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PESTICIDES USAGE AND ITS TOXIC EFFECTS-A REVIEW

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ABSTRACT

The urbanization of agriculture sector leads to an increased chemical affliction on the environment. Pesticides are the chemicals used in agriculture to protect the plants from weeds, pests or diseases and human being from various diseases. In this review, the literature of different types of pesticides, pesticide usage and its toxic effects on mammalian systems are summarized. Most commonly used pesticides are fungicides, insecticides and herbicides to control the weeds and pest from agricultural sites. In the usage of pesticides, India stands 12th in the world even though the use of pesticides in India is low as compared to other nations in the world. However due to their negative impacts on human and the environment there is a requirement for an ecological and sustainable approach, as the public needs the execution of the latest concept of agriculture that is safe for humans and the environment. For the sustainable agriculture development and to protect the environment from adverse effects of chemical pesticides, formulation and utilisation of bio-pesticides should be encouraged.

Key words: Human health, pesticides environment, agriculture, toxicity, india, biopesticides, humans, weeds, diseases, insecticides

Pesticides are the substances used to control pests, weeds and diseases from plants. Pesticides are important for agriculture as many farmers depend on them to keep pests out of their crops. These are known to be associated with human health and environmental issues. These cause various human diseases like skin, olfactory and reproductive due to their accumulation in human body (Aggarwal and Sharma, 2010). Pesticides can pollute different compartments of environment like soils, water or air depending on the mode of application, movement of compound and persistence of particular contaminant in the environment (Chourasiya et al., 2015). Application of pesticides in the field is mainly done by spraying which enters into the environment by different means (WHO, 1990). Direct entry of pesticides into the atmosphere can occur via spray drift and indirectly through vaporization of insecticides from vegetation or wind erosion for so many days after application into the field (Savary et al., 2019). Deposits of pesticides can be formed on lands or shallow waters and then make their way into ground waters by transportation of pesticides through long distances (Samada and Tambunan, 2020). Because of this, there is occurrence of adulteration of the different ecological milieu and the off-targeted environments and organisms may also be exposed, including humans (FOCUS, 2008). Typical examples of pesticides are fungicides, herbicides, insecticides and weedicides (WHO, 1990). Pesticides may be metabolized, stored, excreted or bio accumulated in human body (Pirasaheb, 2015). Pesticide residues can be found in a wide variety of foods, meals, fruit juices, beverages, wine, refreshments and animal feeds (McGill et al., 1968; Chourasiya et al., 2015).

According to FAO four million tons of pesticides are used annually on a global basis, of which herbicides are (56%), insecticides (19%), fungicides (25%) and others nematicides and rodenticides (FAO, 2018). Detrimental effects are produced by indiscriminate and injudicious use of pesticides, as its residues can enter into food chains when the concentration surpasses the maximum limit (McLachlan, 2001; Ghosh and Philip, 2006). With the development of industrialization and urbanization various potential toxic chemicals are liberated into the environment and their exposures to animals have drastically changed its surroundings and lifestyle (Banerjee et al., 1999). Pesticides are one of the most effective measures of pest eradication in the entire world, but their utilization causes several adverse effects on non-target species involving humans by causing toxicity (Ghosh and Philip, 2006). Utilization of pesticides in agriculture has gradually increased to fulfil the rising demands of the population. But inadvertently these harmful chemicals have transcended the tolerance level, creating an imbalance in the system

(Bhardwaj et al., 2014). Acute and chronic exposure to pesticides was also noxious to the human reproductive system. Pesticides induce oxidative stress and amend the defence mechanisms of detoxification (Scandalios, 2005). These harmful composites hinder function of cell, enzyme activity and produce toxicity through the formation of reactive oxygen species (Milatovic et al., 2006; Agarwal and Sharma, 2010). This review article will discuss about the classification of pesticides, their usage in India and worldwide and the toxic effects of pesticides on human health.

I. Classification of pesticides

A. IRAC or MoA classification (Sparks and Naunen, 2015)

1. Acetylcholine esterases: Includes subgroup like carbamates and organophosphates
2. Chloride channel antagonists and GABA gated channels: Include subgroups like organochlorines and phenyl pyrazoles
3. Sodium Channel Modulators: include subgroups like pyrethroids, pyrethrins, DDT and methoxychlor
4. Nicotinamide acetylcholine receptor antagonists: include subgroups like neonicotinoids, nicotine and sulfoxaflor
5. Chloride channel activators: include subgroups avermectins and milbemycins
6. Juvenile hormone mimics: Include subgroups like fenoxycarb and pyriproxyfen
7. Mitochondrial Complex I electron transport inhibitors: Include subgroups like acarisides, insecticides and rotenone
8. Octopamine receptor agonists: Includes amitraz
9. Miscellaneous nonspecific inhibitors: include subgroups like alkyl halides, chloropicrin, sufuryl fluoride
10. Growth regulators includes clofentezine, hexythiazox and diflovidazin

B. Classification on the basis of pest organism it kills (Akashe et al., 2018)

1. Target organism (e.g., rodenticides, fungicides, herbicides, insecticides, pesticides),
2. Chemical pesticides (e.g., biopesticides, inorganic, organic, synthetic)
3. Physical Pesticides (e.g. gaseous)
4. Biopesticides

