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Mini Review

Environmental Pollution and Animal Behavior: A Forerunner to Promote Health and Well Being

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Abstract

The medical community has been made aware of toxicological disaster by animal behavior, frequently long before negative health effects in humans. An animal's first indication that it is uncomfortable in its surroundings is a change in its usual conduct, which should not be disregarded. A change in animal behavior within an ecosystem may indicate that the environment is not suited for humans as well. Although an animal's sensitivity to a pollutant varies by species, almost all pollutants have the potential to cause more or less obvious behavioral changes, increased susceptibility to stressors and diseases, respiratory system damage, neurological issues, decreased production and reproduction, etc. Chemicals, geochemicals, biological, and physical entities that humans purposefully or unintentionally release into the environment and have negative impacts are known as environmental pollutants. A frequent bioindicator of environmental pollution is aquatic life, insects, and other species.

Keywords: Environmental Pollutants; Animal Behavior; Bioindicator

Introduction

Everything that exists naturally, whether biotic and abiotic, is considered to be a part of the natural environment. Earth's enormous diversity of plant and animal species, as well as the various conditions required for their survival, are reflected in the diversity of natural environment. Every living thing has a crucial role to play in the delicate and complicated tapestry of the natural world. This delicate equilibrium is constantly threatened by pollution in all of its manifestations, which frequently has disastrous effects on animals. Every living thing, from the biggest mammals to the tiniest invertebrate, is susceptible to the negative consequences of environmental pollutants. Similar to humans, animals follow physiological behavioral patterns that alter in response to a variety of internal and external stimuli. Environmental pollutants serve as negative stressors. Various animal species serve as indicators of pollution and animals exposed to pollutants exhibit altered behavior such as disorientation, problems interacting with humans and other animals, as well as disruptions in the structures and functions of internal organs resulting in reproductive problems, respiratory, digestive symptoms, etc. [1].

Environmental pollutants are chemicals, geo-chemicals, biological or physical substances intentionally or accidentally released by humans into the environment, causing harmful effects. Bioindicators of environmental pollution commonly consist of aquatic organisms, insects, and other organisms [1]. Sievers., *et al*. [2] bring forth that insecticides increase the frequency of abnormal swimming and decreases escape responses to simulated predator attacks in amphibians. However, little fluctuations in air quality force certain insects to reposition themselves, affecting other plants and animals that associate with them. Animals may relocate to a cooler location (if thermal pollution is present) or quieter location (if noise pollution is present). Light pollution can interfere with daily and seasonal movements, such as migration and have a detrimental effect on nocturnal creatures [3,4].

The medical community has been made aware of toxicological catastrophes by animal diseases, frequently long before negative health effects in people manifest [5]. A rare and serious neurological disease outbreak happened in Minamata Bay, Japan, in 1956. Ingestion of locally caught fish with extraordinarily high methylmercury contents was subsequently identified as the cause. The most severely affected individuals were exposed *in-utero* (through maternal consumption of affected fish during pregnancy).

These kids had severe developmental delays, blindness, and convulsions, among other central nervous system abnormalities, from birth. It was observed that cats in the community displayed aberrant neurologic behavior followed by death throughout the six years before to this outbreak. Ataxia and convulsions were among the symptoms of this behavior, which was eventually identified as the result of methylmercury intoxication [6,7]. The great London fog of 1952, in which a temperature inversion caused severe and long-lasting smog to hang over the city, was responsible for more than 4,000 human deaths. The etiology was not recognized until nearly a year after the event. Retrospectively, sudden death of a group of cattle due to respiratory-related issues at a stock show in London in 1952 was indicative of the air pollution problem before the human deaths were recognized. Had the deaths of the cattle been identified as a sign of public health concern, it might have provided guidance for public health measures to reduce human disease. Similarly, in 1971 in Times Beach, Missouri, an outbreak of equine sudden death brought to the attention of public health authorities the highest level of dioxin exposure in the United States. Animals are frequently a more sensitive indicator of chemical hazard of public health concern due to differences in exposure pathways, receptiveness and latency phases of sickness. If this is acknowledged, such information can help guide public health action to reduce or remove a threat [8].

