Impact of Xenobiotics Under Changing Climate Scenario

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1 Introduction

Xenobiotic pollutants are present everywhere and are introduced into the ecosystem as a result of human activities brought on by rapid urbanization. The most significant and crucial characteristics of xenobiotics are their increased production, environmental persistence, and biological impacts. Concerns have been raised around the world due to studies showing an increase in the number of xenobiotic chemicals discovered in aquatic systems (Embrandiri et al. 2016). In recent decades, there has been a lot of focus on their existence and destiny in urban hydrological cycle (Ternes and Joss 2007).

Animals that are a component of the food chain are the most affected by xenobiotics (Rosi-Marshall and Royer 2012). Xenobiotics are man-made substances behaving as foreign substances in both humans and animals. These have been created in a lab, such as insecticides, antibiotics, synthetic steroids, and substances found in biomedical waste (Bhatt et al. 2019). It is also possible to classify xenobiotics as the anomalous high quantities of any material present, such as the detection of antibiotic medications of humans that are neither normally consumed nor synthesized by the body itself. Occasionally, a natural chemical might be labeled as a xenobiotic when it enters into animals or people. To characterize the biochemical and physiological impacts of extraneous substances, whether they are organic or synthetic on the cellular or organs of animals, Bonjoko (2014) originally created the

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word "xenobiotic." Due to the fact that they are not recognized by any metabolic processes in microbes and plants, numerous xenobiotic substances are harmful to humans and the ecosystem.

The xenobiotic sources that are caused by humans include industrial, domestic, pharmaceutical, agricultural, and transportation sources (Essumang 2013). Xenobiotic substances include pesticides like acephate, diazinon, N,N-diethyl-meta-toluamide (DEET), and hydrocarbons as well as food products, environmental contaminants, and carcinogens. Xenobiotics can have a range of impacts, such as immunological reactions, medicine toxicity, and climate change. Many industries in the chemical and drug fields use these materials to create drugs, polymers, detergents, creams, chemicals for research labs, biological kits, fragrances, pesticides, etc. (Rieger et al. 2002). Xenobiotics are either resistant to biodegradation or merely partially biodegradable and may remain in the ecosystem for a longer period. Xenobiotics, both natural and synthetic, are a major reason of global pollution and are emitted as air pollutants, sewerage, and industrial dumping into waterbodies. Their concentration may increase as these persistent organic pollutants move up the trophic levels of the food chain (Dubey et al. 2014). Xylene, naphthalene, pyrene, and acenaphthene are only a few examples of the many xenobiotic chemicals that are reaching traditional wastewater treatment units. However, because these plants cannot process these substances, they are transmitted untreated into intricate matrices (Thakur 2008).

Xenobiotics could build up in live organisms since they are hard to break down due to their complex structures. Further bigger problems may occur as a result of their partial degeneration (Pande et al. 2020). Knowing the origin of these substances is essential for reducing the amount of xenobiotics in the ecosystem. Environmental pollutants may be emitted directly or indirectly, such as through discharge from the hospital, or these may be emitted as the by-products or as part of production. They may affect environment intentionally or unintentionally and come from moving (such as an automobile) or still sources (industry) (Saravanan et al. 2021). There are numerous regulations and directives for releasing xenobiotics into the environment and also regulating the sources that can lead to the production of xenobiotics (Stefanac et al. 2021). It is important to educate people about the immediate and long-term consequences of xenobiotics on the environment since xenobiotics that come from homes are challenging to control. This chapter will give an overview of impact of xenobiotics on environment under changing environment scenario.

1.1 Xenobiotics in the Environment

Exogenous xenobiotics are xenobiotics that an organism does not naturally make but that still enter the organism through food, medication, or environmental inhalation. Pesticides, herbicides, contaminants, pharmaceuticals, and food additives are a few examples. Wastewater and solid waste emissions from industries such as

Table 1 Different sources of xenobiotic compounds

S. no.	Sources	Example
1.	Agriculture	Pesticides, herbicides
2.	Medicine	Drugs
3.	Food industry	Additives, food
4.	Energy industry	CO_2, SO_2
5.	Transport	NOx, lead, CO_2
6.	Consumer industry	Coating, dyes
7.	Plastic industry	Number of complex organic compound antioxidant plasticizer, cross-linking agents
8.	Petrochemical industry	Oil/gas industries and refineries produced some chemicals, for example, benzene, vinyl chloride
9.	Paper industry	Paper and pulp effluent, chlorinated organic compound
10.	Pesticide industry	These are benzene and benzene derivatives and chlorinated and heterocyclic
11.	Insecticides	Dichlorodiphenyltrichloroethane (DDT)

chemical and pharmaceutical, plastics, paper and pulp mills, textile mills, and agricultural are the main direct sources of xenobiotics. The various sources of xenobiotic compounds are listed in Table 1 (Source: Mishra et al. 2019). Phenolics, hydrocarbons, various colors, painting industry effluent, herbicides, insecticides, etc. are a few of the usual residues discovered in wastewater and other industrial effluents.