C. Classification based on nature- natural, synthetic and chemical (Tudi et al., 2021)

1. **Natural-** These pesticides are present in nature. These are environmentally friendly and safe. e.g. Pesticide extracted from *Chrysanthemum* plants (pyrethrin) and insecticide extracted from the neem tree *(Azadirachtin*). Rotenoids are the group of flavonoids used to control insects. These are synthesized from plant extract rotenone.
2. **Synthetic-** Synthetic pesticides are not natural these are human made pesticides and an inorganic fertilizer, e.g. Potassium chloride (KCl), Ammonium nitrate (NH_4NO3), sodium phosphate (Na_3PO4), calcium sulfate (CaSO4).
3. **Inorganic-** It contains carbon and elemental sulphur. This included compounds containing arsenate and fluorine.
4. **Organic-** This contains carbon and has different types as nereils toxin isolated from marine annelids, neonicotinoids from plants, organophosphorus, organochlorines, and asynthetic organic insecticides including carbamates, pyrethroids, neonicotinoids, pyrazoles, oxadiazine, spinosyns, avermectins and diamides.
5. **Chemical-** Chemical pesticides include fungicides, herbicides, rodenticides and insecticides. These are harmful to human health as well as plants.

D. On the basis of chemical nature (Nayak et al., 2020)

1. *Organochlorine*- Organochlorine pesticides include endosulfan, dieldrin, dicofol, heptachlor and methoxychlor. Organochlorine pesticides are associated with a huge number of health effects, such as endocrine disruptors (Lemaire et al., 2004; Mnif et al., 2011), effects on fetal development (Tieman, 2008), haematological (Karami-Mohajeri et al., 2011) and hepatic damage (Calle, 2002), cancer effects (Chourasiya et al., 2015), metabolism of lipids (Karami et al., 2011), changes in liver and hematology (Freire et al., 2015). These pesticides act on nervous system by deactivating the nerve membranes and inhibit the GABA chlorine complex thus causing the accumulation of acetylcholine at the nerve endings thereby disrupting the nerve impulse transmission and leads to uncontrolled neural excitation (Bannen et al., 1998).
2. *Organophosphorus*- Organophosphorus pesticides can be used as an alternative to organochlorine pesticides (Jaga and Dharmani, 2003). Examples of organophosphorus pesticides are malathion,

parathion and dimethioate etc. The most common organophosphorus pesticide is glyphosate (Thongprakaisang et al., 2013). Glyphosate is the herbicide widely used in agriculture and it disrupts the endocrine system, affects the hematology and is carcinogenic (Swanson et al., 2013). These pesticides inhibits AChE through a chemical reaction in which serine hydroxyl moiety is blocked by phosphorus group and is unable to take part in the hydrolysis of Ach. These pesticides can have effects on function of acetylcholine esterase enzymes, endocrine disruption potential (Gasnier et al., 2009) and distraction of cellular metabolism of proteins, cytotoxic and genotoxic effects (Li et al., 2015), also have effects on cellular functions and causing oxidative stress and other problems related to endocrine system (Karami-Mohajeri et al., 2011).

3. *Carbamate*- Carbamate pesticides also act by inhibiting the AChE in a chemical reaction where inhibition is done by carbamylation of serone hydroxyl moiety. Examples of carbamate pesticides are carbofuran, aldicarb and ziram. These types of pesticides are associated with endocrine disrupting activity, disorders of reproductive system (Jamal, 2015) and effects on cellular metabolism. Carbamate pesticides have the ability to cause cytotoxic, oxidative stress and genotoxic effects. Carbamates can also induce programmed cell death and DNA damage in humans (Li et al., 2011). There are some studies which revealed that carbamate pesticides have also caused effects on brain (Wesseling et al., 2002).
4. Pyrethroids and neonicotinoids- Pyrethroids are the pesticides which cause respiratory allergies and these compounds deteriorate rapidly in the presence of light. Pyrethroid pesticides mainly act on voltage gated sodium channels thereby interfering process of cell to cell communication. Neonicotinoids mainly include imidacloprid, acetamiprid, clothianidin and other insecticides or pesticides which mainly have effect on acetyl choline receptors of brain (Sogorb and Vinalova, 2002). These pesticides generally bind with acetylcholine receptor site and thereby inhibiting the acetyl cholineesterase enzyme (AChE) and causes overestimation of nerve cell.

E. On the basis of mode of action (MoA) by target sites (Sparks and Naunen, 2015)

1. Nerve and muscle targets: Includes Acetylcholinesterase (AChE) inhibitors, chloride channel antagonists, sodium channel antagonists, chloride channel activators and Octopamine receptor agonists
2. Respiration targets: Includes inhibitors of mitochondrial ATP synthase.
3. Midgut targets: Includes microbial pesticides
4. Growth and development targets: Includes juvenile hormone mimics and ecdysone receptor agonists

II. Pesticides usage

Number of registered pesticides in India is 293. And India is using around 104 pesticides being prohibited in one or more nations in the world. In the usage of pesticides India stands 12th in the world (GOI (RC), 2021). According to 2017 data use of pesticides in India is low as compare to other nations in the world (Roser, 2019). The usage of pesticides in India differs from that of world (Figs. 1, 2). Herbicides, fungicides and insecticides are used in India and insecticides are used in majority in total. And in the world pesticide use pattern, herbicides are at highest point, followed by fungicide & bactericide, rodenticide and insecticide. In the world, India is the fourth largest producer of insecticides and pesticides. In 2017 usage of pesticides is low as compared to other countries like Saint Lucia, Hong