Environmental toxicology has evolved in recent decades from an amalgamation of various scientific disciplines including biology, toxicology, environmental chemistry, biochemistry, pharmacology, and ecology. The overall objective of environmental toxicology is to understand the impact of chemical pollutants on ecosystems, encompassing all levels of biological organization– from biochemical interactions in biological organisms to whole animals, populations, and ecosystems [9].

The study of Ecotoxicology stems from the recognition that:

- Existence of humans on earth mainly depends upon the well-being of other species and also upon the accessibility of clean air, water and food.
- Anthropogenic chemicals as well as naturally occurring chemicals can have detrimental effects on living organisms and ecological processes.

Ecotoxicology is thus concerned with how environmental toxicants, through their interaction with humans, animals, and plants, impact their wellbeing Ecotoxicants belongs to a class of substances that have two general properties: they are discharged into the environment and they have the potential to impact on ecosystem at relatively low concentrations [10]. Ecotoxicants can be classified into following categories:

- Heavy metals
- Biocides and their by-products
- Industrial organic chemicals
- By-products of industrial processes and combustion
- Pharamceuticals
- Miscellaneous compounds

Heavy metals

Heavy metals comprise of a diversified group of elements have different chemical properties and biological functions. Heavy metals persist in the environment due to natural processes and human activities; create substantial threats to ecosystems and human health. Presence of metals in surrounding environment is result of natural weathering processes of Earth's crust, mining, soil erosion, industrial discharge, urban runoff, sewage effluents, air pollution etc. While some metals found in our environment are essential nutritionally, others, like "heavy metals" are not. Heavy metals form an important group of environmental pollutants due to their toxic effects on plants, animals and human being. Heavy metals can persist in nature for years thus get accumulated in soils and plants. Soil pollution due to heavy metals results from natural and manmade activities. Manmade activities such as mining, smelting operations, agriculture processes etc. can increase the levels of various heavy metals such as Cadmium, cobalt, chromium, palladium, arsenic, nickel etc. in soil up to dangerous levels [11].

In modern world presence of heavy metals in soil is a major concern for the health of living being. Singh and Kalamdhad [12] documented that heavy metals like arsenic, mercury, cadmium, lead etc. are not essential for growth of plants, as they are not involved in any known physiological function in plants. However, copper, cobalt, iron manganese, molybdenum, zinc etc. are required for normal growth and metabolism of plants, but these elements may lead to poisoning if their concentration exceeds the optimum level. The health of humans and animals may be at risk when heavy metals are absorbed by plants and then build up throughout the food chain [13]. One of the primary ways that heavy metals enter the food chain is through plant roots [14]. Numerous parameters, such as temperature, moisture content, organic matter, pH, and nutrient availability, influence the absorption and accumulation of heavy metals in plant tissue [15].

Many heavy metals can have long-term negative impacts on human health via consumption of plants. Heavy metals have an effect on aquatic life because pollutants migrate from different point or diffuse sources, creating accidental combinations in the environment. As a result, aquatic species, particularly fish, which are one of the main sources of protein-rich food for humans, are in grave danger. Using Cadmium as an example of heavy metal toxicity, the environmental hazard of this heavy metal first came into the spotlight with the historical outbreak of itai-itai-byo or "ouch-ouch disease" in Japan in 1945. Many scientists believe that cadmium is one of the most hazardous trace elements in the environment because of its long-term persistence, the increased use of cadmium and emissions from its production, the production of lead and steel, the burning of fossil fuels, the use of phosphate fertilizers, and the disposal of waste over the past few decades.

In 2013, the World Health Organization estimated that lead poisoning resulted in 143,000 deaths, and contribute to 600,000 new cases of children with intellectual disabilities, each year [7].

