Xenobiotic Pollution and Its Impact on the Environment

Subjects: Biology

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In the industrial revolution and urbanization era, the global environment's poisoning by a complex mixture of xenobiotics has become a major environmental threat worldwide. Xenobiotic contaminants such as azodyes, phenolics, polycyclic aromatic hydrocarbons (PAHs), halogenated compounds, personal care products (PCPs), pharmaceuticals' active compounds (PhACs), pesticides, nitroaromatic compounds, triazines, and chlorinated compounds adversely affect the environment by their long-term persistence and slow or no biodegradation in the ecosystems. Xenobiotic pollution of the environment is a global concern caused by anthropogenic activities such as urbanization and population expansion. The enormous amounts of harmful compounds released into the environment result in widespread ecosystem contamination. Prominent substances such as polycyclic aromatic hydrocarbons, heavy metal ions, pesticides, fertilizers, and oil derivatives are found in soil, sediment, and water.

Keywords: xenobiotics ; enzymes ; microorganisms ; metagenomics

1. Impact of Xenobiotics on Soil

Xenobiotics such as dioxins, 1,1,1-trichloro-2,2-bis (4-chlorophenyl) ethane (DDT), polychlorinated biphenyls (PCBs), chlordane, polycyclic aromatic hydrocarbons (PAHs), and nitroaromatics are the primary threat to the soil ecosystems of developed nations. However, there are reports that a few other pollutants such as benzene, nitrobenzene, toluene, xylene, aniline, ethylbenzene, trinitrotoluene/dibenzofurans, and chlorinated solvents could be xenobiotic, especially in the soil ecosystem [1]. Cosmetics and personal care products also contribute as xenobiotic pollutants, especially parabens in soil and air [2] and azodyes in soil, due to one or more aromatic rings and azo bonds [3].

Anthropogenic activities that stimulate these chemical compounds in soil include industrial activities, fuel combustion, military movement, use of pesticides, fertilizers, and soil modifications in high-production agricultural practices that cause detrimental effects [4][5]. Chemical characteristics of xenobiotics and site conditions influence their bioavailability, and distribution in soil, with soil organic matter(SOM) playing an important role [6]. Pesticides (herbicides, insecticides, fungicides, algaecides, bactericides, etc.) are chemicals used for crop protection and management and are the most widely used toxins in the environment over the last century. Millions of tonnes of pesticides are produced and spread each year around the world [7]. Environmental factors such as temperature, soil pH, and moisture significantly impact the behavior of persistent organic pollutants (POPs) in the soil. One possible strategy is binding xenobiotic compounds to soil organic matter (SOM). Many xenobiotics and their degraded products resemble humic precursors and are frequently used in humification. It has been suggested that this naturally existing process is used to neutralize environmental contaminants found in soil. Inorganic minerals interact well with xenobiotics and play a crucial role in xenobiotic transformation [8].

2. Impact of Xenobiotics on Water

The diffusive and point contributions of anthropogenic activities such as urban industrial production, transportation, building construction, and housing pollute surface and groundwater in urban areas. The presence of chemical substances and indicators of human activity in urban water systems has been the subject of numerous kinds of research [9]. In sewage treatment plants, some common xenobiotics sensors must be treated with municipal wastewater before being discharged into aquatic systems. Several trace metals, xenobiotic substances, and synthetic organic chemicals, such as PAHs, phthalates, and pesticides, are also noticed in different water bodies [10]. Xenobiotic substances can enter water bodies through different sources. These include (a) airborne particulate deposition; (b) surface water running from roads and land surfaces; (c) continuous inputs from commercial and sewage effluents, as well as fossil fuel products; (d) solid waste burning [11]. Xenobiotics substances also reach the water table through the leaching process, which affects the biological integrity of aquatic ecosystems [12]. The presence of xenobiotic pollutants induces oxidative stress among

aquatic organisms. A recent study by Ibor et al. [13] observed a significant increase in oxidative stress response in the fish fauna of an artificial Eleyele lake, Nigeria.