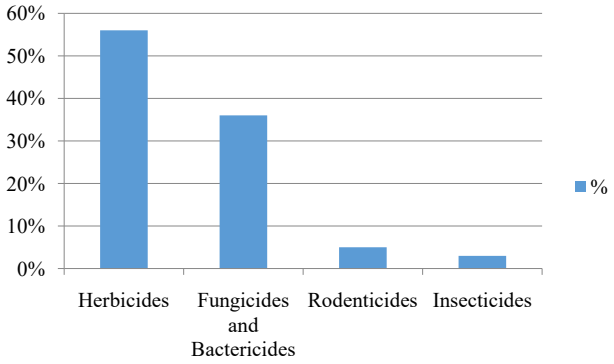


Fig. 1. Pesticide usage worldwide (FAO, 2018)

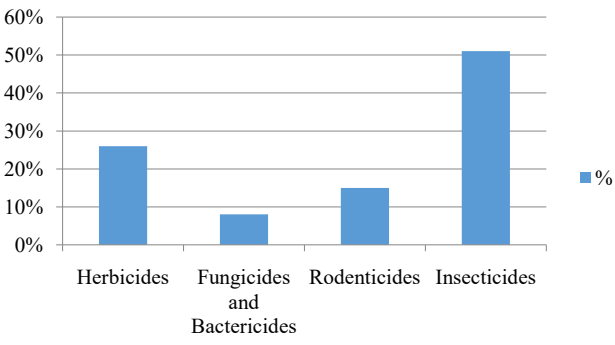
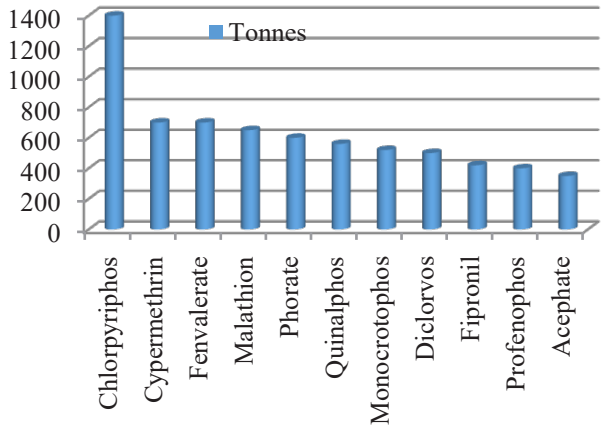


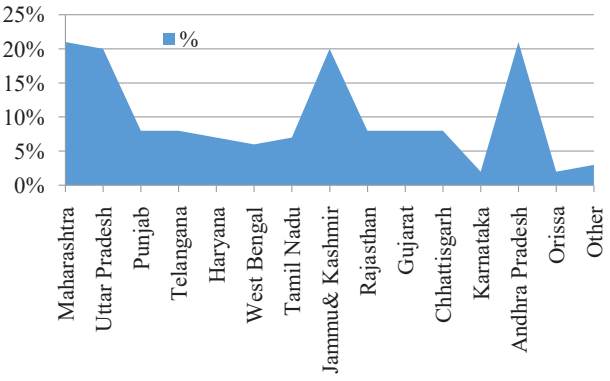
Fig. 2. Pesticide Usage India (FAO, 2018)

Kong, China and America (Roser, 2019). Among all the pesticides, chlorpyriphos is the most commonly used in India. Its usage has increased over the years. The trend followed for usage of insecticides is organophosphates, neonicotinoids and pyrethroids (GoI, 2020). Figure 3 shows the most commonly used pesticides in India during 2019-20. Among these chlorpyriphos is the most widely used followed by cypermethrin, malathion and acephate. Figure 4 shows the statewise pesticide consumption in India. Maharashtra is the highest in pesticide consumption in India followed by Uttar Pradesh, Punjab and Haryana. In developing countries, number of deaths of people due to pesticide consumption in food every year is approximately around 20,000 (Bhardwaj, 2013). Although the usage of chemical pesticides has declined in India from 72,130 tonnes to 56,090 tonnes in the past few years. These fluctuations over the use of pesticides are due to their availability in the market or its relation with weather parameters. Pesticide consumption intensity was found to be highest in Punjab, Haryana and Jammu and Kashmir. Because these are the agricultural prominent states and have negative growth pattern in the usage of pesticides.



Source: (Ministry of Agriculture & Farmers Welfare)

Fig. 3. Most commonly used pesticides- India (2019-20)



Source: (GoI, 2020)

Fig. 4. State wise pesticide usage- India (2019-20)

III. Toxic effects of pesticides on human health

There are many evidences that showed potential risks of pesticides to environment and living organisms specially human beings (Devi, 2010).The economy of India mainly depends on agriculture sector. Farm production can be improved by safe use of pesticides and these can also be used to protect stored products. Fruits and vegetables contain the highest lethal concentration of pesticides. Epidemiological studies had revealed that variations in enzymatic concentration, oxidative stress is proposed methods through which health disorders can be linked to pesticide exposure (Muniz et al., 2008). Toxic pesticides primarily affect the kidney and liver, as they are the most sensitive organs of the body and are predominantly responsible for the metabolism and elimination of pesticides (Kalender et al., 2007). In the past few years the augmented prevalence of diseases are attributed due to aging and chemical pesticides exposure (Debost et al., 2016). Toxicity of pesticides is related to the level of exposure of pesticides and children and elder people are prone to exposure indirectly. (Meenakshi et al., 2012). Oral exposure of pesticides produces more lethality as compared to other routes of exposure (Matthews et al., 2015). Legrand et al. (2016) reported some cancer incidences due to exposure of population to certain cancer-causing agents.