Many heavy metal contaminants affect the cognitive ability of fish, with possible cascading effects on fitness such as the ability of organisms to survive and reproduce. Contamination of water with aluminium impairs the learning ability of Atlantic salmon Salmo salar, with serious consequences on the ability of fish to learn and remember information to escape predators, find food and mates, and avoid polluted areas [16].

Biocides and their by-products

According to European legislation, a biocide is any chemical or microbe that is designed to use chemical or biological methods to eliminate, discourage, render harmless, or regulate any dangerous organism. According to US Environmental Protection Agency (EPA) biocides are "a diverse group of poisonous substances including preservatives, insecticides, disinfectants, and pesticides used for the control of organisms that are harmful to human or animal health or that cause damage to natural or manufactured products". When compared, the two definitions roughly imply the same, although the US EPA definition includes plant protection products and some veterinary medicines.

When pesticides are discharged into the environment, they can have a variety of negative ecological effects, from short-term disruptions to long-term impacts on an ecosystem's regular functioning. Even if pesticides have positive impacts on agricultural and public health, their use typically has negative effects on the environment and public health. Because of their high level of biological toxicity (both acute and chronic), pesticides occupy a special place among environmental pollutants. Toxic chemical agents are what pesticides are by definition. A pesticide is usually capable of harming all forms of life other than the embattled pest species. On account of this behavior then, they can best be described as biocides (capable of killing all forms of life). Even though some pesticides are described to be selective in their mode of action, their range of selectivity is only limited to the test animals [17].

Pesticides applied to the environment have shown to produce long term residual effects or acute fatal effects when not properly handled. Organochlorine pesticides for example have shown to be persistent in the environment, the result of which find their way to contaminate ground water, surface water, food products, air, soil and may affect human being through direct contact. Pesticides exposure to humans have been well documented to be the root cause of some diseases such as cancer, respiratory diseases, skin diseases, endocrine disruption, and reproduction disorders. A pesticide may eliminate a species essential to the functioning of the entire community, or it may encourage the dominance of undesired species or it may simply decrease the number and variety of species present in the community. This may disrupt the dynamics of the food webs in the community by breaking the accessible dietary linkages between species [18].

Some natural pollinators, such as honeybees and butterflies, are very susceptible to the effects of pesticides. Application of pesticides to crops in flowering stage can kill honeybees, which act as pollinators. Pesticides have the potential to kill bees and thus responsible for pollinator decline, the loss of species that pollinate plants, including through the mechanism of Colony Collapse Disorder [19], in which worker bees from a beehive or Western honey bee colony unexpectedly disappear. The USDA and USFWS evaluated that US farmers may suffer the loss of at least $200 million a year from reduced crop pollination because pesticides applied to fields eliminate about a fifth of honeybee colonies in the US and harm an additional 15 per cent [20].

A large proportion of pesticides used in the environment ultimately reach the soil where soil building processes and the cycling of nutrients back into living plants is accomplished. Pesticides can affect the soil organisms involved in these processes directly or indirectly thus hinder the usual nutrient cycling in the ecosystem. When the natural nutrient cycling in the ecosystem is obstructed by pesticides or other sources of pollution, it will lead to decline in soil fertility and soil productivity [18].

Some of the most notable consequences of pesticides have been observed in birds, particularly in the birds which are at higher trophic levels of food chains, such as bald eagles, hawks and owls. These birds are generally prone to pesticide residues particularly for organochlorine insecticides through terrestrial food chains. Pesticides may kill the birds which feed on grains and plants and by this the extinction of many rare species of ducks and geese has been reported. As the number of insects in agriculture fields decreased due to use of insecticides the population of insect eating birds such as partridges, grouse and pheasants have also been decreased. Thus, rare, endangered, or threatened species are at risk of extinction when even a small number of individuals are lost. Some important examples of pesticide-induced bird deaths include the insecticides diazinon and carbofuran, which are known to harm birds in numerous regions of the world [21].

