Pesticides in environment and their management strategies

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ABSTRACT

Indian agriculture has seen a paradigm shift from earlier days of begging bowl to a modern era of food self-sufficiency. Pesticides as plant protection agents play an important role in securing food for a nation of 1.22 billion people. If the credits of pesticides include enhanced economic potential in terms of increased production of food and fibre, and amelioration of vector-borne diseases, then their debits have resulted in serious health implications to man and his environment. The general concept of *"if little is good, a lot more will be better"* has violated the basic concept of need based application of pesticide and hence have become one factor of environmental contamination. This article is aimed to give some light on the evolution of pesticides, there importance and environmental contamination with emphasis on some management strategies.

Keywords: Pesticide, vector-borne disease, environmental contamination

Plant protection is one of the most important key components of intensive agriculture where high yielding crop varieties are susceptible to disease and pest attack. The uncertainty of climatic conditions has further enhanced outbreak of pests and diseases. Under these situations, role of pesticide as saviors of mammalian food, feed and fiber has become unchallenged. A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest (insects, mites, nematodes, weeds, rats, etc.), including insecticide, herbicide, fungicide, and various other substances used to control pests (EPA, 2009). But the general concept of *"if little is good, a lot more will be better"* for pest control has violated the basic concept of need based application of pesticide and hence have become one factor of environmental contamination.

The revolutionary history of pesticides can be divided into several phases, which begins with natural pesticides like sulfur to control pests (before 1870s), followed by the era

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of inorganic synthetic pesticides (the period 1870s-1945) and then came the era of organic synthetic pesticides. Since 1945, the man-made organic pesticides, mainly organochlorines like DDT, 2,4-D, and later HCH, dieldrin etc. have terminated the era of inorganic and natural pesticides. With the development in science and technology, newer molecules were added into the list of the man-made organic synthetic pesticides like organophosphate (OP) insecticides (in the 1960s), carbamates (in1970s) pyrethroids (in 1980s), neonicotinoids (in 1990s) and still continuing. The high volume pesticide molecules have been replaced with more target specific, low to ultra-low volume pesticide molecules.

Importance of Pesticide: Past and Present

The unique ability of pesticides to control pests and diseases has gained enormous attention and has revolutionized agricultural production (Guler *et al.,* 2010). It has been estimated that around 90,000 Mn Mt (50% of the total food production) is lost due to insect pests, plant pathogens, weeds, rodents, birds, nematodes and during storage (Fig. 1). The trend of pesticide use in India is slightly different from the average global trend (Fig. 2) because of its geographical position. Insect pest infestation is comparatively high in humid-tropical Indian subcontinent than other temperate countries which results in high consumption of insecticides as compared to other groups of pesticide (Aktar *et al.,* 2009). As on 10/08/2012 about 240 pesticides belonging to different chemical groups are registered under section 9(3) of the Insecticides Act, 1968 for use

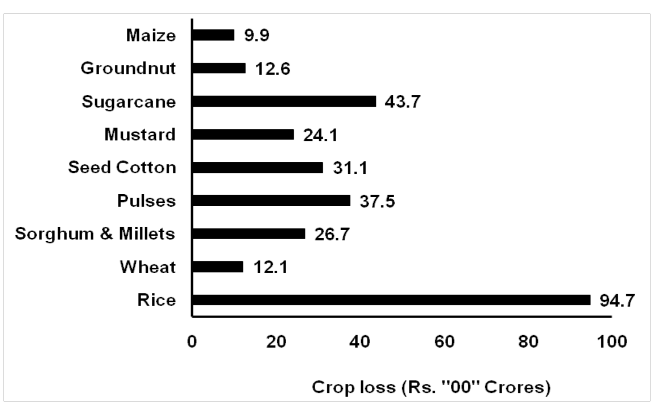

Figure 1. Estimated crop loss (in Rs. Crores) in India.