Acute and chronic toxicity- Acute toxicity generally appears after the short time exposure to pesticides. Chronic toxicity develops after prolonged exposure to pesticides. Pesticide exposure from agricultural fields, during application or unintentional poisoning leads to acute toxicity or illness in human beings (Lee et al., 2011). Symptoms of acute toxicity include headache, dizziness, nausea, panic attacks and in several cases coma (Pan-Germany, 2012). Severity of toxic symptoms in acute toxicity can be related with the mode of application, action and quantity of pesticide used at the time of application (Richter, 2002). In case of chronic toxicity, symptoms will appear after long time or at later stage after pesticide exposure. Farmers are more exposed to the pesticides as compare to general population which is exposed through contaminated food and water (Pan-Germany, 2012). Lu et al. (2018) reported a study to observe the chronic and acute toxicity of pesticides triadimenol and triadimefon on tadpole larva. Results revealed that development of tadpole was inhibited due to triadimenol and triadimefon pesticides.

This was because of disruption of hormonal pathways due to pesticides.

Hepatotoxic and neurotoxic effects- Acute or chronic exposure to pesticides may affect the functioning of liver and kidney of mammals. Several studies showed that the continuous exposure to pesticides may lead to increased marker enzymes of liver such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), alanine phosphatise (ALP) and alkaline phosphatise (AKP) (Azmi et al., 2006; Harnendez et al., 2006). Increased activity of ALT and AST indicates liver dysfunctions (Yousaf et al., 2006). And inhibition of acetylcholine esterase by pesticides may cause deposition of neurotransmitter at nerve endings that causes exhaustion of synapses. A number of studies showed that long exposure of pesticides in agricultural workers have caused several neurotoxic effects (Tapi et al., 2005).

Pesticides as endocrine disruptors- Pesticide exposure is associated with various reproductive effects in women like abortions, decreased fertility, low birth weight, premature birth, teratogenicity and disruption in hormonal function (Schettler, 2003; Henderson, 1995). Pesticides that causes hormonal disturbance are called endocrine disrupting chemicals. Some pesticides have the ability to inhibit hormone synthesis (Vinggaard et al., 2000). Dithiocarbamates like thiram and sodium N-methyl dithiocarbamate (SMD are the pesticides which causes the reduced conversion of dopamine to norepinephrine and ultimately destroys the dopamine receptor activity (Goldman et al., 1994). Some pesticides have shown estrogenicity in vivo, e.g. methoxychlor (Goldman et al., 1999), and toxaphene, DDT, endosulfan, dieldrin, fenarimol, kepone and triadimefon (Hodges, 2000). Some pesticides like dieldrin, methiocarb, fenarimol and endosulfan showed less estrogenecity, but showed their effect when used in combination or mixing with some other pesticide. When used additively, they may induce estrogenicity at lower concentrations than those required individually. Receptors of estrogens also show less sensitivity through prolonged exposure to high concentrations endocrine disruptors (Tudi et al., 2021). Pesticides can act as endocrine disruptors because these can affect the reproductive hormone pathway (Fig. 5). The endocrine disrupting pesticides can reduce or alter the gonodotropin releasing hormone and then alter the male and female reproductive hormones (FSH, LH). There are so many pesticides which are endocrine disruptors. Among them 31% are

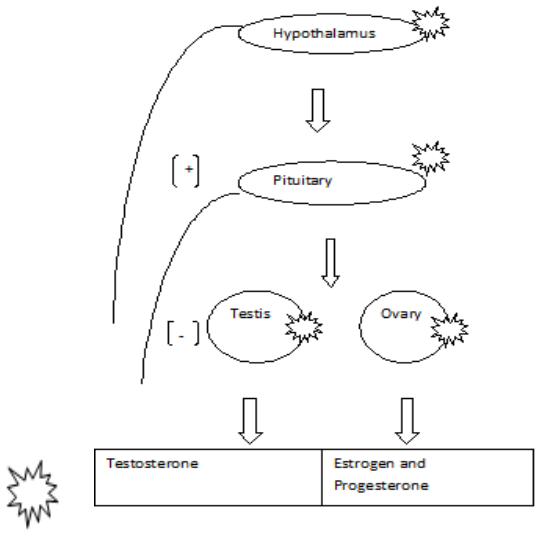


Fig. 5. Endocrine disruption pathway after exposure to pesticides

fungicides, 21% herbicides and 46% are insecticides. Endocrine disruptor pesticides mainly act by interfering the mechanism of natural hormones as they have the potential to bind to androgen receptors. Then they activate the hormone receptors and imitate the natural hormone action. Endocrine disruptor pesticides can also interfere the production, transportation and metabolism of hormones (Tabb and Blumberg, 2006). Endocrine disruptor chemicals or pesticides cause damage at the time of gamete formation and early foetal development in humans, these foetuses got great dose of pesticides from the mother at the time of pregnancy (Birnbaum and Fenton, 2003, Goldman et al., 2004, Sharpe et al., 2006). Table 1 shows the different pesticides and their hormone disturbance effects. The pesticides given in the table bind to the androgen receptors and thereby interfering the mechanism of natural hormone.