Due to molecular interactions and connections, plastics are strong and durable and degrade slowly (Chamas et al. 2020). Polystyrene, polyvinyl chloride, polyethylene, and its derivatives are required for production of plastics. Modern industries use polymers made from crude oil as fuel (Tschan et al. 2012) which can be easily broken down into liquid hydrocarbons. In recent years, microbial decomposition of plastics has attracted attention; however, the fragmented substances can cause further ecological issues. Because of its toxic nature even at low concentrations and its ability to form substitute materials through oxidation and disinfecting reactions, phenolics are one of the most common chemical compounds and pharmaceutical pollutants (Postigo and Richardson 2014). Only a few of its direct environmental effects include the destruction of the ozone layer, modifications of the earth's thermal equilibrium, diminished visibility, and the addition of acidic pollutants to the air (Basha et al. 2010). Prior to wastewater disposal, phenol treatment from industrial wastewaters is crucial in reducing all of these consequences. Since phenol is a carcinogenic substance, it must be biodegraded using a process that produces few secondary compounds as well as safer products (Prpich et al. 2006).

Petroleum by-products primarily consist of saturated hydrocarbons, polycyclic (polynuclear) aromatic hydrocarbons, and a large number of organic compounds containing sulfur, nitrogen, and oxygen (Gojgic-Cvijovic et al. 2012). The significance of bio-treatments, which had an effect on reducing the toxicity of these molecules, was emphasized because remediating such petroleum compounds with physicochemical approaches is not economical and can result in higher environmental instability. In particular, petroleum-contaminated environments are a rich supply of microorganisms that may biodegrade these by-products (Prakash et al. 2014). In comparison with branched alkanes, straight-chain saturated hydrocarbons (n-alkanes) are more susceptible to microbial breakdown. As a chemical's aromaticity grows, biodegradation becomes less sensitive since it takes greater effort to break degrade aromatic components (Milic et al. 2009).

Dye adhesion on microbial surfaces is how this is accomplished. Subsidiary or indirect sources of xenobiotics include things like pharmaceuticals, artificial fertilizers, pesticide residues, and nonsteroidal anti-inflammatory drugs. Synthetic dyes are widely employed in a number of industrial operations, such as the textile industry, printing, and photography (Al-Tohamy et al. 2022). These dyes typically feature intricate aromatic molecular structures. These businesses frequently utilize colors such as azo, anthraquinone, and phthalocyanine (Vigneeswaran et al. 2012; Shahid et al. 2013). These break down into aromatic compounds that can be linked to cancer and mutation. Due to the presence of negatively charged ligands in cell wall components, microorganisms have the ability to not just remove dyes but also detox them (Hemapriya and Vijayanand 2014). This is accomplished by dyes adhering to the surface of microorganisms. Nonsteroidal anti-inflammatory medication, pharmaceutical items, synthetic fertilizers, pesticide residues, etc. are examples of secondary sources of xenobiotics. Pharmaceutically active substances serve as a secondary source of xenobiotic released directly by pharmaceutical companies or as hospital effluents after they have had their desired clinical implications into the environment in either their whole or fragmented form. According to Iovdijova and Bencko (2010), they mostly consist of hormones, anesthetics, and antibiotics that bioaccumulate in an organism and are transferred to other organisms via different trophic levels. Although biomaterials made from synthetic polymeric materials are biocompatible, they can degrade in the body into hazardous chemicals (Baun et al. 2008). Despite being indirect sources, they have a negative impact on the ecological cycle.

Soil and aquatic pollution can harm local flora and wildlife as well as cause hazardous substances to be absorbed and accumulated in food chains. Planning for the long-term disposal of industrial waste in ecosystems requires research on the bioaccumulation characteristics of different ecosystems (Iyovo et al. 2010). Pesticide bioaccumulation and biomagnifications can cause harmful behavioral effects in both animals and humans. Although these pesticides are now prohibited worldwide, dichlorodiphenyltrichloroethane (DDT) and benzene hexachloride (BHC), which have a half-life of one decade, accumulate in plants or in its parts. Nonsteroidal anti-inflammatory medications (NSAIDs) are a class of pharmaceuticals used to treat fever, bodily pain, and inflammation in both humans and animals (analgesic aspects) (Parolini 2020). According to sources, the number of vultures in Pakistan has drastically decreased as a result of the usage of diclofenac sodium in livestock, with a 95% loss in 2003 and a 99.9% fall in 2008 (Oaks et al. 2004). Xenobiotics come from different sources and enter organisms as well as into the aquatic ecosystem.

These can also travel through the food chain and enter the whole ecosystem. Thus, the negative impacts of these compounds are to be kept in mind before taking into consideration their economic benefits.

