CONTROL OF INSECTS IN THE URBAN ENVIRONMENT WITH FILM-FORMING AQUEOUS SPRAY FORMULATIONS THAT MINIMISE THE USE OF HYDROCARBON SOLVENTS

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Abstract—Insecticidal space sprays are widely and effectively used for control of insects in the urban environment. They are especially useful for flying insect control, be it for disease vector or nuisance pest, but space sprays can also be very effective for rapid control of crawling pests such as cockroaches.

Consumer acceptance of insecticide treatments is an increasingly important aspect to be considered for successful insect control. Traditional techniques such as thermal fogging and misting employ large quantities of hydrocarbon solvents to both formulate and dilute the concentrates.

Ultra-low volume (ULV) techniques, which consume up to one hundredth the quantity of solvents used for thermal fogging, are more efficient. However, the move towards using water as diluent is not straightforward because of its greater volatility compared to diesel; this leads to droplets which rapidly shrink after generation and quickly become too small to impact efficiently on insects.

ULV formulations are described in which water is used not only as the diluent but also to replace most of the hydrocarbon solvent normally present in emulsifiable concentrate formulations. As a result of the surface film-forming action of these formulations, evaporation of water from the droplets is demonstrably reduced. Spray characteristics and biological performances against a variety of insect types and under different climatic conditions are described.

INTRODUCTION

Successful control of insect pests in the urban environment is dependent on a number of factors. When examined from the point of view of the user these may include effective and affordable treatments together with the knowledge that the product is safe in use and will not harm him or probably more importantly, his family.

One further factor that is extremely important in any larger scale treatment programme is the ability of the treatment operator to gain access to all areas requiring treatment; this depends on the willingness of the local inhabitants to accept the treatments involved and any of the above factors may be important to a greater or lesser degree.

A number of years ago these factors were examined with reference to space sprays which, it was felt, could be improved in a number of ways, especially for outdoor use. The availability of the highly active pyrethroids meant that they would not need to be used concentrated as was the case with the less active organophosphates such as malathion. In order to maintain a reasonable liquid distribution, pyrethroid space spray concentrates are usually diluted with a relatively involatile hydrocarbon solvent such as diesel.

The diluent is all-important with space sprays. Results from laboratory and field studies indicate that droplets need to remain within an effective size range for 50-100 metres as they drift downwind after generation; this is because as droplets shrink they become progressively less likely to impact on the target ie the insect. The relatively high volatility of water compared to diesel is therefore problematical when the former is used, but water would be the ideal diluent.

A patented range of products (European Patent No. 0331474) was developed that would encompass these features to a greater degree than has been the case for previous space sprays. By careful inclusion of long chain alcohols it was possible to reduce the evaporation of water from small droplets with a corresponding improvement in biological efficacy. Formulations of this type also allowed the reduction of hydrocarbon solvent content of the base formulation itself. It is the purpose of this paper to describe some of the data obtained.

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MATERIALS & METHODS

Formulations

The low solvent formulations to be referred to in this report are of the following type. The example shown is currently marketed as Aqua Reslin® Super, also known as Aqua Resigen®:

% w/v	
10.95	S-bioallethrin & permethrin*
11.00	piperonyl butoxide
1.00	surfactants
3.00	long chain alcohol mixture
9.20	hydrocarbon solvent
64.85	water

A conventional emulsifiable concentrate (EC) used for comparative purposes consisted of:

% w/v	
11.25	S-bioallethrin & permethrin*
11.25	piperonyl butoxide
15.00	surfactants
62.50	hydrocarbon solvents

For field and laboratory evaluation, the formulations were diluted 1 part concentrate + 9 parts of either diesel or water, by volume.

Application rates used during the outdoor field trials were 5-10 g per hectare of permethrin, equivalent to 0.5-1L of diluted formulation per hectare.

A low level of Uvitex OB fluorescent tracer was added to formulations to facilitate rapid analysis of the spray distribution and properties.

Sprays were generated using a variety of equipment producing droplets within the ULV range (volume median diameter, VMD <25 microns, µm), including the petrol-driven Lowndes Leco HDD ULV machine and the hand-held electric Curtis Cyclone.

Physical/chemical studies

In developing products of this type one of the first tasks was to develop techniques that would allow reasonably simple and rapid measurements of water loss from droplets. This was achieved most simply by suspending individual droplets on a fine wire and using image analysis techniques to measure their progressive shrinkage.

