

NATURE AND APPLICATION OF PESTICIDES

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As man continued to modify his environment, the competition from other organisms became more intense. An organized and settled form of agriculture brought about an increase in the pest population. Various systems of pest control evolved and the use of light traps, scarecrows, etc, were among the earliest of such efforts. With increased incidence of pests and diseases and the advancement of science and technology, the use of various types of chemicals to control pests became a common practice.

Pesticides are a group of chemical compounds mostly organic and biologically active. They interfere with one or more of the essential metabolic processes of the organism against which they are applied.

Pesticides used in the past were mainly inorganic simple compounds but those used at present are mostly complex organic compounds. These could be broadly categorised into various groups according to the type of pests they control. The types of pesticides commonly used are indicated below.

Type		Pests controlled
Acaricides	—	mites and ticks
Fungicides	—	fungi
Herbicides (weedicides)	—	weeds
Insecticides	—	insects
Molluscicides	—	molluscs such as slugs, snails
Nematocides	—	nematodes
Rodenticides	—	rodents (rats)

Of the above pesticides the more commonly used ones are fungicides, herbicides and insecticides.

1. **Fungicides** : These are used to control pathogenic fungi and could be categorised into the following broad groups.

(i) **Systemic fungicides** - These are absorbed by plant roots and rapidly transported to the foliage and the apical point, eg. carboxin, benomyl.

(ii) **Sulphur fungicides** - This is one of the first successful protective fungicides. It was used against powdery mildew. The main ingredient of this group is elemental sulphur as a wettable powder. Organic sulphur compounds are also used widely. These are the derivatives of dithiocarbamic acid. Dithiocarbamates of zinc, manganese, iron are commonly used as fungicides and these are less phytotoxic than elemental sulphur.

(iii) **Copper fungicides** - Bordeaux mixture, and aqueous solution of copper sulphate and calcium hydroxide was one of the first few copper fungicides used. This has now been replaced by other copper compounds such as copper oxychloride, cuprous oxide.

(iv) **Mercury fungicides** - Organomercury compounds are more commonly used and more toxic than the other fungicides. Due to their volatile nature these compounds are used for seed treatment. Widely used organomercury fungicides are ethylmercury chloride, phenylmercury acetate, phenylmercury chloride.

Most of the fungicides are complex organic compounds. Their mammalian toxicity is relatively low (see Table 1).

2. **Herbicides** : Most of the herbicides used at present to control weeds are organic compounds. However, a number of inorganic compounds such as ammonium sulphamate, ammonium thiocyanate, boron compounds, sodium arsenate are herbicides and were used in the past. With advances in science and technology, more effective compounds have been developed. Some of the more important groups of herbicides are indicated below.

- (i) **Halogenated aliphatic acids**—eg. Trichloroacetic acid, Dalapon - 2,4, Dichloropropionic acid
- (ii) **Phenoxyaliphatic acids**—eg. 2,4, - D (2,4-Dichlorophenoxy acetic acid), MCPA (2-Methyl-4-chloro-phenoxy acetic acid) 2,4,5-trichlorophenoxy-acetic acid, etc.
- (iii) **Aromatic acids** —eg. 2,3,6 Trichlorobenzoic acid, Dicamba (2-methoxy - 3,6 dichlorobenzoic acid)
- (vi) **Amides** —eg. Diphenamid (Dimethyl - 2-2-diphenyl acetamide) chlorthiamid (2,6-dichlorothiobenzamide)
- (v) **Anilides** —eg. Propanil (3,4 - dichlorophenyl-propanamide), propechlor (iso propyl - chloroacetanilide)
- (iv) **Ureas** —eg. Diuron (3,4 - dichlorophenyl dimethylurea) Fenuron (phenyl-dimethylurea), Monuron (4-chlorophenyl dimethylurea)
- (vii) **Carbamates** — eg. Chloropropham (isopropyl-chlorophenyl-carbamate) Propham (isopropyl-phenyl carbamate)
- (viii) **Triazines** — eg. Simazine (2-chloro-4,6-diethylamino-triazine), Atrazine (2-chloro-4-ethylamino, 6-isopropylamino-triazine)
- (ix) **Pyridines** — eg. Paraquat, Diquat
- (x) **Uracils** — eg. Amitrole (3-amino-1,2,4-triazole) Bromacil

As indicated above, most of the herbicides used are complex organic compounds. Some of these, such as ureas, carbamates and aliphatic acids are translocated. The mammalian toxicity of herbicides, indicated by LD₅₀ values (see Table 1) is relatively low. Some herbicides are selective in action and hence could be effectively used to control weeds in crops. For, example, simazine could be used to control weeds in the maize crop. 2,4-Dichloropropionic acid kills weeds (broadleaved) in a rice crop. Selectivity is based on the physical nature of the plant or on the ability of the resistant plant to decompose the herbicide.

Herbicides in general tend to remain in the soil for a shorter period but there are persistent herbicides too. For example, 2,3,6 TBA, thiocarbamates, triazines are more persistent compared to others.

3. **Insecticides** : As in the case of herbicides, inorganic compounds were used as insecticides. Among these are copper sulphate, lime sulphur (Bordeaux mixture), etc. However, at present mainly synthetic organic compounds are used as insecticides although naturally occurring compounds are also used to a limited extent. The organic insecticides are of different types.

(i) **Organochlorine compounds** — These act as contact and stomach poisons. Most of them have residual effects and hence some are banned. Examples of organochlorine compounds are DDT, Aldrin, Chlorodane, Endrin, etc. All these are characterised by the presence of chlorine atom/s in the molecule. The mammalian toxicity of these compounds is relatively low. (Table 1).

(ii) **Organophosphorus compounds** — Organophosphorus compounds are contact or systemic poisons and interfere with the transmission of nerve impulses by inhibiting the activity of Cholinesterase, an enzyme. The residual toxicity of these compounds is relatively low in that they are decomposed rapidly. However, the mammalian toxicity of these compounds is generally high (Table 1). About 80 organophosphorus insecticides are available. Examples of these compounds are Malathion, parathion, fenitrothion, dimethoate, diazinon, monocrotophos, etc.

