Review Article

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CLASSIFICATION OF PESTICIDES: A REVIEW

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ABSTRACT

Pesticides are the natural or synthetic agents designed to kill all types of pests. Pesticides are used in different fields like agriculture, forestry, aquaculture, food industry etc. Due to its gross use these pesticides threaten public health and ecosystem. Classification of pesticides done according to various criteria like its toxicity or hazardous effects, its use or purpose, its chemical composition, its mode of action, how or when it works, its formulations, its source of origin. By giving importance to public health, WHO has done classification of pesticides on the basis of hazardous effects With the comprehensive knowledge of classification of pesticides, gross use of pesticides can be minimized by using it judicially and it is helpful to public health & ecosystem.

Keywords: Pesticides, Classification, Toxicity, Ecosystem.

INTRODUCTION

Pesticides are chemical compounds that are used to kill pests, including insects, rodents, fungi and unwanted plants (weeds). Pesticides are mainly used for benefits like crops protection, preservation of food materials and prevention of vector borne diseases. They are also used in different field like agriculture, forestry, aquaculture, food industry, processing, transportation and storage of wood and other biological products.[1] Gross use of pesticides cause damage to public health and ecosystem. Incidence of poisoning, as reported, is 13- fold higher in developing countries than in highly industrialised nations, which consumes 85% of world's pesticide production. Most pesticide related poisoning in developing nations can be attributed to lack of training in their use, poor legislative control and carelessness in providing protection to the body during their application.[2] Pesticides have different distribution and persistence patterns in the environment, even if all of them are distributed in some way through air, soil and water.[3]

Pesticides are classified on the basis of various criteria. Most commonly used criteria for classification of pesticides are its mode of entry, its chemical composition and target it kill. But giving importance to public health, World Health Organization (WHO) and Globally Harmonized System (GHS) classified pesticides according to their toxicity or hazardous effects. Without ignoring risk factors of pesticides, we must have to use it for better crop production & food preservation. But by using it judiciously with the help of different classification of pesticides, its gross use, exposure and toxic effects can be minimized.

Review of Literature

Pesticides are natural or synthetic agents which are designed to kill or reduce or repel insects, weeds, rodents, fungi or other organisms. United Nations Organization for Food and Agriculture (FAO) defines pesticides as any substance or mixture of substances intended for growing, destroying, preventing or controlling any pest, including vectors of human disease or animal disease, unwanted species of plants or animals that cause damage or otherwise interfering in the production ,processing, storage, transport or marketing food, agricultural products, 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.[4] Based on code of Federal Regulations (CFR) a pesticide is defined as any substance or mixture of substances intended for use as plant regulator, defoliant, or desiccant.[5]

Classification of Pesticides

Pesticides are classified on the basis of various criteria such as toxicity (Hazardous effects), pest organism they kill and pesticide function, chemical composition, mode of entry, mode of action, how or when they work, formulations and sources of origin.

Classification of pesticides on the basis of toxicity

Toxicity of pesticide mainly depends on two factors namely dose and time. Hence, how much of the substance is involved (dose) and how often the exposure to the substance occurs (time) give rise to two different types of toxicity- acute and chronic toxicity.[6]

Acute Toxicity- Acute toxicity refers to how poisonous a pesticide is to a human, animal or plant after a single short-term exposure. A pesticide with a high acute toxicity is deadly even when a very small amount is absorbed. Acute toxicity may be measured as acute oral toxicity, acute dermal toxicity and acute inhalation toxicity.

Chronic toxicity- Chronic toxicity is delayed poisonous effect from exposure to a pesticide. Chronic toxicity of pesticides concerns the general public as well as those working directly with pesticides because of potential exposure to pesticides on/in food products, water and the air.

World Health Organization (WHO) has highlighted only acute toxicity for the classification of pesticides. According to WHO, pesticides are classified by acute oral and acute dermal toxicity using the estimated respective lethal dose LD_{50} (the pesticide dose that is required to kill half of the tested animals when entering the body by oral or dermal route). At present, widely used 'WHO recommended classification of pesticides by hazard' suggests allocating pesticides to 'the specific WHO Hazard classes'. After revision in 2009 these classes were harmonized with the 'Globally Harmonized System (GHS) Acute Toxicity Hazard Categories[7].