Of course, these types of droplet are relatively large; ultra-low volume sprays usually consist of spray clouds containing droplets of VMD under 25 µm. Outdoors, under more practical conditions, droplets may be measured in a number of ways, all of which can provide a slightly different picture and require separate interpretation:

a) Rotorods which consist of small glass slides which rotate at 330 rpm to collect droplets for either subsequent fluorimetric evaluation of formulations labelled with tracer or optical examination.

b) Passive samplers which are simply mesh squares suspended perpendicularly to the direction of the spray for collection of droplets

c) Cascade impactors which are used to give a quite precise measure of the droplet size spectra.

In order to support these data and allow for their correct interpretation it is necessary to record carefully the meteorological conditions involved at the time of treatment. Information obtained will

* cis:trans isomer ratio = 25:75
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Figure 1: Evaporation From Suspended Droplets at 27°C and 85% RH

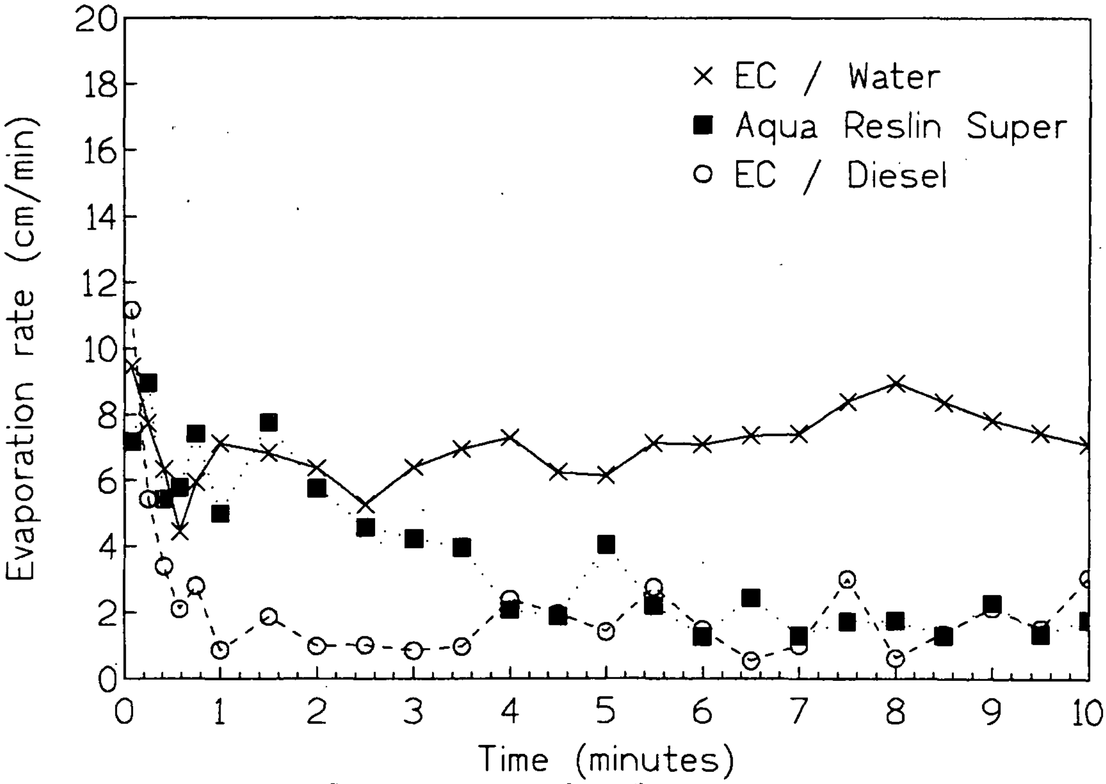
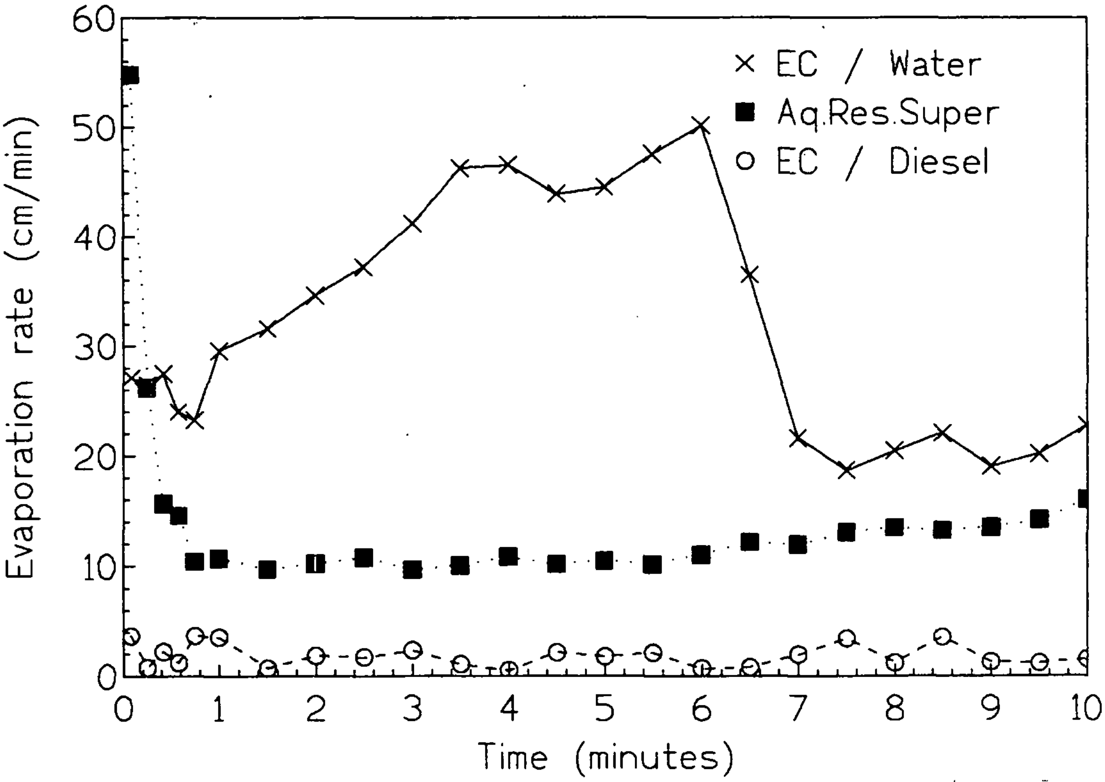