Table 1

LD₅₀ values of some commonly used pesticides

Pesticide	Oral LD ₅₀ (mg/kg)
Herbicides	
2,4-D	300
MCPA	700
Diuron	3400
Monuron	3700
Dalapon	9300
Paraquat	141
Diquat	400
Simazine	> 5000
Fungicides	
Benomyl	>10,000
Captas	9000
Ceresan	200
Zineb	5200
Maneb	6750
Insecticides	
DDT	200
Endrin	7
Chlorodane	400
Aldrin	50
Parathion	10
Malathion	2000
Carbofuran	10
Monocrotophos	20
Trichlorofon	450
Fenthion	250
Diazinon	600

(iii) Carbamate compounds — These are closely related to organophosphorus compounds. They too have a low residual activity.
eg. Aminocarb, methocarb, carbofuran.

(iv) pyrethroids — These are synthetic compounds but are related to naturally occurring pyrethrins which are insecticides of plant origin (*Chrysanthemum*). Pyrethroids are highly effective and are of low mammalian toxicity. They act as contact insecticides and have no systemic activity.

Most pyrethroids are viscous liquids with low vapour pressures, but they are relatively costly.

Allethrin, permethrin and cismethrin are a few examples of these compounds.

(v) Botanical compounds — These are also called natural insecticides as they occur in plants. The mammalian toxicity of these compounds is low and have a very low residual toxicity. Nicotine (extracted from *Nicotiana tabacum*), Rotenone (extracted from roots of *Derris* sp.), Pyrethrum (extracted from *Chrysanthemum* flowers) are a few examples of this group of insecticides.

Toxicity

Pesticides are toxic compounds, although their relative toxicities could vary. The LD₅₀ values of pesticides indicate the dose of a pesticide which kills half of a population of test animals. This is expressed in milligrams of the toxic compound per kilogram of test animal (mg/kg).

The toxicity of pesticides generally decrease after application. This is mainly due to various physical and chemical changes in the molecule. However, some compounds tend to be stable and remain undecomposed for a longer period of time. Decomposition of compounds in contact with soil also takes place due to microbial activity. Some compounds are more resistant to microbial decomposition. In general chlorinated hydrocarbons such as DDT, Endrin, are recalcitrant.

Pesticide application

Pesticide compounds, manufactured as technical materials, have to be formulated so that it could be applied in the field. The active ingredient is blended with a number of inactive, inert ingredients.

A pesticide formulation has a number of ingredients. These are (i) the active ingredient (ii) solvents (iii) carriers (iv) surface active agents (v) special additives. These ingredients are added to make the pesticide more effective and applica-

tion efficient. These are various pesticide formulations.

- (i) Water dispersable powders or wettable powders (WP)
- (ii) Emulsifiable concentrates (EC)
- (iii) Water soluble powders (WSP)
- (iv) Granules (G)
- (v) Dusts (D)
- (vi) Controlled release formulations

Some of these formulations such as WPs, ECs or WSPs have to be diluted with water.

Application equipment

Various types of equipment are used to apply pesticides. Liquid — type pesticides are applied with sprayers. There are hand-operated knapsack sprayers, power sprayers. Mistblowers can also be used. Dusts are normally applied using hand-operated or power dusters.

ENVIRONMENTAL EFFECTS OF PESTICIDE USE

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Introduction

The progress made in genetic and other means of controlling disease vectors and agricultural pests is remarkable but the use of the more selective and specific pesticides will always affect the ecosystem in the target area. If only target pests are decimated, neighbouring organisms which depend upon the target species for food and shelter in the system will also be affected. Effect on non-target species often extend beyond target area because pesticides and their metabolites, and/or degradation products move away from the site of the deposit by vapourization, seepage, surface transport in water or on sediment.

The extent to which these pesticides move throughout the environment is related primarily to their chemical stabilities, solubility characteristics, biological activity and their adsorption on soil and mud.¹ The pesticide residuals going into the environment are usually found in minute quantities and thereby harmful effects to organisms will not be obvious or dramatic as for instance killing of fish, birds or mammals but there should be positive effects on lower terrestrial or aquatic organisms including organisms that are important to vital natural biological waste degradation and/or oxygen production mechanisms.

Pesticides have established benefits in terms of agricultural production and human as well as animal health. Because these benefits outweigh the controlled hazards, the risk of using approved pesticides is considered acceptable even in developing countries like Sri Lanka. Prevention of losses to crops from agricultural pests is a good example and it is therefore worthwhile to describe this in terms of some available statistics. The

estimated percentage losses of potential crop fields in Asia are 57, 71, 49 and 36 for rice, sugarcane, potatoes and vegetables and pulses respectively.² Japan which has the highest order of pesticide usage per hectare (approximately 10.8 kg/ha) has a crop yield of 5.5 mton/ha, while Africa which has the lowest order of pesticides usage per hectare (approximately 127g/ha) has a crop yield of 1.21 mton/ha. This is good evidence for correlating between the amounts of pesticides used and yields of crop, with increase in productivity of several hundred percent after the use of pesticide being not at all uncommon. So increase in usage is encouraged. Even though the pest control is successful it should be noted that this can cause the pollution of food, air, water and soil, so that the environmental effects of these chemicals can take many forms.

Use of Pesticide

In Sri Lanka, relatively little or no information is available on toxicity and hazards of pesticides and their residues to non-target organisms under field conditions. Therefore information concerning the effects of such residues on low aquatic and terrestrial organisms is sparse. Although there is literature available on the effects on individual compounds on isolated organisms or systems in the laboratory or green house over short periods of time, such studies are usually different from field conditions and so these findings cannot be directly related to field conditions. So to study the problems associated with pesticide residues it is necessary to look into their distribution in the non-target area.