1.2 Environmental Impact of Xenobiotics

Xenobiotic pollutants are present everywhere and are introduced into the ecosystem as an outcome of human activities brought on by rapid urbanization. The common contributors of xenobiotics include agriculture and pharmaceuticals (Fig. 1). While the consumption for pharmaceuticals is currently rising as a result of population expansion, this also leads to xenobiotics increment in the environmental components (Embrandiri et al. 2016). The various medications ingested have caused toxins to be discharged into aquatic areas, which have multiple immediate and long-term repercussions on natural ecosystems. Ecosystems are directly impacted by xenobiotics in terms of change in characteristics of the community, structure of the community, diversification, productivity and transfer of energy, and succession and density of population (Grechi et al. 2016). Changes in productivity, reproduction, genetics, and composition will have an impact on population dynamics, an impact on all of the trophic levels and also on the ecosystem as a whole (Gianfreda and Rao 2008; Bhat 2013). Globally, herbal drugs and various botanical plant species are becoming more popular, and these substances may also have some xenobiotic characteristics. Some plants pollute the environment and have the potential to affect the biology of species living in waterbodies (Guengerich 1997a, b). Some plants pollute the environment and may have an impact on aquatic creature's biological processes.

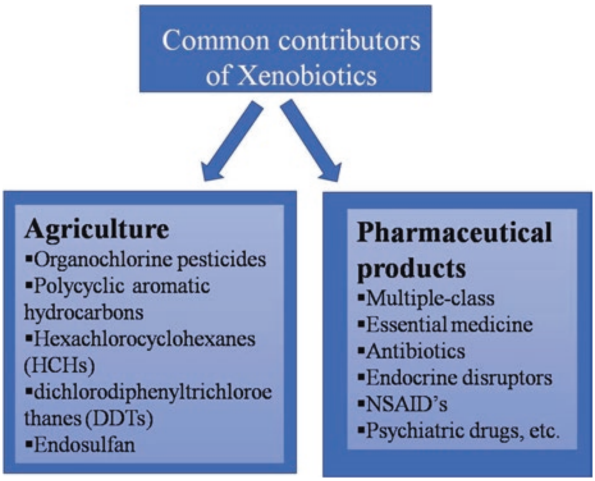

Fig. 1 The common contributors of xenobiotics

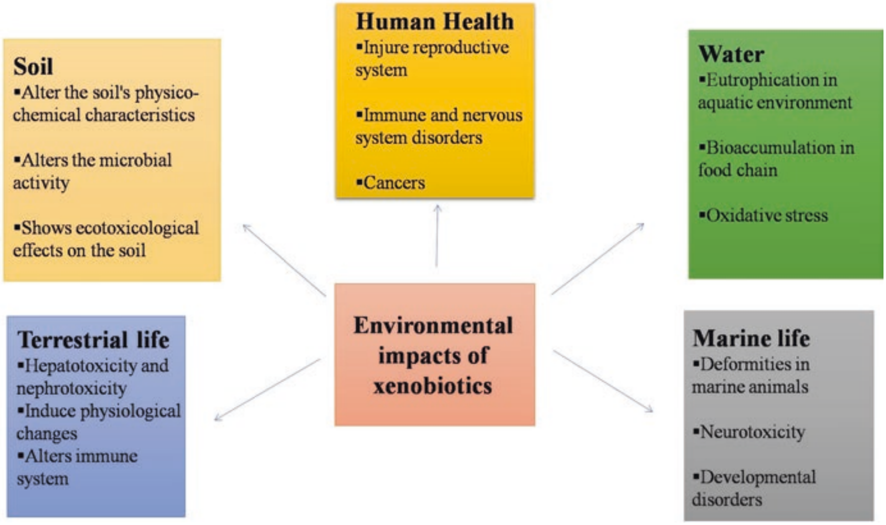

Fig. 2 Impacts of xenobiotics on environment

The environment, plants, animals, and people are all adversely affected by significant xenobiotic substances (Fig. 2). In the below sections, the impact of these xenobiotic compounds on water, air, and soil is discussed.

1.2.1 Impact of Xenobiotics in Water

Until the early 1960s, the primary sources of xenobiotics in surface water and groundwaters throughout most of Western Europe were industrial operations like the manufacturing of coal and steel, as well as the chemical industry. These days, there are a wider variety of sources available. As a result of the introduction of ever-stricter regulations that specifically target industrial pollution, for instance, the Integrated Pollution Prevention and Control Directive, the manufacturing facilities are typically no longer the main sources of xenobiotic emissions to urban waters. For instance, using cleaning supplies and personal care items like dishwashing liquid and laundry detergent results in the immediate release of a variety of xenobiotics into sewerage.

In addition, it is now believed that chemicals that leak or evaporate from products and building materials contribute more to xenobiotics in wastewater than was previously thought (Gupta et al. 2022). Plasticizers, flame retardants, and perfluorinated compounds from various materials, such as flooring, carpeting, and wall coating, evaporate or leak into the indoor atmosphere. Chemicals released into the air by items like furniture, textiles, TVs, and refrigerators can collect in dust, get inhaled, and ultimately end up explicitly or implicitly in the sewage system. During washing, textile agents are liberated.