Figure 2: Evaporation From Suspended Droplets at 35°C and 30% RH



include temperature, humidity and their relative values at various heights, windspeed and direction through the treatment period. Trials involving space sprays especially MUST be supported by the above information to enable a full understanding of the biological results obtained.

Biological studies

Caged and indigenous insect pests have been used to evaluate the efficacy of treatments. Where the insects are caged, the screening effect of the cage material has to be recognised as this will significantly reduce the dose applied to the individual insects. Cage material consisting of the maximum size mesh that will just retain the insects is ideal. Trials on indigenous (free flying) insects have been conducted under a variety of conditions, employing standard techniques for monitoring insect populations such as scudder grill and favoured resting site counts for flies, light trap and human biting counts for mosquitoes.

RESULTS

Physical data

Laboratory data

The evaporation rate measurements in figures 1 and 2 illustrate the difference between the formulations and diluents at 27°C/85% RH and 35°C/30% RH respectively. These correspond to the field conditions under which the formulations were tested, at the extremes. The diesel diluted EC produced the lowest evaporation and will therefore give the most stable droplet size. This is followed in each case by the Aqua Reslin formulations where the evaporation retardant property has been formulated into the system. Evaporation from the water diluted EC is considerably higher such that, at 35°C, evaporation occurs so rapidly that all the water is lost from this relatively large suspended droplet within 7 minutes of application. Subsequent evaporation is due to loss of the more volatile fractions of the hydrocarbon solvent in the formulation.

The extent to which relative humidity affects evaporation from droplets of the water diluted formulations is illustrated in Figure 3. The difference in evaporation rate between the Aqua Reslin formulations and the emulsifiable concentrate diluted with water is greatest at low humidity.

The suspended droplets are between 1000 and 1500 µm in diameter whereas in the field, droplets of typically 15 µm diameter are sampled; a 100 fold difference in diameter between the experimental methods. Measurements on the suspended droplets were made in still air conditions. In the field, however, the droplets are moving in a turbulent air flow at between 1 and 5 ms^{-1}. In such a dynamic situation the diffusion gradients will be far steeper and will tend to increase evaporative loss. Since solvent evaporation rate is dependent on droplet size and diffusion gradient, these factors could override any evaporation retarding property. Hence, although differences in the evaporation properties of the formulations can be clearly shown in the laboratory, they are only of practical use if they can be maintained under field conditions.

Field data

Results in a hot/dry climate (Central Spain) and in a warm/humid climate (Ghana) have generally supported the evidence from the laboratory studies. Variation in droplet volume median diameter (VMD) in Ghana (Fig 4) and Spain (Fig 5) show a similar pattern:

LARGE	DROPLET SIZES	SMALL
←———	———	———→
Diesel diluted EC	Aqua Reslin	water diluted EC

Results from the passive mesh samplers, which provide a measure of the likely deposition on resting and flying insects under the prevailing environmental conditions, clearly show that the deposition rates are in the order expected from the droplet size data. Typical data are presented in Figure 6.