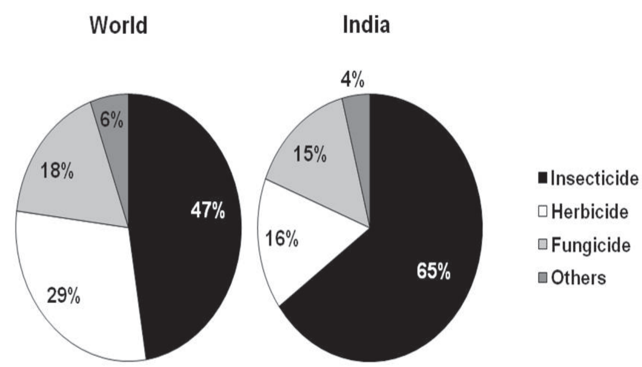

Figure 2. Pesticide usage pattern in world and India.

in the India. From a meager 2000 tones a year during 1950's, the use of pesticides and allied chemicals in India touched a level of 85030 tonnes during 1994-95. However, the total pesticide production showed a stagnation level, whereas pesticide consumption showed a decreasing trend (Fig. 3). The reason could be because of replacement of

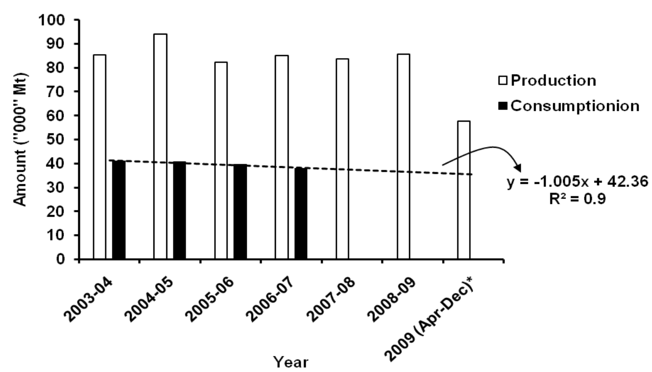

Figure 3. Pesticide production-consumption dynamics in India

(Source: Ministry of Chemicals and Petrochemicals).

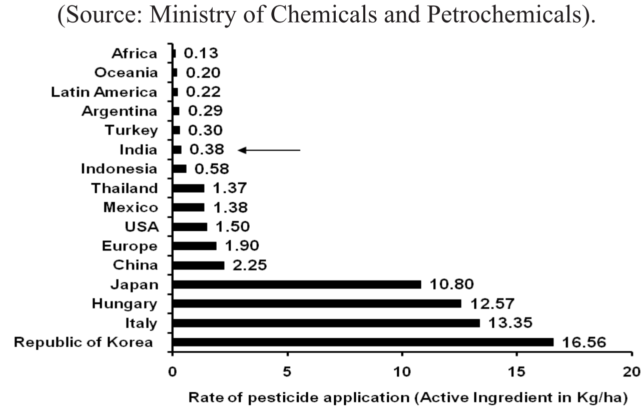

Figure 4. Rate of pesticide application in some countries (Dureja and Gupta, 2009).

high volume pesticide molecule with low to ultra low volume pesticide molecules, coupled with public awareness.

Though rate of pesticide application (active ingredient Kg ha^{-1}) in India is low as compared to several other developed and developing countries, but still it is a serious concern of environmental contamination (Fig. 4).

Environmental contamination

The pesticide molecules which were introduced long back in 1940's and 50's have invaded ecosystem because of their lipophilicity, long persistence and over and above large scale indiscrimate usage worldwide. Even though many of them are banned, but still they are being detected in various environmental components. They have intruded in the food-chain and because of bioaccumulation coupled with biomagnifications; they have contaminated different tropic levels of food-pyramid (Tutu *et al.,* 2011). The treaty, called the Stockholm Convention on Persistent Organic Pollutants (2004) has identified "dirty dozen" for reduction and eventual elimination, on the basis of their toxicity, persistence, long distance transport and potentials to accumulate in fatty tissue. Among them nine are pesticides and most surprisingly all of them are organochlorine insecticides (Table 1) and are still reported from different part of the world (Reddy and Reddy 2010, Kafilzadeh *et al.,* 2012). Pesticides have not only affected the soil microbial community (Kinney *et al.,* 2005; Jansa *et al.,* 2006; Potera 2007) but also soil habitating invertebrates like predatory arthropods (spiders and ground beetle) (Evans *et al.,* 2010), earthworms (Shahla

Table 1. Hale life of some organochlorine insecticides.