Building materials, including paint, concrete, metals, and plastics, also cause pollution. Vehicular exhaust, catalysts, and tires release metals, polycyclic aromatic hydrocarbons (PAHs), and other pollutants into the environment (Revitt et al. 2004). Common xenobiotic receptors can exist in traditional sewage treatment plants, and prior to being released into aquatic environment, it must undergo treatment with municipal wastewater. Water bodies may include trace amounts of metals, xenobiotics, compounds such as PAHs, phthalates, and insecticides (Essumang 2013). The main pharmaceutical breakdown by-products and these xenobiotic substances have an impact on traditional sewage remediation facilities and may check processes like nitrogen fixation. The oxidation of ammonium to nitrite, the initial stage in the nitrification process, is sensitive to the presence of xenobiotic chemicals. Under uncontrolled conditions, xenobiotics can completely stop the biological nitrogen process by inhibiting the first stages of nitrification (Essumang et al. 2009). Xenobiotic substances such as pharmaceuticals, PAHs, phthalates, biocides, and corrosion inhibitors released into surface water can reach the groundwater via leaching, and thus, it should be strongly prohibited as the discharge of these compounds and may impair the biology of marine ecology (Al Shibli et al. 2021). Important biological markers of xenobiotic contamination include some aquatic organisms (Fent et al. 2006). Xenobiotic chemicals can infiltrate the ecosystem as metabolites or in their natural forms. Xenobiotic agents in humans can track the process of intake and excretion with wastewater disposal pathways (Singh et al. 2016a, b).

Overuse of personal grooming products along with pharmaceutical remnants is one of the top challenges faced by the scientific community. Xenobiotics such as surfactants, oil and wax, perfumes, biocides, UV filters, and pigments are all ingredients found in personal care and cosmetic goods (Eriksson et al. 2003). Most customers favor products with synthetic flavors and smell over those without knowing their chemical composition. Most softeners, washing powders, cleaning detergents, etc. also include significant amounts of fragrances like nitro and polycyclic musks. Since cosmetics typically contain significant amounts of water, preservatives, or biocides like triclosan, it has been demonstrated that fragrances, biocides, and UV blockers are released into receiving urban water channels (Poiger et al. 2004). There has been a widespread change in the use of musk fragrances in various items, according to data from some countries beginning in 1980. For instance, the consumption of polycyclic musks reduced in contrast to earlier levels when the bulk of consumer goods in Northern Europe stopped using nitro musk perfumes. The maximum concentrations are currently determined for more odorous chemicals like tetramethyl acetyloctahydronaphthalenes (Bester et al. 2010). These modifications in how different substances are used partly emerge from ecological concerns, but they also respond to changes in the fashion industry. Consumer magazine articles highlighting concerns about nitroaromatics and polycyclic musks attributing to a decline in their usage have helped boost public understanding of environmental problems in nations like Germany and Scandinavia (Tobler et al. 2007). The discovery of individual service products in the aquatic ecosystems continues to be a concern despite changes in consumption trends (Tilman et al. 2001). The most recent class of emerging toxic compounds discovered in the urban environment is illicit drugs. These substances, as previously indicated medicines, unchanged or slightly altered, enter the environment through urban wastewater effluents (Castellano-Hinojosa et al. 2023).

Pharmaceutical leftovers along with their transformed products and their metabolites are released into the ecosystem at trace levels by irrigation techniques or discharges of treated wastewater. They become "pseudo-persistent" when they are continuously introduced into the ecosystem by regular irrigation or other sorts of discharge activities. Their prolonged release may have hazardous or other negative consequences on aquatic or terrestrial ecosystems. Additionally, their potential uptake by plants must also be taken into account (Rosi-Marshall and Royer 2012). The pharmaceutical groups most usually encountered in treated effluents around the world include antibiotics, lipid regulators, anti-inflammatory medications, beta-blockers, cancer medications, birth control pills, and other hormones (Hernando et al. 2003; Nikolaou et al. 2007). The natural excretions of humans result in the presence of steroid hormones in the urban wastewater. With androgenic compounds receiving comparatively little research, estrogenic hormones have received the majority of focus. While men and nonpregnant women also emit estrogenic steroids, their levels are often lower than in pregnant women. Male fish may produce egg yolk proteins in their testicles in response to estrogenic substances, per reports by Jobling et al. (1998). Synthetic steroid hormones like mestranol and ethinylestradiol are used for birth control and hormone therapy. Because it is more potent and less biodegradable than natural hormones, ethinylestradiol's destiny and mass flow have received special attention. There are facts in the published studies that cannot be simply explained by normal excretions exclusively, but it is extremely challenging to evaluate at large volumes in ambient samples. Even if every woman in the specific research region received ethinylestradiol treatment and was excreting this substance entirely unmetabolized, another source, such as manufacturing effluents, would still be necessary (Bester et al. 2010).

For several reasons, xenobiotics such as biocides are presently found in many daily products. These include biocides used for extending the expiry date of products like cosmetics and paints, preventing fruit rot (e.g., carbendazim), preserving wood, stabilizing construction materials (mold and algae growth inhibition), and preventing the growth of vegetation on flat roofs. More significant to urban aquatic systems are construction-related biocides than agricultural pesticide-related ones, and greater levels of biocides like triclosan have been found in wastewater (Wilson et al. 2003). The mass movements of many of these chemicals, however, are still poorly understood. In addition to being widely used anticorrosives and deicing and anti-icing agents in the aviation industry, the complexing agent's benzotriazole and tolyl triazole are also used in dishwashing detergents in urban households (Bucheli et al. 1998; Kupper et al. 2006). Extremely high median benzotriazole concentrations (1 g/L) were found in surface water as a result of inadequate elimination within wastewater treatment facilities (Giger et al. 2006; Weiss et al. 2006). These substances are included among the xenobiotics that are present mostly in higher concentrations in urban groundwater due to surface water leaching, along with other xenobiotics like carbamazepine, sulfamethoxazole, and amidotrizoic acid (Hollender et al. 2007).