3. Impact of Xenobiotics on Plants

Xenobiotics affect the plant's physiological and morphological characteristics in many ways; for example, particulate matter from the automobile sector changes the photosynthetic pigments, protein, cysteine contents, leaf area, and the foliar surface of plants [14]. The extensive range of xenobiotics with diverse structures and designs causes changes in gene expression, regulation, and signal transduction in the higher plants. Xenobiotics, such as phytohormone analogs, have intrinsic interactions with plant hormone receptors and signaling pathways [15]. Metals that are needed for plant growth, such as Cu, Zn, Fe and Mo, have deleterious effects at high concentrations, but metals that are not essential for plant growth, such as Pb, Cd, Hg and As, have adverse effects even at low concentrations in plant growth [16]. Xenobiotics induce DNA damage in the case of plants due to the production of reactive oxygen species and oxidative stress. The signaling pathways get deregulated due to xenobiotic toxicity in plants by influencing various signaling receptors such as G-Protein coupled receptor and receptor tyrosine kinase [17].

4. Impact of Xenobiotics on Marine Life

Xenobiotics negatively impact several metabolic processes of marine animals, particularly in developing fish embryos, causing morphological and functional abnormalities, retarded growth leading to death. Altered body shape, body abnormalities, hatching delays, and death have also been recorded in fishes [18]. Dyes and paints are also considered xenobiotics because they restrict sunlight penetration and inhibit gas exchange even if they are present in the traces [19]. Pesticides and herbicides are significant sources of xenobiotic pollution in marine life. Chemicals, including organophosphorus, nitrophenols, morpholine, synthetic pyrethroids, and carbamates, are often used in agricultural and daily life; later on, these substances enter various water bodies, including the sea and ocean. Insecticide such as β-Cypermethrin is a severe threat to the life of marine life and invertebrates [20].

5. Impact of Xenobiotics on Terrestrial Animals

Xenobiotic exposure is also possible due to application or inoculation of pharmacologic drugs or other chemicals as part of a typical conditioning or experimental operation. The consumption pattern and disposition of xenobiotics determine their toxicity. In addition, the mechanical and chemical properties also play a vital role in determining the toxicity of these xenobiotics' compounds [21]. The xenobiotics and their metabolites may induce physiological changes in animals by altering immunological functions, cardiovascular indices, or organ systems. For example, ivermectin, a popular anthelmintic and acaricide, is harmful to some dog breeds and mouse strains due to a lack of p-glycoprotein [22]. Compared to controls, pazufloxacin and meloxicam cause oxidative damage in rabbits, including decreased glutathione content and considerable lipid peroxidation [23].

6. Impact of Xenobiotics on Human Health

Xenobiotics pollute the environment, so their assimilation by living species has increased dramatically in recent decades. Introducing these substances into ecosystems may increase allergic reactions, organism mortality, genetic alterations, immune system lowering, metabolic disorders, and disruptions in natural ecosystem processes [24]. Humans are exposed to a wide range of xenobiotics, such as medications and non-essential exogenous substances, throughout their lives by ingesting, breathing, dermal contact, or any other intravenous route of exposure that may represent a risk to human health [25]. Xenobiotics may alter the human gut microbiome leading to dysbiosis, which is indirectly linked to various undesirable health outcomes. The continuing biotransformation process consistently seeks to balance the metabolic activation of xenobiotics to the detoxification of their mutagenic metabolites, as it evolved to neutralize and remove body-invading agents. When this balance is disrupted, chronic diseases and DNA damage in the human body can occur. The toxicity of xenobiotics varies significantly between individuals. These oscillations are caused by the organism's enhanced sensitivity and intraspecific variability. A large spectrum of substances is utterly foreign to the human body. These chemicals have harmful and irritating effects on various human organs and systems directly and indirectly [26].

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