Exposure to pesticides leads to endocrine disruption which has the following effects- reduced GnRH release, altered GnRH responsiveness, and FSH and LH levels. Effects on male reproductive system include reduced testicular weight, reduced testosterone level, reduced sperm motility, altered steriodogenesis and spermatogenesis, and Sertoli cell degeneration. Effects on female reproductive system include reduced ovarian weight and follicles, altered steroidogenic enzymes, and arrested estrous cycle

Developmental and reproductive toxicity- Reproduction is an important process for producing new individuals from parents, which is adversely affected by the use of pesticides (Ngoula et al., 2012). Chronic and subchronic exposure of pesticides

Table 1. Different pesticides and their hormone disturbance effects

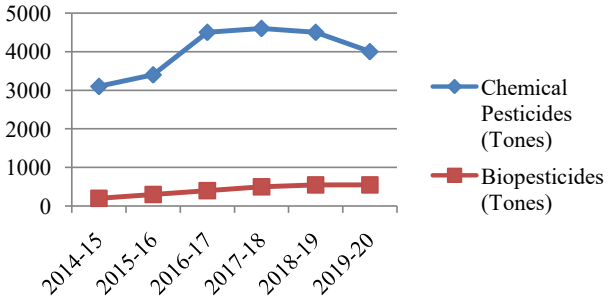
Pesticide	Hormone Disturbance effects
Aldicarb	Inhibition of progesterone and estrogen
Aldrin	Testosterone receptor binding
Carbofuran	Increase in estradiol and progesterone and decrease in testosterone
Dieldrin	Androgen receptor binding
Deltamethrin	Increased estrogens
Chlordane	Androgen receptor binding
Fenoxycarb	Decrease in luteal progesterone, increase in androgens
Lindane	Testosterone metabolism disruption
Parathion	Inhibition of gonadotrophic hormone synthesis
Methoxychlor	Estrogen antagonism in females
Tetramethrin	Estrogenic effects

can cause damage to ovarian and testicular tissue. Insecticide intoxication may result in anomalies in a reproductive system such as disturbed estrous cycle/ ovarian cycle irregularities, infertility, reduction in weight of ovary, testis, epididymis, seminal vesicles and prostate gland and change in other fertility parameters (Tiemann et al., 2000); (Verma et al., 2007). Pesticides are reported to shorten gestation period, have effect on the growth of uterus, fetal neurodevelopment and other male and female reproductive cells. Pesticide-induced male infertility can be adjudged from disturbed spermatogenesis, variations in reproductive hormonal pathways, deteriorated sperm quality and movement (Ghuman et al., 2013). Toxic effect of pesticides on male reproductive system can be observed directly from histopathological changes in reproductive organs and hormonal imbalance in endocrine system (Ngoula et al., 2012). Organophoshates can alter the spernmatogenesis, abnormalities in sperm function and lesser levels of testosterone or inhibition of testosterone synthesis. Carbamates can also cause reduced testicular weight and deterioration of epididymis and seminiferrous tubules (Archana et al., 2007, Shalaby et al., 2010). Qian et al. (2018) conducted a study on the embryos of zebra fish to observe the acute toxicity and sublethal toxicity of boscalid. Results showed that the sublethal effects of boscalid have affected the development in zebrafish. This developmental toxicity could have assessed through altered lipid metabolism, melanin synthesis, and deposition of pesticide within the embryos of zebrafish.

Genotoxicity and cytotoxicity- Genotoxicity is the damage caused to genetic material or DNA by any biological or chemical agent thereby causing alterations or damage in the genesis or polymerization of proteins or enzymes involved in the process of chromosome or chromatin formation. This ultimately leads to genetic mutations (Vinggaard et al., 2000). Cytotoxicity is the damage or injury caused at cellular level thereby harming the overall physiology of the cell. Genotoxicity can be caused due to organophosphates, organochlorines, carbamates and neonicotinoids and can lead to various diseases. Amal et al. (2005) reported a study to show the acute toxicity of organophosphorus pesticides through the bio markers of oxidative stress and apoptosis. In this study assays for different antioxidants enzymes were performed. Results revealed significant alterations in the malonyldialdehyde (MDA) and glutathione (GSH) level and significant reduction in the levels of catalase, glutathione (reduced) and increase in MDA level was found in organophosphorus treated patients (Melchiorri et al., 1996). Negative correlation was observed between cholinestrases and MDA and positive between cholinestrases and reduced glutathione (GSH). Thus showed that organophosphate caused production of free radicals as shown by increased MDA level and decreased glutathione and catalase level. As MDA level is the indicator of oxidative damage and lipid peroxidation to cells and tissues (Verma et al., 2007; Maellaro et al., 1990). Pandey et al. (2018) conducted a study to induce genotoxicity by use of profenofos (PFF) (organophosphate pesticide) in namely *Channa punctatus* which is a fresh water fish. Tunnel assay and comet assays were used to study the DNA damage. The DNA damage was measured in comet tails in erythrocytes in terms of the percentage of DNA damage.

