Are residual insecticide applications to store surfaces worth using?

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Abstract

Field trials undertaken in Ghana, Mali and Indonesia, investigating the efficacy of spray treatments applied to store surfaces with contact insecticide formulations, have indicated that residual activity of such treatments is very short and that such surface applications are unlikely to be cost effective.

A laboratory study was undertaken to assess the efficacy of a range of store coatings to identify a cheap and convenient means of prolonging the residual activity of wettable powder formulations of pirimiphos-methyl and permethrin applied to store surfaces.

Efficacy of the treatments was determined by confining *Rhyzopertha dominica* to permethrin treatments, and *Tribolium castaneum* and *Sitophilus oryzae* to pirimiphos-methyl treatments, for four hours, at intervals from the day of spraying to twenty-eight days after spraying.

Of the different treatments tested, only the gloss painted surfaces sprayed with pirimiphos-methyl gave good residual activity (at least 21 days) against *T. castaneum*. The same treatment maintained a good degree of activity against *S. zeamais* for only three days.

Concrete coated with wax polish before application of permethrin gave good control of *R. dominica* for 14 days; gloss coated surfaces sprayed with permethrin only provided control for three days.

Given that routine surface-spraying regimes are not cost effective, and that continued application of treatments could potentiate resistance, as insects are continuously exposed to sublethal doses, it is recommended that spray applications to store fabric should only be used as non-residual applications, to kill insects present within a warehouse at the time of stack fumigation.

Introduction

It is common practice in many developing countries to spray the fabric of stores with residual formulations of contact insecticides in an attempt to control stored-product insects. This is achieved by first killing the insects present, and secondly by leaving a persistent deposit, which continues to kill insects arriving on the surface.

The surfaces commonly sprayed include walls, floor and bag-stacks. Materials which are likely to be sprayed therefore are concrete, wood, metal and sacking such as jute, sisal, polypropylene and multi-wall paper.

A residual insecticide is first deposited as an overdose which continues to kill the target pests until the concentration of available residue has dropped to a sub-lethal level. Depletion of this available residue takes place by a number of means, including oxidation, volatilisation, sorption into the substrate, and removal by insect pick-up, or other disturbance such as weathering, accidental abrasion or cleaning.

In the past, users of residual sprays have followed the recommendations of the manufacturers, but doubts have been raised over the efficacy of such treatments, due to the apparent brevity of the effective residual activity (Chadwick 1985; Hodges and Dales 1991; Hodges et al. 1992; Hodges 1993).

Investigations by NRI

A series of experiments have been undertaken by NRI in Ghana, Mali, Indonesia and the U.K., to optimise the cost-efficiency of spray applications, and to identify the most appropriate treatment regimes.

Ghana

Hodges and Dales (1991) investigated the biological activity of emulsifiable concentrate (EC) and wettable powder (WP) formulations of pirimiphos-methyl and permethrin, on various surfaces typically encountered in tropical warehouses. Surfaces tested were limewashed or whitewashed walls, cement floors, brick, galvanised iron, jute and polypropylene sacking.

Adults of *Tribolium castaneum*, *Sitophilus zeamais* and *Rhyzopertha dominica* were confined for 4 hours to these surfaces at various intervals of up to 28 days after spraying.

On absorbent surfaces (limewash, whitewash, cement floor, brick and jute sacking) activity of insecticide residues was short, generally less than 1 day, irrespective of pesticide or formulation. On non-absorbent surfaces (galvanised iron and polypropylene sacking) activity of the residues was much greater and WP formulations were generally superior.

Figure 1 shows the effect of residual treatments of pirimiphos-methyl WP and EC on concrete against *T. castaneum* and *S. zeamais*, up to 7 days after spraying. It can be seen that a useful degree of mortality of both insect species was achieved only by the pirimiphos-methyl WP formulation for 3 days, and that by 7 days neither formulation provided satisfactory control.

The conclusion from the trial was that spray treatments that rely on a residual action are not likely to be cost effective in stores which typically contain mostly absorbent surfaces. It was recommended also that laboratory trials be performed to assess the possibilities of improving residual performance through the use of alternative surface coatings for walls and floors.

U.K.

Laboratory trials were conducted to determine whether coating concrete slabs with emulsion paint, gloss paint, size or polish, had any effect in extending the useful residual activity

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of pirimiphos-methyl at 0.5 g active ingredient/m^2 (a.i./m^2), or permethrin at 0.25 g a.i./m^2 (Harris and Gudrups (1994).