Figure 3: Effect of Relative Humidity on the Loss of Water From Suspended Droplets at 27°C

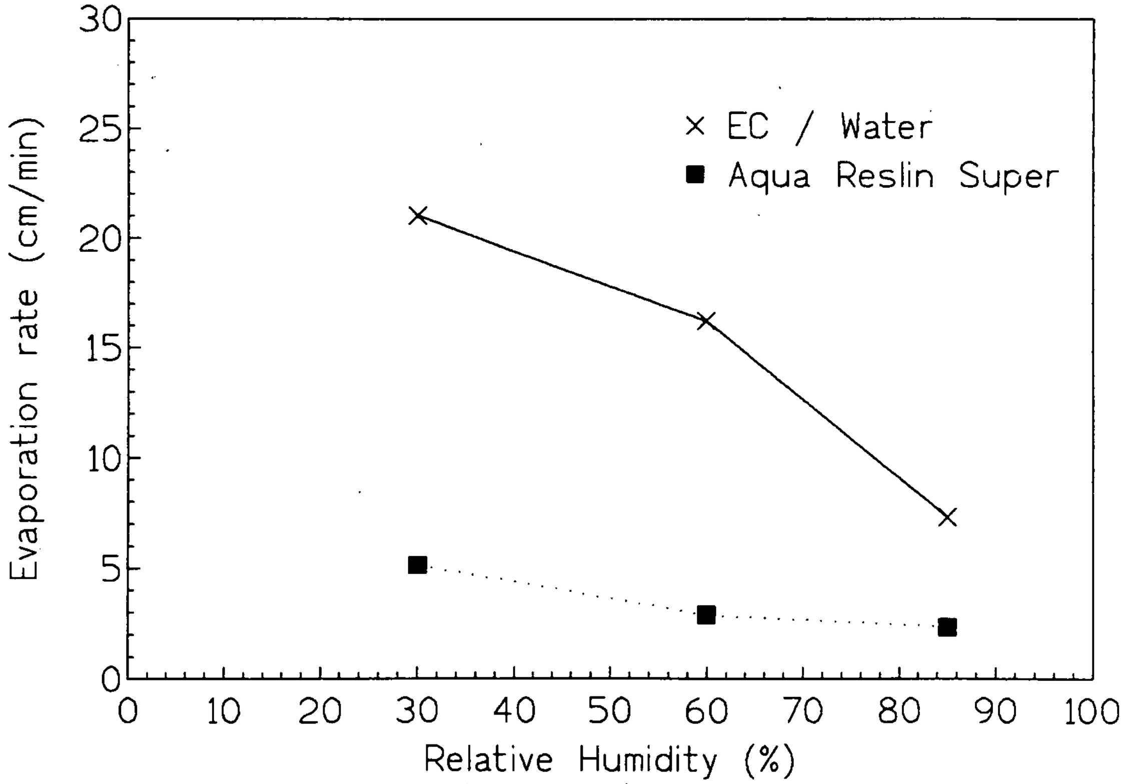


Figure 4: Variation of Droplet VMD With Time Airborne for Rotorod Data Obtained in Ghana