1.2.2 Impact of Xenobiotics on Soil

Some xenobiotic substances, like pesticides, have an impact on both the yield and the functions of the soil. The toxicity of xenobiotics may have an impact on specific soil variables. Different issues could be brought on by certain xenobiotics that persist in the environment, and their presence in the soil for longer period could result in the following:

1. These substances can be taken up by the fauna and may build up in their edible parts.
2. Soil bacteria break down xenobiotic substances, and their metabolites may build up in the soil environment.
3. Xenobiotic substances could build up in the food web and alter the balance in the ecological environment (Alexander 1965).
4. Mineralization that is not complete can produce dangerous intermediate chemicals.

Secondary metabolites of natural resources led to the discovery of new medicines, which frequently act as precedents for the creation of synthetic antibiotics (Kumar et al. 2014).

1.2.3 Impact of Xenobiotics on Air

Humans release large amounts of xenobiotic contaminants into the environment without even being aware of their toxicological impacts. Certain xenobiotic substances, like PAHs, are just environmental contaminants. These organic substances are all around us and are released into the ecosystem as a result of incomplete combustion of resources. Different processes, such as heating and burning fuel, coal, and agricultural waste and occasionally even grilling food, are some of the sources of xenobiotic chemicals, such as PAHs. Trucks, ships, airplanes, and cars are examples of mobile sources that might emit these chemicals into the environment. Major sources of PAHs in the environment are industrial processes such as electricity generation, aluminum manufacture, cement kilns, and oil refineries (Essumang 2013). The distribution and recurrent patterns of food chains and webs are disrupted by these xenobiotic chemicals, which also have an impact on the different trophic levels. These substances may have an impact on the climate and ecosystem and are also carcinogenic resulting in a wide range of problems in humans (Essumang 2013).

2 Pesticides as Xenobiotics in Urban Soil

Pesticides are a general term for the primary groups of chemicals used to interfere with living organism's development and metabolism (Al-Saleh 1994). Insecticides include organochlorines, organophosphates, carbamate esters, pyrethroids, acetamides, triazoles, triazines, and neonicotinoids (Pandya 2018). Environmental scientists are concerned about organochlorines when discussing pollution driven by pesticides since they have a higher probability to do so (Tripathi et al. 2020; Dhuldhaj et al. 2023). Common pesticide classes include chlordane, DDE (dichlorodiphenyldichloroethylene), DDT (dichlorodiphenyltrichloroethane), HCHs (hexacyclochlorohexanes), and DDD (dichlorodiphenyldichloroethane) (Da Silva Augusto et al. 1997). Pesticides and other harmful substance's activity depend on certain environmental reactions that occur naturally. A complex set of chemical, biological, and physical interactions occurs when a pesticide component combines with soil, water, or a living thing (Mahmood et al. 2016).

Due to manufacture, transportation, improper storage, usage, and other factors, pesticides may be discharged into the urban ecosystem and result in significant environmental issues (Relyea et al. 2005). For instance, significant doses of the herbicide glyphosate are released into the environment during the formation of this chemical (Ren et al. 2018). The possible emission routes of pesticides in polluting soil, water, air, plant tissues, and ultimately the ecosystem are inadequate storage, poor mixing, packing into tanks, and washing and rinsing the tanks after application of pesticides (Ramakrishnan et al. 2019). Inadvertent spillage also contaminates soil with pesticide, negatively affecting both human health and the environment. A large amount of soil, water, and air pollution can be caused by pesticides used carelessly or even by spray drift or wash-off from treated plants or seeds (Luo and Zhang 2010; Ramakrishnan et al. 2019). Long-range air transmission occurs after the use of organic pesticides that are volatile and persistent, such as fumigants, polychlorinated biphenyls, and organochlorine pesticides (OCPs) (Meftaul et al. 2020). The soil also serves as a sink for all of these pesticides that are discharged into the environment by direct application, unintentional leakage from storage, spreading sewage sludge on fields, and atmospheric deposition (Pokhrel et al. 2018). According to Ma et al. (2011), persistent organic pollutants (POPs) have accumulated in the soil as a result of global warming and are linked to high amounts of organic matter. According to Yu et al. (2020), urban soil in China was a source of low chlorinated PCB emissions. Numerous studies have already proven the damaging consequences of such illicit substances (opiates, cannabinoids, amphetamines, cocaine, etc.) (Boleda et al. 2009; Wick et al. 2009). Additionally, sewage sludge biosolids applied to soil and wastewater treatment plants (WWTPs) are major sources of pesticide emissions in cities. According to Köck-Schulmeyer et al. (2013), most of the pesticides found in WWTPs are of urban and agricultural origin. In reality, biosolids included around 143,000 compounds registered for industrial use in the European Union (Clarke and Smith 2011). As a result, organic pollutants can readily contaminate the environment, whether biosolids are employed in agricultural or urban areas.