A significant effect of pesticides on environment has been the widespread mortality of fish and marine invertebrates due to the contamination of aquatic systems by pesticides. It may be due to the agricultural contamination of waterways through fallout, drainage, or runoff erosion and from the release of industrial effluents containing pesticides into the water source. Historically, most of the fish in Europe's Rhine River were killed by the discharge of pesticides, and at one time fish populations in the Great Lakes in USA became very low due to pesticide contamination. Some pesticides, such as pyrethroid insecticides, are extremely toxic to most aquatic organisms. It is apparent that pesticides significantly reduce the world's fish production. Furthermore, recent laboratory studies of endosulfan and fenitrothion in the tilapia species from Lake Victoria in Tanzania indicated that this species of fish have ability to absorb endosulfan and fenitrothion from water and these pesticides can rapidly distributed in the organs. Their respective bioaccumulation factors are 33 and 346 L/kg fresh weight [22].

A most widely used pesticide, atrazine have been reported to change the male frogs (African clawed frog; *Xenopus laevis*). Adult frogs exposed to atrazine turn female one in ten (10 per cent). These male frogs are missing testesterone and all things controlled by testesterone including sperm production. So their fertility is as low as 10 per cent when treated in isolation, but when treated with normal males, they stand a zero chance of reproducing. Although 10 per cent of these mutant females can successful mate with male frogs, their offspring are all male because they are genetically male frogs. This ultimately affects the sex ratio of frogs and a serious threat to the species' existence [23]. Kihansi spray toads is one among the world`s rarest amphibian species that threatened to disappear from Tanzania's natural habitat. The species was initially identified in 1996 while conducting an environmental impact analysis for a sizable new hydroelectric project in the southern Tanzanian Udzungwa Mountains. The Kihansi spray toads got their name because they only existed in a five-acre area that was sprayed by a waterfall from the Udzungwa Mountains. Among other reasons that contributed to the decline is the use of pesticides in the environment. To rescue this rare species of toads, a colony of them was taken to Bronx zoo and Toledo zoo in USA where they were reared and bread in laboratories for 10 years [24].

Industrial organic chemicals

Biphenyl serves as the fundamental structural unit of a family of synthetic chlorinated organic chemicals known as polychlorinated biphenyls (PCBs). From 1929 until their manufacture was illegal in 1979, PCBs were produced domestically. They range from thin, light-colored liquids to yellow or black waxy solids, and their toxicity varies as well. PCBs were utilized in hundreds of commercial and industrial applications, such as electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics, and rubber products; in pigments, dyes, and carbonless copy paper; and in numerous other industrial applications because of their non-flammability, chemical stability, high boiling point, and electrical insulating qualities.

Although structurally belonging to chlorinated hydrocarbons, they are not pesticides. However, because of their wide use and resistance to degradation in the environment, PCBs are known as one of the major organochlorine pollutants found in the environment. The food chain is heavily contaminated with PCBs, worldwide. The production of PCBs was prohibited by the US Congress in 1979 and the Stockholm Convention on Persistent Organic Pollutants in 2001 due to their toxicity and designation as a persistent organic pollutant. The majority of the chemicals in this group that share structural similarities and a hazardous mode of action with dioxin are the basis for concerns regarding the toxicity of PCBs. Other chemicals in the category are similarly linked to harmful effects like neurotoxicity and endocrine disruption. Therefore, the current maximum containment level as stated by the EPA for PCBs in drinking water systems is 0.5 ppb (parts per billion, or 0.5 μg/l). PCBs are steady compounds and do not decompose easily. This is due to their chemical inability to oxidize and reduce in the natural environment. Furthermore, PCBs have a long half-life (8 to 10 years) and are insoluble in water, which contributes to their stability. It is difficult to destroy PCBs by chemical, thermal, and biological processes, and partial oxidation poses a risk of producing very hazardous dibenzodioxins and dibenzofurans.

