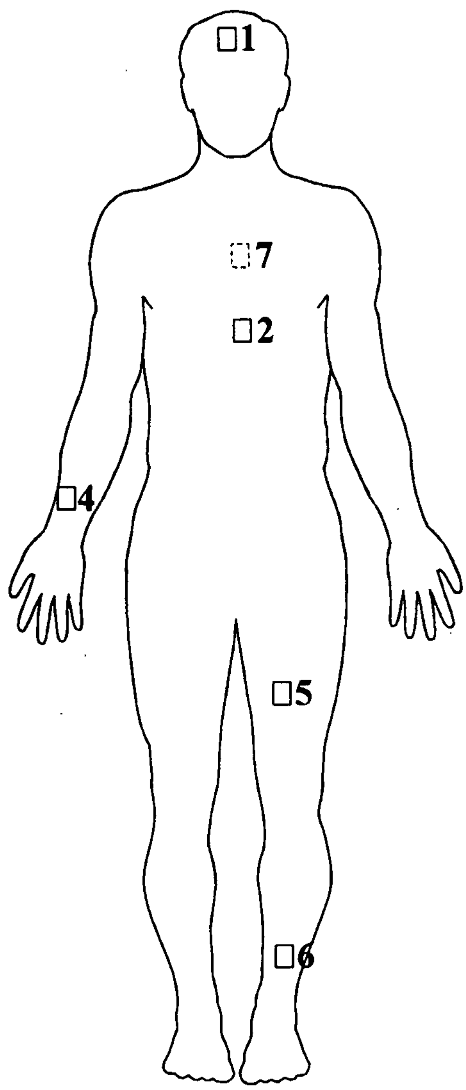
Survey/ Participant	Mass of Pesticides (in mg)		
	Whole Suit Method	IOM Patch Method	HSE Method
01/1	7.4	9.7	5.4
01/2	1.31	1.7	1.3
07/1	15.2	13.1	8.5
07/2	34.1	65.4	27.3
10/1	98.6	155.5	80.6
10/2	38.8	65.7	47.6
12/1	41.5	105.0	41.7
12/2	46.8	56.9	44.5

c) EAF Paint Sector

Survey/ Participant	Mass of Pesticides (in mg)		
	Whole Suit Method	IOM Patch Method	HSE Method
04/1	4543	5231	3766
04/2	*	*	*
04/3	2953	2013	1597
05/1a	4275	6069	3838
05/2	2960	2577	2354
05/1b	13508	23171	14757
11/1	3921	803	434
11/2	1539	182	152
13/1	8336	12007	8184
13/2	1161	841	177

* - patch lost

Figure A7.1.



Patch No.	Position	Multiplication factor
1	Head	14.5
2	Chest	46.2
4	Arm	20.2
5	Thigh	36.4
6	Lower leg	36.4
7	Back	46.2

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