Environmental Contaminants as Significant Threats to Ecological Health: A Mini Review

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Abstract

Environmental contamination has been established as one of the major global problems, posing a serious threat to ecological health and systems. These contaminants are spread through various channels, and find their way into the food chain via varying natural and anthropogenic sources and vary in concentrations within the ecosystems. The presence of these contaminants within the environment is majorly instigated by anthropogenic activities. The persistent accumulation and ubiquity of environmental contaminants in species, predisposes living organisms to toxicity effects. Hence, toxic effects of environmental contaminants to humans and animals include haemato-biochemical changes, immunosuppression, reduction in fitness, interference in reproduction, oxidative stress damage, genotoxicity, neurotoxicity, histopathological and behavioural alterations. There is need to curb levels of exposure to environmental contaminants through the promotion of eco-friendly activities that could enhance ecological health.

Keywords: Environmental contaminants, Wildlife health, Toxicology, Human health

Introduction

Ecological health is a term often used to describe the condition of an ecosystem that is sustainable, conserves all life-forms and that society deems acceptable and beneficial (1). It is basically an ecological term used in relation to both human health and the condition of the environment. In addition, it focuses on the health of flora and fauna species existing in different environmental matrices (terrestrial and aquatic). The detrimental effects of anthropogenic activities on ecosystems have continued to receive growing attention over the past decades (2, 3, 4). These activities have been identified to generate environmental contaminants whose persistence and bioaccumulation within the environment is of huge concern. Environmental contaminants are largely distributed through diverse environmental media resulting from various industrial processes and anthropogenic inputs of the industrial age. Nowadays, technological advancement, scientific knowledge and socio-economic awareness, have made individuals to become more concerned about the extensive distribution of environmental contaminants. As a matter of fact, environmental contamination has been reported as one of the major distressing ecological crises confronting the world, particularly in developing countries.

The impact of contamination on the aquatic and terrestrial environment has reached a level of concern that cannot be overstressed. As such, the effects of contamination are seen not only at organismal and local levels, but at community, ecosystem and regional levels.

These contaminants portend ecological threats and potential risks, to living organisms. Hence, there is a need to identify and evaluate their impacts on terrestrial and aquatic life. This mini review focused on the critical issues of exposure, contamination, source and effects of environmental contaminants and their significance as threats to human, animal and ecological health.

Environmental contaminants

Plastics and Microplastics

Plastic is a terminology that denotes a group of organic polymers obtained from petroleum sources. It is obtained from organic polymers such as polyethylene (PE), polyvinylchloride (PVC), polystyrene (PS), nylon and polypropylene (5). Plastic is one of the most commonly utilised and manufactured materials globally, due to its outstanding features. It can undergo different degradation pathways such as photo, thermo-oxidative, biological, mechanical, thermal, and hydrolysis (6). However, high demand for and use of the plastics as well as poor management of their wastes have given rise to negative impacts on ecosystems. Although plastics may disintegrate into smaller pieces over time, and become 'microplastics', an enormous proportion is anticipated to remain in the environment in one form or another (7). Microplastics are water-insoluble polymeric matrices or synthetic solid particles, with irregular or regular shape and size extending from 1 µm to 5 mm. These microplastics form a major threat in the environment (8). Microplastics have been categorized into primary and secondary forms. Primary microplastics (like plastic pollution pellets and microbeads) are produced intentionally or manufactured specifically in the microplastic range size while secondary microplastics (like fibres) are mostly formed by the disintegration and/or weathering of bigger plastic items to smaller pieces either through wear or from their discharge into the environment. These microplastics find their way into drinking water, food and other edible products and eventually end up in human and animal bodies, indirectly or directly (9, 10, 11).