Numerous detrimental impacts on health have been shown to be caused by PCBs. It has been demonstrated that PCBs cause cancer in animals. Numerous significant non-cancer health impacts in animals, including as those affecting the immunological, reproductive, neurological, and endocrine systems, have also been demonstrated to be brought on by PCBs. Studies in humans provide supportive evidence for potential carcinogenic and non -carcinogenic effects of PCBs. The different health effects of PCBs may be interrelated, as alterations in one system may have significant implications for the other systems of the body [25].

By-products of industrial processes and combustion

Polycyclic aromatic hydrocarbons (PAHs), also known as poly-aromatic hydrocarbons or polynuclear aromatic hydrocarbons are an important group of atmospheric pollutants that consist of fused aromatic rings. A very common polycyclic aromatic hydrocarbon is naphthalene. Polycyclic aromatic hydrocarbon present in oil, coal and tar deposits and they are byproducts of fuel burning (whether fossil fuel or biomass). PAHs are usually released into the air, or they evaporate into the air when they are released to soil or water [26]. Polycyclic aromatic hydrocarbon generally adsorb on dust particles in atmosphere, where they undergo photo oxidation in the presence of sunlight. This oxidation process can break down the chemical in some days to week. As polycyclic aromatic hydrocarbon are insoluble in water, they are usually adsorbed on particulate and precipitated in the bottom of lakes and rivers, or solubalize in any oily matter which may contaminate water. Microbial population in the sediment or water system may degrade polycyclic aromatic hydrocarbon over a period of weeks to months. The toxicity of polycyclic aromatic hydrocarbon is affected by metabolism and photo-oxidation, and these compounds are more toxic in the presence of ultraviolet light. Polycyclic aromatic hydrocarbon have moderate to high toxicity to aquatic life and birds. PAHs in soil are not likely to exert toxic effect on terrestrial invertebrates, except when soil is polluted [27]. Adverse effects on these organisms include tumors, undesirable effects on reproduction, development and immunity, mammals can absorb PAHs by various routes e.g. inhalation, dermal contact and ingestion. Plant can absorb polycyclic aromatic hydrocarbon from soils. Roots absorb these chemicals and their uptake rates are generally governed by concentration, water solubility and their physicochemical state as well as soil type. Polycyclic aromatic hydrocarbons are moderately persistent in the environment, and have capacity to bioaccumulate. The concentration of polycyclic aromatic hydrocarbon found in fish and shell fish are expected to be much higher than in the environment from which they are taken. Bioaccumulation of these chemicals has been shown in terrostrial invertebrates also; however the metabolism of these compounds is sufficient to prevent biomagnification [28].

As a pollutant, they are of concern because some compounds have been identified as carcinogenic, mutagenic, and teratogenic. Dioxins are by-products of various industrial processes, and generally regarded as highly toxic compound that are environmental pollutants and persistent organic pollutants (POPs). The toxic effects of dioxins are measured in fractional equivalencies of TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), which is the most toxic member of this class. Toxicity is mediated through interaction with a specific intracellular protein, the aryl hydrocarbon (AH) receptor, a transcriptional enhancer, affecting a number of other regulatory proteins. This receptor is a transcription factor which is involved in expression of many genes. TCDD binding to the AH receptor induces the cytochrome P_{450} 1A class of enzymes which function to break down toxic compounds, e.g., carcinogenic polycyclic hydrocarbons such as benzo(a)pyrene. While the affinity of dioxins and related industrial toxicants to this receptor may not fully explain all their toxic effects including immunotoxicity, endocrine effects and tumor promotion, toxic responses appear to be typically dose-dependent within certain concentration ranges.

Pharamceuticals

Environment is polluted not only by heavy metals, pesticides and emissions from gasoline engines, but also with pharmaceutical chemicals. These pharmaceuticals can gain access in the environment through various routes causing harmful effects.