Atmospheric Deposition

Pesticides are among the manmade contaminants introduced into the atmosphere through insects, fungus, nematodes, rodents & weed control activities. During application to soil or crops, pesticides may be lost as spray drift or by volatilisation. Because the vapour pressures of many pesticides are high, a portion of the applied pesticides is lost from plants, soils & surface waters into the atmosphere. The pesticides are carried by the wind into the atmosphere either as vapours or by occlusion on dust particles and are subsequently precipitated out. The processes responsible for removal of pesticides from the atmosphere are wet deposition, dry deposition and dry vapour deposition. Pesticides like DDT, DDE, Dieldrin, Endrin, Malathion, Parathion etc, have been detected in the atmosphere.³

Moreover the persistent pesticides like DDT have become a global problem as a result of exposure to air. It has also been shown that non-volatile pesticides like DDT evaporate into the atmosphere quite rapidly, particularly in hot moist climates where pesticides are desorbed from the clay and organic fractions in soil.⁴

About 90% of organochlorine insecticides can disappear from the soils in the tropics per annum and most of the evidence is that this is by volatilisation.⁵ However, in spite of these various routes of exposure, there is little evidence of serious effects of pesticides on human health due to exposure in air, other than where pesticides are used in enclosed and unventilated spaces. It is also difficult to decide whether wild life species are endangered by pesticide exposure through air.

If the stable plateaus in the case of exposure to air-borne pesticides, are not maintained, the amount of pesticides in an animal could decline with time regardless, of whether the amount of exposure is increasing, stationary or decreasing.⁶ The deleterious effects on that species is possible but these could be explained only by toxicological study. But certainly the amount of pesticides in an organism represent the current amount of pesticides present and hence shows the level of pesticide pollution in such an environment.

Exposure through Water Pollution

Many of the human disease vectors are controlled by spraying or treating aquatic systems with insecticides. Herbicides are applied to water to control aquatic weeds. In addition, water can be polluted by:

- (1) discharging surplus formulation after spraying operations into rivers, ponds and lakes,
- (2) pouring the washing waters of spraying equipment into rivers, ponds and lakes,
- (3) extending sprayed crops to the water's edge,
- (4) accidental spillage of pesticide formulations,
- (5) run off and erosion from treated soils,
- (6) fall-out from air pollution by pesticides.

This can result in local effects on the environment and the killing of fish by pesticides is quite common.

By all these routes, drinking water can become contaminated. Monitoring of water purity is far less rigid in developing countries. Nevertheless, average exposure to pesticides in drinking water is generally not serious, although occasional incidents occur where drinking water becomes polluted badly with pesticides.

Solubility characteristics: Some pesticides are more soluble in living tissues than in water (eg. Aldrin, Dieldrin, etc.) and this favours transfer of chemical from water to living tissues.⁷ As a result, residues are not lost by dilution in the inorganic components in the environment, but instead are accumulated by organisms and retained within the food chain. Many organisms not in direct contact with a contaminated environment receive residues in their food supplies so that entire food pyramids can become contaminated.⁸ Such organisms eg, birds, can be exposed to lethal effects by living in the vicinity of a pesticide applying area. Further, carnivorous birds are especially vulnerable in this respect.

But if the non-target area is far away from the spraying area, the concentration of pesticides found in aquatic bodies is very much lower due to dilution and so it is important to study the sub-lethal effects on various non-target organisms on a longterm basis. Changes in normal growth or behaviour pattern, effects on reproductive success, alterations in enzyme systems and the variety of physiological phenomena can nevertheless have a major impact on the communities of living organisms. The concentrations of pesticides in precipitation are very much lower than those found in surface runoff (of the order of 10^3 lower)⁹; the impact from this can never be predicted without a longterm epidemiological study.

Exposure through Soil

Soil is treated with pesticides for the control of many soil-inhabiting agricultural insects, nematodes or diseases. Moreover, it has been calculated that as much as 50% of sprays applied to crops or as herbicides miss their target and fall on to the soil surface. Organochlorine and a few other pesticides can persist in soils for years. Pesticides may be taken up into crops from soils even if they are not systemic. If grass is grown, the residues in the grass can be transferred to herbivores such as cattle, and eventually find their way into meat and milk. Fortunately, some pesticides become adsorbed on to clay and organic matter fractions in soils and adsorbed in a form in which they are not readily taken up into plants. In part, however, they may end up in ground water supplies. There is little evidence that pesticides contamination of soils has serious effects on human health, because amounts taken up by crops are small, and result in little food contamination.

Direct Responses by Organisms

Since most of the pesticides drift away, the toxic effects of such chemicals on ecosystems should be a subject of concern, not only to the pesticide manufacturer and user but also to scientists in related disciplines and to the public. It is important to understand the bio-degradation of pesticides in non-target organisms or more precisely of detoxication. Detoxication of pesticidal chemi-

cals involves one or more of the following processes.

Initial metabolism to less toxic or more polar molecules, conjugation of the initial metabolite with an endogenous molecule such as amino acid, or carbohydrate, to render it water soluble and inactive.

Various typical detoxifying reactions that pesticides undergo in biota are oxidation, hydrolysis, dechlorination, reduction, and ring cleavage. Each of these reactions is catalysed by a specific enzyme or groups of enzymes.

Microorganisms can hydrolyse a number of commonly used pesticides such as carbaryl, DDT, Dieldrin, 2,4-D, fenitrothion, Diazinon and parathion. Microorganisms because of their simple structure can excrete pesticides and their metabolites through their membranes or walls.¹⁰ Reductions such as dechlorination, and ring cleavage mainly occur in anaerobic or in environments low in oxygen but the latter do not occur in higher organisms.

Pesticide detoxication also occurs in plants. Some examples are carbaryl, 2,4-D, malathion, organophosphates and carbamates. Some of these pesticides like 2,4-D can be decarboxylated by algae and fungi as well.¹⁰ Multicellular plants, however, lack excretory systems and thus conjugate pesticides extensively; this facilitates the storage of the conjugates in metabolically inactive regions such as vacuoles.

In animals also, a pesticidal chemical may be degraded by one or more of the above detoxication reactions. The aquatic forms are in rapid and constant exchange with the water of their environment and can excrete pesticides and their metabolites through the general body surfaces or through specialized areas such as gills.¹¹ Carbaryl, malathion, parathion, DDT, DDD, organophosphorus and carbamates are some pesticides detoxified by animals.

General Situation

Our knowledge of pesticide degradation by non-target food chain organisms in the Sri Lanka

context is very limited. But it should be noted that there are selective toxicity differences among the target and non-target group of organisms in the detoxication of the pesticides. Thus most of pests are killed selectively including some non-target biota as well. When better field services and other advice to users along with extensive training, education in safe handling and use of pesticides are lacking, there is a greater tendency to use more pesticides with the idea of getting better results. From the broad spectrum of pesticides which are commonly used in Sri Lanka (Table 1), application could cause harmful effects to biota at different levels for different types of pesticides. Also the residues remaining in the food could cause harm to consumers and the non-target organisms feed on such contaminated food.

