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Insecticide Toxicity: Consumption, Assessment Methodologies and Safety Issues in India

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Abstract: Insecticides are extensively used in agriculture to foil the crop yield losses. Due to long persistence in the environment insecticides cause undesirable effects on human health and environment. Most of the people especially farmers are the vulnerable section of population exposed to insecticides in different ways and degrees. This review briefs insecticide toxicity of the banned insecticides, their consumption and accidental exposure including the status and production in India. Since pesticides and their metabolites are harmful to the atmosphere causing human health hazards in terms of toxicity, it is essential to examine pesticide contamination and the health effects of pesticides on exposed health workers and other non-target organisms. Pesticide risk assessment on non-target organisms can be analyzed by using different test methods to determine the toxicity grade.

Keywords: Insecticides, Agriculture, Risk assessment, Insecticide toxicity, Safety issues, Toxicity

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Introduction

Insecticides are tool for integrated pest management which is widely used to control insect pest population. Among different categories of pesticides, the insecticides are the most widely used compounds in terms of value. Traditionally insecticides have been categorized into five major chemical groups based on their chemical nature--organophosphate (e.g. chlorpyrifos, triazophos, profenofos); organochlorine (e.g. chlordane, endosulphan, DDT); carbamates (e.g. aldicarb, carbaryl, carbofuran); pyrethroids, the synthetic insecticides (e.g. allethrin, cypermethrin, pyrethrins) and neonicotinoids (e.g. imidacloprid,

thiacloprid, thiomexotham) (IRAC, 2016). The insecticides are classified on the basis of chemical composition, mode of entry in insect, mode of action, toxicity and the stage of specificity. The toxicity of insecticides is expressed in quantitative terms, such as LD₅₀ (Lethal Dose) and LC₅₀ (Lethal Concentration) i.e. the dose and concentration which kill 50% of population within a specified period (Singh, 2012).

Increases in land conversion and agricultural intensification due to insecticide use have accelerated the loss of soil biodiversity, resulting in a 60% decline in soil ecosystem services (Singh

et al., 2019). Therefore to determine the toxicity level of these pesticides, the different procedures and methods were used to assess pesticide poisoning in organisms related to the agroecosystem along with different risk assessment procedures, comparing the toxicity of pesticides to target pests and non-target beneficial organisms.

Indian scenario of Insecticides use and production:

India is primarily an agrarian society and rank 2nd worldwide in agriculture production. Growing demand for food production signify the high demand for insecticides for crop protection. In India, among different class of pesticides the insecticides holds the largest segment i.e. 60% (Fig. 1) whereas globally the consumption of insecticide is 44% (Mathur, 1999; FICCI, 2019). Organophosphate (the major class of insecticides) based on its active ingredient accounted major market share in 2017. The Global insecticide market in year 2017 was valued at US\$ 18.47 Billion and expected to grow at CAGR (Compound Annual Growth Rate) of 5.9% from 2018 to 2026 (Credence Research 2018) whereas the national market consumption trends highlights (Fig. 2) that the insecticide market of India is export-oriented than import (DPPQS, 2019).

Fig. 1: Agrochemicals Segmentaion of Pesticides.

Status of insecticide safety in India and Developed countries:

Agriculture practice aimed to increase the crop production in a sustainable manner to meet the

demand of ever growing human population. The service used by the farmers to increase the productivity is causing ignorance to human-health and environment by over application and inappropriate mixing of insecticides at its own convenient scale. In many developing and some developed countries, the technology used for insecticide application has not been improvised. The risk from insecticides in India is extensively higher than in industrialized countries. The major factor affecting proper application of insecticides is the operator knowledge and other is the health concern which lack personal protective equipments like gloves boots and glasses and poor storage and disposal (Figure 3). Improper handling and unsafe spraying of the agrochemicals also cause high risk of health hazards reported in past studies (Damalas and Koutroubus, 2011).

The safety parameters are being followed very strictly in the developed countries while spraying the insecticides in agricultural field it is performed by highly mechanized techniques i.e. automated machines and robotic gliders. The costume and gears used by the individuals fulfill all safety guidelines of EPA (Environment Protection Act), PAN (Pesticides Action Network) etc. Contrary, in developing countries including India, safety parameters are neglected or not up to safety guidelines that cause main health hazards even causing the death of the farmers.