Microplastic pollution is an emerging environmental threat generating a lot of concern in terrestrial and aquatic ecosystems (12). There is an abundance of microplastics within the marine and freshwater environments. These microplastics have been found throughout the water column, in sediments; in the respiratory structures, digestive systems, and tissues of aquatic species (13, 14, 15). Microplastics are typically hydrophobic and have large surface areas, allowing them to accumulate organic pollutants such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons [PAHs], polybrominated dichlorodiphenyltrichloroethane [DDT], and diphenylethers [PBDEs] (16, 17). Additives associated with microplastics such as bisphenol A (BPA) and phthalates are known disruptors of the endocrine systems of aquatic species, affecting their reproduction, kinesis and growth (18). The impacts of exposure to microplastics depend on translocation and accumulation within tissues, potential for trophic transfer and capability of the species to excrete the particles (19). In fact, the potential toxicity of microplastics has been reported to emanate from three pathways (14). These include; leakage of plastic additives; stress of ingestion; and exposure to microplastics-associated contaminants. Whereas the effects of microplastics on algae may be positive in locales where algae are abounding, there is a tendency for the disruption of food chain especially when primary producers are negatively impacted (21). In plants, exposure to microplastics has been implicated in the reduction in growth and quantity of cellular chlorophyll-A content (for example: *Scenedesmus obliquus)* (20). In lower animals, microplastics can also be ingested by mussels, crabs, zooplankton, corals, sea cucumbers, barnacles, polychaete worms, molluscs, amphipods crustaceans, and fish (22, 23). Specifically in crustaceans, chronic microplastics exposure may lead to developmental and reproductive implications. For instance, chronic exposure of *Tigriopus japonicas* nauplii and adults led to reduction in fecundity and survival as well as developmental delays in most offsprings (24). In *Daphnia magna*, it instigated neonate and clutch size reduction as well as defects in the offsprings (20). In some species, the uptake of microplastics may result into alimentary canal obstruction and connected appendages (25), while microplastics may be absorbed by the epithelial cells of the gastro-intestinal tract thereby causing toxicity (26). Nevertheless, the negative effects of microplastics differ among species, with some animals being affected only at certain stages of their life cycle. In addition, microplastics can easily move from one trophic level to another within the food chain through lower animals (27, 28). Thus, being transferred to animals high up in the food chain including humans via consumptive utilization of polluted water or food (29). The ingestion of microplastics by humans may occur when the whole of a contaminated species is eaten (e.g. oysters, mussels, anchovies, sprats). Microplastics may also intensify the levels of persistent organic pollutants in the tissues of fish and shellfish, causing additional danger to those who consume them (30).

To control microplastic pollution within the environment, there is need for the identification of their sources and transport, occurrence and factors influencing their dispersion. It is highly pertinent to have a rock-solid comprehension of the social, ecological and economic influence of plastics and microplastics. This will ensure a worldwide transition from the production and use of plastics to more environmentally friendly products (34). Pico and Barela (35) opined that strict emphasis must be made on source control through awareness programs and legislation; as well as remediation and compact clean up, to expunge the microplastics already available within the aquatic and terrestrial biota.

Heavy Metals

Heavy metals are momentous environmental contaminants whose toxicities are of concern and have ever-increasing implications for evolutionary, ecological, environmental and nutritional motives (36). Heavy metal contamination is a worldwide phenomenon receiving a great deal of attention, because of its influence on ecosystem functionality and structural integrity (37, 38). There is a lot of debate on the actual definition of the term *heavy metals*. Most scholars have now agreed to define heavy metals using their atomic mass, high density and/or chemical toxicity in relation to living organisms. Heavy metals are seen as metallic elements with comparatively high densities and toxicity even at low concentration (39). They are among the most severe environmental pollutants and could remain in the environment for extended periods of time (3). They are ubiquitous and make-up an actual diverse family of elements commonly differing in their biological functions and chemical characteristics. Some heavy metals are vital for life and are known as essential elements, which support many physiological and biochemical processes. However, they may be toxic when available in large quantities (40). Non-essential metals do not often have any important function they play in the living organisms, but they may also cause toxicity as they can affect the quantity of an essential element in the body (41). Some examples of essential elements include Zinc, Copper, Chromium, Cobalt, Manganese and Iron, while those of non-essential elements include Lithium, Barium and Zirconium (42). The origin of heavy metal contamination could be linked to either natural or anthropogenic sources with great variations in levels within the ecosystems (2, 44). Thus, heavy metal pollution has been linked to anthropogenic activities such as mining and metal processing, foundries, smelting, leaching of metals from sources such as waste dumps, landfills, runoffs, road works and automobiles (45). In addition, heavy metal utilization within the agricultural sector has been identified as an ancillary origin of heavy metal pollution, through pesticide use, fertilizer application, insecticide use and others. Some anthropogenic activities (or products) with their associated heavy metals are presented in Table 1. Furthermore, natural causes can also cause an upsurge in heavy metal pollution from sources such as metal corrosion, volcanic activity, metal sediment re-suspension, evaporation from soil and water, soil erosion and geological weathering (46).