It is possible to observe residual levels in all members of the food chain. Persistent pesticides having high solubility characteristics could lead to accumulating and magnifying in bodies of higher organisms of the food chain sometimes resulting in fatal incidents from pesticides such as organochlorines, (DDT, Eldrin, Dieldrin, etc). Their chemical stability is a potent factor responsible for widespread occurrence in the environment.

Unstable pesticides or pesticides that tend to lose their activity fast are organophosphates and carbamates. Though their biodegradability is higher than the persistent pesticides they seem to be causing a greater damage or nuisance for non-target species. These exert a generalised cholinergic action by inhibiting central and peripheral cholinesterases. Toxicity of these compounds to mammals is essentially the same.¹²

In a stable ecosystem, whether it is aquatic or terrestrial, the species diversity is very high indicating a good equilibrium between organisms at

different levels of the food chain. Because the pesticides or their residues applied selectively have different toxicities on different species, there will be a greater damage on one kind thus reducing the species diversity in that ecosystem.

This is not uncommon to an unstable ecosystem or an environment exposed to pesticides and their residues. Such an ecosystem can be created within the target area or outside the target area including water and soil. Fewer dominant species in very high numbers are present in these ecosystems hence it may become good breeding grounds for fewer pests in large numbers from time to time producing more problems to target areas and sometimes to other areas as well. Some of those pests may not be damaging crops but will create a greater nuisance in the absence of all types of other balanced natural biota. In addition the affected ecosystem may take a different route by limiting food for the higher orders of organisms living in that food web. This is mainly caused by selectively destroying some microorganisms and planktons used as food for higher levels. These environments are not only irreparable, but also these become more vulnerable to unwanted pests.

Undoubtedly, pesticide application levels in Sri Lanka are no less than that in other countries in the SAARC region. Unfortunately neither chemical nor laboratory data are available for low levels of pesticide exposure in Sri Lanka.

Susceptibility of local fauna to these chemicals is not well known. Statistics are also not available for deducing longterm epidemiological features of pesticide application. In view of recent knowledge about health related factors of pesticides, it is important that this kind of research be initiated in our country.

Table 1. Pesticides Most Commonly Used in Sri Lanka

Code No.	Insecticide	Type	LD ₅₀ mg/kg	Code No.	Weedicide	Type	LD ₅₀ mg/kg
4750	Mathamidophos	org-P	7.5	5240	Paraquat	org-N	57
360	Monocrotophos	org-P	2.1	3060	3-4-D-P	others	—
1040	Carbofuran	org-N	5.3				
791	BPMC	org-N	410	4340	MCPA	Org-N	700
3520	Fenthion	org-P	215	2740	Duiron	Organic	437
—	Carbosulfan	org-N	—				
2080	Diazinon	org-P	70	2940	2,4-D	Others	370

*Oral administration to male rats

(Ref. Analytical reference standards & supplemental data: EPA-600/

4-84-082, 1984).

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PESTICIDE POISONING IN SRI LANKA

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Agrochemicals include basically two groups of chemical substances, namely, pesticides and fertilizers. Though either of these can cause poisoning or other adverse effects if misused, pesticides are the major group of substances causing human toxicity today.

Pesticide means any substance or mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as a plant-growth regulator, defoliant, dessicant, or fruit thinning agent or agent for preventing the premature fall of fruit and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport.

By definition therefore pesticides must kill pests which are living organisms. If misused they must be harmful to man. If there is a pesticide that is not harmful to human beings, that is not a pesticide.

Pesticides have five main areas of use in Sri Lanka. They are widely used in public health programs to kill vectors of malaria and filaria.

Secondly pesticides are used for domestic and personal use for application to kill, for example, insects like cockroaches or on the skin to control

scabies or head lice. Thirdly, pesticides are used for industrial purposes like fumigation of ships and buildings. Fourthly, pesticides are used for protection of material by incorporating in or on paint, timber, glue, and leather to prevent or retard attacks by insects or fungi. Finally, in agricultural production, on garden crops, forests, livestock and agricultural produce, pesticides are used.

The effects of pesticides on man can be acute or chronic. The major problem in Sri Lanka is acute toxicity. The gravity of the problem of poisoning with pesticides can be seen in the statistics shown below.

Total admissions and Deaths in Hospitals following Poisoning—1986

	Admissions	%	Deaths	%
Chlorinated hydrocarbons	1635	(7)	170	(8)
Organophosphates and Carbamates	10263	(40)	1022	(46)
Other Pesticides	2515	(10)	260	(12)
Medical agents	3136	(12)	102	(5)
Other poisoning and Toxic effects.	7976	(31)	640	(29)
	<u>25525</u>		<u>2194</u>	

The number of deaths from pesticide poisoning, surprisingly, is more than the total number of deaths from rabies, snake-bites, polio, diphtheria, tetanus, whooping cough, malaria, and all mur-

ders in Sri Lanka for the year 1986 (more than the combined total of all those causes of deaths). In fact, poisoning is now the second leading cause of death in our state hospitals.

A study done on pesticide poisoning in 1979, reported in the Bulletin of WHO in 1982, by Dr. Jeyaratnam and others had revealed that 73% of cases were due to deliberate ingestion. 17% cases were occupational, 8% were accidental and in 2% the cause was not ascertainable from the hospital notes. This study also revealed that of all the poisoning cases, 31% involved people between 11-20 years and 47% between 21-30 years; in other words, 78% cases were between 11-30 years.

Annual morbidity rate for pesticide poisoning was 79 cases for 100,000 population. This study further showed that 5 per 1000 of agricultural workers were hospitalised annually for pesticide poisoning. These revealing data showed that Sri Lanka probably has the highest rate of pesticide poisoning in the world! In the world literature poisoning shows about a 5% mortality rate but our mortality is around 9-10%.

Accidental and occupational poisoning can occur under special circumstances. Firstly, they can occur during research work in the laboratories. During field studies people can get accidentally poisoned. Secondly, during pesticide production, manufacturing, packaging, transportation and waste disposal, occupational poisoning may occur. Storage of human and animal food with pesticides can cause poisoning, and finally, during spraying poisoning can occur. Poisoning due to deliberate ingestion is very common in Sri Lanka because of the easy availability of highly concentrated and toxic pesticides.