The import, transport, manufacture sale, distribution and use of insecticides is regulated according to Insecticides Act 1971, however, owing to the rising prevalence of pesticides linked fatalities by spraying of pesticides on the crops and other concerns again attracted the attention towards Regulation of pesticides. Thus, a new law was suggested to replace the Insecticides Act of 1971 and new legislation was formulated in 2008 as the Pesticides Management Bill (FICCI, 2019).

Pesticide-induced suicide:

Highly Hazardous Pesticides with World Health Organization toxicity classifications Ia, Ib, and II, such as the organophosphorus insecticides—

Fig. 2: Indian scenario of Insecticides use and production according to Directorate of Plant Protection, Quarantine and Storage (DPPQS 2014-2019).

Fig. 3: Insecticide application without prescribed costume and gadgets.

monocrotophos, phorate, methyl parathion, and herbicide paraquat, have been responsible for the majority of pesticide suicides globally during the previous five decades (Eddleston, 2000; Gunnell *et al.*, 2007; WHO, 2020). Currently, over 318 pesticides are licensed for use in India, of which 18 are very harmful to human health and classified as Class Ia or Ib hazardous by the World Health Organization (WHO) (Bonvoisin *et al.*, 2020). It was reported that in 2015, the National Crime Record Bureau documented 1,33,623 suicides, of which 23,930 (17.9 per cent) were due to pesticides. In the past two and a half decades, 2.45 million people in India have committed suicide

using different ways, and the number of people who have killed themselves with pesticides was 441,918 (18% of the total) (NCRB, 2015).

Banned insecticide and their use in India and world:

The production, marketing and use of insecticides is regulated under 'The Insecticides act, 1968' and other legislation in India like the Insecticide Rules, 1971, Environment Protection Act, (EPA) 1986 and Prevention of Food Adulteration Act, 1954 which ensure to provide the safe, efficacious and quality insecticides to agricultural sector. In August, 2018, the MoAFW (Ministry of Agriculture and Farmers Welfare) banned 18 pesticides, but it

Fig. 4: Class I insecticides extensively used in India and banned in other countries Insecticides [Source: Pesticides Action Network (2017) and DPPQS (2019)].

left out two heavily-used Class I pesticides: Monocrotophos and Carbofuran. However, the insecticides which are found causing harmful effect on human and animals is being banned or restricted by the government. But the recent findings depict that the banned insecticides are still in use and implicates the deaths of dozens of farmers in India (Fig. 4). Major examples of banned insecticides used in India are acephate, DDT, profenofos, phorate, monocrotophos and triazophos (PAN, 2017; DPPQS, 2019).

Risk Assessment Methodologies:

An ecological risk assessment is used to identify the threats to human health, animals, and the environment caused by a pesticide and whether modifications to intended uses of the product are necessary to safeguard these entities. Scientists from the registration authorities collect all available data in order to measure the environmental hazards of a pesticide product. Data are typically obtained from a variety of tests (Table 1) mainly focusing on metabolism patterns, acute toxicity, sub-chronic or sub-acute toxicity, chronic toxicity, carcinogenicity, genotoxicity,

teratogenicity, generation studies, and irritancy trials using rats as model mammals or, in some cases, dogs and rabbits (Matthews, 2006).

Conclusion

Worldwide use of insecticide has become a necessity to meet the food production and food security challenges, as the conventional and organic farming is very limited across the world. It is very important to rationalize the use of insecticides and their application, it needs to be used in a scientific manner after the proper toxicological studies and human health hazards issues during and after the use of these anthropogenic xenobiotic compounds. There is also an urgent need of awareness to all stakeholders while applying insecticides to minimize the mortality and causalities.

Pesticides can provide both a health and environmental threat, and several signs have been employed to detect that risk. Nevertheless, their usage conveyed less assurance, and as a result, they are an indication that supports the necessity for creation of alternative, more accurate and reliable indicator measurements that may help in