In early 1990s, India and South Asia were rich in the population of Gyps vultures which are considered as large raptors in the world. However, within a decade, the populations of three species, White-rumped Vulture *Gyps bengalensis*, Indian Vulture *G. indicus*, and Slender-billed Vulture *G. tenuirostris*, had declined so quickly that all three came under the category of critically endangered. The population of Indian and Slender-billed Vulture declined in India by almost 97% between 1992 and 2007. White-rumped Vultures feared even worse, dropping by 99.9 percent, to just one thousandth of their 1992 population. Vultures are keystone species that perform a very important service in ecosystem by disposing of carrion and their decline has had dramatic ecological and socio-economic consequences [29].

Different categories of progestogens have been identified in waterways in various countries. Levonorgestrel, a specific progestogen, can cause sterility in female frogs at concentrations not much higher than those present in the environment. When female tadpoles swim in water with low levels of levonorgestrel, they exhibit a higher percentage of immature ovarian egg cells and are sterile because they lack oviducts [30].

The possible effect of natural and synthetic estrogens on aquatic ecosystems has become a subject of interest in recent years. Field reports of reproductive problems in some European freshwater fish populations created worry about the possible role of environmental estrogens as relevant factors. Synthetic estrogens like 17-α- ethinyle-estradiol, which is widely used in contraception and related pharmaceutical purposes, have also been shown to enter the aquatic environment via effluent discharges from sewage treatment works and its very low concentration in aquatic environment causes feminization of male fish [31].

Miscellaneous compounds

Sunlight, nitrogen oxides, and volatile organic compounds in the atmosphere can create a “photochemical smog” by forming highly toxic ozone through a chemical reaction. This type of smog is often referred to as summer smog (or Los Angeles smog) because it is more common in urban areas with sunny climate [32]. This pollution was coupled with irritation of eyes and upper digestive tract in dogs and pet birds in Los Angeles in 1954 [33]. In addition, Dey., *et al.* [34] found that the rate of dogs biting humans in urban areas increased with increasing temperature and ozone exposure (and higher UV irradiance).

Poor air quality in poultry houses with elevated NH_3 concentrations may be a trigger for the occurrence of damaging behaviors in laying hens, such as feather pecking [35,36]. Chronic exposure to elevated ammonia levels resulted in lower live weight gain in broiler chickens [37]. Dust or the tiny particles suspended in air is an invisible threat to the health of human and animals. Dust alone has harmful and irritating effects and is usually related to pulmonary lesions. In an outbreak of cough in pigs, it was called "dust disease" in the United Kingdom [38].

In recent years, special attention has been paid to research on the effects of microplastics on humans and animals. Due to the small size of the particles (< 5 mm), microplastics are rapidly spread by wind and water. As a result, the particles are found in the air, soil, water, polar ice, deep ocean and living organisms [39]. Accumulation of microplastic in body can result in behavioral and physiological modification such as avoidance behavior, unstable swimming, signs of rapid fatigue, decreased swimming speed, inhibited hunting ability, etc. [40].

Conclusion

Environmental pollutants have a significant impact on animal health and behavior. A shift in typical behavior of an animal is the first sign that it is uncomfortable in its environment and this should not be ignored. In an ecosystem, a shift in animal behavior could be a sign that the surroundings are unsuitable for human as well. Almost all pollutants have the capacity to produce more or less obvious behavioral changes, increased susceptibility to stressors and diseases, damage to the respiratory system, neurological problems, decrease in production and reproduction etc. although the degree of sensitivity of animal to a pollutant varies by species. Environmental pollution has a negative impact on life on Earth and should be reduced as much as possible. Life on Earth is dependent on its environment, so care must be taken to ensure that its balance is maintained. By adopting sustainable practices, supporting conservation efforts and advocating for stronger environmental regulations, the damage can be mitigated and a better planet can be created for all living creatures.

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