Name of the pesticide	Half life	References	Banned in India
Aldrin	5 years	(WHO, 1989a)	2003
Chlordane	189 days	(Parrish *et al.,* 1978)	2001
DDT	10-15 years	(Keller, 1970)	1989
Dieldrin	5 years	(WHO, 1989a)	2003
Endrin	12 years,	(Hansen *et al.,* 1977).	2001
HCH	2.7 to 22.9 years	(Environment Canada, 1993)	1997
Heptachlor	2 years	(WHO, 1984b)	2001
Mirex	10 years	(WHO, 1984c)	-
Toxaphane	100 days to 12 years	(WHO, 1984d)	2001

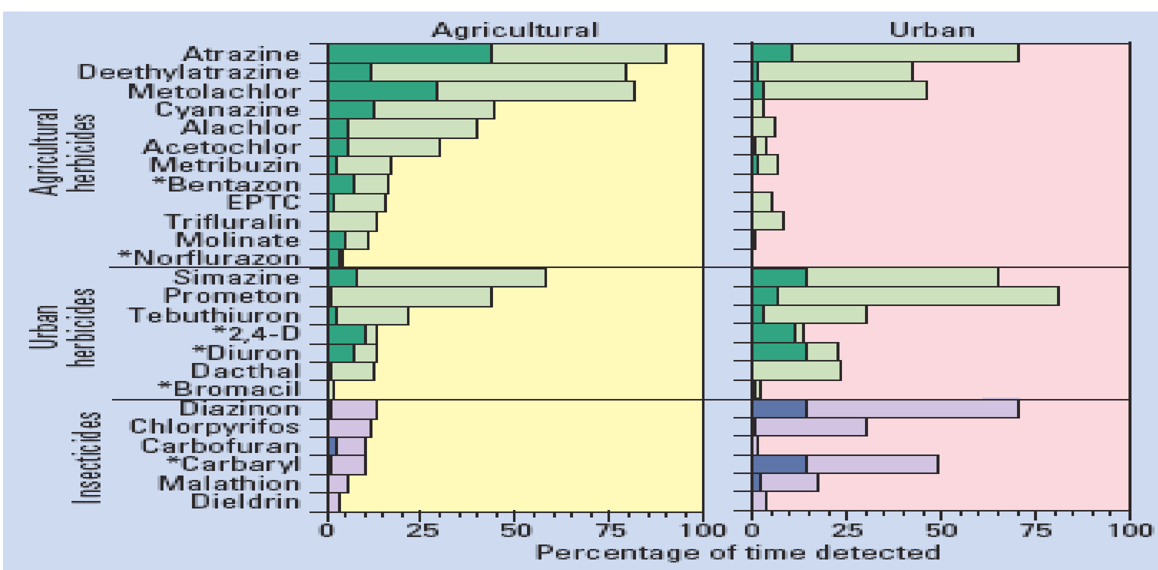

Figure 5. Most frequently detected pesticides in agricultural and urban streams.
The full length of each bar represents all detections, regardless of concentration, and the dark portion represents detections ≥0.1 µg/L. Pesticides marked with an asterisk could not be detected reliably at concentrations <0.1 µg/L; thus, reported frequencies for these pesticides <0.1 µg/L are minimum estimates (Source: Gilliom 2007).

Table 2. List of banned/ withdrawn/ refused/ restricted pesticides or pesticide formulations in India under the Insecticides Act, 1968 as on 10/08/2012.