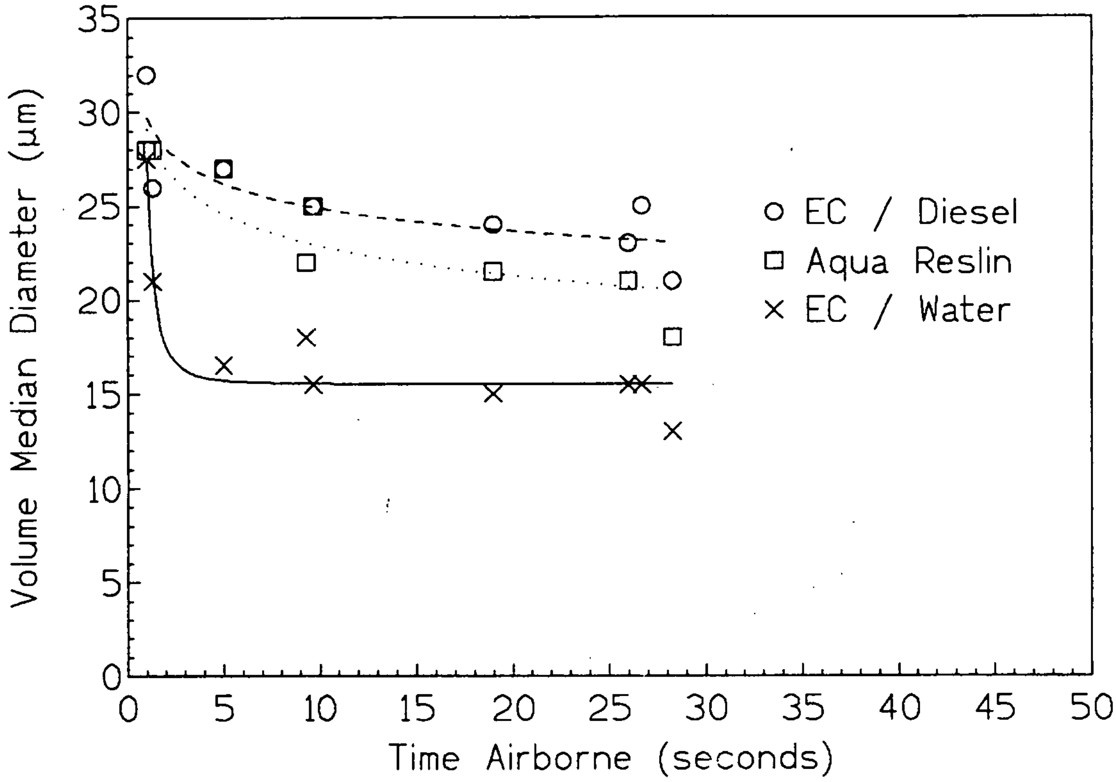


Figure 5: Variation of Droplet VMD With Time Airborne for Rotorod Data Obtained in Spain

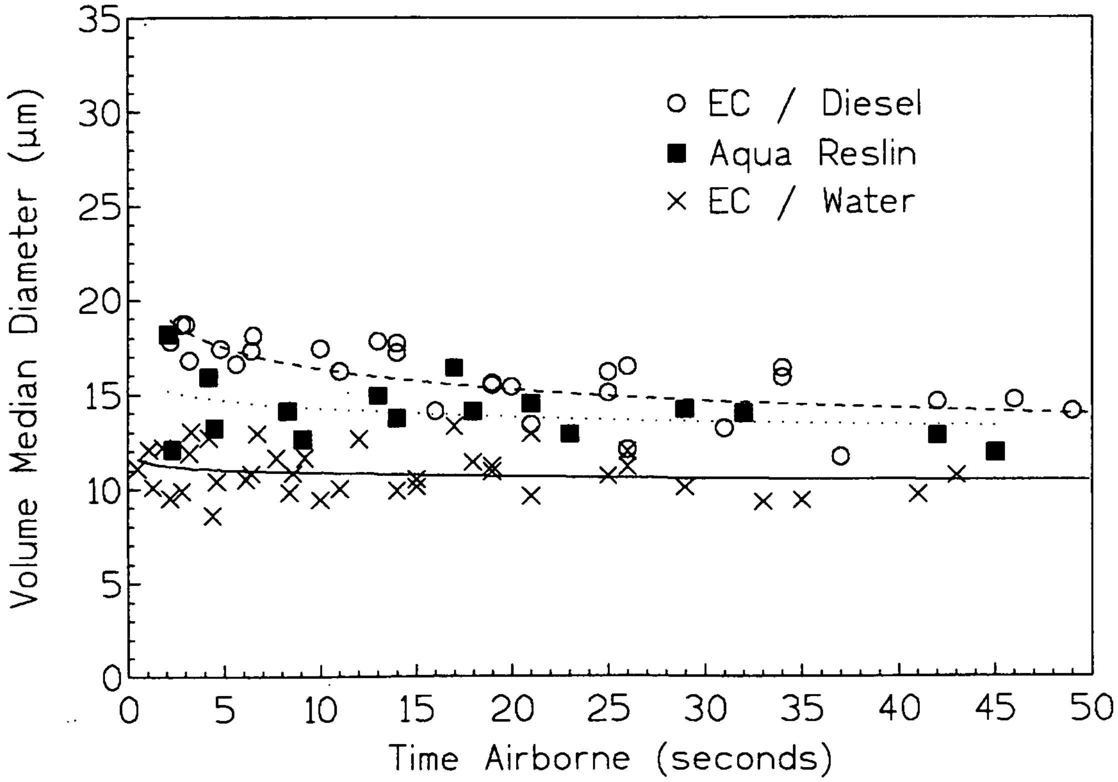
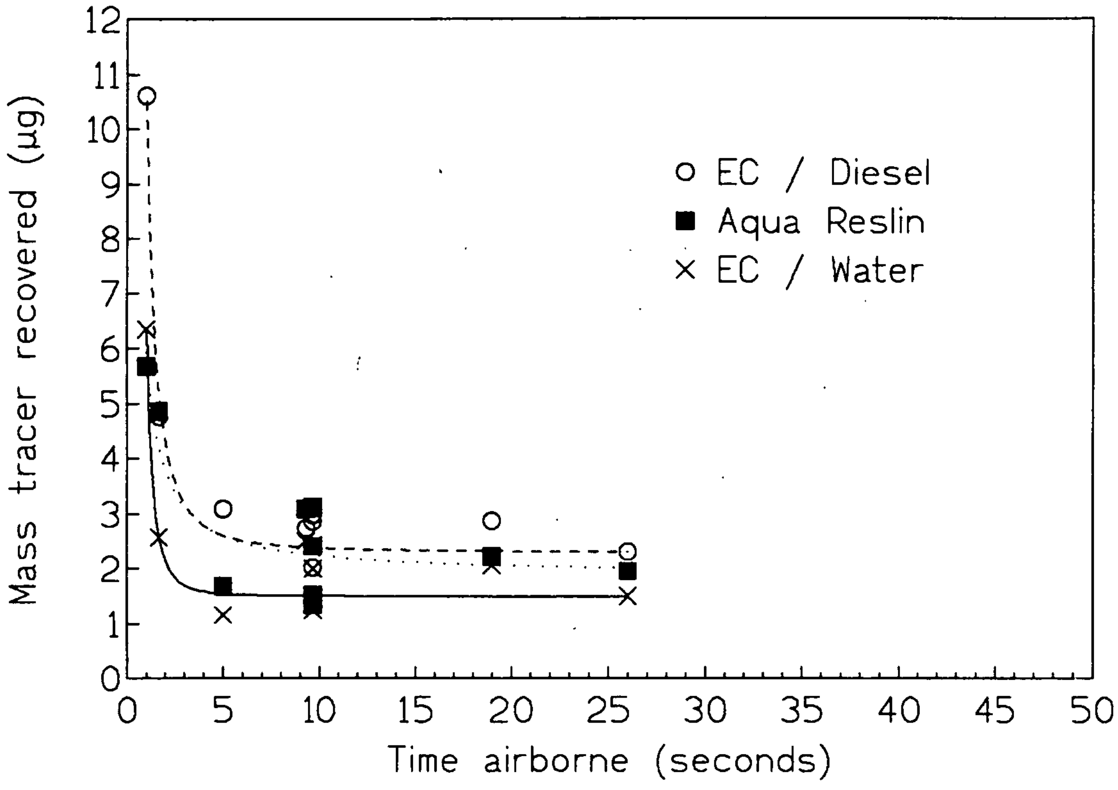