3 Antibiotics as Xenobiotics in Soil

Effective natural antibacterial biosynthesis is present in soil microbial communities and plant roots (Thomashow et al. 2019); these communities frequently contain fungal, pseudomonad, and actinomycete species (Raaijmakers et al. 2002; Butler and Buss 2006). According to the reports, producing antibiotics in naturally occurring microbial communities may enhance microbial competitiveness, fitness, defense, signaling, and gene regulation (Mavrodi et al. 2012). Antibiotics are therefore viewed as a component of soil disease management. Fast breakdown, significant substantial sorption to the surrounding soil, and quantities that are close to the detection limit make it difficult to detect and quantify natural antimicrobials in nutrient-poor soil (Raaijmakers et al. 1997; Mavrodi et al. 2012). Antibiotic resistance is thought to have emerged in naturally occurring microbial communities as a result of exposure to antimicrobial substances that present in the ecosystem (Singh et al. 2021). The reaction to man-made synthetic antibiotics can likewise be altered by such exposure (Aminov and Mackie 2007). More and less strains that are resistant to antibiotics are likely found in soil microbial communities, indicating coadaptations to some anthropogenic antimicrobials. A major issue is the pollution of terrestrial soil and aquatic ecosystems with anthropogenically produced antibiotics, which starts with animal excretion and hospital waste (Kumar et al. 2019).

The majority of antibiotics have relatively short half-lives and are intended to be easily eliminated after administration (Pico and Andreu 2007). Antibiotics are susceptible to microbial change when introduced to the solid phase of soil. Sulfonamides are one class of chemicals that have been widely employed in pig production and animal husbandry (Zhou et al. 2012). The use of photodegeneration in soils as a secondary pathway for the degradation of pharmaceuticals is constrained by insufficient illumination (Ozaki et al. 2021). Because of surface runoff and particle-facilitated environmental transfer, all antibiotics might disperse (Burch et al. 2014). This explains why the majority of antibiotics added to manure-containing soils typically end up in the uppermost layer of soil (Ostermann et al. 2013; Pan and Chu 2017). One of the greatest threats to public health in the twentieth century is the enrichment of antibiotic-resistant bacteria in soil environments (Singh et al. 2021). By adding animal dung from animals treated with antibiotics to soils, which is thought to be a reservoir for resistance genes, these genes are introduced into the food supply (Rauseo et al. 2019). The spreading of sulfonamide resistance genes to soil bacteria is caused by the use of pig dung (Hruska and Fránek 2012). Furthermore, even though the cows that produced the manure were not given antibiotics, adding cow manure to soil accelerated the proliferation of genes that code for lactamases and naturally present antibiotic-resistant microbes (Allen 2014). Human infections could increase as a result of the proliferation of resistance genes to antibiotics. The possibility of creating new resistance increases when the human microbiota carrying the residues is introduced into the ecosystem where the bacteria-enriched resistant components are present (Scarpellini et al. 2015). Thus, it is emphasized that residuals from hospitals should be kept to a minimum at all times in order to prevent the exchange of genetic material (Sire's and Brillas 2012). Due to its possibility for spreading pathogens into the environment and high pathogenic potential, hospital discharge poses a threat to human health due to its high pathogenic potential and propensity for transferring infections into the environment (De Souza et al. 2006). In addition to medicines, antibiotics, antiseptics, pain killers, trace metals, and non-metabolized drugs, these discharges also transmit resistance-causing genes via horizontal gene transfer into the urban ecosystem. Opportunistic infections, frequently present in free-living organisms, can attain resistance characteristics through extensive genetic exchange during effluent treatment (Szczepanowski et al. 2008).

The ability of wastewater treatment systems (WTS) to reduce the chemical and physical properties of the pollutants to permissible level is used to measure how effective they are, frequently omitting crucial biological parameters (such as microbial abundance). The transmission of antibiotic-resistant microbes into urban areas, however, may be facilitated by hospital sewage treatment systems, according to a growing body of data (Chitnis et al. 2004; Sayah et al. 2005; Kim and Aga 2007; Prado et al. 2008; Fasih et al. 2010; Robledo et al. 2011). Hospital waste is regularly thrown into water bodies and municipal wastewater systems in developing countries, frequently without any kind of treatment meant to reduce the risks to the public's health (Meirelles-Pereira et al. 2002). Therefore, one of the biggest problems facing healthcare facilities is handling hospital sewage and healthcare waste to reduce possible concerns for nearby populations. Action must be taken right now to stop the spread of the numerous hospital and aquatic ecosystem reports of resistant and multiresistant bacteria. Since numerous isolates of the genus *Pseudomonas* have been found in hospital effluents and frequently exhibit antibiotic resistance, this genus is of particular importance (Fuentefria et al. 2011). The diverse range of ecological niches that *Pseudomonas* species may invade includes water, sewage, soil, plants, and animals (Goldberg 2000). This genus contains a number of potentially harmful species that are known for their significance to both health and the economy (Widmer et al. 1989).

