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 adsorbtion 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, fungis, nematodes, rodents & weed control activities. During application to soil or crops, pesticides may be lost as spray drift or by volatalisation. 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 volatalisation.[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 chemicals 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.[1 2]

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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