Figure 6: Variation of Dose Reaching Passive Mesh Samplers With Time Airborne (Ghana)



Biological data

Laboratory data

a) Insects were held in petri dishes or similar containers and the space spray was generated using a Curtis Cyclone ULV sprayer in a 370 m^3 room.

mlm^{-3} of diluted Aqua Reslin (mgm^{-3} pd*)	% mortality *Ec*	*Cc*	*Cl*	*Pa*	*Bg*
43 (0.47)	100	100	-	-	-
171 (1.9)	-	-	100	98	75

Ec = *Ephestia cautella* * pd = total pyrethroid
Cc = *Corcyra cephalonica*
Cl = *Cimex lectularius*
Pa = *Periplaneta americana*
Bg = *Blattella germanica*

Good performance was observed against all insects at quite low dose rates. Space sprays are quite often used for the control of these types of insect and when used on a regular basis can provide a consistent reduction in pest numbers.

b) When sprayed directly on insects a rapid knockdown and kill results. For example, one shot from a trigger-type sprayer of Aqua Reslin from 75cm resulted in the following performances:

	KT50Φ	*KT95Φ*	*KILL (%)*
Musca domestica	3.1	5.1	100
Culex quinquefasiatus	2.8	4.4	100

ΦKT value is time in minutes to achieve 50 or 95% knockdown.

Whereas droplets from trigger sprayers are coarser than is optimal for space spraying, it may be seen that the performance of evaporation retarded sprays is quite rapid. This is a feature often favourably viewed by the consumer.

Field data

Caged insects: Laboratory strains of insects were transferred to the field in cages for evaluation under end-use conditions of climate, meteorology etc. Sprays were generated using vehicle-mounted ULV generators and insects held at various distances downwind of the sprayer, 1.5m above the ground.

a) Spain - Species: *M. domestica* (35°C/30% RH average)

Spray	% mortality at . . . . . metres downwind *10*	*20*	*50*	*70*
Aqua Reslin	100	95	75	80
EC water diluted	81	92	62	56
EC diesel diluted	100	100	92	98

Here, under hot, dry conditions the evaporation-retarded formulation gave an improved performance over an equivalent water-diluted EC. The diesel-diluted spray was slightly superior on this occasion.

b) Malaysia Spray: Aqua Reslin compared with 95% pure malathion. Conditions: 26°C/81% RH average.