Table 1: Toxicity testing methods for various invertebrates

Types of organism	Type of Toxicity	Exclusive Method of Testing	Targeted Life Stage or Organism (s)
Arthropods	Acute toxicity	[I] Direct Contact Assay	
		1) Dipping the Test organism	Coccinellid Eggs, Predatory Mite Eggs, Spiders and Mirid Bugs and Mites Pasted in Slides
		2) Micro-immersion for Predatory Mites	Predatory mites
		3) Direct Sprays Using Potter's Precision Tower	Coccinellid, Chrysopid (Larvae), Predatory mites and Predatory Bugs
		4) Direct Spray Using Motorized Spray Chamber	Larvae
		5) Direct Spray Using Atomizer	Eggs of <i>Chrysoperla carnea</i>
		6) Topical Application Using Hamilton Syringe	Coccinellid and Spiders
		7) Topical Application Using Electric Microsyringe	Spiders
		8) Topical Application Using Automatic Micro-syringe Pump	Grubs of coccinellid predators
		[II] Indirect Contact Toxicity	
		1) Dry Film Residue: Scintillation Vial Bioassay	Mirid Bugs, Chrysoperla Grubs, Coccinellids and Mites
		2) Petri Dishes Sprayed Using Potter's Tower	Grubs of predatory coccinellids
		3) Glass Plates Sprayed Using Comelis Spray Chamber	<i>Galleria mellonella</i> larva
		4) Drum Cell Cages for Predatory Bugs	Eggs
		5) Glass Plates for Predatory Mites	Predatory Mites
		6) Sprayed Soil and Filter Paper for Spiders	Spiders
		7) Treated Nylon Bags for Spiders	Spiders
		8) Leaf Residue Bioassay Method	Coccinellid larva
		[III] Ingestion Toxicity	
		1) Prey Contamination Bioassay	Eggs of <i>Corcyra cephalonica</i> , Aphidsa, Predatory Mitesa and Spiders
		2) Food Contamination Bioassay	Adults of <i>Chrysoperla carnea</i> , Predatory Bugs
	Chronic Toxicity Assays	1) Through Drinking Water to Bugs	Bugs
		2) Through Treated Hoppers to Spiders	Spiders
	Persistent Toxicity Assays	1) Persistent Residual Toxicity in Sprayed Plants	<i>Orius laevigatus</i> and <i>Macrolophus caliginosus</i> .
		2) Persistent Residues in Sprayed Petri Dishes	<i>Orius insidiosus</i> , <i>Chrysoperla rufilabris</i> and <i>Hippodamia convergens</i>

	Sub lethal Toxicity Assays	1) Life Table Studies	Eggs of <i>Chrysoperla carnea</i>
		2) Predation, Reproduction and Longevity	Predatory Bugs, Mites and Coccinellid
		3) Predation by a Combination of Predators	Nymph of mirid, grub of coccinellid and predatory mite
		4) Functional Response of Predators	Larvae
		5) Repellency	Beetles
		6) Locomotion	Spiders
		7) Susceptibility to Predation	Beetles and Spiders
Pollinators	Acute Toxicity	[I] Direct Contact Toxicity	
		1) Direct Spray Method	Bees
		2) Bell Jar Duster Method	
		3) Potter Spray Tower Method	
		4) Topical Application on Thoracic Dorsum	
		5) Topical Application on Ventral Thorax	Bees (bumble Bee)
		[II] Indirect Contact Toxicity	
		1) Indirect Contact Tests Using Filter Paper	Bees
		2) Indirect Contact Toxicity Using Tin Sheets in Cages	
		3) Indirect Contact Using Cages with Removable Bottom	
		4) Indirect Contact Tests Using Leaves	
		5) Indirect Residual Tests Using Foliage	
		6) Indirect Contact Tests Using Flowers	
		7) Residual Contact Test Using Corn Tassels	
		[III] Oral or Ingestion Toxicity	
		1) Acute Oral Toxicity Test with Capillary Feeders	
		2) Oral Toxicity Tests: Bees Singly Fed	
		3) Ingestion Toxicity Tests Using Cotton Swabs	
		4) Ingestion Tests After Starvation	
		5) Ingestion Toxicity Test Using a Flower Method	
		6) Ingestion Toxicity Test Using an Artificial Flower Method	
		7) Oral Toxicity Test Using Pollen	
		8) Oral Toxicity to Larva	
		[IV] Fumigant Toxicity	
		1) Using Wire Gazed Circular Holder	