Sl. No.	Banned for manufacture, import and use (28)	Pesticide / Pesticide formulations banned for use but their manufacture is allowed for export (2)	Pesticide formulations banned for import, manufacture and use (4)	Pesticide withdrawn (7)	Refused registration (18)	Restricted use (13)
1	Aldrin	Nicotin Sulfate	Methomyl 24% L	Dalapon	Calcium Arsonate	Aluminium Phosphide
2	Benzene Hexachloride	Captafol 80% Powder	Methomyl 12.5% L	Ferbam	EPM	DDT
3	Calcium Cyanide		Phosphamon 85% SL	Formothion	Azinphos Methyl	Lindane
4	Chlordane		Carbofuron 50% SP	Nickel Chloride	Lead Arsonate	Methyl Bromide
5	Copper Acetoarsenite			Paradichlorobenzene	Mevinphos	Methyl Parathion
6	CIbromochloropropane			Simazine	2,4, 5-T	Sodium Cyanide
7	Endrin			Warfarin	Carbophenothion	Methoxy Ethyl Mercuric Chloride
8	Ethyl Mercury Chloride				Vamidothion	Monocrotophos
9	Ethyl Parathion				Mephosfolan	Endosulfan
10	Heptachlor				Azinphos Ethyl	Fenitrothion
11	Menazone				Binapacryl	Diazinon
12	Nitrofen				Dicrotophos	Fenthion
13	Paraquat Dimethyl Sulphate				Thiodemeton / Disulfoton	Dazomet
14	Pentachloro Nitrobenzene				Fentin Acetate	
15	Pentachlorophenol				Fentin Hydroxide	
16	Phenyl Mercury Acetate				Chinomethionate (Morestan)	
17	Sodium Methane Arsonate				Ammonium Sulphamate	
18	Tetradifon				Leptophos (Phosvel)	
19	Toxafen					
20	Aldicarb					
21	Chlorobenzilate					
22	Dieldrine					
23	Maleic Hydrazide					
24	Ethylene Dibromide					
25	Trichloro acetic acid					
26	Metoxuron					
27	Chlorofenvinphos					
28	Lindane					

and D'Souza 2010) etc. Pesticides have also negative impacts on nontarget organisms like bees (Brittain et al,. 2010), butterflies (Adamski *et al.,* 2009) birds (Taylor *et al.,* 2006). Not only organochlorines, the list of contaminating water pesticides, around the world, is increasing and includes mostly insecticides, herbicides and fungicides of different classes (Gilliom, 2007; Añasco *et al.,* 2010; Reddy and Reddy 2010; Lamers *et al.,* 2011) (Fig. 5). Pesticides in aquatic systems may directly or indirectly harm various aquatic organisms like planktons/ periphytons (Relyea and Hoverman 2008), amphibian species (Relyea 2003), macro invertibrates etc. (Beketov and Liess, 2008) Depending upon the contamination reports and consequences studies several pesticide molecules have been scanned by the government authority and some of the molecules have either been banned or refused or restricted to prevent environmental contamination and harmful effect of pesticide on ecosystem. As on 10/08/2012 about 28 pesticides and 4 pesticide formulations are banned for manufacture, import and use, one pesticide and one pesticide formulation is allowed only for manufacture to export, 7 are withdrawn, 18 are refused for registration and 13 are restricted for use under the Insecticides Act, 1968, in the India (Table 2). Recently lindane and endosulfan have been banned for production, use and sale, all over India since March, 2012 and May, 2012, respectively.

Effect of pesticide contamination of Indian export

Use of pesticide has not only secured the food production but also enhanced the amount of produce. This increased production enables one country to earn foreign exchange through export of agricultural produce. The contribution of agriculture in Indian GDP is 13.9% (2011-12). But indiscriminate use of pesticide has resulted in agricultural produce with significant amount of pesticide residue and in recent past many foreign consignments has been rejected

