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Review Article

Environmental Toxicology- Introduction & Legislation

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Abstract

Environmental toxicology is a field of study that determines the harmful impacts of chemical, biological, and physical substances on living beings. This paper traces the evolution and significance of environmental toxicology, mainly driven by global and uniquely Indian concerns. This paper traces critical events in its evolution: **The Green Revolution**, the Bhopal Gas Tragedy, and the use of Agent Orange in the Vietnam War, which help us understand the environmental impacts. The paper also considers how industrial and agricultural growth contributed to several global environmental changes, including concerns mandated by Climate Change, Air and Water pollution, and Ozone Depletion. An analysis of the impact of environmental toxicity from heavy metals, pesticides, and industrial chemicals on human health and ecosystems is discussed. **Legal frameworks** such as the Water Act, the Air Act, the Environment Protection Act, and the National Green Tribunal Act work in an interdisciplinary fashion to prevent pollution. The paper discusses the involvement of **forensic personnel** in examining environmental disasters and highlights the importance of environmental toxicology in safeguarding the health of organisms and the environment.

1. Introduction

In Environmental toxicology is a multidisciplinary field of science concerned with the study of the adverse impacts of various chemical, biological, and physical agents on living organisms. Environmental toxicology has expanded its scope in the last twenty years. Toxins from pollutants, herbicides, insecticides, and fertilizers may impact every living creature. Toxicity levels might differ based on where an organism is positioned in its food chain. Bioaccumulation is the process in which an organism accumulates toxins in its adipose tissue. This may result in a trophic cascade, where some toxins undergo bio magnification. Biodegradation produces carbon dioxide and water as by-products that are released into the environment. Environmental toxicology focuses on investigating the impact of toxins, whether intentionally introduced (such as pesticides) or resulting from human mistake or negligence in industrial activities, on both health and the environment.[1] Toxicants are substances that are eliminated into the environment that may harm the health of living species, such as people, animals, and plants.

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Environmental toxicology developed not just to understanding that the survival of humans depends on other species and on an environment with clean air, water, and food, but also because both anthropogenic and naturally occurring chemicals can cause deleterious effects on living organisms and ecological processes. Environmental toxicology is very important in understanding the impacts of pollutants on the structure and function of ecological systems.[2]

2. Environmental toxicology in the international and Indian context

Development of industries in the later part of the 18th century, which continued up to the first half of the 20th century, converted western agricultural societies into industrialized societies. After the end of World War II (1939-45), chemical industries evolved speedily. Synthesis of chemical fertilizers, pesticides, and herbicides in 1960s transformed the global agricultural sector. This development came to be known as the 'GREEN REVOLUTION'. In India, also during mid-20th century the development of chemical fertilizers and new high-yield strains of cereals, has increased the production of food grains. A number of food-deficient nations, including India were producing enough quantities of grain food to satisfy their requirements.

The general decline in air and water quality is symptomatic of the adverse effects of such progress. This development has led to increase in diseases due to environmental pollutants, particularly in human-beings due to food products they consume. Some industrial agents released into the general environment or in the work-place are known or suspected to be carcinogenic. A physician, Percival Pott of London, made the first note of occupational (industrial) cancer in 1775. He observed an unusually high incidence of scrotal cancer among the chimney-sweeps of London and associated (rightly) this with soot. The rise in deaths due to urban smog and danger due to toxic substances like sulphur dioxide and nitrogen oxides alarmed the world.[1]

Rachel Louise Carson (May 27, 1907 – April 14, 1964) was the American marine scientist and environmentalist who made environmental toxicology a distinct field in 1962 through her book SILENT SPRING. Its publication led to a reversal in national pesticide policy and then nationwide ban on DDT and other pesticides. It was the beginning of a grass root environmental movement, including the creation of the U.S. Environmental Protection Agency.[2,3,4] In May 1985, a team of British researchers discovered a hole in the earth's protective ozone layer. So, the increased ultraviolet radiation reaching the earth's surface may lead to an increase in skin cancer, slow the growth of crops, and may disrupt the food chain of marine species. The gradual addition of carbon dioxide due to the combustion of fossil fuels leads to greenhouse effect (1986) with its consequences.[3,5,6]

