REVIEW ARTICLE Agricultural Reviews, Volume 42 Issue 4: 450-454 (December 2021)

Ecotoxicology and Its Impact on Ecosystem: A Review

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10.18805/ag.R-2206

ABSTRACT

Ecotoxicology is a relatively new science that helps to protect the existing ecosystem from toxic environmental pollutants. The scientists are working towards prediction, observation, monitoring, risk assessment and prevention from these toxicants and their harmful effects on population, community and ecosystem. It is a multidisciplinary field, which integrates toxicology, chemistry and ecology. Presently the human interventions and chemical production without proper disposal are one of the most responsible factors for presence of harmful pollutants in the biosphere. The toxic chemical may cause detrimental effects like change in behavior pattern of population, reduced growth, physiological and molecular changes and developmental changes ultimately may change the whole exposed ecosystem. Although, ecotoxicologists are facing a lot of problems to predict the effect of a chemical on an individual living population, they are doing a great job to protect our ecosystem.

Key words: Chemicals, Ecosystem, Ecotoxicology, Environment, Pollutants.

Ecotoxicology is the study of the effects of toxic chemicals on the structure, function and behavior of population biodiversity, especially at the population, community and ecosystem levels. It is a new discipline and originated as a separate discipline few decades ago, associated to explore, predict, analyze and control the negative impact of chemical toxicants on the environment. These toxic chemicals may cause adverse effects from the physiological to molecular level of population, community and ecosystem levels of biological organization (Zhang *et al.,* 2018). Ecotoxicology is concerned with the understanding of three main disciplines: toxicology, ecology and chemistry. Environmental toxicology and Ecotoxicology have a basic difference of their effect on individuals, communities and ecosystems. Ecotoxicology deals with the study of mechanisms which affects the normal biological performance by manmade toxicants and tries to detect the detrimental effects of the environmental contaminants (Bhat, 2013).

Environmental toxicology investigates the effects of toxic agents on individual organisms, organs, tissues, cell types, organelles and biochemical reactions whereas ecotoxicology is a multidisciplinary research area in which biologists, chemists, geologists, statisticians and computer modelers study the toxic effects of environmental agents on biological populations, communities and ecosystems (Tollenson, 2018).

Many toxic chemicals such as heavy metals, dioxins, polycyclic aromatic hydrocarbons, pesticides, phthalates and many more radioactive elements are the harmful pollutants of environment affecting all living organisms of the ecosystem (Thompson and Darwish, 2019). These manmade toxicants negatively affect the ecological competence of population or individual. Manmade toxicants like heavy metal, pesticides, volatile hydrocarbons and phthalates may exhibit lethal or sub-lethal effects on the population. A common example of such type of toxicity is surface water contaminated with manmade toxicants. These harmful contaminants may affect the whole community of animals and plants (Irena, 2004). The formation of reactive oxygen and nitrogen species by these chemicals is one of the most dangerous mechanisms by which oxidation modification occurs in the cellular level of poisoned organism and ultimately may change the physiological and molecular mechanism of victims (Drzezdzon *et al.,* 2018). The current trends favor to approach the ecological risk assessments (ERA) by the development of the international norms and regulations for the protection of the ecosystems. The present regulatory guidelines are good enough to protect the planet from the use of toxic chemicals along with improvement of environmental quality. However, the influence of human activity and anthropogenic stress factors on nature is still a major factor to create serious damage to ecosystems (Ashauer and Brown, 2013). The demand for clear-cut guidelines to approach the risk assessment of toxic chemicals on ecosystem is now well demonstrated by scientific community and has been brought out by European Commission (Vighi and Villa, 2013).

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How to cite this article: Singh, R.P., Chandra, N., Swamy, M. and Bharti, S. (2021). Ecotoxicology and Its Impact on Ecosystem: A Review. Agricultural Reviews. 42(4): 450-454. DOI: 10.18805/ag.R-2206.