IV. Biopesticides as an alternate to chemical pesticides

Biopesticides are pesticides that have their origin in natural sources such as plants, animals and microorganisms. Biochemical pesticides and microbial



Source: GoI (2020)

Fig. 6. Chemical and biopesticide consumption in India

pesticides are included in this category (Samada and Tambunan, 2020). Bacteria, fungi and viruses can be used as biological pesticides or agents for the control of pests in place of chemical pesticides as these have no effect on other organisms. Figure 6 shows the use of chemical and bio-pesticide in India during the last six years (GoI, 2020). Although the usage of bio-pesticides is lesser as compare to chemical pesticides but bio-pesticides are eco-friendly than the chemical pesticides. Bio pesticides are healthier, safer, cheap, biodegradable, target specific and harmless.

Agriculture is facing lot of problems caused by pests and it has been controlled by the use of pesticides. Initially pesticides were used to increase the agriculture production by controlling the infectious diseases, pests and weeds. But due to indiscriminate use of pesticides several health and environmental issues have been raised. Therefore there is a need for some alternative which is eco-friendly with environment. Pesticides are not only one substance, but consist of different substances having diverse toxic effect and may act through different mechanisms. Bio-pesticides is an alternate to chemical pesticides as bio-pesticides are eco-friendly and sustainable alternatives. It is anticipated that the viable and public zone work collectively to help farmers at the grassroots level by evolving an integrated guidelines and policies for the use of chemical pesticides and bio-pesticides. More and more agricultural research is required to incorporate bio pesticides into production system which can provide better quality and low cost product availability to the customers.

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CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Aggarwal A and Sharma B. 2010. Pesticide induced oxidative stress in mammalian systems: Review article. International Journal of Biological and Medical Research 1: 90-104.

Akashe M M, Pawade U V, Nikam A V. 2018. Classification of pesticides: a review. International Journal of Research in Ayurveda and Pharmacy 9(4): 144-150.

Alewu B, Nosiri C. 1990. Pesticides and human health: Public health impact of pesticides used in agriculture. Stoytcheva M. England: World Health Organization. 133 pp.

Amal A M, Howaida A N, Gihan M, Sharara M H Abdel A. 2005. Role of oxidative stress and apoptosis into acute organophosphorus intoxicated patients. Journal of Medical Research Institute 26: 255-263.

Archana R, Sahai A, Srivastava A K, Rani A. 2007. Carbaryl induced histopathological changes in the testis of albino rats. Journal of the Anatomical Society of India 56: 4-6

Azmi M A, Azmi N M A, Aslam, M. 2006. Effect of pesticide on health and different enzymes levels in the blood of farm workers from Gadap (rural area) Karachi- Pakistan. Chemosphere 64(10): 1739-44.

Banerjee B D, Seth V, Bhattacharya A, Pasha S T and Chakrborty A K. 1999. Biochemical effects of some pesticides on lipid peroxidation and free radical scavengers. Toxicological Letters 107: 33-47.

Bannen K C, Devaud L L, Liu J P and Lauder J M. 1998. Prenatal exposure to neuro toxicants dieldrin or lindane alters tert-butyl-bicyclophosphorothionate binding to GABAA receptors in fetal rat brain stem. Neuroscience 201: 34-41.

Bharadwaj J K and Saraf P. 2014. Influence of toxic chemicals on female reproduction: A review. Cell Biology: Research and Therapy Journal 3: 1.

Bhardwaj T and Sharma J P. 2013. Impact of pesticides application in agricultural industry: An Indian scenario, International Journal of Agriculture and Food Science Technology l4 (8): 817-822.

Birnbaum L S, Fenton S E. 2003. Cancer and developmental exposure to endocrine disruptors. Environment Health Perspectives 111: 389-394.

Calle E E, Frumkin H, Henley S J, Savitz D A, Thun M J. 2002. Organochlorines and breast cancer risk. CA A Cancer Journal for Clinicians 52: 301-9.

Chourasiya S, Khillare P S, Jyethi D S. 2015. Health risk assessment of organochlorine pesticide exposure through dietary intake of vegetables grown in the peri urban sites of Delhi, India. Environment Science and Pollution Research 22: 793-806.

Debost-Legrand A, Warembourg C, Massart C, Chevrier C, Bonvallot N, Monfort C, Rouget F, Bonnet F, Cordier S. 2016. Prenatal exposure to persistent organic pollutants and organophosphate pesticides, and markers of glucose metabolism at birth. Environment Research 146: 207-217.

Devi P I. 2010. Pesticides in agriculture- boon or a curse? A case study of Kerala. Economic and Political Weekly 45: 26-27.

FAO. 2018. Pesticide Use Data-FAOSTAT. http://www.fao.org/faostat/en/ #data/RP.

FOCUS 2008. Pesticides in air: Considerations for Exposure assessment. Report. Working Group on Pesticides in Air, EC Document Reference SANCO/10553/2006.

Freire C, Koifman R J, Koifman S. 2015. Hematological and hepatic alterations in brazilian population heavily exposed to organochlorine pesticides. Journal of Toxicology and Environment Health 78: 534-48.

Garey J, Wolff M S. 1998. Estrogenic and antiprogestagenic activities of pyrethroid insecticides. Biochemical Biophysical Research Communication 251: 855-859.

Gasnier C, Dumont C, Benachour N, Clair E, Chagnon M C, Séralini G E. 2009. Glyphosate-based herbicides are toxic and endocrine disruptors in human cell lines. Toxicology 262: 184-91.

Ghosh P K and Philip L. 2006. Environmental significance of atrazine in aqueous systems and its removal by biological processes: An overview. Global NEST Journal 8(2): 159-78.