4 Xenobiotics and Changing Climate Scenario

Xenobiotics are a significant environmental stressor, along with eutrophication and global warming (Niinemets et al. 2017). The interaction between xenobiotic compounds and climate change, however, has only been the subject of a small number of researches; it would be intriguing to examine how xenobiotics respond to changing climatic conditions. There's a good chance that xenobiotic usage will rise soon (Navarro et al. 2000; Bloomfield et al. 2006), potentially causing significant environmental pollution. Solubility in water and evaporation rate, and other ecological parameters such as moisture and temperature differences, the origin of the molecules, and density of fine particulates, all influence the presence of xenobiotics in the ecosystem and also affect it. Climate change and the environment are impacted by the release of xenobiotic chemicals from vegetation and soil, wind-driven soil erosion, and airborne pollution emissions (Mosleh et al. 2005; Coscolla et al. 2011).

4.1 Xenobiotics with Changing Temperature

Temperature variations cause numerous alterations in xenobiotic substances and also have an impact on the dynamic process of marine ecosystems (Gagne et al. 2007). A significant rise in temperature can boost organism's metabolic activity and reduce the pace at which xenobiotics, especially toxicants, are absorbed by the environment. As surroundings change, xenobiotic characteristics and behavior patterns will change which could have an impact on the global climate (Brubaker and Hites 1998; Wania 1999; Sinkkonen and Paasivirta 2000; MacDonald et al. 2002; Meyer and Wania 2008). Temperature variation could cause changes in biotransformation in water, soil, as well as some biota. It has the potential to raise the xenobiotic pollutant's levels and make it easier for them to enter the water bodies (MacDonald et al. 2002). Rising soil and water temperature can accelerate the breakdown of xenobiotics, potentially increasing the level of xenobiotic contaminants from eluent depletion procedures (Sinkkonen and Paasivirta 2000; Moyo et al. 2020). As temperatures rises, there may be a steadily rising volatilization of xenobiotic compounds in the ecosystem. They will be susceptible to transportation damage and photodeterioration in these situations (Feitkenhauer et al. 2001; Scheyer et al. 2005). Certain biological parameters can influence xenobiotic behavior and alter species migration patterns, which can have an impact on the changing climatic conditions. Some climate change distributional mechanisms such as climatic variations will modify the recurrence and quantity of xenobiotics used in farming (Choudhary and Kumar 2019).

4.2 Xenobiotics with Increased Pesticide Use

Pesticide use is an inevitable step in present farming practices, and changing climatic conditions affect pesticide use as well as pesticide losses to the environment (Noyes et al. 2009). In the event of a changing climate, the occurrence of dry months, wetter humid months, and excessive temperature and rainfall events will likely increase (Salinger 2005; Wang et al. 2013). Pesticide losses to the environment will increase as the climate changes. The reasons could be increased rainfall frequency and intensity, which has led to an increased likelihood of leaching through soil macropores, as well as higher precipitation events, which significantly raise pesticide losses through the surface runoff (Meite 2018). Leaching of pesticides brought on by rainfall may occasionally be countered by a stronger thermal deterioration brought on by a high temperature. However, higher temperatures can cause extreme drought, which slows the degradation of pesticide (Castillo and Torstensson

2007; Dhakal et al. 2019). It is generally known that soil organic matter and pesticides can bind together to reduce pesticide leakage (Zhang et al. 2020). However, as a result of the decay of organic material brought on by greater temperatures, its capacity to bind pollutants may be diminished. As a result of the interaction of these different variable parameters, pesticide fate forecasting is highly challenging. The balance between sorbed and non-sorbed pesticides will be altered by periodic freezing and thawing, which will modify the amount of pesticides that are available for decomposition, leaching, and runoff (Boe 2017). In addition to these immediate effects, climate change might lengthen the growing season for crops, which would give pesticides more time to breakdown. However, an extension of the crop growth season during wet months may make the leaching event worse as the frequency of rainfall occurrences is predicted to rise.

Crop agronomic practices are being affected by climate change as well, which affects the type and quantity of pesticides required and, ultimately, the fate of those pesticides (Dadhich and Meena 2014; Delcour et al. 2015). It is anticipated that increased pesticide use will result from elevated precipitation and temperature events that can enhance the incidence of pests and diseases and alter weed flora. Therefore, increased usage of insecticides and fungicides may eventually replace occasional usage of pesticides in temperate areas. The growth of bacteria is influenced by climate change, and the functional makeup of the soil has a big impact on the network of bacteria that break down pesticides (Chakraborty et al. 2012; Ukhurebor et al. 2021). Pesticides and other xenobiotics have thus raised serious concerns since how they are handled will determine how healthy our ecosystem is (Bernardes et al. 2015). It is clear that the significant climate change will have an impact on agronomic practices. Temperature, precipitation, and wind action are examples of weather variables that have an impact on the environmental retention and mobility of pesticides (Chen and McCarl 2001; Tiryaki and Temur 2010; Gentil et al. 2020).