Submitted: 26-03-2021 **Accepted:** 07-07-2021 **Online:** 04-08-2021

Common environmental toxicants

The common environmental toxicants are as follows:

Pesticides

Pesticides are chemical substances that are used for controlling pests. Pests like insects, mites, ants, nematodes and mollusks destroy the crops so pesticides are used widely

to enhance production in agriculture. Term pesticides include insecticides, pisicides, rodenticides, insect repellents *etc*. For example methyl parathion, a toxic chemical used in agriculture causing harmful effects and can be life-threatening (Kalipci *et al*., 2010). These pesticides may affect the ability of reproduction of animals and may cause weakness, paralysis, skin and eye irritation, cancer and other illness (Gupta *et al*., 2017).

Phthalates

These are esters of phthalic acid and primarily used as plasticizers. These are commonly found in plastic wrap, plastic bottles and plastic food storage containers. These are also used in the enteric coating of medicinal pills, nutritional supplements, as lubricant or binders and emulsifying agents. They may cause adverse reproductive disorders, endocrine disruption, neurotoxicity and developmental effects on persistent exposure.

Volatile organic compounds (VOCs)

VOCs like formaldehyde, benzene, methylene chloride, xylene and ethylene glycol *etc*. are organic chemicals that have a high vapour pressure at room temperature. Most of the volatile organic compounds are manmade. These may be produced in the manufacturing process of pharmaceutical drugs, paints and refrigerants *etc*. These VOCs may show symptoms like irritation to eyes and respiratory tract, headache and visual disorders or memory impairment on short-term exposure. However, exposure to high concentration and for long-term exposure may cause many health issues like prolonged eye, chronic headache, loss of coordination, liver or kidney damage and some types of cancer.

Dioxins

These are the group of persistent environmental pollutants and are very harmful for health. These chemicals may cause detrimental effects on reproductive, developmental and immune systems and may lead to different types of cancer.

Asbestos

Common sources of asbestos are ceilings, water pipes and heating ducts *etc.* Persistent exposure of asbestos to a population may increase the risk of lung damage, pleural disorders and neoplasm of lungs.

Heavy metals

The heavy metals are mercury, arsenic, lead, aluminum and cadmium *etc*. Heavy metals like lead may pose risk and can cause numerous immunological, biochemical and reproductive disturbances in animals through surface and ground water, soil and fodder contamination by runoff (Dash *et al.,* 2019).

Possible routes of exposure to toxic chemicals

An ecosystem is made up of different communities of living things in which plants can absorb toxins through their roots and leaves from soil and water. However, animals and humans are always exposed to chemicals by the air they breathe, things they touch and what they put in their mouth. Toxic chemicals can transfer from one animal to another via food chains and affects the ecosystem adversely. Even the animals at the top of an ecosystem may go to the brink of extinction because of the food chain that exists through the different communities. Animals and humans can be poisoned to eat other animals or plants that are already poisoned, which will transfer from one to another, referred to as secondary poisoning or relay toxicity (NPIC, 2011).

Bioavailability and behaviour of chemical toxicants in land ecosystems

The ecotoxicology mainly developed as terrestrial toxicology and aquatic toxicology, terrestrial ecotoxicology studies lag aquatic ones, as stated already 20 years ago (Straalen, 2003). A lot of hazardous pollutants generated by human activities may settle in soil which acts as sinks for these chemical pollutants. Many pollutants which are a cause of concern like dioxins, pesticides, heavy metals and polycyclic aromatic hydrocarbons (PAH) are generated by industrial processing plants, coke production, combustion of woods, petroleum refining and other high-temperature industrial produced waste, *etc*. Industrial pollutants persist in the environment after short-term or long-term exposure results in the reduction of microbial diversity and good population in the soil.