Here, conditions were quite variable from treatment to treatment, and results are plotted according to the time taken for sprays to reach the insects. These data are presented in Figs 7 & 8 for *Aedes*

Figure 7: Mortality Versus Time Airborne for Adult Female *Aedes aegypti*

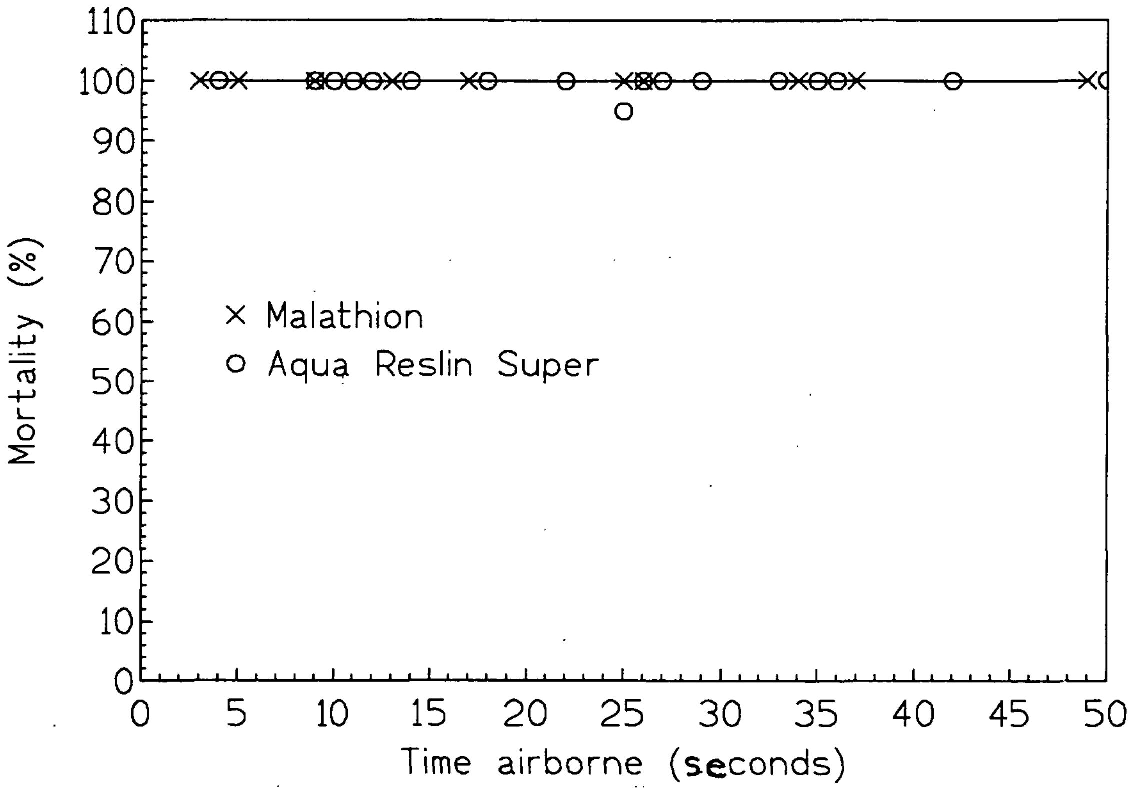
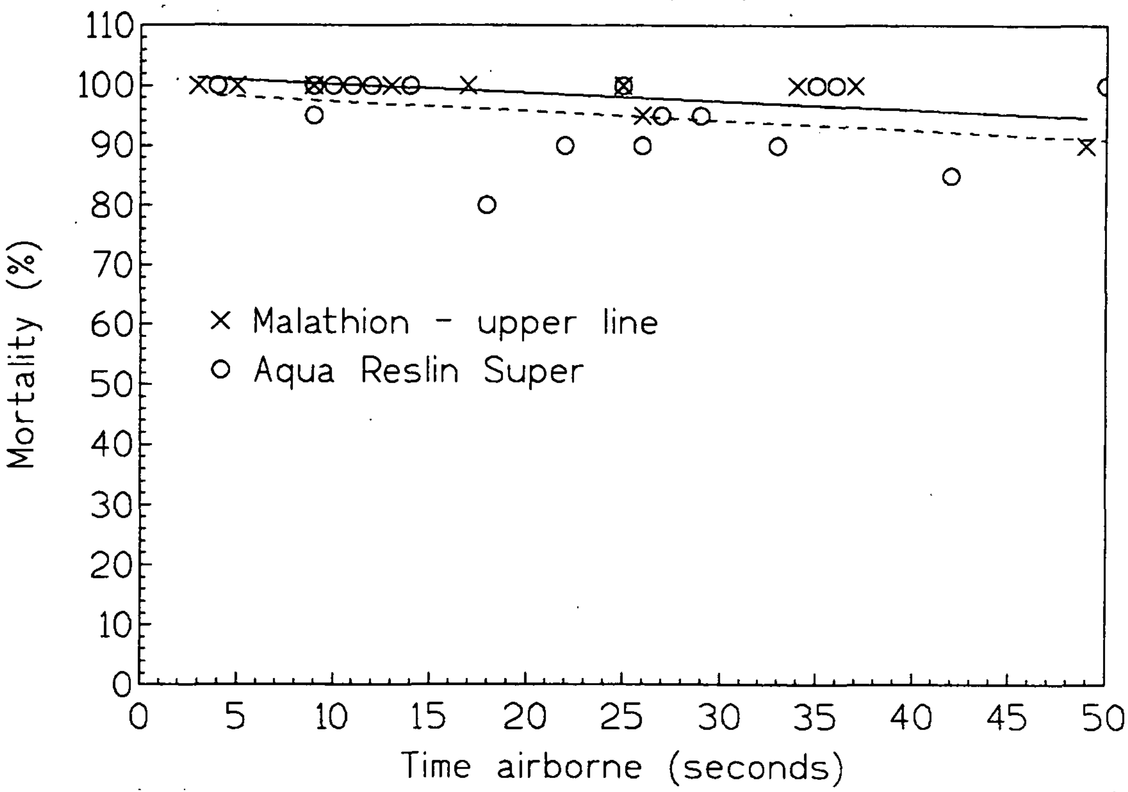