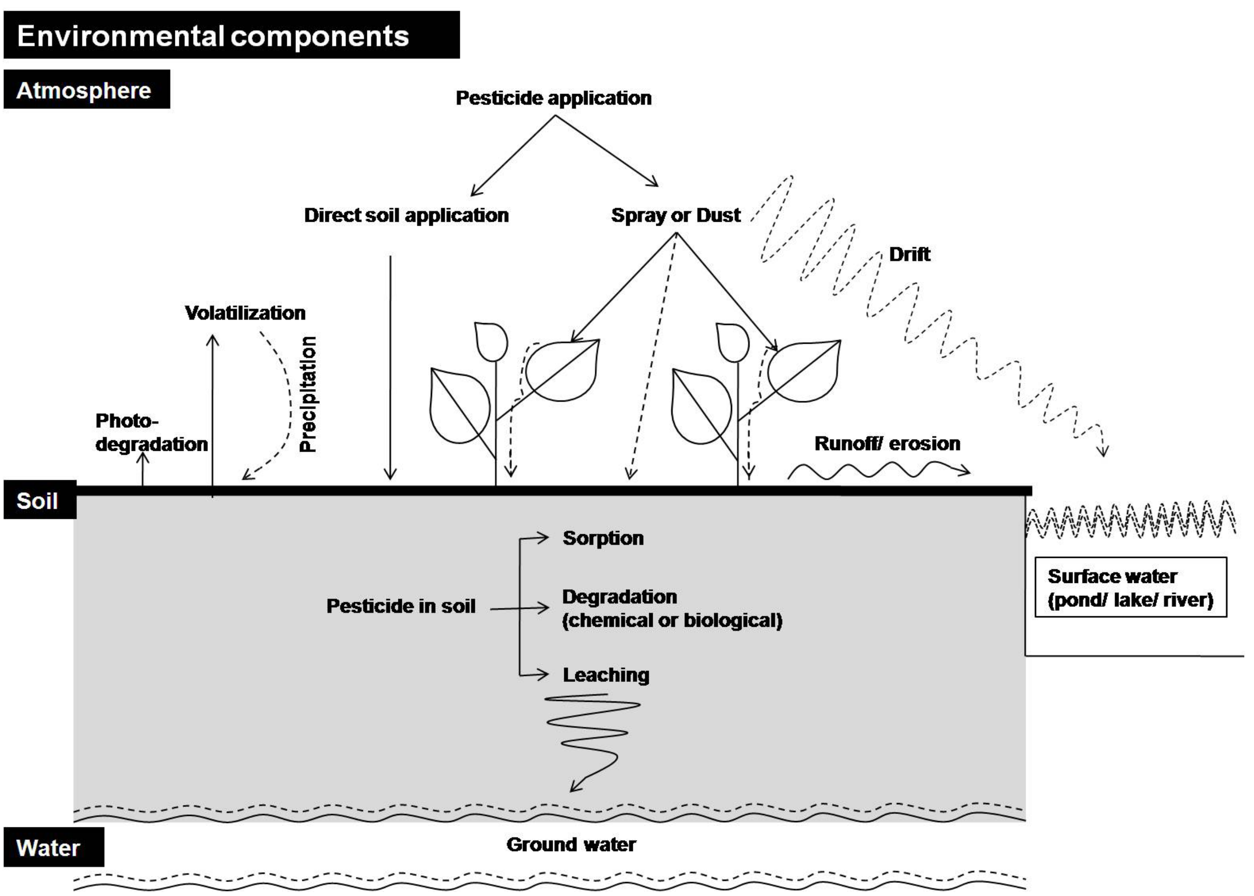

Figure 1. Fate of pesticide in environment.

by the importing countries like in 1995 Germany rejected Teekanne Darjeeling Gold brand tea consignment because of presence of tetradifon (0.24 mg kg-1 dry leaf) 24 times higher than MRL. Similarly, in 1997 Australia & EU rejected chilli, in 2004 Belgium & Netherlands rejected chilli and grape, in 2006 Finland rejected basmati rice because of methylbromide. These huge economic rejections because of pesticide residue have blown our society. These events again indicated indiscrimaneted use of pesticide in Indian agriculture.

Fate of pesticide in environment

The pesticide molecule enters the environment whenever it is applied to control some pests/ diseases for agriculture or for public health purposes. Once it comes in contact with environment, apart from desired pest controlling action, its fate is determined by several natural processes (Fig. 5). Insight knowledge on the fate of pesticides will be helpful to identify the chances of pesticide contamination and to formulate effective management strategies.