The heavy metal distribution and effect within the environment are often reliant on the characteristics of the metals and impacts of environmental influences (49). The major concerns with heavy metal presence are related to their quantity, toxicity, bioavailability and capability to bioaccumulate in biological tissues, resulting in several deleterious health effects (2).

Table 1: Anthropogenic Activities (or Products) and their Associated Heavy Metals

Anthropogenic Activity	Associated Heavy Metals
Inorganic Agriculture	Pb, Cd, Cr, As, Zn, Cu, Ni, Sb, Co, V
Mining	Au, As, Cd, Pb, Zn, Cu, Hg, Fe, Al, Mg, Se
Coal Combustion	Pb, Hg, Ni, Sn, Cd, As, Sb
Sewage	Cu, Zn, Ag, Pb, Hg, Ni, As, Cr, Cd
Industrial Effluents	Cr, Ni, Cd, Cu, As, Pb, Zn
Automobile Exhaust	Cd, Pb

Source: Adapted from (43, 47, 48)

Note: Pb = Lead; Cd = Cadmium; Cr = Chromium; As = Arsenic; Zn = Zinc; Cu = Copper; Ni = Nickel; Sb = Antimony; Co = Cobalt; V = Vanadium; Au = Gold; Hg = Mercury; Fe = Iron; Al = Aluminium; Mg = Magnessium; Se = Selenium; Sn = Tin; Ag = Silver

For instance, the availability of heavy metals and their toxicity may have an inhibitory influence on plant growth, their photosynthetic activity, enzymatic activity, and the build-up of other plant nutrient elements, while also disrupting the root system (50, 51).

For animals, contact with heavy metals even at low levels have been shown to cause histological, biochemical and morphological alterations in animal species (52). As a matter of fact, heavy metal contamination, such as lead poisoning, could threaten the conservation status of some species (1). Lead has no function in metabolic activities of species but possess the capability to induce tissue toxicity even at low concentrations (53). Though metals such as manganese and iron have functions in metabolic activities and are necessary for development, growth, and body maintenance, their elevated levels in the body have consequent negative health effects (54).

Cadmium has detrimental impact on varying levels of the trophic chain due to its bioaccumulation and eventual toxic impact on kidneys, testes, liver, foetus, immune systems and lungs (55). These effects have been connected with carcinogenesis and teratogenesis (45, 56). Cadmium has also been documented to cause pneumonitis and pulmonary oedema, acute hepatic and renal failures in mammals (57). Zinc poisoning has been documented to result in epigastric pain, pancreatitis, vomiting, ataxia and breathlessness (58). Inhibition of growth, muscular dystrophy, anaemia, impaired reproduction and decreased longevity have been reported as effects of copper toxicity (59). Mercury toxicity has been implicated in decreased yearly survival, inhibited immunocompetence, altered hormone profiles, embryotoxicity, motor incoordination and reduced reproductive success (60, 61). Various levels of genotoxicity, cytotoxicity and clastogenicity have been linked to Chromium toxicity (62, 63), while arsenic toxicity has been implicated in the alteration of cell proliferation, altered DNA methylation, co-carcinogenesis, and tumor formation (64). Generally, the toxic effects of heavy metals on the health and well-being of fauna species may include immunosuppression, reduction in fitness, interference in reproduction, oxidative stress damage, histopathological and behavioural alterations, and so on (1, 36, 65, 66).

