

## EFFECTS OF AGROCHEMICALS ON BIODIVERSITY

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### Abstract

Agrochemicals are one of the most used substances which became essential due to its ease and rapidity. During the initial stage of application it shows positive effects but as the dependency on these chemicals becomes more, it starts to show its adverse effect on Biotic and Abiotic factors which ultimately affects our Biodiversity. As there are various types of Agrochemicals which show different types of effects (positive and negative) on an organism, that disturb the whole food web in an ecosystem. At present, India is the largest producer of pesticides in Asia and ranks twelfth in the world for the use of pesticides with an annual production of 90,000 tones. India uses 50% of organophosphate whereas the use of biopesticides is around 1% among all pesticides. These chemicals not only contaminate the surrounding environment but also affect the life of many organisms.

**Keywords:** Agrochemicals; Pesticides; herbicides; Environment ; biodiversity, Health effects; Pollution; Fertilizer; Biotic & Abiotic

## Introduction

**A**grochemical' are substance which are used in agriculture for various purposes which can lead to better or higher yield. These chemicals are used as pesticides, herbicides, fertilizer, or other chemicals used in crop and animal husbandry. The first use of Agrochemical was done by 'Sumerians' from 4500 years ago in the form of sulfur compounds as an insecticide. And 1300 year later Chinese used mercury and arsenic compounds to control body lice.<sup>[1]</sup> In India these Agrochemical are introduced in Agricultural field in the form of Fertilizer, insecticide and pesticides in the beginning of the "Green Revolution". Which are used in surface irrigation and mineral fertilizers such as nitrogen, phosphorus and potassium for increasing the food production. But the use of pesticides began in 1948 when DDT was imported for malaria control and BHC for locust control.<sup>[2]</sup> As the pest got adapted to these chemicals, more and more new Agrochemicals were developed causing side effects in the environment.



## Definition

Agro-chemicals are commercially produced, usually synthetic, chemical compounds used in farming — such as a fertilizer, pesticide or soil conditioner.

## Types of Agrochemicals

There are various types of agrochemicals which are used to safely maintain the global food supply to ensure high quality food for widespread consumption. In most cases, agrochemicals refer to pesticides.<sup>[3]</sup> Types of agrochemicals includes:

## Pesticides

These are chemicals engineered(or a biological agent) to kill, repel, or control pests which grow beyond Economic threshold level(ETL) and can damage crop and livestock to reduce farm productivity is known as pesticides. For eg, Insecticide, herbicides, fungicides etc.

1. **Herbicides/Weedicides:** The chemicals which are used in crops to kill weeds (unwanted plant) are known as weedicides. For eg, 2,4-D Ethyl ester, Neem extract, etc.
2. **Insecticides:** The chemicals which are used to kill insects are known as Insecticide. For eg, Boric acid, Carbaryl, etc.
3. **Fungicides:** The biocidal chemical compound or biological organism used to kill parasitic fungi or their spores is known as Fungicides. For example, Mancozeb, nabam, zineb, etc.

4. **Rodenticides:** The chemicals which are used to kill rodents that affect the crop and livestock in various ways is known as Rodenticide. For eg, Bromadiolone, zinc phosphate, etc.
  5. **Bactericides/Bacteriocides:** The chemical agent that helps to prevent the formation of bacteria is known as bactericide. For eg, streptomycin sulfate, oxytetracycline, etc.
  6. **Larvicides:** The chemicals which are used to kill the specific stage of insect i.e., larval stages that cause the most damage in leafy plants are called Larvicides. For eg, temephos, methoprene, oils, monomolecular films.
- **Synthetic Fertilizers/Fertilizer:** The chemical substance (or manmade inorganic compounds) which are produce in industries and applied in soil or plant tissue to encourage crop growth by saturating soils with nutrients is known as Synthetic fertilizer. These are mainly derived from the by-product of petroleum industry. For eg., Ammonium nitrate, Superphosphate and Potassium Sulfate.
  - **Acidifiers and Liming Agent:** These are chemical which are used to alter the pH levels of soil according to the requirements of crops to a more appropriate range for its better growth and development throughout its cultivation process. It brings the soil to its balance conditions if it is too acidic or alkaline (basic). For eg, lime ( $\text{Ca}[\text{OH}]_2$ ) as a liming agent and Sulfur Compounds as a Acidifiers.
  - **Soil conditioners:** It is a product which is used as a supplement for the soil to improve the physical qualities of a soil such as its texture, water holding capacity (WHC), cation exchange capacity, bulk density, permeability and temperature, etc. For eg, PAMs (polyacrylamide), phosphogypsum, flue gas desulfurization (FGD),etc.
  - **Growth hormones:** These are chemical substances which are used in small amounts to modify the growth of plants by stimulating or inhibiting part of the natural growth regulatory system. For eg, kinetin (aromatic cytokinin), NAA Naphthaleneacetic acid (auxin), Morphactins, etc.