The greatest extension of residual activity attained was of pirimiphos-methyl against *T. castaneum*, the activity of which was extended from 1 day to at least 21 days, by a coating of primer and gloss paint; useful control of *S. zeamais*, however, on the same treatment, was extended to only 3 days.

Treating concrete with polish before insecticide application extended the useful life of permethrin residues from less than 1 day to 3 days only, while the gloss-painted surfaces achieved useful mortality for only 1 day.

It was concluded that, given the poor performance of both insecticides on the different coatings, it is extremely unlikely that the use of any combination of them as residual treatments would prove cost effective for the reduction of insect infestation or reinfestation in stores. If spraying is considered necessary, the use of a cheaper non-residual dose of insecticide, to kill insects present in the store at the time of treatment, may prove beneficial.

A comparison of some of the findings from the work performed in Ghana by Hodges and Dales (1991) and Harris and Gudrups (1994) is presented in Table 1. It clearly shows that increased absorbency of a substrate is associated with poor levels of residual activity of insecticides.

Mali

The experiments performed in the hot dry climate of Mali were undertaken to assess the bioefficacy of the practical treatments carried out by the pest control services. The residual toxicities of emulsions of pirimiphos-methyl (0.5 g a.i./m^2 and 1.0 g a.i./m^2) and fenitrothion (1.0 g a.i./m^2 and 2.0 g a.i./m^2) were investigated (Hodges 1993). The insecticides were sprayed onto smooth rendered concrete, or emulsion-painted store walls. Residual efficacy was tested by confining adult *T. castaneum* and *R. dominica* to wall surfaces for 4 hours, immediately after spraying, or at various intervals up to 72 hours after spraying.

Residual activity was poor—within 24 hours from spraying the mortality of *T. castaneum* confined on emulsion-painted or concrete wall surfaces was less than 80%, when treated with the manufacturer's recommended rates of 0.5 g a.i./m^2 pirimiphos-methyl and 1.0 g a.i./m^2 fenitrothion.

Table1. Residual activity[a] in days of insecticide treatments giving 95%+ mortality of *Tribolium castaneum* (Tc) or *Sitophilus zeamais* (Sz) confined to various test surfaces sprayed with pirimiphos-methyl wettable powder.

Surface	pH	Absorbency[b]	Residual activity	
			Tc	Sz
Whitewash[c]	7.0+	309	<1	<1
Brick[c]	7	121	<1	<1
Limewash[c]	8.5	120	<1	<1
Cement[c]	10–11	75	<1	<1
Cement[c]	8.5–9	13	5	5
Cement	9.5–10	4.8	2	2
Emulsion 1	7.0–7.5	1.8	5	2
Emulsion 2	7.5	1.7	5 5	
Size	7–7.5	1.6	5 5	
Polish	7.0–7.5	1.2	5	5
Gloss	5.5	0.8	>21	5
Galvanised iron[c]	–	0–1	17.5	17.5
Polypropylene[c]	–	0–1	10.5	10.5

[a] Where necessary, number of days estimated at mid-point between two bioassay intervals.
[b] Absorbency measured as: Time to disappearance of 0.1cm3 on glass tile/Time to disappearance on test surface
[c] Data from Hodges and Dales (1991). Unmarked entries from Harris and Gudrups (1994).

Figure 2 shows the percentage mortality of *T. castaneum* adults bioassayed after treatment with the recommended application rates of each insecticide. It is clear from this that unsatisfactory levels of kill were achieved even 24 hours after treatment.

Surfaces treated with double the manufacturer's recommended rates showed substantially increased performance, resulting in 80–100% mortality even 72 hours after spraying.

None of the treatments, on either the emulsion-painted or concrete walls, were fully effective against *R. dominica*. The