Ghuman S P S, Ratnakaran U, Bedi J S, Gill J P S. 2013. Impact of pesticide residues on fertility of dairy animals: A review. The Indian Journal of Animal Sciences 83: 1243-1255.

GOI, 2021. Insecticides /pesticides registered under section 9(3) of the Insecticides Act, 1968. for use in the country.

Goldman J M, Stoker T E, Cooper R L, McElroy W K, Hein J F. 1994. Blockade of ovulation in the rat by the fungicide sodium N-methyldithiocarbamate: relationship between effects on the luteinizing hormone surge and alterations in hypothalamic catecholamines. Neurotoxicological Teratology 16: 257-268.

Goldman L, Falk H, Landrigan, P J, Balk, S J, Reigart R, Etzel R A. 2004. Environmental pediatrics and its impact on government health policy. Pediatrics 113: 1146-1157.

Hernandez F A, Gomez M A, Perez V G, Lario V J, Pena G Gill F. 2006. Influence of exposure to pesticides on serum components and enzyme activities of cytotoxicity among intensive agricultural farmers. Environment Research 102:70-76.

Henderson P T, Borm P J A, Kant I J. 1995.Basis boek Arbeidstoxicologierisicoinventarisatie en -evaluatieZeist: UitgeverijKerckeboschbv.

Hodges L C, Bergerson J S, Hunter D S, Walker C L. 2000. Estrogenic effects of organochlorine pesticides on uterine leiomyoma cells in vitro. Toxicological Science 54: 355-364.

Jaga K, Dharmani C. 2003. Sources of exposure to and public health implications of organophosphate pesticides. Reviews of Panam Salud Publications 14: 171-85.

Jamal F, Haque Q S, Singh S, Rastogi S. 2015. The influence of organophosphate and carbamate on sperm chromatin and reproductive hormones among pesticide sprayers. Toxicological Industrial Health: 1-10.

Kalender S, Kalender Y, Durak D, Ogutcu A, Uzunhisarcikli M, Cevrimli B S and Yildirim M .2007. Methyl parathion induced nephrotoxicity in male rats and protective role of vitamins C and E. Pesticide Biochemistry and Physiology 88: 213-18.

Karami-Mohajeri S, Abdollahi M. 2011.Toxic influence of organophosphate, carbamate, and organochlorine pesticides on cellular metabolism of lipids, proteins, and carbohydrates: a systematic review. Human Experimental Toxicology 30(9): 1119-40.

Lee D H, Lind P M, Jacobs D R, Salihovic S, Van Bavel B, Lind L. 2011. Polychlorinated bis phenyls and organochlorine pesticides in plasma predict development of type 2 diabetes in the elderly. The Prospective Investigation of the Vasculature in Uppsala Seniors (PIVUS) study. Diabetes Care 34: 1778-1784.

Lemaire G, Terouanne B, Mauvais P, Michel S, Rahman R. 2004. Of organo-chlorine pesticides on human androgen receptor activation *in vitro*. Toxicological and Applied Pharmacology 196: 235-46.

Li D, Huang Q, Lu M, Zhang L, Yang Z, Zong M. 2015. The organophosphate insecticide chlorpyrifos confers its genotoxic effects by inducing DNA damage and cell apoptosis. Chemosphere 135: 387-93.

Li Q, Kobayashi M, Kawada T. 2011. Ziram induces apoptosis and necrosis in human immune cells. Archives of Toxicology 85: 355-61.

Lifshitz M, Shahak E, Bolotin A, Sofer S. 1997. Carbamate poisoning in early childhood and in adults. Journal of Toxicology and Clinical Toxicology 35: 25-7.

Maellaro E, Casini F, Del Bello B, Comporti M. 1990. Lipid peroxidation and antioxidant systems in the liver injury produced by glutathione depleting agents. Biochemical Pharmacology 39: 1513-1521.

Matthews G (ed). 2015. Pesticides: health, safety and the environment, 2nd edn. Wiley, New York. ISBN 978-1-118-97602-9.

McGill A E, Robinson J. 1968. Organochlorine insecticide residues in complete prepared meals: a 12-month survey in S.E. England. Food and Cosmetics Toxicology 6: 45-57.

McLachlan J A. 2001. Environmental signalling: What embryo and evolution teach us about endocrine chemicals? Endocrinology Reviews 22: 319-41.

Meenakshi, Sharon, P, Bhawana M, Anita S, Gothecha VK. 2012. A short review on how pesticides affect human health. International Journal of Ayurvedic Herb Medicine 2(5): 935-946.

Melchiorri D, Reiter R, Sewerynek E, Hara M, Chen L, Histico G. 1996. Paraquat toxicity and oxidative damage. Reduction by melatonin. Biochemical Pharmacology 39: 1095-1099.

Milatovic D, Gupta R C and Aschner M. 2006.Acetylcholinesterase toxicity and oxidative stress. Science World Journal 6**:** 295-310.

Mnif W, Hassine A I H, Bouaziz A, Bartegi A, Thomas O, Roig B. 2011. Effect of endocrine disruptor pesticides: a review. International Journal of Environment Research and Public Health 8: 2265-2203.

Muniz J F, Cualey L, Scherer J, Lsarev M, Kow Y W and Kisby G E. 2008. Biomarker of oxidative stress and DNA damage in agricultural workers: A pilot study. Toxicology and Applied Pharmacology 227: 97-107.