The uses of these Agrochemicals vary depending on area and types of chemicals which can be shown in percentage, such as

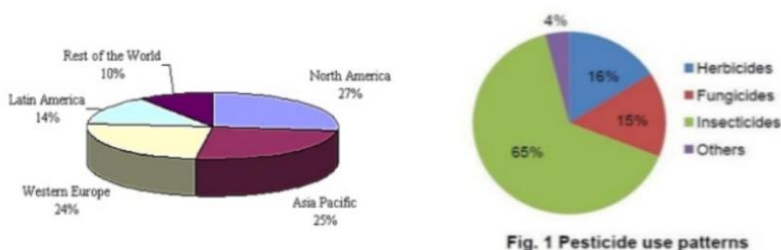


Fig. 1 Pesticide use patterns

## Advantages of Agrochemicals

- **Pest Control:** In world-wide the major loss to farmers occurs due to insects and pests. It is estimated that every year insects destroy 15% of crops, disease pathogens and weeds around 13% each and pests during postharvest period damage 10% of crops.<sup>[4]</sup> Apart from for uses in agriculture, they are also used to control specific insects in society which cause damage to humans directly(disease caused by mosquitoes) or indirectly(damage caused by mice or rats). Pesticides help in minimizing these losses by protecting crops and society in an efficient manner which decreases the cost of labor and fuel. These pesticides work very rapidly (within 2-3 days) which is best for insects having higher reproductive rate.
- **Weeds Control:** The major disease and insect causing damage to standing crops occurs due to the weed which acts as source for their growth and development. As well as in society, the weed creates a lot of problems such as growing weeds and trees under power lines which left unchecked results in power outages. Herbicides/weedicides are mainly used to destroy the growth of these weeds easily with less inputs then doing it manually. The unwanted vegetation in roadside, parks, national highway and public areas are controlled to maintain safety and convenience to the public.
- **In Food Processing:** The major problem in the food industry is the protection of its raw materials from insects and rodents from infecting them during processing, manufacturing and packaging stages. To control these insecticides and rodenticides are used widely in food storage.

There are also various types of Agrochemicals which are as preservatives for increasing the shelf life of products having low storage life.

- **Increasing Yield:** The reason a gardener and farmer use chemicals is to grow crops bigger and brighter than other crops. There are various types of Fertilizing Agrochemicals which provide the soil with required nutrient chemicals such as Nitrogen, phosphorus or potassium which helps in the growth of plants. Whereas

weedicides are used for removing the competition between plants and suppression by weed.

- **Decreasing the Cost of Food:** The major problem of a middle class family is the increasing price of food which results in compromising with the daily needs. By increasing the yield of a crop it increases the efficiency of food production which decreases the cost of food and helps to keep food prices in check for the consumer at moderate range.
- **Consumer Benefits:** The high quality produce that are free from insect attack and contamination are produced using crop protection chemicals such as pesticides which allow the consumer to purchase these products free from insect fragments.

### Effects of Agrochemicals

There are various types of effects which are caused by agrochemicals from which pesticides are the main cause of major types of problems because of toxic chemicals meant to kill specific pest species that can affect non-target species, such as plants, animals, and humans. Due to the method of spraying these agrochemicals in the entire agricultural field, About 98% of applied insecticides and 95% of herbicides reach a destination other than their specific target species and effects the environment.<sup>[5]</sup>

Globally about 60% of agricultural land is “at risk of pesticides pollution by more than one active ingredient”, and that over 30% is at “high risk” of which a third are in high biodiversity region.<sup>[6][7]</sup> These agrochemicals come with a specific set of environmental concerns, and may have some undesirable effect which leads to them being banned, while having regulation for limited or reduced use of others. The global spread of pesticide use, including the use of older/obsolete pesticides that have been banned in some jurisdictions, has increased overall.<sup>[8][9]</sup> The organochlorine (OC) insecticides which are used in successfully controlling a number of disease such as malaria and typhus, were banned or restricted after the 1960s in most of the technological advance countries.<sup>[10]</sup>

### Impacts on Abiotic factors

**Air:** The use of agrochemicals can lead to the cause of air pollution which mainly occurs due to suspended particles of pesticides with air and altering their composition. These particles are later easily carried by wind to other areas causing contamination.<sup>[11]</sup> These pesticides can cause harm to nearby areas and may become a threat to wildlife due to its volatilisation.