It has been found that only 1-10% of total applied pesticide reach plant target part. Upto 30% of total applied pesticide is lost in atmosphere either by volatilization or as drift/ dust. Nearly 1-5% of applied pesticide is lost due to runoff/ surface erosion and roughly 1% is lost by leaching, however these can generate undesirable amount of pesticide residue. The major amount ~50% (100% incase of soil applied pesticides) come in soil and under go processes of adsorption, chemical/ biological degradation, erosion and leaching to groundwater. Moreover with varying agro-climatic conditions and soil physicochemical properties the fate of same pesticide becomes unpredictable. So, necessary management strategies should be adopted to reduce pesticide load in environment.

Management strategies

Before application we do have control over the pesticide molecule. Once they enter into the environment we can not control their behavior. So following strategies can be considered:

Agronomic practices

- Clean cultivation should be followed to reduce pest incidence. Pest/ disease tolerant or resistant varieties should be preferred.
- Agronomic practices like crop rotation should be practiced to control pest outbreak.
- Allow natural predators for controlling insects. However, it requires regular monitoring.
- Regular monitoring of pest population is required till it reaches economic threshold level (ETL). If pest population is below ETL, there is minimum risk of yield harm. This requires scientific interventions to determine ETL level of crops for target pests.
- Integrated pest management (IPM) system should be practiced to reduce pest level below ETL.
- Biopesticides and biological control should preferably be used.
- Trap crops and crops with allelopathic effect should be practiced.
- Use synthetic pesticides, compatible with IPM module, only when there are no other options left.
- Before application, consult a competent authority for selection of a pesticide for particular agro-climatic region.
- Physicochemical properties of soil should be considered as more than 50% of applied pesticide come to soil. Soils with low organic matter and clay content generally have poor adsorption capacity and thus provide unrestricted movement of water which increases pesticide leaching. So suitable amendments should be applied to improve soil physical health as well as reduce downward mobility of pesticide. Now-a-days different agro-industrial byproducts are in use, but this requires scientific intervention. Besides being effective, low-cost and locally available, the ideal amendment should also have another key attribute that it should not contaminate the environment.
- Pesticides should not be used directly adjacent to surface water because of the high potential for pesticide contamination from runoff and drift. An untreated buffer around the surface water will provide some protection.
- Runoff loss increases with steepness of

slope, heavier soils, and conventional tillage. Application of organic amendments increases pesticide binding capacity of soil. Conservation tillage decreases chances of runoff loss.

Pesticide selection and application

- Pesticides, registered for a particular crop, should be used (check the label claim).
- Pesticide mixtures with different mode of action should be preferred as it reduces the chance of resistance development.
- Pesticides should be selected on the basis of low dose, less toxicity, target specificity, leachability and fast degradation with no/ low residue on produce.
- Use suitable formulation as chances of loss is more for dust than water soluble formulation.
- Control release formulations should be preferred.
- Use suitable equipment for pesticide application.
- Apply pesticide when chances of rain/ heavy wind are less which ensures less loss of pesticide via runoff or drift or soil erosion.
- Prepare pesticide solution/ mixture on a loading floor which ensures contamination due to spillage.
- After application, pesticide containers should be carefully disposed.
- Harvest should be performed after following suitable waiting period to reduce pesticide load in the final produce.

Government agencies and scientific intervention

- Pesticide products should be regularly monitored to ensure label claim.
- Misbranded, sub-slandered and spurious pesticides should be identified and marked. Crop loss due to use of these pesticide is about Rs. 25,000 Crores (Dikshit, 2009).
- Public awareness should be created regarding banned, restricted, misbranded, sub-standered and spurious pesticides.

Conclusion

Pesticides are wonderful creation of science which has become an integral part of modern intensive agriculture. The role of pesticides as saviors of mammalian food, feed and fiber has remained unchallenged, even though, these plant protection chemicals have various undesirable effects such as induction of pest resistance, pest resurgence, deleterious effects on the non-target flora and fauna, hazard to man and his environment. Suitable management strategies, acceptable and applicable by the farming community, hold the key of safe and sustainable environment.

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