Homicidal pesticide poisoning is extremely rare.

Some of the problems encountered regarding management of patients who have been exposed to pesticides are :

- (1) Undue delay in admission.
- (2) Lack of proper first-aid prior to admission.
- (3) Delay in the treatment after admission.
- (4) Lack of drugs and equipment necessary for proper treatment.
- (5) Wrong treatment due to the inability of correctly identifying the pesticide involved.
- (6) No psychiatric referral prior to discharge from hospital in attempted suicidal cases.

It is unrealistic to expect doctors to remember constituents, toxic effects, symptoms, signs and appropriate treatment for poisoning with an infinite array of pesticides, drugs, household products and industrial chemicals.

Recognizing this, all developed countries and many developing countries in the world, have established institutions from which doctors, emergency services and para-medical personnel can obtain immediate and accurate information on the identification, toxicity and treatment of poisonous substances. These institutions are known as Poisons Information Centres.

In Sri Lanka, doctors realised the need for such a Centre over a decade ago. However, it is only in 1987, that a National Poisons Information Centre was established in the General Hospital, Colombo. The Centre provides information on poisoning 24 hours a day throughout the year. Its telephone numbers are 96143 and 91111 extension 306. It is expected that the Centre will help to reduce the rising incidence of morbidity and mortality from pesticide poisoning.

PESTICIDE LEGISLATION IN SRI LANKA

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Introduction

The use of pesticides today is an integral component of the package of agricultural practices. Their assets, such as ease of application, efficacy, wide use and temporary economic return have themselves been the basis for the negative impacts they have caused, such as environmental contamination and residues in food, potentially chronic health hazards, ecological disruptions and development of pests resistant to pesticides. With their increased use and misuse came the resultant awareness and concern on the hazards posed when toxic products are mishandled and misused.

A question that comes to mind could be "What are the activities that could achieve the benefits that are required from pesticides without causing significant adverse effects on people or on the environment?" The hazardous nature of pesticides calls for action by all concerned, including the Government, the Pesticide Industry, and Pesticide Users to eliminate as far as possible, and within the scope of their responsibilities, unreasonable risks to health and to the environment.

Such activities must encompass three areas, **education** — to increase public awareness on the diverse properties of pesticides and the need for safety in use; the **reduction** of the demand or dependence on pesticides for crop protection and by **restricting** the availability of highly hazardous pesticides by regulatory action.

All these activities have been the concern of the Department of Agriculture for sometime now.

The Agriculture Extension Service is the main arm with which this Department educates the end users. It provides practical information on the need for pest control, the proper and correct application methods and the safety precautions to be followed. The Department's Research policies have been directed towards the development and improvement of alternate pest control strategies for crop protection, the breeding and selection of resistant varieties, the improvement of pesticide management techniques and the adoption of integrated pest management (IPM) approaches in crop protection.

Over the years steps have been taken to reduce the dependence on pesticides in rice through IPM techniques and to issue seed paddy resistant or tolerant to some of the major pests and diseases of rice. Further, in its endeavours to contend with problems associated with pesticide use, the Department has been instrumental in regulating pesticides, so that undesirable pesticides such as DDT, Endrin, 2 4 5 T, were prohibited from import and use even prior to the enactment of pesticide legislation.

History of Regulatory Activities

In the history of pesticide marketing in Sri Lanka, it is evident that various measures were instituted by the Department of Agriculture over the last 2½ decades to bring pesticides under Government control. Conventional pesticides were more or less

1. Registrar of Pesticides, Department of Agriculture, Peradeniya.

freely imported into this country (by 40–50 importers) up to 1962. In 1963, to conserve dwindling foreign exchange reserves, the Controller of Imports and Exports limited the exchange for the import of agrochemicals to Rs. 5.23 million. Vehement protests by the importers resulted in the appointment of a Government committee to look into the matter. The committee recommended that a policy of strict import restrictions would negate the nations' efforts to boost local production and drew up a list of "Drugs, Chemicals and proprietary preparations required for use in Agriculture".

The Department of Agriculture recognizing the need to exercise control over the supply, distribution and use of pesticides, prepared and submitted a draft Bill entitled an "Act on Poisons Used in Agriculture" to the Legal Draftsman in 1964. However, it did not come into fruition.

In order to revive the Bill on Pesticide Legislation the Department of Agriculture then took steps to seek advice and consultative assistance from the Food and Agricultural Organization on the establishment of a national infrastructure for the Control of Pesticides. (FAO Report Bangkok 1972). Consultants came, submitted recommendations, Governments changed and time passed without enactment of legislation. To further aggravate the situation, open import policies became the order of the day and the doors were left wide open for unscrupulous traders to import hitherto prohibited products such as DDT and Endrin. With further agitation and lobbying by the Department of Agriculture and other Government and non-government bodies Pesticide legislation was finally enacted in 1980.

Control of Pesticides Act No. 33 (1980)

1. This Act makes provision to regulate the Import, Formulation, Packing, Labelling, Storage, Transport, Sale and Use of Pesticides.
2. The basis of regulation is the compulsory registration of all pesticide material. In order to register a pesticide a separate application must be filed for each formulated product,

as well as for each source of the technical material. Data must be submitted on toxicology, analytical methods, the bio-efficacy of the products, residues at harvest and the fate in the environment to be subsequently evaluated by experts.

3. No import or local formulation, distribution, or sale of a pesticide can take place without first having the label evaluated for various requirements as indicated in the Act and the container approved.
4. When registration requirements are fully satisfied, a licence covering 3 years disposal and use is granted, or, after registering the pesticide and pending the issue of a licence, provisional permit for limited marketing is issued, generally with restrictions, or the application is rejected.
5. Importation of pesticides whether Active ingredient or Formulation, is permitted by the Controller of Imports only after approval by the Registrar of Pesticides.
6. Sections of the Act dealing with Consumer Protection cover adulterated and deteriorated products, storage in juxtaposition to foodstuff, deceptive advertising and harvesting after a prescribed period, to avoid unacceptable residues.
7. Penalties and forfeiture are specified for contravening or failing to comply with any provision of the Act and range from cancellation or suspension of licence, to fines and imprisonment.