Heavy metals enter animals through direct inhalation, ingestion, dermal contact, absorption or transfer via the placenta (67). These metals cannot be disintegrated and are non-biodegradable, hence species may decontaminate metal ions by concealing the main element within a protein or placing them in intracellular granules in an insoluble state to be egested through the faeces (45). This has then subsequently contributed to their persistence within the environment (68).

Phthalates

Phthalates are a group of synthetic organic substances that are broadly utilized in the form of plasticizers within the polymer industry to advance the flexibility, softness and extensibility of a variety of plastic products (69). Notably, they are used for the production of polyvinyl chloride (PVC), making it effortlessly processable. Well over 3 million metric tonnes of phthalates are produced annually (70). They make up about 40% (w/w) in plasticized PVC and can be included in many products for overall utilization, including various solvents, medical devices, toys, tubing, personal care and household products, pesticides, adhesives, glues, food packaging, electronics, and building materials (71, 72). These industrial substances have become broadly distributed within the ecosystem and have been seen as the most abundant unnatural environmental pollutant (72, 73). There are varying types or classes of phthalates, with mounting indications that the types have different impacts on ecological health. Edjere *et al.* (70) reported that they exist primarily as diethylhexyl phthalate (DEHP), dibutyl phthalate (DBP), and in much lower concentrations such as dimethyl phthalate (DMP), diethyl phthalate (DEP), Butylbenzyl phthalate (BBzP or BBP), Di-n-octyl phthalate (DnOP), and Diisononyl phthalate (DINP). Di-2-ethylhexyl phthalate (DEHP) has been regarded as the most common phthalates, utilized as plasticizers in polymer products to ensure plastic flexibility (74).

Another classification was documented recently by Dominguez-Romero and Scheringer (76), and consist of four groups: *group A* (whose lead compound is DEHP); *group B* (whose lead compounds are BBP and DBP); *group C* (whose lead compounds are DEP and DMP); and *group D* (whose lead compounds are DIDP, DINP, DnOP). Each of this phthalate group comprises of either one or several parent phthalates that follow similar metabolic pathways. Most times phthalates are not chemically attached to materials and can migrate at a persistent proportion from plastic products upon exposure with fats or liquids or under pH or temperature variations to the surrounding environment (77, 78). The physicochemical characteristics of phthalates generally regulate their environmental kinetics, industrial usage, and human exposure routes (79). Exposure to phthalates has been via inhalation, ingestion and dermal or parenteral routes (80). Even though the route of exposure does not generally have a crucial impact on the pathway of phthalate metabolites, it has been reported to have an impact on the bio-availability and elimination of phthalates. Nevertheless, there is need to evaluate the rate of exposure of humans and animals to phthalates, considering their ubiquitous nature, general utilization and environmental concern. Fortunately, phthalates are susceptible to photo-, anaerobic- and biological degradation, implying that they are mostly not persistent within the environment (81).

While some phthalates have been seen to have endocrine-disrupting properties (69), some others display anti-androgenic, estrogenic and anti-thyroid activities (84, 85). For instance, Matsumoto *et al.* (86) noted a relationship between shorter duration of pregnancy and higher DEHP serum levels. This and other reproductive effects such as decreased semen quality and cryptorchidism may be due to the capability of monoesters of phthalate to navigate the placental barricade and gain entrance into the foetal umbilical cord blood (87). Some studies have reported alterations in male reproductive parameters including DNA sperm damage, decreased reproductive hormone levels, and anogenital distance due to environmental phthalate contact (88, 89). Phthalates are also metabolized in many tissues of animals, including intestine, liver, and plasma (76). In rats, it has been reported to cause peroxisome proliferation in the liver thereby leading to cancer (72). Reports have also indicated that long-standing dietary exposure to dibutyl phthalate (DBP) and diethyl phthalate (DEP) brought about multi-generational impacts on reproductive outcomes and body weight in rats (90), while parental contact with di (2-ethylhexyl) phthalate (DEHP) led to adversative transgenerational impacts on behaviour and stress hormones (92), and reproductive capability in male mice (92). Prenatal contact with an environmentally germane phthalate mixture was also reported to have pointedly increased uterine weight, induced enlarged cystic ovaries, caused breeding complications, reduced fertility-related indices, and disrupted estrous cyclicity in mice (83). It has also been opined that DBP is accountable for the solid decline in reptiles around the world (82). In another study, phthalates, principally DEHP, lowered testicular weight, contributed to the atrophy of seminiferous tubules, and decreased sperm production, in male rats (75). Phthalates are a major threat to environmental health and there is need for adequate restrictions on their usage, while increasing the utilization of peculiar replacements especially plant-based alternatives as plasticizers.