**Water:** Agrochemicals can reach surface water mainly through runoff from a nearby field, drifting from outside the intended area, eroding soil or by accidental spilling. The factors affecting the contamination of water mainly depend upon the solubility of agrochemicals, weather, soil type and method used to apply the chemical. The contamination of surface water in an area greatly affects all the available life forms in that particular environment which acts as a natural resource for them to maintain their daily life. Whereas, in case of

ground water pollution the water table gets contaminated due to leaching of agrochemicals from the top soil. In a survey in India, samples from various wells and hand pumps were taken from Bhopal. In which about 58% of drinking samples were contaminated. As the water table gets contaminated it takes years for it to clean itself from the toxic chemicals from which it gets contaminated. <sup>[12]</sup>

**Soil:** The main cause of soil contamination is pesticides and its transformation products (TPs) which remain in the soil for a longer period of time. <sup>[13][14]</sup> As there are certain factors which influence the persistence and movement of these chemicals such as water solubility, organic matter, soil texture, cation exchange capacity and water filtration rate, etc. The most influential soil characteristic is the organic matter content. The larger the organic matter content, the greater the adsorption of pesticides and TPs. The capacity of the soil to hold positively charged ions in an exchangeable form is important with parquat and other pesticides that are positively charged. Soil pH is also of some importance as it increases the Adsorption with decreasing soil pH for ionizable pesticides (e.g. 2,4-D,2,4,5-T, picloram, and atrazine). <sup>[15]</sup>

In agriculture, the deposition of these chemicals in soil is caused by their excess use then their required amount. These excess chemicals remain in the soil for a longer period of time and continue to contaminate the soil and its surrounding ecology. Micro-organisms and macro-organisms which maintain the ecology of an environment get greatly affected by the overuse of these chemicals. As their rate declines the rate at which soil degrades gets faster and results in soil erosion.

### Impacts on Biotic Factors

**Micro-Organism:** These organisms which can't be seen by naked eye play a major role in decomposition of organic plant and animal waste into simpler substances (that are harmless) which are later used up by plants and animals. Thus, helps in making the environment clean. These microorganisms get greatly affected by the heavy use of Agrochemicals (mainly pesticides) into the soil causing their population to decline until it gets extinct from the soil. There are various beneficial microorganisms which help in the growth of a plant have their functions inhibited due to the indiscriminate use of chemicals. For example, tricypyr are toxic to several species of mycorrhizal fungi and oxadiazon reduced the number of mycorrhizal fungal spores. <sup>[16][17]</sup> 2,4-D reduces nitrogen fixation bacteria that live on the root of beans, inhibits bacteria which transform ammonia into nitrite and growth of nitrogen- fixing blue-green algae. <sup>[18][19][20][21]</sup>

**Macro-organisms:** These organisms which can be seen by the naked eyes and maintain the ecology of an area such as:

**(i) Insects:** There are various types of insects which play their role in the ecology of the agroecosystem. Some of which helps in the cultivation of land for the production of different crops or animals, such as Earthworms which are also known as "farmer friends" for improving the soil fertility, aeration and other physical properties of soil. Ladybird beetles which are used for controlling major insect pests of crops like aphids, whiteflies,

scales, mites, mealybugs and other soft-bodied insects. Butterflies and bees which act as pollinators for pollination, etc. The heavy usage of the chemical results in affecting the life cycle of insects which results in reducing or increasing their population. The causes of these heavy usage is due to not taking in account the underlying ecology of the agroecosystem, poisoning through food chain, and indirect effect related to the stress that toxic chemicals induces on organism. Pesticides such as

*Triazine*: which affect the earthworms to become infected with monocystis gregarines. [22]

*Thiamethoxam*: which affects the worker bees mortality due to homing failure. [23] (risks for colony collapse remain controversial). [24]

*Spinosyns*: which affects the physiological and behavioral traits of beneficial arthropods particularly hymenopterans. [25]

*2, 4-D*: It indirectly increased the density of sugarcane borer (Herbicide) pests, and this was attributed to reductions in parasitoid *Trichogramma minutum* (Hymenoptera: Trichogrammatidae) caused by direct toxicity of the herbicide. [26]

**(ii) Birds**: The major cause of decline in the population of birds is due to two factors such as, the decline in the number of population of plant and invertebrate species on which the birds feed and the effects of toxic chemicals on their productivity. The use of DDE (Dichlorodiphenyl, dichloroethylene) induced egg shell thinning especially affecting the population of bird in European and North American area. [27]

There are also some fungicides which are used in peanut farming that are toxic to earthworms and may kill them, reducing the populations of birds that feed on them. [28] And the use of herbicides which further destroys the native habitat and directly endangers bird populations.