Implementation of the Act

There has been some delay in putting the Control of Pesticides Act into operation owing to circumstances prevailing in the country, which has created the impression that no action is being taken by the Government to reduce or eliminate the hazards involved in pesticide use.

Implementing an Act is dependent on the support it receives for enforcement. It requires trained manpower i.e. expertise and skills for evaluating

and analysing data as well as pesticidal formulations, supporting laboratory and field facilities for monitoring and implementing the Act and adequate funds. Within the limited resources available to the Registrar of Pesticides the main thrust in the work has been the setting up of the registration process. As a high level of technical expertise is required for certain facets of work, an interdepartmental technical advisory committee called the Formulary Committee assists the Registrar in evaluating data and determining the need for restrictions in use. Registration of Pesticides for Public Health and household use is based generally on decisions made by a Committee appointed by the Ministry of Health to evaluate Health Hazards from Household Pesticides.

The evaluation of the pesticide label is closely linked to the Registration process. The label must be of such a design and quality that it does not deteriorate on handling. Every label must be conspicuously printed and firmly affixed to the container and in such a position that it is not damaged or removed when the container is opened. The label must contain the word "Poison" and the skull and crossbone symbols for Class I compounds (WHO 1984, 1986). The information on the label ensures its (a) **Identification** by Trade Name, Common Name of Active Ingredient, percent content, physical nature, the name and address of distributor, Batch No. and Licence No. (b) **Directions for Use** specifying pests and weeds to be controlled, frequency of application and any limitations. (c) **Precautions and Warnings** followed by First Aid and Antidote.

In order to translate the Act into practice, it has been necessary to revise, substitute or delete sections of the Act and to draw up regulations to enable ease of implementation. These amendments embodied in an Act to Amend the Control of Pesticides Act No. 33 of 1980. have yet to receive Cabinet approval and gazetting. As the Act stands, the required data on the label has to be given in all three languages. This information must be visible and hence a regulation was needed for the print size. Further, there is no provision in the Act to gazette banned pesticides, hence press notification has to be made until the amendments are gazetted.

Deadlines for carrying out various technical requirements were considered but only a few have been set such as :

1. The deadline for stopping imports of Parathion and Dieldrin products for agricultural use.
2. The deadline to firms with exstocks of products carrying unapproved labels.
3. The deadline for enforcing 100 ml as minimum pack size for highly toxic chemicals.

Disposal of Unapproved Products

With the promulgation of legislation, all pesticides retailed at that time were required to be registered, though many had not received official approval.

After much discussion and with expert consultation it was decided that it would be more practical for such pesticides (which were originally registered for sale, but which had not received official approval) to be used up over a period of time instead of recall without the required facilities being available in the country for disposal.

Post-Registration Activities

After a pesticide is registered, a wide range of monitoring and other activities are required to ensure that a pesticide is being handled, distributed and used properly in accordance with label directions and in compliance with rules and regulations. These monitoring activities include :

- (i) Monitoring of Pesticide outlets to ensure compliance with rules and regulations to be observed when storing pesticides in general and when selling "Restricted" pesticides.
- (ii) Detecting of unauthorised packing, repacking and labelling activities to enforce legal action and to weed out substandard/or hazardous products from entering the market.

- (iii) Analysis of formulations for maintaining quality products and determining if surplus or unmarketed quantities of pesticides are still usable for their intended function.
- (iv) Analysis of crops and commodities for pesticide residues to provide information that can be used to assess the safety of consuming treated foods, detecting residues from improper use of pesticides and to facilitate export trade in food commodities.
- (v) Establishing maximum limits for pesticide residues on various crops and commodities based on experimental data derived under good agricultural practice to ensure safety in dietary intake. The data could also provide the basis for modifying use patterns.
- (vi) Monitoring pesticide poisoning cases due to exposure during formulation, packing and use.

Information on these aspects can be a basis for active training, informational needs and other regulatory purposes leading to restricting the use of, or totally banning products found unsuitable under our socio-economic conditions, or to taking enforcement action against pesticide misusers. The first two activities is the responsibility of the thirty-two Authorized Officers at the district level, nominated by the Director of Agriculture. Inadequate laboratory facilities prevents the accomplishment of activities (iii), (iv) and (v), while the establishment of a Poison Centre by the Health Services would go a long

way in monitoring occupational poisoning due to pesticides.

The monitoring activities inherent in regulatory procedures enables the evaluation process necessary to safeguard food production and the health of user and consumer. These activities would enable a full evaluation of risks associated with the use of pesticides and to take action to cancel, revoke, restrict questionable pesticides or revalidate the licence of others.

Currently, such post-registration activities cannot be carried out except on an *ad hoc* basis due to lack of staff, expertise, capital outlay and back-up laboratory and field support requirements.

As indicated before, implementing an Act is dependent on the support it receives. It requires trained manpower, supporting laboratory and field facilities and adequate funds. To the extent that these are constraints, the impression created by and large will continue to be that legislation is only so much paper.

C O P 1980 - Control of Pesticides Act No. 33
5th September 1980.

W H O 1984 - The WHO recommended Classification of Pesticides by Hazard
VBC/84.2 WHO Geneva.

W H O 1986 - The WHO recommended Classification of Pesticides by Hazard
VBC/86.1 WHO Geneva.

ALTERNATIVE METHODS OF PEST CONTROL

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Alternative methods of pest control mainly deal with methods, other than the use of chemicals. Agrochemicals have caused an enormous threat to the environment. As such biologists and chemists are looking for alternative methods of pest control. At the moment, a number of such methods are in use. Also much work is being done in devising new methods.

Some of the alternative methods are :

- a. Biological control
 - b. Alternative crop methods, or rotation of crops
 - c. Good housekeeping
 - d. Use of Pheromones
 - e. Use of suitable traps
 - f. Radiation methods
- a. **Biological Control**

In the natural environment, both fauna and flora are in a state of balance. The food supply and the climatic conditions are the main factors that may affect this balance. If there is an abundance of food supply for a certain sector of animals, they may multiply beyond control. This article is mainly concerned with the insect pests and certain weeds that affect our agricultural crops.