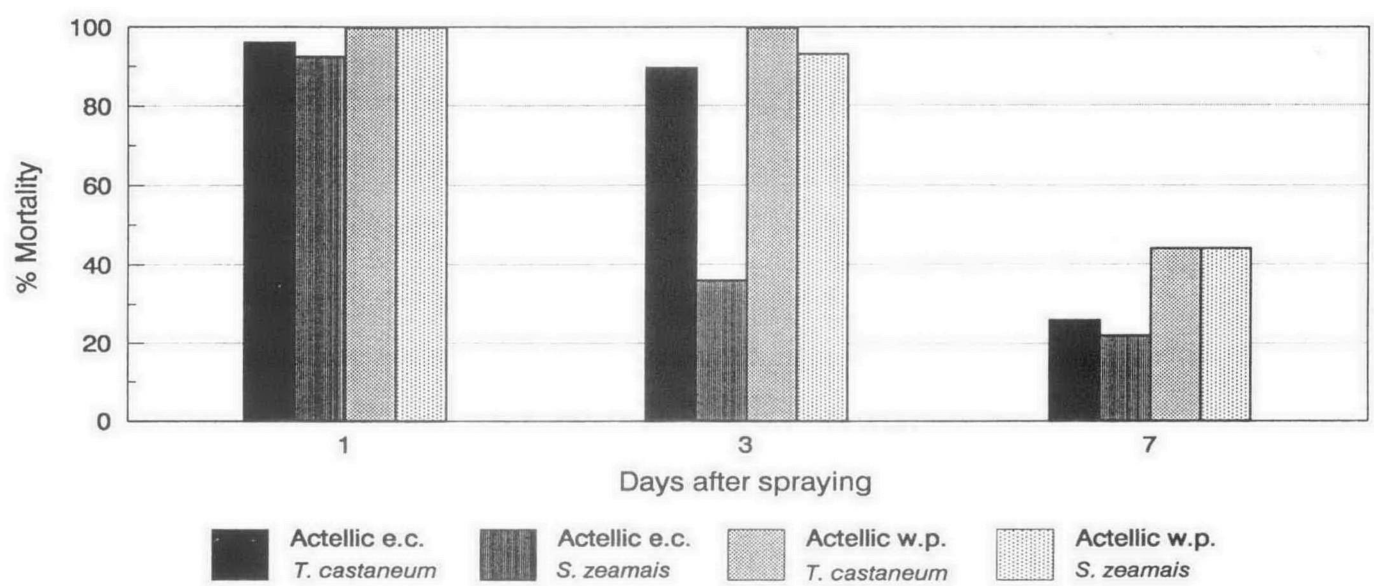

Fig. 1. Mortality (%) of adult *T. castaneum* and *S. zeamais* bioassayed on rendered cement floor treated with actellic spray prepared from emulsifiable concentrate or wettable powder.

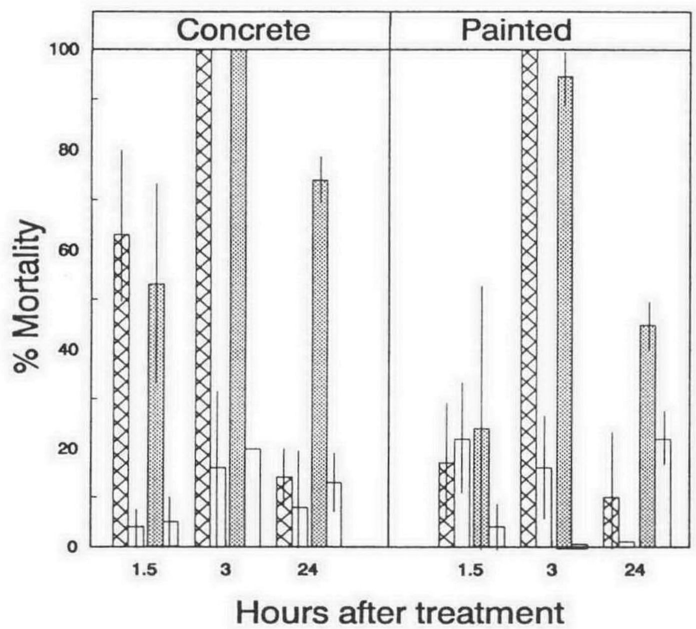

Fig. 2. Mean mortality (%) ± sd of *T. castaneum* adults bioassayed on concrete or painted wall surfaces at various intervals after treatment with 1% pirimiphos methyl or 2% fenitrothion. 1% pirimiphos methyl, 2% fenitrothion, control.