Organophosphates are involved in 335 separate mortality events inflicting the deaths of about birds in the USA between 1980 and 2000. [29] Worldwide, over 100,000 bird deaths caused by mono-crotophos, the worst organophosphate, are documented. [30] Application of diazinon, another widely used OP pesticide, to lawns, golf courses, and turf farms have killed thousands of birds in the U.S. [31]

**(iii) Aquatic life**: The aquatic life forms play a major role in our ecosystem to maintain nutrient cycle, purifying water, attenuate floods, recharge ground water and provide habitat for wildlife and recreation for people. These valuable environmental functions get greatly affected due to loss of aquatic life. The major factor which disturbed the aquatic ecosystem is the use of agrochemicals such as pesticides.

Agricultural field pesticides generally runoff to reservoirs or drainage systems by rain or irrigation. [32] There are three ways an aquatic organism can get affected by pesticides (a) Skin : as the aquatic organisms are always in contact with water they can form harmful effects through their dermal pores. (b) Orally: aquatic organisms also develop harmful effects by feeding on pesticide contaminated prey such as insects or plants (which is a secondary infection). (c) Gills: they can directly uptake pesticides through gills during respiration. Through these three ways an aquatic organism can get

directly killed if a pesticide is lethal or may develop various physiological or behavioral changes within an organism in case a pesticide is sub-lethal (repeated exposure).<sup>[33-34]</sup>

In case of herbicides, it is observed that glyphosate is mostly used for controlling the terrestrial and aquatic weeds, which negatively affects the non-target organisms in the aquatic environment in recent years.<sup>[35,36,37,38]</sup> The use of herbicides can also kill aquatic life by suffocating the organism due to decaying processes which consume oxygen in large amounts. In 2012 the National Marine Fisheries Service (NMFS) drafted a biological opinion to the Environmental Protection Agency (EPA) concluding that three herbicides (oryzalin, pendimethalin, and trifluralin) pose a direct threat to approximately 50% of endangered Pacific salmon and Puget Sound steelhead species, and adversely impact their habitat.<sup>[39]</sup>

**(iv) Amphibians:** They are cold-blooded animals that spend a part of their lives on both land and water which play an important part in the food chain. Due to susceptibility towards environmental threats they are the most threatened class of animal in nature. And in recent decades, amphibians populations have declined across the world, though the reason remains unexplained but pesticides may be a part of it.<sup>[40]</sup> Frog, crocodile and turtle are the major amphibians which gets affected by the exposure of pesticides such as,

*Organochlorine endosulfan:*  
(Pesticide) It kills the tadpoles and cause behavioral and growth abnormalities.<sup>[41]</sup>

*Atrazine:*  
(Herbicide) It turn the male's frogs into hermaphrodites and decreases their ability to reproduce.<sup>[42]</sup>

Polychlorinated biphenyls:  
(PCBs). The embryonic exposure in turtles leads to sex reversal, decrease in hatching success, skin lesion, feminization and other abnormalities.<sup>[27]</sup>

Pesticide mixture: They have a toxic effect on frogs. Tadpoles have longer metamorphosis, decrease their ability to catch prey and avoid predators.<sup>[42]</sup>

**(v) Humans:** The overall increase in the use of agrochemicals greatly affects human health in many ways which can be lethal to the human body over time. At present, India is the largest producer of pesticides in Asia and ranks twelfth in the world for the use of pesticides with an annual production of 90,000 tonnes. India uses 50% of organophosphate whereas the use of biopesticides is around 1% among all pesticides.<sup>[43]</sup> Pesticides enters a human body through inhalation of aerosols, by drinking or consuming from contaminated sources, or through direct contact or exposure to skin.<sup>[44]</sup> Pesticides cause three type of effect on human body depend on toxicity and duration of exposure which are:

- (a) **Acute effects** - The illness or injury that appears immediately for a short period of time. Its symptoms for pesticides poisoning includes headache, dizziness, tremor, slow heartbeat abdominal pain, numbness, etc.