The recent emphasis on greater production of both grain and seed crops has produced an abundant supply of food for the insects. A few decades ago the farmer had only one crop per year.

With the development of better varieties with shorter maturity age, e.g. rice, he could cultivate throughout the year. As such there was enough food throughout the year for the insects. As the

insect population grew, the natural enemies were unable to keep them under control. This is why the farmer had to use various agrochemicals to destroy the pests.

As agrochemicals cause environmental pollution in various ways, researchers are looking for various natural enemies of the insects. In the recent past, the coconut pest *Cumingi* was brought under control using a biological control method. Although the biological control of insect pests does not pose a threat, there is a certain element of risk that the control agent may itself become a pest.

b. **Rotation of Crop Method**

Often an insect may depend upon one type of food crop. It thrives only if this source of food supply is available. If the food source is removed, the insect will perish. Thus if a farmer grows one type of crop throughout the year it is difficult to eliminate the insect pest dependant on it. Rotation of crops should be done in consultation with the agricultural adviser. It may not harm the environment and at the same time aim at controlling the insect pest.

If grain type of crops is grown in one season, in the other seasons tuber or seed type crops or even leafy type could be grown. Pest feeding on grain may not feed on leaf or vice versa. The rainy condition and other weather and climatic conditions have to be reasonably well established for the rotation of crops to be successful.

c. **Good Housekeeping**

This simply means to have clean farms, where insects find it difficult to thrive. Often insects lay their eggs in dark sheltered corners with plenty of

debris. As far as possible the farmer should clear up any sheltered areas and odds and ends should be burnt. Very often, quite unnoticeably some grain or seed may accumulate in unattended corners. Such places should be cleaned.

d. Use of Traps and Pheromones

Many insects are attracted to light, especially in the blue and ultra violet areas. Once drawn to the light, they should be trapped and killed. High tension voltage, sticky gummed tape or even suitable insecticide could be used to destroy the trapped insects.

In this connection the use of pheromones (insect sex attractants) also could be used. If a female pheromone is placed in a suitable place, many of the male insects in the vicinity will be attracted. They could be trapped and destroyed. Recent

research has shown that alarm hormones could be used in a similar way. Many insects when disturbed or in the process of being destroyed secrete some alarm hormones. When such insects are ground up in water and sprayed over the field, many insects were seen to run away, apparently disturbed by the alarm hormones. Snails and slugs are also repelled by alarm hormones.

Other areas of alternative methods of pest control are being investigated. Use of ultrasonic waves, appropriate electromagnetic waves and radio isotopes are some of them. The ultrasonic waves have already proven to be an effective method of repelling insects and rodents. These sound waves do not harm any organism or cause environmental pollution. Electromagnetic waves could adjust to either attract or repel the insect pest. The radio isotopes are used to produce sterile male insects, thereby eliminating the pest.

SLAAS PROJECT ON THE "SAFE USE OF AGROCHEMICALS"

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A severe problem confronting Sri Lanka today, is the high incidence of poisoning by agrochemicals which has become a major health hazard to the entire population.

During the last few decades, the national pattern of development has been characterized by an emphasis on increasing agricultural production to meet the needs of the expanding population and to save foreign exchange now spent on food imports. As traditional methods of controlling pests could not be effective or possible on large-scale cultivations, the increased use of agrochemicals became essential. The increasing dependence on vast quantities of fertilisers, pesticides, weedicides and fungicides however, also required increased levels of scientific awareness among the users. Unfortunately the use of agrochemicals by ignorant farmers even in the remotest areas of Sri Lanka has resulted in widespread misuse.

A WHO survey conducted in November '83 reported that Sri Lanka has the highest death rate in the world resulting from pesticide poisoning. According to a national survey carried out recently, 16,000 people suffer from pesticide poisoning annually. However, medical authorities believe that the number of cases of chronic and undetected poisoning caused by regular, unintentional intake of small quantities of pesticides as residues in food are far greater and could be of a more real danger to the population at large.

The section of the population that is most vulnerable to acute poisoning by agrochemicals is the rural farming community. Illiterate farmers, ignorant of the nature of the chemicals they handle, test their mixtures of chemicals by dipping a finger into the mixture and testing it with their tongue. Some use the same vessel, already

used to prepare the chemical mixture, to bathe. Empty chemical cans and bottles are used to store coconut oil and other consumer liquids or even medicine. Agrochemicals are transported along with consumer goods such as rice, flour and sugar in the same vehicles and stored over consumer goods in stores and boutiques. Although legislation regarding the use of pesticides was passed in 1980, the enforcement of the laws has proved difficult and inadequate to control the existing situation.

In 1981, the Committee for the Popularization of Science (CPS) of the Sri Lanka Association for the Advancement of Science (SLAAS) launched a programme to combat the misuse of Agrochemicals. They decided that the proper education of the users, the farmers, by bringing them a simple and effective message regarding correct use would be the most practical approach to solve the growing problem. Instruction to farmers in the usage of pesticides as a part of agricultural extension work had been carried out for several years, but various constraints made it difficult to be sufficiently effective. The CPS therefore decided that another agent, selected from the farming community itself should be utilised to carry the message to the rural areas.

The effectiveness of school children in the communication of messages to peers and parents is being recognised today in many parts of the world. The CPS felt that they would be the best choice as agents of change for development support information transfer particularly at rural level. Students are amenable to training, enthusiastic and idealistic and enjoy a position of confidence among their peers as well as in the village community, which was the ultimate target. Besides, the interaction involved in carrying out

the program would ensure that the liaison achieved between the school and the village community would be an added benefit.

The broad objective of the exercise was to select a group of senior students from schools in each of the predominantly farming, districts in Sri Lanka, equip them with the necessary knowledge regarding the correct use and hazards of the improper use of agrochemicals and to impart to them the communication skills necessary to motivate parents, peers and neighbours in the proper use of these chemicals. Twenty-four rural educational districts in Sri Lanka were selected for the Programme giving preference to underprivileged areas. Schools from each district were requested to nominate five students and one teacher each, to follow the Programme. The students who were drawn from Grades 10 (Ordinary level) to 12 (Advanced level) had to possess a science background and also show a fair degree of communication skills.