The diversification and many beneficial activities of microbial population are important indices of soil quality (Lasat, 2002). The bioavailability of the chemical pollutants depends on the time of exposure either it is long term or short term. The important factors that make the soil more prone to contamination are higher organic content and pH of the soil. Chemical pollutants may bound firmly with the acidic soils rich in organic matter and may occur for longer bioavailability and residence time in soil. Changes in the behavior of living species may result in reducing population growth, alterations of ecosystem maintenance and shifts in interspecies interactions. For example, well-known farmers friend earthworms if not re-colonize or emigrate at the polluted sites due to alteration in behavior, may result in loss of their functions and unable to improve the quality of the soil (Bayen, 2012).

Bioavailability and behaviour of chemical toxicants in aquatic ecosystems

An aquatic ecosystem made up of a group of interacting living organisms is somewhat complex than the land ecosystem, which includes freshwater lakes, swamps, oceans, lakes, ponds and rivers, *etc*. All the living organisms of an aquatic ecosystem shows a wide variety of adaptations which may involve developmental stages of invertebrates and vertebrates, structural and behavioural adaptations and may be very sensitive to a chemical toxicant. The chemical stressors can change the planktonic stages of the whole invertebrate population which are bottleneck in a changing marine ecosystem. The aquatic environment gets large amounts of toxic pollutants daily from industrial wastes that

may occur in sediments or in suspended particulate matters causing many behavioral and growth changes in the marine population and the population of a living community. The disposal of sewage water and municipal wastes are important aspects of water pollution (Kanwar and Sandha, 2000). The toxic chemicals mainly cause stress *via* free radicals and reactive oxygen species generation. Exposure to these toxic pollutants depends on the particular dietary and ecological lifestyles of the aquatic organisms (Valavanidis *et al.,* 2006).

In aquatic ecotoxicology, the invertebrates are most sufferers to toxic chemicals. Toxic chemicals affect adversely their developmental stages. Ocean acidification is also an important factor that has negative impacts on developmental stages and suppression of metabolism of ocean population and is a major threat to marine calcifiers because it reduces carbonate saturation and shows deformity in skeleton formation processes (Hendriks *et al.,* 2010). Aquatic ecotoxicology is nowadays addressing a new challenge to assess the impacts of an emerging set of stressors, ocean warming, acidification and hypercapnia. Aquatic organisms are more susceptible to exposure and toxicity as compared to terrestrial organisms including mammals and in this respect; they may provide experimental data for evaluation of slight effects of oxidative stress, mutagenicity and other adverse effects of pollutants.

The bioavailability of toxic chemicals in the ocean is difficult to estimate on particular biota because of the massive dilution of toxic chemicals in water and the difficulty in receiving representative water samples from contaminated sites. However, in small ponds or rivers, it is easy to estimate because metals and other heavy contaminants get settled down in sediments and precipitated due to less flow rate of water. Aquatic ecosystems are more sensitive than terrestrial to toxic chemicals or pollutants of industrial, agricultural, or municipal origin. Among the marine species, fishes are more prone to acute toxicity to these chemicals and notably observed a few decades ago, are now rarely observed in most industrialized countries, however, even sub-lethal toxicity can lead to severe impacts on entire populations (Carr *et al.,* 2006).

Toxic effects

A large number of chemical contaminants causing toxic effects on flora and fauna of ecosystem can compromise the ecological fitness of a population of our ecosystem. The toxic effect of harmful chemicals or compounds depends on the relative sensitivity of a population or species or whole community exposed to them as well as persistency or lethality of the compound. Acute, sub acute or chronic toxicity caused by any chemical toxicant depends on its lethality and exposure time. The lethal effects in affect populations by these toxic chemicals mainly seen in acute cases, However, toxins that are not able to produce lethal effects may become a potential source for changing the behavior and vigor of an organism (Relyea and Hoverman, 2006). The chronic effect of chemicals like pesticides may pose the risk of causing abnormalities in chromosome structure, reproductive disorders, congenital defects and developmental changes upon long-term exposure to the population in our ecosystem. The possible toxic effect may occur by direct contact with a toxin by breathing, eating or may cause direct intoxication through drinking water and a various multiple intoxicants through environmental contamination (Ravikumar *et al.,* 2021). However, a toxin can also affect the species indirectly *e.g.* loss of concerned food by a chemical toxin on which particular species depended. Endocrine disruption by chemical disruptors is more frequent now a day and can affect the endocrine system of the population who are exposed to such toxic chemicals at certain doses. These disruptions can cause cancerous tumors, birth defects and other developmental disorders in the ecosystem (Gore *et al.* 2014).