- (b) **Chronic effects** - It occurs due to the exposure of toxic chemicals over a longer period of time. Initially less/no symptoms appear to victims but over periods of time as the exposure gets continued and toxic substances either accumulate in body tissue (fat cell) or minor irreversible damage to each exposure causes clinical symptoms such as speech difficulties, sleepwalking, insomnia, impaired memory and concentration, cancer, leukemia, blood and nerve disorder, etc. It also causes Reproductive harm which includes birth defects, still birth, spontaneous absorption, sterility and infertility.<sup>[44]</sup>

In North America, there is an increase in cases of childhood cancer, such as leukemia due to somatic cell mutations which are associated with pesticides.<sup>[45]</sup> The distribution in estrogenic activity is due to DDT and its breakdown product DDE which can possibly lead to breast cancer. Fetal DDT exposure reduces male penis size in animals and can produce undescended testicles.<sup>[46]</sup>

- (c) **Allergic effect** - The harmful effects which some people develop in reaction to specific substances. These effects do not occur during the first exposure which cause the body to develop a repelling response. Later exposure results in allergic response. Symptoms of allergic effects due to pesticides are skin irritation (rash, blister), eye or nose irritation (water eyes, itchiness, and sneezing).

The major cause of these effects on humans are due to contamination of food stuff. In 1997, 13 pesticides (acephate, carbendazim, chlorothalonil, chlorpyrifos, DDT, diazinon, endosulfan, methamidophos, iprodione, metalaxyl, methidathion, thiabendazole, triazophos) were assessed in five commodities (mandarins, pears, bananas, beans, and potatoes). Some 6 000 samples were analyzed. Residues of chlorpyrifos exceeded MRLs most often (0.24%), followed by methamidophos (0.18%), and iprodione (0.13%). With regard to the commodities investigated, around 34% contained pesticide residues at or below the MRL, and 1% contained residues at levels above the MRL. In mandarins, pesticide residues were most frequently found at levels at or below the MRL (69%), followed by bananas (51%), pears (28%), beans (21%) and potatoes (9%). MRLs were exceeded most often in beans (1.9%), followed by mandarins (1.8%), pears (1.3%), and bananas and potatoes (0.5%).<sup>[47]</sup>

In India, the first report of poisoning due to pesticides was from Kerala in 1958, where over 100 people died after consuming wheat flour contaminated with parathion.<sup>[48]</sup> A study was conducted to assess the pesticides residue in food commodities where it is noted that an average total DDT and BHC consumed by an adult were 19.24 mg/day and 77.15 mg/day respectively.<sup>[49]</sup> Fatty food was the main source of these contaminants. In another study, the average daily intake of HCH and DDT by Indians was reported to be 115 and 48 mg per person respectively, which were higher than those observed in most of the developed countries.<sup>[50]</sup>

Another major problem associated with agrochemicals use is bioaccumulation and biological magnification. Bioaccumulation is when a substance builds up in the body because the body doesn't have the proper mechanism to remove it. These synthetic chemicals cause harmful effects to the organism or can be passed on to a predator. As the predator consumes more exposed individuals, the concentration of chemicals gets

increased. A higher level organism in the food chain will have more concentrations of pesticides than lower organisms.

**Biological magnification**, also known as **biomagnification**, is the term used to describe when chemicals, such as pesticides increase in concentration with each level of the food chain.

### Conclusion

All the agrochemicals have the potential to be harmful to human, animal, soil, water and other organisms under a biodiversity. To avoid the harmful effects of agrochemicals on our surroundings, the major key is to reduce the use of these chemicals as much as possible. The most toxic chemicals which cause most environmental hazards like DDE and organochlorine should be prohibited or restricted and only be used in a minimum amount. The effects on human health can be reduced by using proper tools like wearing PPE and avoiding exposure to the human body. During application, labels should be read thoroughly to avoid heavy doses and a safe working habit. Implement different cropping patterns and methods such as INM, IPM, intercropping and mixed cropping with legumes crop, etc to maintain the use of agrochemicals to a minimum level. Organic manures, jeevamrut and bio pesticides can be used as an alternative for fertilizer and pesticides. In case of removing the dependency of chemicals on a field it is required to decrease its dosage while increasing the dosage of organic fertilizer gradually over a period of time.

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