WHO recommended classification of 'Pesticides by Hazard' is shown in Table 1 and revised Globally Harmonized System (GHS) classification of pesticide is shown in Table 2

Table 1: WHO recommended classification of Pesticides[8]

WHO Class		LD 50 for rats (Mg/kg body wt.)		Examples
		Oral	Dermal	
I_a	Extremely Hazardous	< 5	< 50	Parathion, Dieldrin, Phorate
I_b	Highly hazardous	5 -50	50 – 200	Aldrin, Dichlorvos
II	Moderately hazardous	50-2000	200-2000	DDT, Chlordane
III	Slightly hazardous	Over 2000	Over 2000	Malathion
U	Unlikely to present acute hazard	5000 or higher		Carbetamide, Cycloprothrin

Table 2: GHS Classification of pesticides [9]

GHS Category	Classification Criteria			
	Oral		Dermal	
	LD_{50} (mg/kg bw)	Hazard Statement	LD_{50} (mg/kg bw)	Hazard Statement
Category 1	< 5	Fatal if swallowed	< 50	Fatal in contact with skin
Category 2	5 – 50	Fatal if swallowed	50 – 200	Fatal in contact with skin
Category 3	50 – 300	Toxic if swallowed	200 – 1000	Toxic in contact with skin
Category 4	300 – 2000	Harmful if swallowed	1000- 2000	Harmful in contact with skin
Category 5	2000 – 5000	May be harmful	2000 – 5000	May be harmful

Classification of pesticides on the basis of pest organism they kill and pesticide function (Use)

Under this classification pesticides are classified on the basis of pest organism they kill and their functions which is shown in details in Table 3.

Table 3: Pesticides classification on the basis of pest organism they kill and pesticide function (Use) [10, 11]

Sl. No.	Type of pesticide	Target pests/Functions	Examples
1.	Acaricides	Substances that are used to kill mites and ticks or to disrupt their growth or development	DDT, dicofol, chlorpyrifos, permethrin, etc
2.	Algicide	Substances that used to kill or inhibit algae	Copper Sulphate, diuron, oxyfluorfen, etc
3.	Antifeedants	Chemicals which prevent an insect or other pest from feeding	Chlordimeform, azadirachtin, etc
4.	Avicides	Chemicals that are used to kill birds	Strychnine, fenthion, etc
5.	Bactericides	Compounds that isolated from or produced by a microorganism or a related chemical that is produced artificially, which are used to kill or inhibit bacteria in plants or soil	Streptomycin, tetracycline, etc
6.	Bird repellents	Chemicals which repel the birds	Diazinon, methiocarb, etc
7.	Chemosterillant	Chemicals that renders an insect infertile and thus prevent it from reproducing.	Diflubenzuron
8.	Desiccants	Act on plants by drying their tissues	Boric acid
9.	Fungicides	Chemicals which are used to prevent, cure eradicate the fungi.	Cymoxanil, thiabendazole, Bordeaux mixture
10.	Herbicide softener	A chemical that protect crops from injury by herbicides, but does not prevent the herbicides from killing weeds.	Benoxacor, cyometrinil
11.	Herbicides	Substances that are used to kill the plants, or to inhibit their growth or development.	Alachlor, paraquat, 2,4-D
12.	Insect attractant	A chemical that lures pests to trap, thereby removing them from crops animals and stored products	Gossyplure, Gyplure
13.	Insect growth regulator	A substance that works by disrupting the growth or development of an insect	Diflubenzuron
14.	Insecticides	A pesticide that is used to kill insects or to disrupt their growth or development	Azadirachtin, DDT, chlorpyrifos, malathion, etc.
15.	Larvicides	Inhibit the growth of larvae.	Methoprene