Agent Orange in Vietnam War: From 1962 to 1971, the United States military used about 20,000,000 U.S. gallons of chemical herbicides and defoliants in Vietnam. The Vietnamese Ministry of Foreign Affairs said that 4.8 million Vietnamese were affected with 400,000 fatalities and 500,000 children born with congenital disabilities. Dioxin, 2,4-D, and 2,4,5-T, which are Phenoxy herbicides, were used as a chemical weapon. The objective was to defoliate the forested area and deny food to guerrillas. The initiative was also a part of a strategy of forced urbanization, The report given by Vietnam Red Cross mentions 3 million Vietnamese were affected by Agent Orange and 150,000 children had birth abnormalities. The primary harmful impact is hepatocellular carcinoma.[3]

Greatest acute chemical disaster- Bhopal Gas Tragedy, 1984: The Bhopal Gas Tragedy is the most infamous example of environmental toxicity in India. The incident occurred on December 2, 1984, when forty tons of the extremely hazardous chemical methyl isocyanate (MIC) spilled from a pesticide plant. The gas spread into the densely populated neighboring areas, resulting in the deaths of at least 4000 people and injuries to over 150,000. The lung was the primary organ affected by MIC.[3,7]

3. Environmental changes due to industrial & agricultural growth

1. Global climatic changes
2. Increased air and water pollution
3. Acid rain
4. Mounting amounts of solid waste
5. Destruction of the ozone layer by chlorofluorocarbons (CFCs)
6. Presence of a rising number of endocrine disrupters in the environment

4. Sources of environmental toxicity

Various sources of environmental toxicity may introduce hazardous substances into our food, water, and air:

1. Organic and inorganic pollutants
2. Pesticides & Biological agents

3. Specific sources of contamination such as drainage from a particular plant.
4. Non-point sources, such as rubber from automobile tyres, include various chemicals and heavy metals.

5. Effects of pollutants

Heavy metals such as mercury, arsenic, gold, cadmium, lead, and silver have a tendency to accumulate in the kidneys, rendering this organ very susceptible to their effects. They have the power to modify genetic composition, affect the human neurological system, and induce memory loss, mental confusion, irritation, allergies, high blood pressure, exhaustion, skin rash, and immune system malfunction.[8]

Lead (Pb)- is not essential for the human body's dietary needs. Lead contamination mostly impacts metropolitan areas but may also extend to agricultural land, lakes, and rivers, potentially contaminating animal food sources. Pica is a contributing factor to lead poisoning. Airborne lead poisoning may result from factories and automotive exhaust. However, the use of unleaded gasoline and better industrial emission control has decreased lead emissions. The Centre for Disease Control and Prevention (CDC) states that lead poisoning is the most prevalent and severe environmental illness that impacts young children. Lead has several hazardous consequences such as hindering the development of RBCs, kidney damage, and harming neurological system.[1,2,3,9]

Cadmium (Cd) - toxicity may result from contamination of the air, water, or soil. An outbreak of a chronic ailment known as "itai-itai-byo" or "ouch-ouch disease" occurred around the Jintsu river. The individual had intense bone pain and finally the weakened bones disintegrated even under little strain, resulting in fractures. The mine's wastewater, together with cadmium-laden vapors, contaminated the grown rice and drinking water when utilized for irrigating the rice crop by the inhabitants. Cadmium poisoning produces renal tubular damage, lung cancer, and hepatotoxicity.[3]

Mercury (Hg)- is a common water contaminant. The metal accumulates in living organisms and may dissolve in fats. Mercury from the atmosphere is deposited on land by rainfall and then transported into lakes, ponds, and rivers. Mercury poisoning in humans causes severe neurological abnormalities, including numbness, unsteady walking, slurred speech, tunnel vision, hearing loss, convulsions, lunacy, and death. Divalent mercury inorganic salts are very harmful to the gastrointestinal system. Under anaerobic circumstances, it is transformed into very poisonous methyl- and dimethyl mercury by methylation by bacteria. These chemicals easily pass through biological membranes and accumulate in fish/shellfish. An epidemic of mercury poisoning (methylmercury)- "Minamata disease" occurred in Japan. Infants with severe neurological disease were born to women who these contaminated salmon.[1,3,10]

