CONSUMER BASED STRATEGIES FOR HOUSEHOLD INSECT CONTROL

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INTRODUCTION

From the coincident emergence of the aerosol spray and modern, synthetic insecticides in the 1950's, the household insect control industry has grown to provide increasingly convenient, safe and effective methods of insect control for the general public (referred to herein as consumers of packaged goods or simply consumers). These products have become a first line of defence for consumers against insect pest problems that may adversely affect their quality of life. So, in a sense, household insecticides have found a place with other household cleaning products in maintaining a comfortable and sanitary indoor environment. As we shall see, the viewpoints of this particular end-user, the consumer, and their only passing acquaintance with insects and insect control, have a major impact on the development of products for use in the home. It is these influences, and the resultant strategies for insect control product development, that will be addressed here. By way of further definition, this paper relates to household insect problems occuring indoors world-wide. It will not discuss insect control on the person, indoor plant or lawn and garden insect control. It should also be understood that this is a subjective interpretation of trends in the retail products of the industry supplying solutions to home insect problems.

Before discussing strategies intended for consumer use, it is important to ask what characterizes these rather specialised insect control products. How do they differ from other insect control areas? This understanding will help clarify the basis for the insect control strategies employed.

1. Relative to other insect control activities, the end user is an amateur, with little knowledge of the insect or the control device/chemical.
2. The insect target is more generalised. The product may be used against many different insect problems, even outside of the recommended use.
3. Since the user has little understanding of the product, there is considerable potential for misuse or misapplication. Therefore, the product must be somewhat "foolproof" in its formulation and design to ensure that the consumer will obtain a satisfactory result.
4. The products themselves involve technologies very different from those used in other areas of pest control. They are ready- to-use, so active ingredients are present in a dilute form. However, although the products may be different, the active ingredients are frequently the same as those used in other areas.
5. The targets are different. The pest problem that one might hire a professional to handle may differ from pest problems that an individual feels they may address without assistance. Professional pest control in households tends to focus more on crawling insects than flying, e.g. cockroaches, termites, fleas. However, there are many flying insects that present irritating problems in the home environment. These include moths, flies, mosquitoes and various wasps. In fact, one can envision a continuum of pest problems ranging from pests in the home that do not require professional assistance to those that can only be solved by a professional. This might appear as follows:

MOSQUITOES HOUSEFLIES ANTS COCKROACHES FLEAS WASPS TERMITES

Easily addressed by consumer	Needs professional expertise

This list is not intended to be exhaustive, but illustrative.

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6. The intended result may be different from the professional. The consumer may satisfactorily solve their problem through repellency, prevention of injury, or direct and rapid kill.

These differences in characteristics of consumer-based home insect control obviously result in differences in approach or strategy to the development of products to accomplish insect control. In fact, in many instances, insect control may be a misnomer. First, one might say that most users of these products lack technical knowledge or sophistication to achieve true insect control. We also must acknowledge that many of the products are not designed to yield insect population control. Instead, individual or multiple insect elimination may be a more apt description of the result. In either case, elimination or control, the guiding principle is to effectively satisfy the need or desire of the consumer for solution of an insect problem.

STRATEGIES

There are three generalised strategies that are employed in consumer-based home insect control. As they are rather general, they may apply to professional pest control as well. However, the difference is in how they are executed, as we will see below. The three major strategies are:

1. Products that actively engage and kill the insects. These are directed in a general or specific manner towards the insect in a process of active elimination. These products may be referred to as **Active Elimination** products. The desired effect is short term and focused on insects that have been observed. It is unlikely that long term insect contol can be obtained by this method. This strategy mainly includes the insect sprays, aerosol and non-aerosol. It is intended to satisfy the consumers' need for instant action and resultant dead insects.
2. Products that actively engage the insect, which they may kill, but for which repellency is sufficient. These are directed in a general manner in order to prevent an insect problem or to protect from a potential problem. These products may be referred to as **Active Control** products. They generally work by insecticidal vapour and include electric heater products, mosquito coils, mothproofers and fly strips. The desired result is long term prevention of insect irritation or damage. Population control, rather than individual or multiple insect elimination, is required for these products. It is directed at the basic consumer need for elimination of insects from the living space and prevention of their recurrance over a specified time period.
3. Products that are passive and require the insect to encounter them. These **Passive Control** products may also be used in a preventative or protective manner. They include residual treatments, baits and traps. The strategy is intended to satisfy the consumer need for control, as stated above, but accomplishes it with insecticide which remains localized, where it was placed by the consumer.