A Sub-committee on Agrochemicals drawn from the CPS was appointed in August 1981 to plan, coordinate and monitor the entire programme. The Sub-committee was interdisciplinary in nature, being composed of scientists, engineers, doctors, information scientists, etc. The Committee aimed to cover the farming districts of the entire island during the course of the Programme.

The subject areas covered by the Programme included (a) the nature and use of agrochemicals, (b) their hazards, both environmental and pathological, (c) alternative methods of pest control, (d) safety measures in the handling, storage and transport of agrochemicals and (e) simple principles of communication methodology to enable participants to organise seminars at the village level. The resource personnel were all professionals in the chosen fields and drawn from University staff, Research scientists, Medical specialists, Environmentalists and Plant Protection Officers from the Department of Agriculture. Thus the Sub-committee ensured that the best available human resources were utilised for the project.

The Programme has been carried out in 3 stages:

Stage 1 — A selected batch of about 250 rural students are exposed to a one-day awareness-

creating programme. Lecture/demonstrations, discussions, slide-shows and films are included in the schedule. The Seminar is supported by an exhibition of the safe-use of agrochemicals provided by the major firms dealing with agrochemicals in Sri Lanka. As follow-up to *Stage 1*, the trainees are required to conduct a local survey on the use/misuse of agrochemicals in their villages. A brief report of the survey is a pre-requisite for attendance at Seminars in the next stage of the Programme.

Stage 11 — Smaller groups of 50 to 60 students drawn from *Stage 1* are subjected to a two-day intensive training workshop held at a resident agricultural research institute. The subject matter covered includes the same areas as *Stage 1* but in more detail as well as additional modules on common agricultural pests in Sri Lanka, effects of pesticide use on the soil, practical demonstrations of safety measures and field visits. Instruction in basic communication methodology is included at this stage to enable the students to organise similar seminars to disseminate information at the village level.

Stage 111 — The organisation of seminars at the village level by trainees from *Stage 11* for their peers and the farming community in their respective localities. The trainees are expected to carry out the major part of the planning and execution of *Stage 111* with marginal assistance from the Sub-committee. These seminars were designed to provide a forum for the farmers to discuss freely with the resource personnel about local problems in the usage of agrochemicals and how they might solve them.

The communication technique for the entire project was planned taking into full consideration current attitudes and practices and patterns of behaviour in the local farming community. The typical Sri Lankan farmer has deep-rooted traditional beliefs and values and traditional ways of doing things. Nevertheless in recent years the older generation has exhibited an increasing respect for the new knowledge and skills acquired by the younger generation through expanded and increasingly science oriented curricula in schools. It was envisaged that the effect of directing the message through children would have a far greater impact on their elders and their home

environment than through the occasional visits of agricultural extension officers. It was also felt that the trained students would be more successful in persuading their parents to participate in the village level seminars.

The materials used for the project were planned and developed to be directly relevant to local needs and issues. Emphasis has been laid throughout to use materials and examples that the participants are familiar with. The medium of instruction throughout the programme has been in one of the national languages, Sinhala, and the materials used have been translated from English, when necessary.

Pre- and post-activity questionnaires were served to the trainees at each stage of the project. Based on the feed back received and suggestions made by participants, there has been a constant updating of training materials and techniques. The course content has therefore evolved during the 5-year period into an intensive and practical one, well adapted to local needs and problems. Throughout the project, interpersonal communication was supplemented with a wide range of instructional methods. The traditional lectures were freely illustrated with colour slides. Audio-visual presentations, exhibitions of posters and visual aids, discussions, field visits, practical demonstrations and films were used to reinforce the message and for greater impact. A set of colour slides has been specially prepared for the project by one of the resource personnel (a Research Officer from the Department of Agriculture,) to illustrate the lecture on the correct use of handling and storage, which has proved to be very effective. Although posters were gifted to the Sub-committee by the International Group of National Associations of Manufacturers of Agrochemical Products (GIFAP), they could not be utilized as they depicted situations and images unfamiliar to local farmers. Instead, hand-drawn posters loaned from the Department of Agriculture have been used throughout the project. One of the future objectives of the Sub-committee is to produce posters in the national languages depicting the do's and don'ts of handling pesticides for free distribution to farmers, nationwide.

A video film of the Project was also prepared in April 1986 using funds donated by the British

Council. The film will be shown at future village level seminars. The added entertainment value of using films and videos goes a long way to make the programme interesting and effective in the villages.

Equipment belonging to the SLAAS such as AV equipment, film and slide projectors and a portable recorder are transported in the SLAAS van for all the village-level activities. Technical personnel from the SLAAS are responsible for maintaining and operating the equipment.

Since the programme was launched in 1981, the Committee has organized six *Stage 1* Workshops for approximately 250 participants each. These have been followed by Workshops at the second stage at the Central Agricultural Research Institute. Each group of trainees has organized *Stage 111* Workshops in their respective localities for the farming community.

The Sub-committee members who visited the villages for *Stage 111* Workshops have observed a high degree of confidence in the trained students by their communities. Success is indicated in the village level activities that have been catalysed by the Programme. Farmer participation in *Stage 111* Workshops has proved to be very high. Requests for more seminars have been received by the Sub-committee from other farmer groups, outside the scope of the Programme itself. Although it is difficult to assess the direct benefits of the Programme, the Sub-committee feels that the awareness created among the farmers regarding the hazards and safe use of agrochemicals is a sufficient measure of the success of the programme. The ultimate test would be to investigate whether agrochemicals use has become less harmful, but such figures are difficult to obtain.

The entire programme was planned as part of the science popularization activity of the SLAAS. Apart from the funding obtained from the parent association, inputs to the programme of professional expertise by the members of the Sub-committee have been purely on a voluntary basis. In 1986, the Queen's Silver Jubilee Trust provided funding through the British Council to support the programme for one year.

As an example of a science communication project for rural development, the success of Programme on the Safe Use of Agrochemicals demonstrates a clear and urgent need for such projects in Third World countries such as Sri Lanka. The inexpensive method which utilises interpersonal communication for the transfer of information stands in contrast to the cost effec-

tiveness of the mass media programmes with admittedly more coverage but much less effect on the individual. Examples of such development related problems are plentiful in the Third World, where the availability of simple but essential scientific information can mean the difference between health and disease, life and death.