Dichlorodiphenyltrichloroethane (DDT) -is an organochlorine pesticide that was extensively used by farmers to eliminate agricultural pests. Its metabolite, DDE (dichlorodiphenyldichloroethylene), was also often employed. Bio magnification impacts bird species by causing the accumulation of DDT and DDE in their tissues, leading to egg-shell thinning and decline in bird population. DDT accumulates in soil as it does not readily break down. Water systems become contaminated, leading to the accumulation of DDT in the tissues of marine organisms like fish and shellfish. Animals that eat fish also ingest the chemical, showing bio magnification in the food chain. DDT adversely affects the liver, nervous system, and reproductive system in humans and may also result in preterm births. In 1972, the US Environmental Protection Agency (EPA) prohibited the use of DDT. Public concern is about the health risk posed by pesticide residues, which are probable carcinogens, found on fruits and vegetables.

Polychlorinated biphenyls (PCBs) - are organic pollutants (not insecticide) that are still found in the environment even though they were prohibited by the ministry in 1986 under the Environment (Protection) Act. These are chlorinated hydrocarbons present in water contaminated by factory effluent. They may lead to skin irritation, neurological issues, pregnancy loss, and congenital abnormalities. Several aquatic species, such as wild salmon (Salmo salar) in the Baltic Sea, have elevated amounts of this molecule. Due to their chemical stability and non-flammability, they are widely used in several commercial and industrial practices.[3]

PFAS chemicals- also known as per and poly-fluoroalkyl (chemicals forever) compounds, are a category of almost 15000 chemicals. The first PFAS compound, polytetrafluoroethylene (PTFE), known as Teflon, exhibited resistance to water, oil, and high temperatures. They are used in many household items like nail paint, cosmetics, shampoos, soaps, toothpastes, menstruation products, garments,

contact lenses, and toilet paper.[1,3] PFAS can cause changes in kidney and thyroid function, ulcerative colitis, weakened immune system, low birth weight, fertility problems, and various malignancies (kidney, testicular, and liver).[11,12,13]

CFCs (Chlorofluorocarbon) - might lead to stratospheric ozone depletion. In the 1930s, they were developed and widely used in many industrial applications such as propellants for aerosols, plastic-foam blowing agents, refrigeration and air conditioning fluids, cleaning fluids for electronic equipment, fire extinguisher fluids. They have the benefit of being chemically stable, non-flammable, and nontoxic. Now a days R-22 (Freon) and R410A (Puron) are used.

Rubber and Asbestos- Tyre wear is nearly 360 mg/km per vehicle, pollutants, mostly concentrated on the highway and its surroundings. Rubber particles from tyres add to air and water pollution. Tyres are mostly made of natural latex. Natural latex proteins are recognized as antigens that may trigger hypersensitivity reactions.[1]

Indoor Air Pollution- Sick building syndrome is a condition that may lead to many ailments including headaches, depression, exhaustion, irritability, allergy-like symptoms, heart disease, and cancer due to exposure to several chemicals like xylenes and decane. They are found in some new buildings at levels 100 times greater than in the outside air. As buildings become older, their density significantly declines.[1]

Nitrates- Due to their high water solubility, they leach readily from the soil, leading to contamination of surface, groundwater, and enter food chain. Nitrites, when consumed by water, may lead to methemoglobinemia and hypertension in children. Nitrites reacting with some pesticides may produce nitrosamines (carcinogenic and mutagenic).[14] Nitrogen dioxides can play a role in acid deposition by forming nitric and nitrous acids.

Sulfur dioxide - produced by the burning of coal and petroleum products, petroleum refining. It undergoes conversion in the atmosphere to sulfuric acid. Sulfuric acid is transported by wind and deposited on the earth's surface via precipitation, known as acid rain.[1, 2]

VOC (Volatile organic compounds)- are petroleum hydrocarbons- aliphatic and aromatic. They can cause irritation, inflammation, nausea, vomiting, narcosis in CNS, pulmonary edema, asphyxia. Benzene is known carcinogenic.

5. Legal framework

The Water (Prevention and Control of Pollution) Act, 1974- It aims to prevent and regulate water pollution and preserve the purity of water in different water sources. CPCB and SPSB are regulatory entities established by this act. They are authorized to set and enforce effluent regulations for industries that release pollutants into water bodies. It regulates the release of sewage and industrial effluent by accepting, denying, and issuing discharge permits.