A detailed examination of the characteristics of these strategies, and the tools that are provided to consumers to achieve them, provides further insight into the consumer-based strategies for household insect control.

Active Elimination Products. These products include aerosol sprays, sprays activated by mechanical action such as flit guns, pumps and trigger sprayers and heat-activated smoke devices. The propelling force of pressurized gases in a can, mechanical action, chemical reactions and heat vaporisation are mainly used in these applications to direct the active ingredient toward the target insect. The ease of use of the aerosol product form makes it the most widely accepted of the consumer-based insect control products.

This category of products may be further subdivided into several sub- categories related to product characteristics and the target insect. These are:

Sprays intended for flying insects - particularly flies and mosquitoes.
Sprays intended for crawling insects.
Wasp sprays
Fogging products

Flying insect products are used in two ways. First, they may be sprayed in the air in a general, non-directed way to clear a room of unwanted flying insects. Second, they may be used to directly spray an individual flying insect. The critical elements of such products are the size of the dispensed particle and formulation. The particles must be of a size that will remain suspended in the air for long enough to encounter all of the flying insects in the room in order to accomplish the first objective. It also must be large enough to impinge on the flying insect and discharge the toxin. The need for direct spray knockdown and kill, the second objective, has a somewhat opposing effect in that larger particles may be needed to produce a more rapid knockdown of the insect. These relative particle sizes are easily achieved in aerosol sprays with various combinations of hydrocarbon propellant (such as butane/propane) and aerosol valving. However, the smaller particle sizes, useful in clearing a room, are difficult to produce with the mechanical action products, such as liquid triggers.

There are generally two active ingredients in a flying insect killer formula. The first is a compound to produce fast knockdown. Since many of the fast knockdown compounds used in these formulas will not kill the insects at the normal dose, a synergist or a second, killing compound is required to prevent the insect from recovering. An examination of products from around the world suggests that most products in this sub-category utilise non-persistent insecticides. It can reasonably be assumed that this is because the products may be sprayed in a general way into the air and it is not necessary or desirable to cover the broad area where the spray falls with a residual insecticide. However, there are a significant number of products that do use a residual insecticide, assuming I believe, that all products may be used to provide a residual effect in some instances. These "residual" insecticides may also be added to provide a killing effect in the spray encountered by an insect. Pyrethrins and synthetic pyrethroids, are most widely used in these formulas. Tetramethrin, pyrethrins and compounds of the allethrin series are typical of the knockdown compounds. However, DDVP, an organophosphate, is also a very effective and inexpensive compound in wide use for knock-down in flying insect killers. Compounds such as phenothrin and resmethrin are often used as killing actives. Piperonyl Butoxide (PBO) is unquestionably the most widely used synergist. The active ingredients may be formulated in a solvent or, with emulsifiers, water base.

Crawling insect killer sprays may be considered to include cockroach, and flea spray products. They are also developed to perform two functions. First, to provide direct spray knockdown and kill as with the flying insect killers just described. But, secondly to spray surfaces, leaving a residual layer of insecticide to kill or repel insects that might encounter it. This kind of spray must encounter insects with sufficient particle size to knockdown and kill them, but must also be able to be sprayed on surfaces without creating a mess. These relatively larger particle sizes are easily achieved with all types of spray products.

Crawling insect killers also generally use at least two active ingredients. One to produce the rapid knockdown effect, important to consumers, and the second to produce the residual effect. Knockdown effect is produced by compounds similar to those mentioned above for flying insect killers. Residual effect is provided by a variety of compounds such as propoxur, chlorpyrifos, permethrin, cypermethrin, cyfluthrin and tralomethrin. These materials may provide residual activity for days to months depending on the active. However, it is doubtful whether these products provide their full residual activity in the household because of dirt, dust, cleaning and negative interactions with household surfaces. Cockroach and flea control products may also contain insect growth regulators which can provide long-term residual activity.