Nayak S, Sahoo A, Kolanthasamy E, Rao K. 2020. Retrieved from https:// doi.org/10 .26832/aesa-2020-edcrs-03.

Ngoula F, Ngouateu O B, Kana J R, Defang H F, Watcho P, Kamtchouing P. 2012. Reproductive and developmental toxicity of insecticides. In: Perveen F, editor. Insecticides, Advances in Integrated Pest Management. UK: Intech Open. 429-457 pp. ISBN: 978-953-307-780-2.

Pandey A K, Nagpure N S, Trivedi S P. 2018. Genotoxicity assessment of pesticide profenofos in freshwater fish *Channapunctatus* (Bloch) using comet assay and random amplified polymorphic DNA (RAPD). Chemosphere 211: 316-323.

Pan-Germany, 2012.Pesticide and health hazards. Facts and figures. 1-16 (www.pan germany.org/download/Vergift_EN-201112-web.pdf)

Pirsaheb M, Limoee M, Namdari F, Khamutian R. 2015.Organochlorine pesticides residue in breast milk: a systematic review. Medical Journal of The Islamic Republic of Iran 29: 228.

Richter E D. 2002. Acute human pesticide poisonings. Encyclopedia of Pest Management. pp. 3-6.

Samada L H, Tambunan U S F. 2020. Biopesticides as promising alternatives to chemical pesticides: A review of their current and future status. On Line Journal of Biological Sciences 20(2): 66-76.

Savary S, Willocquet L, Pethybridge S J, Esker P, Mc Roberts N, Nelson A. 2019. The global burden of pathogens and pests on major food crops. Nature Ecology and Evolution 3(3): 430-439.

Scandalios J G. 2005. Oxidative stress: Molecular perception and transduction of signals triggering antioxidant gene defenses. Brazilian Journal of Medical Biological Research 38: 995-1014.

Schettler T, Solomon G, Kaplan J, Valenti M. 2003.Generations at Risk: How Environmental toxicants may affect reproductive health in California Brisbane, CA: George Lithograph.

Shalaby M A, El Zorba H Y, Ziada R M. 2010. Reproductive toxicity of methomyl insecticide in male rats and protective effect of folic acid. Food and Chemical Toxicology. 48: 3221-3226.

Sparks T C, Nauen R 2015. IRAC: Mode of action classification and insecticide resistance management.

Sharpe R M. 2006. Pathways of endocrine disruption during male sexual differentiation and masculinisation. Best Practices of Research and Clinical Endocrinology Metabolism 20: 91-110.

Sogorb M A, Vilanova E. 2002. Enzymes involved in the detoxification of organophosphorus, carbamate and pyrethroid insecticides through hydrolysis. Toxicology Letters 128: 215-228.

Soloneski S, Kujawski M, Scuto A, Larramendy M L. 2015. Carbamates: a study on genotoxic, cytotoxic, and apoptotic effects induced in Chinese hamster ovary (CHO-K1) cells. Toxicology In Vitro 29: 834-44.

Sparks T C, Nauen R. 2015. IRAC: Mode of action classification and insecticide resistance management, Pesticide Biochemistry and Physiology 121: 122-28.

Swanson N L, Leu A, Abrahamson J, Wallet B. 2014. Genetically engineered crops, glyphosate and the deterioration of health in the United States of America. Journal of Organic Systematics 9: 6-37.

Tabb M M, Blumberg B. 2006. New modes of action for endocrine-disrupting chemicals. Molecular Endocrinology *20*: 475-482.

Thongprakaisang S, Thiantanawat A, Rangkadilok N, Suriyo T, Satayavivad J. 2013. Glyphosate induces human breast cancer cells growth via estrogen receptors. Food and Chemical Toxicology 59: 129-36.

Tapi L R, Leyva A, Laynez F, Santed F S. 2005. Chronic neurosycological sequelea of cholinesterase inhibitors in the absence of structural brain damage: Two cases of acute poisoning. Environment Health Perspectives 113(6): 762-66.

Tiemann U. 2008. In vivo and in vitro effects of the organochlorine pesticides DDT, TCPM, methoxychlor, and lindane on the female reproductive tract of mammals: a review Reproductive Toxicology 25: 316-26.

Tudi M, Ruan H D, Wang L, Lyu J, Sadler R, Connell D, Chu C, Phung D T. 2021. Agriculture development, pesticide application and its impact on the environment. International Journal of Environmental Research and Public Health 18(3): 1112.

Verma R S, Mehta A, Srivastava N. 2007. In vivo chlorpyrifos induced oxidative stress: Attenuation by antioxidant vitamins. Pesticide Biochemistry and Physiology 88: 191-196.

Vinggaard A M, Hnida C, Breinholt V, Larsen J C. 2000. Screening of selected pesticides for inhibition of CYP19 aromatase activity in vitro. Toxicology In Vitro 14: 227-234.

Wesseling C, Keifer M, Ahlbom A, McConnell R, Moon J D, Rosenstock L. 2002. Long-term neurobehavioral effects of mild poisonings with organophosphate and n-methyl carbamate pesticides among banana workers. International Journal of Occupational Environment Health 8: 27-34.

Yousaf M I, Awad T I Mohammad E H. 2006. Deltamethrin- induced oxidative damage and biochemical alterations in rat and its attenuation by Vit. E. Toxicology 227: 240-47.

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