Figure 8: Mortality Versus Time Airborne for Adult Female *Culex quinquefasciatus*



aegypti and *C. quinquefasciatus* respectively. For *A. aegypti*, control was high throughout and little difference between malathion and Aqua Reslin was observed. Against the more tolerant *C. quinquefasciatus* slightly lower mortalities were observed although again, the Aqua Reslin spray remaining airborne for 50s (equivalent to 50m in a 1ms-1 wind or 100m in a $2ms^{-1}$ wind) provided >90% kill.

Indigenous insects

a) Ghana: Data presented by us elsewhere has shown that a >98% reduction in housefly population in a township outside Accra was achieved. The following reductions in numbers of insects were recorded when different treatments were applied on the same site in order to reduce variation between sites.

	% reduction in *M domestica*		
	Replicate		
	1	*2*	*Mean*
Aqua Reslin	92	84	88
EC water diluted	81	21	51
EC diesel diluted	97	73	85

Some difference between the formulations was again observed, consistent with the physical data showing the following order of efficacy:

EC diesel diluted is approx. equal to Aqua Reslin > EC water diluted

b) Spain: Under the hot, dry conditions of central Spain, previously described, a high infestation of houseflies (M.domestica) was treated within and around a pig weaning unit. Diluted Aqua Reslin was applied at a rate of 100ml per 1000mn. A post-spray reduction of 84% was recorded in this situation with one treatment.

Other features

3.3.1 Flammability

Hydrocarbons pose a flammability hazard. Whereas diesel for example is difficult to ignite, it can do so under extreme conditions. Water is clearly advantageous in this regard. Evaporation retarded formulations of the type described are non-flammable both as concentrates or after dilution and therefore offer reduced hazard in manufacture, storage, transport and use.

Marking/staining

A greater than 95% reduction in the application of hydrocarbons means that the capacity of sprays to cause damage by leaving greasy deposits, which can result in permanent staining, is markedly reduced.

DISCUSSION

Formulations for ULV space spray treatments of the type described herein, which reduce the evaporation of water from droplets and minimise the use of hydrocarbon solvents, have a number of advantages over more conventional treatments if the efficacy of the former can be maintained. It has been shown that by simply replacing quite involatile hydrocarbon solvents such as diesel with water as for a standard EC, a reduction in biological performance can be anticipated. This hypothesis was suggested by physical/chemical measurements made on sprays and has been confirmed in several studies reported herein. Differences are most likely to be observed during outdoor treatments where insect/insecticide contact time will be limited. The performance of evaporation-retarded formulations has been further demonstrated in a number of situations and climatic conditions.

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Aside from efficacy aspects a number of other benefits are provided by these types of formulations and these have been discussed.

In conclusion, there are a number of advantages in the use of formulations of the type described, both for the operator and especially for the consumer. The willingness of the latter to use or allow use of a product on or within his property is key to successful insect control, especially where large areas require comprehensive and thorough treatment.

ACKNOWLEDGEMENT

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