Wasp sprays require a different tactic than the above products because of the danger and fear of insect stings. Although knockdown and kill are required, as in the Flying Insect Killer and Crawling Insect Killer sprays, wasp sprays are made to project the spray longer distances. This allows the user to treat an individual insect or a nest from a safe distance. Of course, the speed of knockdown and kill are particularly important to the consumer in these wasp killer products.

The long-distance "jet stream" spray is produced through carefully designed valving and formulation. Fast knockdown may be the result of a combination of the active ingredients, the physical force of the spray and a cooling effect of formula ingredients (Appel, 1990a). Active ingredients of choice include propoxur, bendiocarb, chlorpyrifos, pyrethrins and pyrethroids. If the product claims nest kill it must also contain an active ingredient with residual effect. This allows consumers to eliminate the nest by spraying its entrances. Wasp killer products are somewhat

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peculiar to the United States where the style of outdoor living and common occurrence of single family homes with large yard areas combine with the presence of various wasp species (Vespidae) to create consumer problems.

Fogging is an important tactic or sub category of the the Active Elimination strategy. It is in many ways an excellent consumer solution for indoor insect problems. It requires very little knowledge of insect behaviour or location and is nearly fool-proof to use, two attributes that are critical to the success of a do-it-yourself insecticide product. These products produce a generalised dispersal of insecticide which can enter insect refugia that may be difficult to reach with other products. In most instances, the smaller the particle size produced by the product the more complete the coverage will be. This can be achieved through aerosol technology or by the use of heat producing an insecticidal vapour or smoke.

A review of fogging product labels indicate that they are used mainly for contol of fleas and cockroaches. Consumers frequently have trouble locating and treating infestations of these insects and so the fogger may be a good solution for them. Fogger active ingredients also cover the range of materials available for home use. This includes propoxur, DDVP, chlorpyrifos, pyrethrins and pyrethroids. Although foggers are generally considered a short-term answer to a pest problem, the use of residual active ingredients can provide a longer-lasting result. Insect growth regulators have been used in these products with some success, mainly for fleas. The fogging products can be somewhat inconvenient to use since they may require preparation of the room before use (removal of eating utensils, food, etc.) and some clean-up afterwards. Also, the broadcast nature of the product results in widespread insecticidal residues.

Active Control. The second major strategy is similar in many ways to the fogging products except that killing is not necessarily the key to it's success. Repelling or prevention of injurious activity is generally sufficient. Another distinction is that these products may be used whether or not an insect is seen, whereas Active Elimination products are used almost exclusively when insects are seen. A further distinction is that Active Control products remain active over an extended time period, from hours to days. The Active Control products include mosquito coils, electric heaters with insecticide impregnated mats, electric heaters with liquids, fly strips and mothproofers. These are active products that engage the insect but work by vapour, generated by heat or at room temperature depending on the chemical and formulation. They may be used to prevent biting by mosquitoes in a room, particularly while sleeping, to repel or kill moths/beetles in preventing fabric damage or to repel or kill flies in a room.

Approximately one billion US dollars of mosquito coils are sold each year around the world. They therefore represent the greatest sales of any household insecticide product in the world. These products are particularly widely used in tropical countries and countries where screening is not used on windows. The burning of materials containing Pyrethrins to kill or deter insects is a practice which has long been in use. Most current mosquito coils are made from a combination of sawdust and other materials, still including pyrethrins or certain pyrethroids as active ingredient (e.g. allethrin series). Lighting the coil produces a smoke, which apart from the insecticide may inherently repel mosquitoes. However, the smouldering coil vaporises the insecticide which, with the smoke, produces the desired repellent effect.

We have improved on this coil technology by producing smokeless anti-mosquito products. The first significant improvement was the paper mat, impregnated with insecticide, which is placed on an electric heater to evaporate the insecticide. These mats emanate insecticide for eight hours and so are effective for an overnight period. The next improvement was the use of a bottle containing liquid insecticide which is evaporated from a wick by an electric heater. The liquid reservoir allows longer term use, which ranges from 30 to 60 days according to manufacturers' labels.