Pesticide degradation, reemission behavior, mobility, source-sink connections, availability, transport, and lethality throughout food chains are all directly impacted by climate change (Delcour et al. 2020). Climate change may also result in an increase in the application of pesticides because crops will be under more stress due to a potential rise in pest and disease incidence (Shrestha 2019). However, the effectiveness of insecticides will decline because of their high rate of degradation in a changing climate scenario (Delcour et al. 2015). The formation of more toxic metabolites could result from altered pesticide degradation pathways caused by climate change, which could have detrimental consequences on both human and aquatic health (Tripathi et al. 2020; Singh et al. 2022). Because of the changing climate and the high leaching of pesticides, there is a possibility of more frequent pesticide detection in groundwater and other waterbodies (Bloomfield et al. 2006). Although there is a lot of data regarding what will happen to persistent organic pollutants (POPs) in the event of climate change, cumulative information on pesticides is alarming. Organochlorine pesticides such as DDT and toxaphene are included in persistent organic pollutants (POPs), according to the UN Stockholm Convention, and their fate under a scenario of climatic change has been extensively discussed

(Hardy and Maguire 2010). However, due to the widespread use of pesticides like atrazine, chlorpyrifos, and aldicarb, less information is accessible, making it difficult to predict what will happen to them over time as a result of shifting climatic circumstances (Noyes et al. 2009).

4.3 Effect of Xenobiotics on Humans Under Changing Climatic Scenario

Changing climatic scenario can result in bioaccumulation and biomagnification of xenobiotics, such as organic pollutants in the environment; thus, concerns exist regarding their impact on animals at various trophic levels (Borga et al. 2010; Derby et al. 2021). The importance of such pollutants has recently grown as various xenobiotics have been identified as culprits of hormonal disruption, compromising the functionality of both reproductive and endocrine systems in animals as well as humans (Maurya and Malik 2016). Such pollutants can persist in lipid molecules for longer times resulting in chronic disorders such as birth deformities, decreased immunity, interruption of patterns of development, neurological problems, genetic abnormalities, intellectual disabilities, respiratory problems like asthma, and behavioral abnormalities in both people and animals (Harrison et al. 1997). Environmental pollutants are a reason for concern in the domain of reproductive and immunological dysfunction, hormone difficulties, cancer, and neurobehavioral disorders, according to the findings of ecological studies undertaken (Kelce et al. 1995; Kavlock et al. 1996). A decrease in resistance, diseases, neurobiological dysfunction, developmental anomalies, and tumor induction can all be consequences of exposure to these toxins in children and unborn children. Children are more sensitive as they progress through their developmental phases because cells during developmental stages are more vulnerable to environmental xenobiotics and hence more prone to being exposed to and influenced by these toxic molecules (Crinnion 2009).

4.4 Effect of Xenobiotics on Species Diversity and Ecosystem

Some microbes in an environment rely on species relationships, but xenobiotics may cause these connections to break, potentially resulting in the loss of a keystone species (McClanahan et al. 2002). A keystone species is one that has a strong connection to other species further down the food chain. There are numerous other links to keystone species since they govern the organization and structure of an entire group (Jordan 2009). The disappearance of a keystone species could result to the loss of other species in the ecosystem, which could have an effect on the trophic level, food chain, and numerous chain linkages (Mills et al. 1993; Hale and Koprowski 2018). A large proportion of xenobiotic chemicals are utilized in the ecosystem that ultimately reaches the soil, where they are transferred into plants through the nutrient cycling. Microorganisms present in the soil combine with some xenobiotics, which have an impact on nutrient cycle processes in an ecosystem, either directly or indirectly. Xenobiotics present in soil inhibit the process of nitrogen fixation, which is essential for the growth of flora (Lu et al. 2020). Natural pollinators like honeybees and lepidopterans are especially vulnerable to xenobiotic chemicals. Natural pollination is suffering as a result of the extinction of pollinator species and the decline in pollinator species induced by xenobiotics, which might result in lower seed and fruit yield (Ara and Haque 2021). As a result, xenobiotics may have an impact on ecological behavior, economy, and climate change (Landis et al. 2003).

5 Conclusions and Future Recommendations

With increased population and urbanization, there is a considerable risk of xenobiotic exposure in our food and drinking water systems. The presence of hazardous xenobiotics has been identified in items ranging from personal care to agricultural purposes. Despite the fact that there are a variety of water treatments and monitoring technologies, xenobiotics are quickly turning into a hazard to our ecosystem, since long-term consequences are unavoidable. Since xenobiotics have the potential to disrupt the ecosystem, especially air and aquatic bodies, additionally to healthcare, the vast majority of scientists are currently focusing on the influence of climate change on xenobiotic metabolism. Increases in temperature will speed the breakdown of xenobiotics; these xenobiotics may penetrate both surface water and groundwater and damage aquatic life. The food cycle and all tropic levels are impacted by xenobiotic contaminants that infiltrate food chain and the ecosystem. The addition of xenobiotics to humus is controlled by a number of environmental variables that change with the season, weather conditions, soil type, and agricultural methods. To lessen the future effects of xenobiotics on the environment, it may be more economically advantageous to innovate novel synthetic compounds that integrate with the naturally existing metabolic abilities of the bacteria. Soil is the initial chain in the food production process in terms of ecological health, and after that it significantly affects both humans and animals. As a result, investigations on xenobiotics in the food system must be linked between ecological and microbial perspectives.

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