16.	Lampricides	Target larvae of lampreys which are jawless fish like vertebrates	Nitrophenol
17.	Mammal repellent	A chemical that deters mammals from approaching or feeding on crops or stored products	Copper napthanate, trimrethacarb, etc.
18.	Mating disrupters	Chemicals that are interfere with the way that male & female insects locate each other using airborne chemicals, thereby preventing them from reproducing	Disparlure, gossyplure, etc.
19.	Molluscicides	Substances used to kill slugs and snails.	Metaldehyde, thiadicarb, etc.
20.	Moth balls	Stops any damage to cloths by moth larvae	Dichlorobenzene
21.	Nematicides	Chemicals which are used to control nematodes	Carbofuron, chlorpyrifos, methyl bromide, etc.
22.	Ovicides	Inhibit the growth of eggs of insects and mites	Benzoxazin
23.	Piscicides	Acts against fishes	Rotenone
24.	Plant growth regulators	Substances alters the expected growth, flowering or reproduction rate of plants	2,4-D, gibberellic acid, etc.
25.	Rodenticides	Substances used to kill rats and related animals	Strychnine,Warfarin, zinc phosphide, etc.
26.	Silvicides	Acts against woody vegetation	Tebuthiuron
27.	Synergists	A chemical enhances the toxicity of a pesticide to a pest but that is not by itself toxic to pest	Piperonyl butoxide
28.	Termiticides	Kill termites	Fipronil
29.	Virucide	An agent having capacity to destroy an inactivate viruses	Ribavirin
30.	Miscellaneous	-	Aluminium phosphide, sodium cyanide

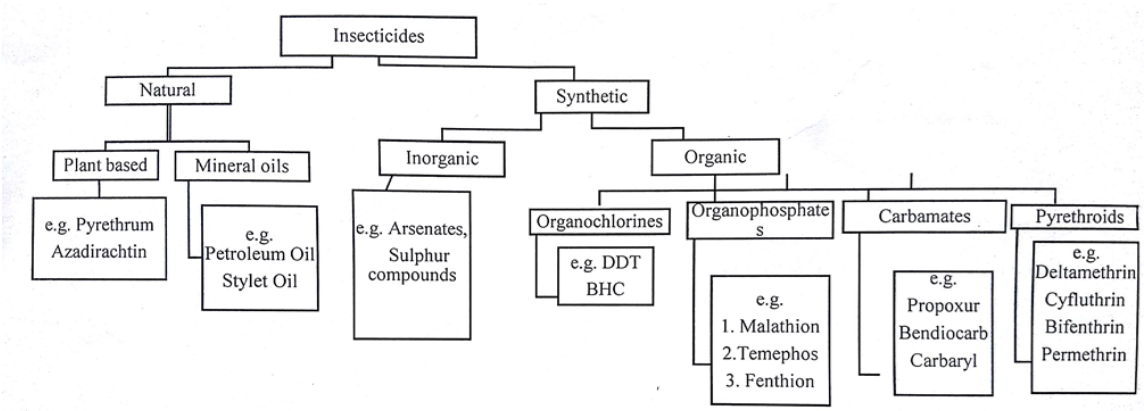

Fig.1: Classification of Insecticides

Classification of Pesticides on the basis of Chemical Composition[12]

This is the most common and useful method of classifying pesticide which is based on their chemical composition. Pesticides like insecticides, fungicides, herbicides and rodenticides are also classified on the basis of their chemical compositions as follows

Insecticides: On the basis of chemical composition insecticides are classified as, Carbamates (Carbaryl), Organochlorine (Endosulfan), Organophosphorus (Monocrotophos), Pyrethroids (permethrin) Neonicotinoids (Imidacloprid), miscellaneous pesticides such as Spinosyns (Spinosad), Benzolureas (diflubenzuron), Antibiotics (abamectin), etc.

Insecticides are the important pesticides that can be further classified into several sub-classes which is shown in Fig. 1.[13]

Fungicides: Fungicides are classified as aliphatic nitrogen fungicides (dodine), amide fungicides (carpropamid), aromatic fungicides (chlorothalonil), dicarboximide fungicides (famoxadone), dinitrophenol fungicides (dinocap) etc.