Despite the apparent simplicity of these newer products, a certain amount of sophistication is required in their development. The mats, for example, involve the interaction of heater temperature, thickness and composition of the mat, a solvent (to assist even evaporation), an antioxidant (preventing unnecessary loss of the active ingredient) and an active ingredient that is suited to this application. Similar materials, are required in the liquid products but instead of the mat the critical factors are the nature of the wick material and its pore sizes. The active ingredients are pyrethroids, primarily in the allethrin series, including d-trans allethrin, esbiothrin, prallethrin, etc.

The fly strip products resulted from the development of a single active ingredient, DDVP or

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dichlorvos. DDVP volatilizes at room temperature in sufficient concentration to kill insects in a closed room. The insecticide may be generated from a cellulose pad or rod or from a polyvinyl chloride carrier (resin strip). Polyvinyl chloride may be the more reliable long-term generator, but the general idea is the same for the pads or strips. DDVP itself has been under question for toxicological considerations by regulatory authorities, but as yet these products remain in wide use around the world.

The room temperature volatility of paradichlorobenzene, camphor and napthalene have been exploited for a long time as mothproofers. These products are most frequently used in the crystalline form and are placed inside a container which separates the product from the clothing it is meant to protect. These products have a characteristic strong odour that is associated by many people with the mothproofing process. Of course, fabric protection is not simply related to moth (Tineidae) control, but also to prevention of damage by carpet beetles (Dermestidae). The longevity of the product is related to the volume of material contained in the product and the nature of the space in which it is used. Recently, pyrethroids that are volatile at room temperature (e.g.. empenthrin and benfluthrin) have been developed and commercialised for this purpose. The first of these, empenthrin, is now widely used as a mothproofer in Japan. It is generated from a variety of carriers, but primarily cellulose. It lacks the pungent odour associated with traditional moth-proofers which may be appreciated by future consumers.

Passive Control. This third strategy involves products which do not engage insects, but are encountered by them. These are baits or traps and products that are residual in nature, but which have no active, attacking or knockdown component. In addition, they are characterized by a long residual life with no further consumer involvement after application.

Residual materials may be deposited as sprays or powders in areas frequented by insects. Since these products generally have very little attractancy for insects they work best when distributed as widely as possible in areas of insect movement and harborage. This, then, increases the frequency of insect encounter. Unfortunately, the consumer lacks the experience and the knowledge to make the more directed applications of these products that improve their effectiveness (e.g., Braness and Bennett 1990). These residual products are most frequently intended for crawling insects such as cockroaches and ants. It is more difficult to cover all of the potential landing places for flying insects. Further, the consumer frequently doesn't wish to spray or dust these areas for reasons of aesthetics or perceived safety. A pen or marker type product is sold though that contains a pyrethroid in a transparent liquid, which may be used on windows for flies. Also, pyrethroid sprays, often containing Permethrin, may be used directly on fabric to prevent moth or beetle damage.

Residual insecticide products for crawling insects come in a variety of forms, but the most common are sprays and dusts. We have already discussed the residual component in crawling insect killer sprays and examples of the insecticides used, under the active elimination strategy. However, there are other sprays such as foaming aerosols and trigger sprays whose use is primarily residual in nature. Powders or dusts are widely used, particularly for cockroach control. Conventional active ingredients, such as those discussed above as crawling insect killers, may be formulated in these products, however, the dusts themselves may provide cidal action simply by abrasion of the insect cuticle and the resultant desiccation. Dusts are very effective carriers for active ingredients and provide effective residual control. However, their appearance and perhaps the consumers perception of safety restrict their use in the consumer market. There is also the question of how the dust may be applied in a less messy manner. An insecticidal chalk is being sold in many countries which apprears to be an attempt to address this issue.