The Air (prevention and control of pollution) act, 1981- It aims to prevent, regulate, and reduce air pollution. It also mandates the creation of boards at national and state levels to enforce the act. Air pollution sources including internal combustion engines, industries, cars, power plants, etc., are prohibited from emitting particulate matter, lead, carbon monoxide, sulfur dioxide, nitrogen oxide, volatile organic compounds (VOCs) or other harmful pollutants above set limits.

The Environment (Protection) Act, 1986- The umbrella legislation to enforce the resolutions made at the United Nations Conference on Human Environment at Stockholm in June 1972. They pertain to safeguarding the human environment and preventing risks to humans, living beings, plants, and property. Additionally, ensure coordination of actions in accordance with other environmental legislation such as the Water Act and the Air Act.

The National Green Tribunal Act, 2010- It aims to provide legal and regulatory assistance to those affected by toxins and environmental harm. It aligns with Article 21 of the Constitution, which provides everyone with the right to a healthy environment. The National Green Tribunal (NGT) adjudicates civil matters pertaining to environmental issues governed by seven specific legislations. The Central Pollution Control Board, a division of the Ministry of Environment and Forests, has released guidelines for setting up and accrediting environmental labs in accordance with the Environment (Protection) Act of 1986.[15]

Amendments: There is need of constant policy change and amendments in laws related to poisons.[16-18]

6. International covenants

In USA to protect the environment, the National Environmental Policy Act (NEPA) was written. The main point that NEPA brings to light is that it "assures that all branches of government give proper consideration to the environment prior to

undertaking any major federal actions that significantly affect the environment." This law was passed in 1970 and also founded the Council on Environmental Quality (CEQ). The importance of CEQ was that it helped further push policy areas. CEQ created environmental programs including the Federal Water Pollution Control Act, Toxic Substance Control Act, Resources Conservation and Recovery Act (RCRA and the Safe). CEQ was essential in creating the foundation for most of the "current environmental legislation except for Superfund and asbestos control legislation."[19] Throughout most of the last century, international environmental law primarily reflected bilateral or regional disputes over shared resources, such as rivers or lakes that cut across national boundaries. In addition to the peaceful resolution of environmental conflicts, international environmental law also is relied on to balance the planet's ecological limits with the world's ever-growing economy to prevent irreversible environmental harm in the first place.

The United Nations first convened countries to address the global environment at the 1972 UN Conference on the Human Environment in Stockholm. The Stockholm conference highlighted the international aspects of emerging environmental challenges and legitimized the environment as an area for international cooperation. The Stockholm conference also created the United Nations Environment Programme (UNEP). Since the 1972 Stockholm Conference, the world has met regularly in a series of major summits aimed at shifting the world generally toward a path of sustainability. The most important by far has been the 1992 UN Conference on Environment and Development (UNCED), also known as the Rio "Earth Summit.' At both Stockholm in 1972 and at Rio in 1992, the countries adopted a set of basic principles (see, e.g., the Rio Declaration on Environment and Development). Some of these principles are emerging as customary law, helping to resolve environmental disputes and guide negotiations of the various environmental treaties. Beginning in the late 1970s scientists warned that certain widely used chemicals could be depleting the earth's protective stratospheric ozone layer. In response, countries first negotiated the 1985 Vienna Convention for the Protection of the Ozone Layer.

International environmental law has successfully addressed many serious issues. Many harmful chemicals are now controlled, the ozone layer is recovering, and populations of important wildlife species, including whales and sea turtles, are increasing because of international environmental agreements. The strong record of international environmental cooperation from Stockholm to Paris provides hope for the future.[20]

7. Role of forensic personnel

Protection of site, establishment of identity of victims, preservation of viscera and other trace evidence, proper preservation and handling of remains, determine cause of death & time since death, photography and documentation, provide information to press and relatives, counselling the relatives, aid in determining cause of disaster and maintain chain of custody for physical evidence.

8. Conclusion

Environmental Toxicology is the examination of poisons present in the environment and their effects on all living species in the surrounding ecosystem. It is a fast expanding and crucial subject of research that plays a vital role in safeguarding the well-being of all living beings and their surrounding environment.

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