Herbicides- The herbicides are anilide herbicides (flufenacet), phenoxyacetic herbicides (2, 4-D), quaternary ammonium herbicides (Paraquat), chlorotriazine herbicides (atrazine), sulfonylurea herbicides (chlorimuron), etc.

Rodenticides – They are classified as inorganic rodenticides (Zinc phosphide, Aluminium Phosphide), coumarin rodenticides (organic) (bromadiolone, coumatetralyl)

Classification of pesticides on the basis of Mode of Entry[14]

The ways pesticides come in contact with or enter the target are called modes of entry which is shown in Table 4.

Table 4: Classification of pesticides on the basis of mode of entry

Sl. No.	Type of Pesticide	Description	Examples
1.	Systemic Pesticides	These are pesticides which are absorbed by plants or animals and transfer to untreated tissue	2,4 –D, glyphosate
2.	Contact pesticides	It acts on target pests when they come in contact	Paraquat, diquat
3.	Stomach poisons	It enters the pest's body through their mouth and digestive system	Malathion
4.	Fumigants	Pesticides which acts or may kill the target pests by producing vapour and enter pest's body through tracheal system.	Phosphine
5.	Repellents	Repellents do not kill but distasteful enough to keep pests away from treated area. They also interfere with pest's ability to locate crop.	Methiocarb

Classification of pesticides on the basis of Mode of Action[15]

Pesticides are also classified according to their mode of action which is shown in Table 5.

Table 5: Classification according to mode of action

Sl. No.	Type of pesticide	Mode of Action	Example
1	Physical poison	Pesticides bring about killing of one insect by exerting a physical effect	Activated clay
2	Protoplasmic poison	Pesticides are responsible for precipitation of protein.	Arsenicals
3	Respiratory poison	Chemicals which inactivate respiratory enzymes	Hydrogen cyanide
4	Nerve poison	Chemicals inhibit impulse conduction	Malathion
5	Chitin inhibition	Chemicals inhibit the chitin synthesis in pests.	Diflubenzuron

Herbicides which are included in pesticides are also classified on the basis of mode of action as follows[16]

a) Growth regulators- Compounds which disrupts hormone balance and protein synthesis by which plant ultimately dies. e.g. 2,4-D
b) Amino acid synthesis regulators – Compounds which inhibits specific enzyme which is responsible for synthesis of amino acids. e.g. Glyphosate
c) Lipid synthesis inhibitors – Prevents formation of fatty acids which are essential for production of lipids. e.g. Clodinafop-propargyl
d) Seedling growth regulators- inhibits cell division and lipid or protein synthesis in seedling. e.g. Butachlor
e) Photosynthetic inhibitors – inhibits the electron transfer in photosynthesis and conversion of sunlight into chemical energy. e.g. Atrazine
f) Cell membrane disrupters – disrupts cell membrane. e.g. Paraquat
g) Pigment inhibitors- prevents formation of pigments necessary for photosynthesis. e.g. Clomazone

Classification of pesticides on the basis of how or when they work

Pesticides can also be classified according to how or when they work[17]

Contact Pesticides – These pesticides control a pest as a result of contact. Insects are kill when sprayed directly or when they crawl across surfaces treated with a residual contact insecticide.

Systemic pesticides – Pesticides which are absorbed by plants or animals and move untreated tissues. Systemic insecticides or fungicides move throughout treated plants and kill certain insects or fungi.

Foliar Pesticides – These are applied to plants leaves, stems and branches.

Soil applied Pesticides - These are applied to soil. Some of these are taken up by roots and trans- located inside the plant.

Fumigants – Chemicals that are applied as toxic gas or as a solid or liquid which forms a toxic gas and it will penetrate cracks and crevices of structures or soil.

Pre-plant herbicides- These are applied to soil before seedling or transplanting.

Pre-emergent herbicides- These are applied to soil after planting but before emergence of crop or weed.