The bait portion of this strategy relies, for effectiveness, on combinations of food materials that encourage an insect to ingest a sufficient dose of toxicant to incur mortality and a toxicant that is non-repellent and does not deter feeding. The use of baits has become a popular alternative for treatment of household insect problems, particularly for people that are concerned about broadcast use of pesticides in the home environment. The use of a bait station, which may be certified as child resistant, supports the notion that this is a "safe" product for home use. These stations, constructed of metal or plastic, house the toxic bait and have openings large enough to accommodate the target insect. The station may also attract insects as a harborage, as is the case for cockroaches.

Baits have been found useful both in professional and homeowner pest control. They are particularly useful for homeowners since, as long as sufficient numbers are used according to label

directions, a knowledge of insect location is not necessary. Numbers of baits placed in areas where cockroaches have been seen, for example, result in increased probabilities of encounter by the roaches. In fact, field research has demonstrated the effectiveness of increasing numbers of bait stations per unit area against German cockroaches *(Blatella germanica)*. In the US, most bait products sold for German roaches, are sold with twelve bait stations. This is not the case in many other parts of the world where four to eight bait stations are generally sold in a product. However, other cockroach species may predominate in these areas, for which optimal numbers of baits per unit area has not been established.

Performance of insect baits is partly a function of food materials in the formula. Ants are a particular problem as there are many different species that may be household pests, each of which may have different food preferences. Food preference may also vary seasonally and by geographic location (Knight and Rust, 1991). Cockroach food preferences may also vary by species and by life stage (Appel, 1990b). These are the two major insect pests for which products are sold in the consumer market. There are also some baits sold to consumers for use against house flies (*Musca domestica*). Attractants seem to play little role in the bait products. Probably because there aren't any attractants that attract strongly enough to add significantly to bait performance. However, food materials in baits that may act as arrestants, causing the insect to spend more time at the bait, or feeding stimulants, encouraging ingestion of the bait, seem to be more widely in use and of greater significance.

Traps are sold for a wider variety of pest insects, including fleas, flies, cockroaches and wasps. These products use either adhesive or a funnel trapping system to catch and retain insects. Food or visual attractants may be used to improve the effectiveness of traps. As with baits, increasing the density of traps increases encounter rate and thus effectiveness in population infestation control. These products tend to be appealing to consumers because they contain no insecticide. However, they have not gained widespread popularity apparently because they cannot provide sufficient efficacy (population control).

Quite a bit of attention has recently been devoted to the utility of various insecticides in insect bait formulations. There is a division between the function of insecticides in baits for social insects, such as ants and wasps, versus non-social insects such as flies and cockroaches. Long term control of social insects requires distribution of the toxicant in the nest. This suggests the use of delayed action toxicants. Having said this, a number of these same delayed action toxicants have also found use against cockroaches primarily because the same compounds seem to cause little feeding deterrence. It has also been shown in the laboratory that for insects that aggregate, such as German cockroaches (*Blatella germanica*), the toxicant may be passed to other roaches that have not visited the bait (Silverman et al., 1991). However, the significance of this effect has not been measured in field situations. From a consumers point of view, the drawback of this delayed action effect is that they may find little evidence that the product is working for some time after they have applied it. The absence of insect pests one or two weeks after application may not be fast enough to satisfy consumers or they may not associate control with use of the bait product. Further, the absence of dead insects means that they have no direct evidence that the product is working since they also may not see insects visiting the bait. This desire to see dead insects and a fast result may vary culturally in different regions of the world. This may account for the success of these products in the United States and relative lack of success elsewhere. However, other factors, such as target insect species, may also be involved. Insecticides that are currently used and marketed in baits that have this delayed action property include hydramethylnon, abamectin and sulfluramid. All three were shown to work in ant baits and have also been incorporated into cockroach baits. Of course, many other insecticides are used in bait products including chlorpyrifos, propoxur, fenitrothion, boric acid, sodium arsenate, phoxim, azamethiphos and cyfluthrin.

Strategic Influences

There are a number of factors that significantly influence how the strategies we have discussed are executed for consumer based insect control. An examination of these influences may also reveal future trends in this area. The factors reviewed here include active ingredient considerations, product testing, regulatory influences and public opinion.