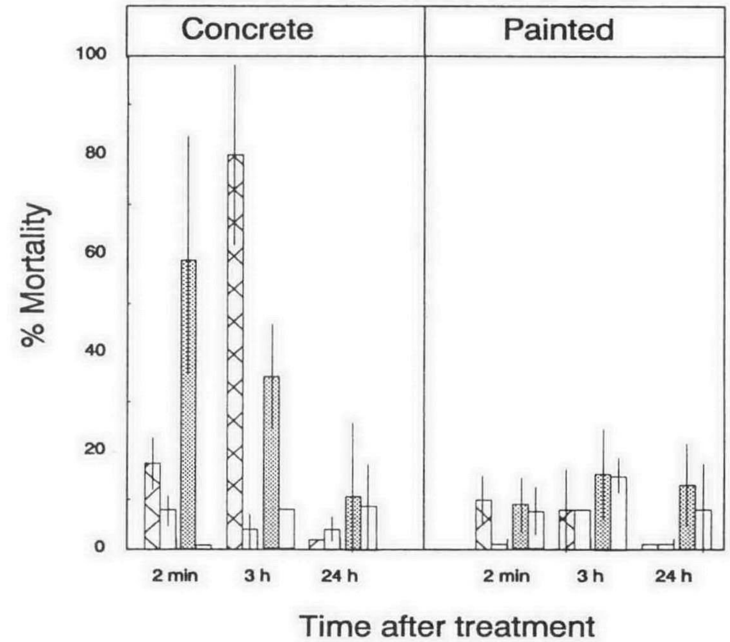

Fig. 3. Mean mortality (%) ± sd of *R. dominica* adults bioassayed on concrete or painted wall surfaces at various intervals after treatment with 1% pirimiphos methyl or 2% fenitrothion. 1% pirimiphos methyl, 2% fenitrothion, control.

highest mortality when this species was exposed to 1.0 g a.i./m^2 pirimiphos-methyl just after spraying, was only 78%. Treatments on the emulsion-painted walls were less effective than those on the concrete.

The mortality of *R. dominica* exposed to treatments of pirimiphos-methyl and fenitrothion is shown in Figure 3. It can be seen from this that, even immediately after treatment, levels of kill were unsatisfactory.

If it is assumed that a 4-hour bioassay on store walls is representative of the practical conditions under which insect pest control is attempted, then it is clear that residual treatments of fenitrothion and pirimiphos-methyl on store walls are inadequate against *R. dominica* and that, even for *T. castaneum*, higher than normal doses are required.

Indonesia

In Indonesia, three different spraying regimes in operational rice stores were compared, to investigate the possibility of improvements in the cost-efficiency of pest control (Hodges et al. 1989). Spray coverage of methacrifos emulsion was either over the complete store and stack surface (100%), all surfaces except those made of metal (69%), or only stack and floor surfaces (41%). Spraying took place at the time of stack fumigation and then every 42 days. Insect pest population build-up was monitored with bait-bag traps and spear sampling of the outer layers of stacks.

Although each application of spray led to an apparent reduction in the rate of pest build-up for approximately 11 days, it was followed by a return to a normal rate of population increase. It was not possible to include an untreated store in the experimental design so it was not possible to assess the practical significance of the temporary decline in pest increase following each spray treatment. There was no difference detected in the rate of population increase between any of the spraying regimes.

From the experimental findings it was considered that routine spraying of insecticidal emulsions should be limited to stack and floor surfaces only. It was calculated that this would reduce the annual pesticide bill by as much as 59%.

A further investigation into the cost efficiency of respraying store surfaces with residual insecticides was carried out in Indonesia by Hodges et al. (1992). Six stores under study were sprayed immediately after fumigation and then four were resprayed at monthly intervals with fenitrothion EC or WP.

Store reinfestation was monitored using bait-bag traps and spear sampling. The mean numbers of insects per bait-bag, at five trapping periods after fumigation, from bag stacks subjected to one of three spraying regimes are shown in Table 2. As the only statistically significant difference between treatments occurred at the third trapping period, it may be concluded that the trial results provided little, if any, suggestion of systematic differences between the three regimes.

The performance of the treatments was assessed in terms of the calculated minimum delay to refumigation required for cost-effective pest control. Neither of the respray treatments was found to be cost effective.

It was concluded that reliance on fumigation, together with a single non-residual spray treatment at the time of fumigation, would be likely to be more cost efficient, despite the fact that it may necessitate a slight increase in the frequency of fumigation.

Discussion

It is clear from the results of the experimental trials described here that the effective life of residual sprays of insecticides, used to treat tropical warehouses, is extremely limited.

Many laboratory studies have been performed on non-porous substrates such as glass, iron, and ceramic tile, but it is now well-established that residual activity on such non-porous surfaces is much greater than on the majority of surfaces found in tropical warehouses, such as concrete, sacking

Table 2. Mean number of insects[a] per bait bag, at five trapping periods after fumigation, from bag stacks subject to one of three fenitrothion spraying regimes.