Post-emergent herbicides- These are applied after crop or weed has emerged.

Selective Pesticides – They will only control certain pests.

Non-selective (or broad- spectrum) pesticides – They will control a wide range of pests.

Suffocating pesticides- They clog the breathing system of insects and may affects eggs.

Residual pesticides – They do not break down quickly and may control pests for long time.

Non-residual pesticides – They are quickly made inactive after application and do not affect future crops or pests.

Classification based on type of Pesticide Formulations[18]

Pesticide formulations are the mixtures of technical grade pesticides with inert diluents and auxiliary chemicals. Pesticide formulations can be divided into three main types: solids, liquids and gases. Some formulations come ready to use while others must be mixed before use. The commonly used pesticides are listed in the table 6.

Table 6: Types of pesticide formulations

Sl. No.	Type of Pesticide Formulations	Description	Typical Uses	Examples
		Solids		
1.	Bait	Mixture of active ingredient and food that attracts pests in the form of meal, pellets.	For insects, rodents, birds, or slugs	Maxforce FC, Niban, Amdro etc
2.	Dry flowable (DF)or Water Dispersible Granules (WDG)	Mixture of active ingredient and inert material made into small pellets, granules. Forms a suspension in water.	Sprays for insect's disease and weed control.	
3.	Dust (D)	Finely ground inert particles i.e., talc, clay, and volcanic ash.	Spot treatment, Animal powder, Seed treatment	Deltadust, Ficam D, Drione, Sevin D, Malathion D
4.	Ear tag/ Vapour Strips	Solid material with volatile or solid active ingredient slowly release vapour	Animal ear tag, Fly control	
5.	Granules (G or GR)	Dry inert materials (i.e., clay, walnut shell, corn cob) combined with active ingredient	Sol treatment for insect or weed control.	Dursban G, Talstar G
6.	Pellets	Inert material containing active ingredient like granules, but has more uniform shape and weight.	For control rodents, slugs	
7.	Soluble powder (SP)	Dry powder or granules which dissolves in water to spray solution.	Mostly sprays for insects & weed control.	
8.	Wettable powder (WP or W)	Finely ground inert ingredients with active ingredient Forms a suspension in water.	Sprays for insect, disease and weed control.	Demon WP, Tempo WP
		Liquids		
9.	Aerosols (A)	Usually contain small amount of active ingredient and a petroleum solvent. Two main Types: 1. Ready-to-use small pressurized containers. Fog generators are not under pressure; equipment breaks the liquid into fine mist or fog.	Spray cans used for home/ garden insecticides. Used in greenhouses or mosquito control.	Wasp Freeze, ULD-BP-50, Ultracide, Ultraguardian
10.	Emulsifiable concentrate (EC)	Contains active ingredient, petroleum solvent and emulsifiers. Pesticide is suspended in spray which is milky coloured.	Sprays for insect, disease and weed control	Chlorpyrifos EC Cypermethrin EC.
11.	Flowable (F)	Finely ground particles suspended in an inert liquid carrier. Forms suspension in spray mix like WP	Sprays for insect, disease and weed control	Carbaryl AF
12.	Gel	Semi liquid emulsifiable concentrate	Herbicides and insecticides	
13.	Micro- encapsulated materials	Consists of pesticide surrounded by aplastic coating. Mixed with water and sprayed. Break down slowly.	Insecticide and pheromone sprays	Demand ES
14.	Solution(SN)	Active ingredient dissolved in liquid. Forms a solution in spray mix.	Sprays for weed control.	Premise SC, Termidor SC, Bora-care
15.	Ultra-low volume concentrate (ULV)	Liquid with very high concentration of active ingredient designed to be used as is or slightly diluted in ULV equipment.	Insecticide sprays inside greenhouses or for forestry.	
		Gases		
16.	Fumigants	Volatile liquids or solids packaged to release a toxic gas	Greenhouses, mushroom houses, graineries. Pre-plant soil treatment for soil borne pests.	Phosphine, Phostoxin,
		Packaging		
17.	Water-Soluble Packets	Pre-weighed amount of WP or SP formulation in a special plastic bag which dissolves in spray tank and releases contents.		Demon WP

Classification based on sources of origin[19]

Pesticide are natural or biological agents that are used to kill unwanted plants or animal pests. Based on the source of origin, pesticide may be classified into bio-pesticides and chemical pesticides.