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Active ingredients. Some of the strategies for active ingredient selection have been discussed above in relation to the various products. A brief review of the active ingredients most frequently used shows that the synthetic pyrethroids are widely used for knockdown effect, residual effect and in the vaporising products used to kill and repel mosquitoes. The repellent effect of the pyrethroids, however, has limited their use in bait products. Bait products employ a diversity of structurally unrelated compounds marking a unique category of insecticide use. Organophosphates and carbamates are represented by only a few compounds (relative to pyrethroids) in consumer products but these are used widely. Juvenoid insect growth regulators have been used successfully in flea control products but less successfully in cockroach control. Clearly, IGR's have a far greater chance for acceptance in use against fleas since the immature flea stages are not seen by consumers. The cockroach immature stage is very visible and so cockroach control tactics with IGR's require an effective initial control of the insect to make the product acceptable. Even then, it may be difficult for consumers to associate an action they took (applying the IGR) several months ago (e.g. Brenner et al. 1988, Yonker and Runstrom 1986) with the absence of cockroaches.

It is well accepted that safety is a major concern that consumers express today about insecticide products. This primarily relates to acute and chronic toxicity of the active ingredients. In most countries both the active ingredients and the final product are subjected to careful scrutiny by objective, competent authorities in the registration process. The result is that formulas sold in the marketplace have had an independent judgement of suitability for consumer use.

This assessment of safety has been repeated by government officials in many different countries around the world for many different products. This independent, objective judgement is important to manufacturers in the current emotional atmosphere regarding insecticides. This is a welcome result of regulation which in other ways may have a constraining effect on consumer product strategy.

There is also some tendency towards a tactic of developing consumer products that utilise natural ingredients. This is often more a marketing tactic than an attempt to improve household insect control. The use of some form of a "natural" claim may be intended to imply safety in a product to consumers. This tactic is somewhat deceiving as more often than not the product contains other synthetic ingredients either as actives or inerts. Also, natural materials are not necessarily safer from a toxicological point of view than synthetic materials. This is not to say that natural materials do not have a role to play in household insect control, but simply to argue against the use of deceptive "natural ingredient" marketing claims.

Similarly, another tactical direction pursued in the search for new active ingredients is the use of living organisms or their derivatives. Fungi and bacteria have figured prominently in the efforts to provide alternatives to current chemical control. Again, this alternative may appeal more to marketing interests than to a real improvement in insect control. However, the potential of organisms to develop an epizootic within the target species may provide an organic parallel to the delayed-action toxicants. In this case, the toxicant may be spread among insects without the consumer being required to have knowledge of the pest's habits or habitat. Additionally, it should be understood that such "non-chemical" or even "natural" products may provide chemophobic people with a product through which they may comfortably gain some relief from an insect problem.

The use of living organisms or even more complex natural products may also have a benefit in the treatment of insect populations that exhibit insecticide resistance. We do not currently understand the degree or extent of the occurrence of insecticide resistance in consumers homes, particularly on a world-wide basis. Many studies have made it clear that there are numerous populations of resistant household pests (e.g., Cochran 1989), but how widespread are they? Unquestionably resistant insects have caused the failure of household insecticides, particularly active control and passive control type products. However, the problem does not seem to be extensive enough to have caused a consumer reaction that impacts the sales of consumer-based products, which is probably our best way at present of judging product failure.

It is also widely assumed that consumer products are not used in a way that will generate resistance. However, this is not necessarily true, especially in the case of foggers, baits, vaporising products and residual treatments. These products can be used on a repeated basis over long periods of time and large areas, and therefore do have the potential to cause an insect population to develop

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resistance. Having said this, consumers are less likely to apply products with great frequency due to their expense and they generally do not do a very thorough job of treating. Both of these elements mitigate the potential for development of resistance.