Persistent Organic Pollutants

Persistent Organic Pollutants (POPs) are carbon-based chemicals largely produced during industrial activities, either as by-products or intentionally and remain in the environment for extended periods of time (93). They are mostly of anthropogenic origin and are complexes with relatively high toxicity and environmental stability. They have the capability to move in food chains; possess high bioaccumulation, bio-magnification and long-range transport potential (94). They are the most popular class of man-made lipophilic compounds (95). Few natural sources such as vegetation fires and volcanic eruptions are also accountable for the release of these contaminants into the environment (96). Most POPs are resistant to biological, photolytic, and chemical degradations (97, 98). Persistent organic pollutants include many groups of pesticides, drugs, and industrial by-products (99, 100).

The Polyaromatic hydrocarbons (PAHS) do not firmly belong to the POPs and were only known as POPs under the Aarhus Protocol (101) due to the fact that they could be metabolized and, as such, avert additional bioaccumulation (102). Despite this, PAHS have now been documented as POPs in many studies as a result of their continuous release and lipophilicity (103, 104, 105).

Exposure to POPs may be via dermal contact, inhalation, and ingestion (106). The major human contact pathway to POPs is from wide-ranging environmental exposure to these contaminants through the consumption of dairy products, meat, and fish that have been predisposed to POPs (107). Reports have indicated that prenatal contact to POPs may be connected with increased blood pressure (108), and reduction in birth weight (109). Initial toxicity reports opined that dioxin is the major toxic compound among the POPs due to its attraction to the aryl hydrocarbon receptor (110). However, more recent anthropological studies have proposed that the damaging impacts of low-dose POPs may have been underestimated (95, 111). POPs when ingested, manifest in animals over time. For instance, Jenssen (112) described the impacts of hexachlorobenzene, dichloro-phenyl-dichloroethylene, and oxychlordane on hormonal disruption especially in Arctic species, resulting in ecological disorder. The impacts were noted in sex steroid hormones, thyroid hormone, and cortisol; and led to behavioural and morphological alterations. In zebra fish, POPs were discovered to cause alterations in liver enzymes like changes in alanine aminotransferase, gamma-glutamyl transferase, bilirubin, and alkaline phosphatase as well as embryo defect (113). Omonona *et al.* (114) reported the alteration of biochemical parameters and tissue changes in guinea pigs exposed to single oral dose of cypermethrin (pesticide).

The exposure to low levels of POPs can result in serious implications and negative health impacts, including impairment to critical tissues, cardiovascular effects, teratogenic effects, miscarriages and mortality in humans and animals (115, 116). Since wide-ranging POPs utilization produces organism resistance leading to altered ecological equilibrium and threatened habitats of endangered species, there is need for the enforcement of strict regulations against the deliberate production and use of most of these POPs.

Conclusion

Exposure to environmental contaminants is a serious issue that threatens human health and the survival of living organisms. The contaminants compromise ecological integrity, create imbalances and disrupts natural processes. Most of these contaminants emerge from anthropogenic activities and have been implicated in the decline of species and the spread of environmental health problems. Therefore, human activities that are not environmentally friendly should be minimized to the barest minimum. Protection of the environment from contamination is very crucial to the survival and existence of all living species and must be a top priority, as well as, concern for humans.

Conflict of Interest

The author has not declared any conflict of interests.

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