Bio-pesticides- These act on the target pests and strongly linked organisms. Bio-pesticides include microbial pesticides (containing a live bacterium, fungus, virus, protozoan or alga as active ingredient), and chemicals that are derived from animals, bacteria, fungi and plants. They are less toxic, decomposed easily and required in small quantities. There are three major classes of Bio-pesticides.

a) Microbial pesticides- The active ingredient is microorganism such as bacteria or fungi. Eg. Bacterial toxins produced by *Bacillus thuringiensis*, and *Bacillus sphaerius* acts on mosquito larvae, black fly larvae.

b) **Plant incorporated protectants** –Pesticides produced by plant naturally and genetic material introduced together is termed as plant incorporated protectants.
c) **Biochemical pesticides** – Pesticides which include natural material that have non-toxic mechanism to controls pests. Eg: Insect sex pheromones

Chemical pesticides- These are of wide range which affect large group of non- target organisms. Chemical pesticides are quite toxic and not always biodegradable. Chemical pesticides are further divided into organochlorine, organophosphate, carbamates and pyrithroids.

Classification of Pesticides in the perspective of Forensic Medicine and Toxicology[20]

Pesticides may be described as any physical, chemical or biological agent that will kill an undesirable or troublesome animal, plant or micro-organism. Pesticide is a generic name for a variety of agents that may be classified more specifically on the basis of pattern of use and organism killed.

Pesticides are classified as follows in textbook of Forensic Medicine and Toxicology[21]

1. **Insecticides** – Compounds which kill or repel insects and related species. e. g. Organophosphates, Organochlorine, Carbamates etc.
2. **Herbicides** – Compounds which kill weeds/ prevent growth of undesirable herbs or weeds in the field. e. g. parquet, atrazine etc.
3. **Fungicides** – Compounds which kill fungi and moulds. e. g. Captan, Captofol etc.
4. **Rodenticides** – Compounds which kill rats, mice, moles and other rodents. E.g. anticoagulants, arsenic, strychnine etc.
5. **Acaricides** – Compounds which kill mites, ticks and spiders. e. g. azobenzene, chlorobenezilate etc.
6. **Nematicides** – Compounds which kill nematodes. e.g. Ethylene bromide
7. **Molluscicides** – Compounds which kill the molluscs such as snails and slugs. e. g. Metaldehyde.
8. **Miscellaneous Pesticides** – Compounds of lead, Copper, Mercury, nicotine etc.

DISCUSSION

Various classification of pesticides from different sources are reviewed in this article. These pesticides are used for different benefits such as for better yielding of crop production, protection of plants & preservation of food materials. Judicious use of pesticides may ensure quantity and quality of product, gives economic benefits and decrease man power whereas injudicious use of pesticides affect the public health and ecosystem. Following important points can be explored from this reviewed article-
It seems that toxicity-based classification of pesticides recommended by WHO help to minimize the use of highly hazardous pesticides by knowing their dose and toxicity level.

Pesticides classification on the basis of pests they kill, their chemical composition, their mode of entry, their mode of action and how or when they work help to kill specific targeted pests and its vague use can be restricted.

Classification of pesticides based on source of origin helps to replace use of chemical pesticides by bio-pesticides as chemical pesticides are more hazardous than bio-pesticides.

Classification of pesticides narrated in textbook of Forensic Medicine & toxicology, highlights commonly used pesticides, their toxicity & medico-legal aspects.

CONCLUSION

Farmers and the persons who are coming in contact with pesticides are unaware about types of pesticides and their hazardous effects. With the thorough knowledge of classification of pesticides, its gross use, exposure and toxicity can be minimized by using it judicially and it is helpful to public health & ecosystem.

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