Product Testing. Because it is difficult and costly to evaluate active ingredients and products in a real-world, field environment, many of the products in the marketplace today are formulated to laboratory test standards. These tests were developed to emulate the anticipated use of the product and gage performance in key product performance characteristics. Some of the most important tests are:

Direct Spray Knockdown	-	Flies and Cockroaches
Residual Tests	-	Cockroaches
Space Spray	-	Flies and Mosquitoes
Carpet Test	-	Fleas
Cockroach Bait	-	Feeding Preference & Mortality
Ant Bait	-	Feeding Preference & Mortality
Large Room Fogger Test	-	Cockroaches
Large Room Electric Mat and Liquid Test	-	Mosquitoes

These tests are referred to in a general sense because there are no standardised tests throughout the industry or on a world-wide basis. Individual countries and regions have developed standardised tests, but they differ from those of other regions. It is hoped that a set of world-wide standards can be developed. These are controlled tests, developed to reduce variability and to detect small differences between products. They may not be an adequate measure of the performance of a product in a consumers hands. When products are formulated only to these laboratory test standards they may be over-formulated. That is, they provide a significant, laboratory effect that is missed or unused in the consumers household environment. For example, consumers desire rapid knockdown in spray products. Whether a cockroach dies in 10 seconds or 30 seconds after being dosed with 0.5 grams of insecticide formula may be immaterial to the consumer who generally will spray the insect until it stops moving (using considerably more than 0.5 grams of product). In the case of residual insecticides, we should ask whether the ability to produce multiple weeks or months of residual activity in the laboratory has any relevance in the home. A consumer is probably not generally aware of where these compounds must be applied to best advantage and frequently fails to read the product label directions. Further, the material is probably eliminated more rapidly through subsequent cleaning than by other environmental factors.

This suggests that we have not adequately defined economic threshold limits as a consumer-based strategy. The definition of these thresholds should not be as difficult as it might seem. Using today's consumer research techniques, it should be possible to effectively determine the numbers of the various kinds of insects that people can live with and the product effects that would be considered a satisfactory result. For example, it has been suggested that there are up to a thousand cockroaches in the walls for every visible cockroach. It is probably not necessary to eliminate all of these roaches in the walls, but simply to reduce the numbers and maintain them at a level that is not bothersome. Similarly, how much toxicant is required in a flying insect spray to knockdown insects quickly enough to satisfy consumers? Economic threshold limits in agriculture imply a rather complicated system of monitoring insect populations and timing of pest management treatments. Obviously this is not appropriate for the household user. We need to identify the level of insect activity at which, on the average, a specific pest becomes bothersome in the home (threshold level) and what is the minimum effect that will reduce the problem below the level that requires action (see Olkowski *et al.*, 1976)

All of this is not to suggest that laboratory testing is unimportant, indeed it is crucial, but instead to suggest that we need to go beyond laboratory testing. We need to develop a better understanding of the product as used by the public, and their needs and expectations. This must be an integral strategy not only for consumer-based household insect control but for the household insect control industry in general.

Regulatory Influences. Government regulatory agencies, through legislative mandate, influence the time it takes to get a product to market, ingredients that can be used in a product and, indirectly, the risk

that a company will assume to develop a new product. The degree of regulation of consumer-based household insecticides varies widely around the world. Countries such as Holland and Belgium pose very exacting data requirements, whereas countries such as France and Germany do not presently require authorisations for household insecticides sold at retail. Although most countries have at least some kind of regulatory scheme, one can make a case for the lack of regulation found in Germany and France. First, given the dilute, ready-to-use nature of household insecticides sold at retail, they differ little in danger or toxicity to users from other household products sold further down the store aisle. The active ingredients used in these products have, as a rule, already been proven for safety in agriculture or public health applications before entering the retail household market. Lastly, a review of the German and French marketplaces shows that active ingredients and product formulations differ very little from those found in regulated countries. It would be very difficult to make a case that German and French consumers have been endangered by the lack of a regulatory apparatus in their countries for these products. Despite all of this, it is clear, as noted above, that an independent review by a governmental agency is very positive at a time when there are many concerns about the safety of insecticide products.

The range of active ingredients that may be used in a product is directly influenced by governmental regulatory agencies when they remove an ingredient from the market. However, they may also indirectly influence the availability of new compounds coming from active ingredient manufacturers. Complex and extensive regulatory requirements have made the business of developing insecticides more costly and time consuming. The net result is a reduced number of new active ingredients, which are also much more expensive to the formulator. The formulator, in turn, is less likely to use more expensive ingredients that will subsequently require additional spending to develop a new registration package. The costs involved in product authorisation, then, make everyone, from insecticide producer to formulator, risk averse. Therefore, marketing companies are unlikely to commit to spending against a new insecticide or product unless it can clearly be defined as a success in early stages of R&D.