Trapping period	Control	Emulsifiable concentrate respray	Wettable powder respray	Analysis of variance[b]
1	0.00[a]	0.00[a]	0.04[a]	ns
2	0.13[a]	0.12[a]	0.41[a]	ns
3	2.50[ab]	1.70[a]	4.16[b]	c
4	12.06[a]	6.72[a]	22.30[a]	ns
5	62.60[a]	43.80[a]	63.00[a]	ns

[a] *T. castaneum*, *E. cautella* and *C. cephalonica*
[b] Analysis of variance performed on data transformed to square root.
[c] Between treatment $F = 48$ df 2,2 $p<0.05$,
Between site $F = 566$ df 2,1 $p<0.05$
Means in the same row of the table with no letters in common are significantly different at $p<0.05$. ns = no significance at this level.
Source: Hodges et al. 1992.

or mud (Giga et al. 1991; Pawar and Yadav 1980; Chadwick 1985; Hodges 1993; Hodges and Dales 1991).

On many porous substrates, the insecticide is carried into the fabric by sorption, making it unavailable for insect pick-up, even though the persistence of the insecticide may be prolonged. By conducting bioassays on treated jute and polypropylene sacking, followed by residue analysis, Webley and Kilminster (1980) clearly showed that loss of biological activity is not necessarily due to chemical breakdown of insecticide.

It is known that the use of WP formulations on porous substrates may help to attain a longer period of residual activity, since the active ingredient, along with its carrier, rests on the surface of the substrate rather than penetrating deeply inside (Parkin 1966; Watters and Grussendorf 1969; Williams et al. 1982). Although this was largely true for the findings of Hodges and Dales (1991) in Ghana, the increase in the residual life in days was sometimes so small that this would be of little practical importance.

Degradation of the insecticide residue may be accelerated by high temperatures as may be experienced in tropical warehouse conditions. Increased temperature also affects the physiology and behaviour of the target pests. At high temperatures insects respire more rapidly and may move around the treated surface more extensively, resulting in a greater pick-up of active ingredient.

Volatilisation of insecticides may be increased by conditions of high temperature. Furthermore, volatilisation from different substrates may also be affected by changes in humidity: residues on hydrophilic substrates are more readily volatilised at high relative humidities, while those on lipophilic substrates are less readily volatilised under these conditions (Samson 1985; Gerolt 1963; Ebeling and Wagner 1965). However, the effects of changing relative humidity on the efficacy of residual insecticides is probably slight (Samson 1985).

Many organophosphates are known to show poor residual activity on concrete or limewashed surfaces (Parkin 1966; Lemon 1966), due to the increased rate of chemical degradation (hydrolysis) of the active ingredient under alkaline conditions (Okwelogu 1968). Malathion, for example, shows extremely poor persistence on concrete but shows good residual activity on wood and sacking (Parkin 1966).

Many researchers have investigated the potential role of various coatings to increase the persistence of contact insecticides on concrete. The use of appropriate coatings on absorbent surfaces has, in some cases, been shown to extend the useful life of insecticide residues.

Tyler and Rowlands (1967), for example, found that a formulation of malathion with the addition of 0.5% sodium carboxymethyl cellulose (size) increased the persistence of the residual film active against *T. castaneum* on a cement surface, from less than 4 weeks (WP) and less than 1 week (EC), to 14 weeks for both formulations.

Parkin and Hewlett (1946) found that coating bricks with starch paste, size and undiluted waterglass increased the percentage kill of *T. castaneum* when exposed to films of pyrethrum in oil for 6 hours.

Burkholder and Dicke (1966), working with the black carpet beetle (*Attagenus piceus*), found that painting concrete with a traffic-marking paint extended the effective life of malathion WP or EC residues from less than 1 week to 18–20 weeks. The effective life of fenthion WP was extended by 10 weeks, although the effective life of fenthion EC was not extended. A silicone water repellent extended the useful life of malathion WP by only 2 weeks.

While the activity of many insecticides on wood is reasonable, their activity often decreases when applied to painted wood (Pawar and Yadav 1980; Weaving 1974). Webley (1985) states that the pyrethroids tend to react with some gloss and emulsion paints, resulting in rapid loss of activity.

Conclusions

It is considered ineffective to continue regular respray insecticide treatments of warehouse fabrics. Such treatments are unlikely to be cost effective, due to the brevity of effective residual activity of the deposits. In addition, the risk of potentiating insect resistance in such circumstances is relatively high and further argues against such treatments.

Nevertheless, spraying of warehouse fabrics at the time of fumigation, preferably just before fumigation commences, is still recommended.

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