Impact of ecotoxicity on a population, community and overall ecosystem level

Loss of relationship and behavior between predator and prey due to a chemical toxin results in the decline of predator population. The ecotoxicological impacts on the community level can be analyzed by the study of effects of chemical pollutants on each species of a community and their biodiversity pattern, species interactions, ultimately on whole community composition. A community that has a large number of species populations may have a better chance to recover from an ecotoxicant, rather than a community that has less species population. A species could be easily extinct due to the long persistence of toxic chemical contaminants. Protecting distinct community levels, such as large species containing populations and their biodiversity is essential for maintaining a healthy and well-balanced ecosystem (Clements and Jason, 2009).

There is a detrimental impact on part of the biotic component (vulnerable species) as related to the intensity and type of pollution and alteration to the community structure and in most cases, there is a decline in the number of species present. There are possibilities of changes in matter and energy flow within the ecosystem. There are chances of removal of larger organisms with longer life spans and the appearance of opportunistic species with short life spans exhibiting large population fluctuations in time and space (Matthies *et al*., 2004). If a population is dependent on plants that are under extinction due to a chemical toxin then dependent species may either die due to lack of food (plants) or consumption of plants already exposed to chemical toxicants. So, ecotoxicology is an ongoing battle that stems from many sources and can affect everything and everyone in an ecosystem (Zhou *et al.,* 2009).

Regulatory control and ways of prevention

Regulatory control is the most important instrument for any country against the toxicity of manmade chemicals or natural origin to reach the environment which may affect each

individual of an ecosystem. The United State Environmental Protection Agency (USEPA) is one of the leading regulatory bodies with a formal policy specifying how it would interact with governments of other countries including India to protect the health of each individual of our environment. The EPA Policy for the Administration of Environmental Programs on Indian Reservations, signed in 1984, remains the cornerstone for EPA's Indian program includes identification and evaluation of the chemical exposure and making risk assessments of chemical toxicants and predictions about their frequency to mitigate or eliminate future exposures or to reduce the severity of the health effects of individuals or whole ecosystem. Regulation and enforcement of government is making effort to keep the environment safe by the actions for the promotion of safety and health in the manufacture, transport, storage, use and disposal of chemicals and chemical products.

Manmade hazardous chemicals like pesticides, fertilizers should be properly labeled so that they must be disposed or recycled. Appropriate methods should be used for such procedures to ensure the safety of human health and the environment. Based on ecotoxicological studies and estimation of hazardous effects on the environment, toxicants may be classified. At the time of manufacturing less harmful and easily decomposable chemicals may be given preferences. Ensure to keep close track of the labeling when using a fertilizer, or pesticide. Try to look for products that will have a lesser impact on the environment (USEPA, 2011).

CONCLUSION

Ecotoxicology discipline has developed just a few decades ago which deals with the analysis of environmental contaminants and their harmful effects on all levels of living biota of an existing ecosystem. It also protects by predicting the harmful events in an existing ecosystem for future generations. Pesticides and most of the industrial waste chemicals are at the topmost harmful pollutants of ecosystem. At present, the prognosis and estimation of ecotoxicological data and its maintenance is a tough task to the engaged scientists due to various types of manmade chemical toxicants present on the terrestrial and aquatic ecosystem. Despite this ecotoxicologists are doing a great job to protect the environment by predicting and analyzing the risk assessments of these harmful chemicals on the ecosystems, in turn, safeguarding future generations and contributing to save the food resources of agriculture, aquaculture and other places of an ecosystem around the globe.

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