Another indirect effect of regulatory agencies on consumer based strategies is categorisation of active ingredients and the attendant labelling requirements. The consumer products business is very sensitive to labelling, since this may influence the buyers choice of products at retail. It is clearly an important consideration for the companies to avoid active ingredients (or inerts) that may require labels that may be "frightening" to consumers. These companies will also wish to avoid any bad publicity that may be associated with a regulatory review of an ingredient.

In fact, it is not only active ingredient regulation that affects consumer product strategies, but also changes in laws affecting inert ingredients. Legislation in the US regarding Volatile Organic Compounds (VOC's), designed to help reduce consumer product contributions to low-level smog, is a case in point. Products that were once formulated with petroleum-based solvents, to achieve faster knockdown, now must be reformulated to meet these VOC guidelines. This generally results in a move towards water-based rather than solvent-based products. This, in turn, also affects which active ingredients are used since they must be compatible with water-based formulas. There have also been restrictions of other common chemicals used in pesticide formulations, such as methylene chloride and trichloroethane.

Public Opinion. Public opinion and the media have a significant impact on consumer product development strategies. As mentioned above, the sale of these products are reliant on public good will. Negative attention focused on a product is to be avoided whether or not the claims are scientifically valid. Therefore it is a key strategy for consumer product companies to stay ahead of potential media focus and the resultant shifts in consumer attitude. This requires close working relationships with producers of active ingredients. It also requires an awareness of discussions in government regulatory agencies and in environmental/consumer safety groups.

Many efforts are made to improve the consumers perception of the products. Odour, packaging and even the sound of the product may be altered to influence how users feel about it. Adjustments in product performance or formulation may also be made to allow further marketing claims. These secondary benefits, in general, have little effect on insect control but are oriented towards influencing the consumers purchase. In any case, these efforts are a significant tactic in product development for the consumer market.

Proceedings of the First International Conference on Urban Pests.
K.B. Wildey and Wm H.Robinson (editors). 1993

CONCLUSIONS

Clearly, providing an insect control product directly to consumers requires that we examine all elements of the product from a unique perspective. First of all, we have seen that the product must be judged safe by all reasonable, and even some unreasonable, criteria. Similarly, the product must be effective for the naive user to be acceptable. We have also seen that product characteristics are directly determined by the needs and desires of consumers in addressing insect pest problems. This includes a demand for immediate action, longer-term prevention and protection, and improved product aesthetics.

It is also clear that insect control products sold to consumers at retail have an important role to play in household insect control in general. There are many situations where professional assistance is not appropriate or is not possible. Consumers wish to exert control over their living space, so just as a consumer is provided products to clean their oven, it is appropriate also to provide products to control insect problems. Further, in many cases, these products have the potential to provide relief from an insect problem that is equivalent to that provided by a professional. Some problems should only be addressed by professionals, however. This will depend on the nature of the individual consumer, the severity of the problem and the identity of the pest insect.

Several actions have been identi¥ed that could improve the quality of the product delivered to consumers. We need to determine the degree of occurrence of insecticide resistance in as many areas as possible to ensure that our active ingredient choices are appropriate. There is a need for global, uniform laboratory test methods, so that we are able to discuss product performance criteria more clearly within industry, to regulators and to consumers. Lastly, we need to establish economic threshold limits to encourage the development of products more closely attuned to real consumer needs.

In the future, it is clear that regulatory in¤uences and public safety concerns will continue to affect the course of R&D devoted to consumer-based insecticides. Presumably these influences will encourage further development of Passive Control products, particularly baits and traps, since they involve localised as opposed to broadcast use of insecticides. This also will require further investigations into the use of attractants and an increase in our knowledge of pest insect biology and behaviour. This product strategy has, in the very long term, the potential to replace the use of many Active Control products. However, although product form may change, the immediate relief provided by Active Elimination products will continue to be important to consumers. Without question, the future will require increased sophistication in our products and in understanding how they work for our user in the household environment.

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