		[I] Repellency Test for Pesticides	
		1) Larval Morphogenic Test	Brood of Honey Bees
		2) Larval Test for Bumble Bees	Brood of bumble Bee
Annelids	Acute Toxicity	[I] Contact Toxicity Tests	
		1) Topical application	Earthworm
		2) Vial coating/contamination bioassay	
		3) OECD filter paper method	
		4) Filter paper test using Petri dishes	
		5) Immersion test	
		[II] Ingestion Toxicity Tests	
		1) Forced feeding test	
		2) Voluntary feeding – Contaminated feed test	
		[III] Ingestion and Contact Toxicity: Soil Contamination Assays	
		1) Soil contamination test in glass containers	
		2) Soil contamination assay in earthen pots	
		3) Soil contamination assay in big plastic tubs	
		4) Soil contamination assay in plastic buckets	
		5) Soil contamination assay in polycarbonate boxes	
		7) Tubifex test	<i>Tubifex</i>
		[IV] Injection Bioassays	Earthworm
	Sublethal Toxicity Tests	[I] Sublethal Toxicity Assays for Life History Traits	
		1) Assays for growth of earthworms	
		2) Assays for reproduction – cocoon production and hatching	Cocoon and adult earthworm
		[II] Sublethal Assays for Change in Behaviour and Activities	
		1) Avoidance test – Two chambered	Earthworm
		2) Avoidance Test: Six Chambered	
		3) Avoidance Test: Vertical Stacking	
		4) Daniel's Funnel test for litter burial	
		5) Effects (short term) on burrowing - 2D terraria	
		6) Effects (Long Term) on Burrowing: 3D Soil Cores	

		7) Assay on cast production	
		[III] Sub lethal Toxicity Assays for Respiration	
		1) Assays for Respirometry Measurements	
		[IV] Effect of Pesticides on Immunity or Lysosomes	
		1) Neutral Red Retention Assay to Study Lysosomes	

Source: Stanley and Preetha (2016)

the mitigation of probable harmful impacts on human health and the environment.

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References

- Bonvoisin T, Utyasheva L, Knipe D, Gunnell D and Eddleston M. (2020) Suicide by pesticide poisoning in India: a review of pesticide regulations and their impact on suicide trends. BMC Public Health 20: 251. <https://doi.org/10.1186/s12889-020-8339-z>.
- Credence Research, Global Insecticides Market – Growth, Future Prospects and competitive analysis 2018-2026. (2018) <https://www.credenceresearch.com/report/insecticides-market>.
- Damalas CA and Eleftherohorinos IG. (2011) Pesticide exposure, safety issues, and risk assessment indicators. Int J Environ Res Public Hlth. 8(5): 1402–1419.
- DPPQS (Directorate of Plant Protection, Quarantine and Storage). (2019) Ministry of agriculture and farmer welfare, Government of India. <http://ppqs.gov.in>.
- Eddleston M. (2000) Patterns and problems of deliberate self-poisoning in the developing world. QJM. 93(11): 715-731. doi: 10.1093/qjmed/93.11.715.
- FICCI. (2019) Role of agrochemicals in sustainable farming. A report on Indian Agrochemical Industry, pp. 1-44.
- Gunnell D, Fernando R, Hewagama M, Priyangika WDD, Konradsen F and Eddleston M. (2007) The impact of pesticide regulations on suicide in Sri Lanka. Int J Epidemiol. 36:1235-1242.
- IRAC (Insecticides Resistance Action Committee). (2016) Insecticide mode of action classification scheme. Version 8.1. www.irac-online.org. pp. 1-26.
- Mathur SC. (1999) Future of Indian pesticides industry in next millennium. Pest Inform. 24(4): 9-23.
- NCRB (National Crime Records Bureau). (2016) Accidental deaths and suicides in India 2015. http://www.ncrb.gov.in/StatPublications/ADSI/adsi_mainpage.htm.
- PAN (Pesticide Action Network). (2017) Pesticide database. <http://www.pesticideinfo.org>.
- Singh DK. (2012). Pesticide chemistry and toxicology. Bentham Science Publisher. pp. 50-61.
- Singh J, Schädler M, Demetrio W, Brown GG and Eisenhauer N. (2019) Climate change effects on earthworms - a review. Soil Org. 91: 114-138. doi: 10.25674/so91iss3pp114.
- Stanley J and Preetha G. (2016) Pesticide Toxicity to Non-target Organism (Exposure, Toxicity and Risk Assessment Methodologies), Springer, pp. 1-531. doi: 10.1007/978-94-017-7752-0.
- WHO (World Health Organization). (2020) The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification, 2019, pp. 1-98.