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Effect and Remediation of Environmental Pollution on the Concept of Chemistry - Review

Musa Yahaya Abubakar[1], Mohammed Haladu[2], Ogunwole Adeshewa Titilayo[3], Ansar Bilyamin Adam[4]

[1,2,4]Federal University Wukari, Nigeria

[3]Federal College of Education Odugbo, Benue State, Nigeria

yahayaabubakarmusa2015@gmail.com

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Abstract

The science of chemistry has been greatly impacted by environmental degradation, which has led to important breakthroughs and changed educational perspectives. This review highlights the role of chemists in tackling global environmental concerns by examining the diverse effects of environmental contamination on the study of chemistry. Green chemistry principles, which attempt to design safer chemicals and processes that limit waste and lessen detrimental environmental impacts, have been motivated by pollution. Environmental chemistry, which focuses on the behavior, consequences, and mitigation of pollutants, has emerged as a crucial sub-discipline as a result of the pressing need to address pollution. In addition, pollution has made it necessary to integrate interdisciplinary techniques, bringing together the fields of chemistry, biology, environmental science, and engineering to provide novel ways to pollution treatment and control. Educational curricula have evolved to incorporate these trends, emphasizing sustainable practices and the environmental implications of chemical processes. This review highlights how the growing awareness of environmental pollution continues to drive innovation and shape the future of chemical education and research, underscoring the importance of chemists in developing sustainable solutions to protect our planet.

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Introduction

The study of chemistry has led to the awareness on the causes and effect of environmental pollution. Pollution is caused by some factors such as industrial, Agriculture and other environmental activities such as irregular dumping of refuse, released of contaminants to water bodies and refuse burning. Generally, environmental pollution is greater in middle- and low-income countries than in developed countries, possibly due to poverty, poor legislation, and being unaware of pollution forms. It is likely that humans face pollution daily without knowing it or we may have possibly become immune to it in our fast-paced lives (Muralikrishna and Manickam, 2017). As improbable as it may seem, people who are ignorant of the different types of pollution engage in activities that produce harmful byproducts in amounts and forms that the environment can no longer neutralize without severely altering its system. Examples of activities that lead to pollution of the air, land, and water include deforestation, bush burning, disposing of household and agricultural waste in water bodies, using chemicals to harvest aquatic species, and improperly disposing of technological waste. Furthermore, as the density of human population rises, so does the amount of human activity and the resulting increase in environmental effect. In addition to people, other aquatic and terrestrial creatures are also affected, including microbes, which due to their diversity and abundance typically maintain their biogeochemical function necessary for sustaining the ecosystem. In addition to mining, exploration, urbanization, and population increase, other factors that contribute to environmental pollution include the transboundary migration of pollutants from developed to developing nations and vice versa. One reason why pollution is still a problem on a worldwide scale is transboundary contamination. Pollution is defined as nearly any human action that lowers or deteriorates the quality of the natural environment. Although environmental pollution is not a recent occurrence, it continues to be the biggest issue facing humanity and the primary cause of disease and mortality in the environment. More than three times as many people died from AIDS, TB, and malaria combined as were estimated to have died from pollution-related illnesses in 2015, accounting for 9 million premature deaths (Landrigan et al.,)

Causes of Pollution

Environmental pollution is a significant global issue caused by various factors, including industrial activities, transportation, agricultural practices, waste disposal, and energy production. Here are some of the primary causes of environmental pollution:

Industrial Activities: Factories and power plants contribute to air pollution by releasing pollutants into the atmosphere, such as sulfur dioxide (SO_2), nitrogen oxides (NOx), particulate matter, and volatile organic compounds (VOCs) (EPA, 2021). Industrial processes also generate hazardous waste, which, if improperly managed, can contaminate soil and water sources (EEA, 2019).

Transportation: Vehicles powered by fossil fuels (gasoline and diesel) generate carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons, and particulate matter, contributing to air pollution and smog formation(WHO, 2016). Noise pollution is another effect of high traffic in metropolitan areas (EPA, 2020).

Agricultural Practices: The use of pesticides and fertilizers in farming can lead to the contamination of water bodies through runoff, affecting aquatic ecosystems and drinking water supplies(FAO,(2019). Livestock farming produces methane (CH_4), a potent greenhouse gas that contributes to climate change (EPA, 2020).

Waste Disposal: Inappropriate solid waste disposal, which includes the discharge of plastics, pollutes the land and endangers ecosystems and wildlife (NGS, 2020). Methane and leachate from landfills can contaminate groundwater and increase air pollution (EPA, 2019).

Energy Production: When fossil fuels (coal, oil, and natural gas) are used to generate heat and electricity, greenhouse gases (GHGs) including carbon dioxide (CO_2) and methane (CH_4) are released into the atmosphere, which exacerbates climate change and global warming (IEA, 2020). Even while nuclear energy production emits few greenhouse gases, it produces radioactive waste that needs to be carefully managed over an extended period of time (WNA, 2021).

$CO + O2 \longrightarrow CO_2$: CO oxidation

$HC + O_2 \longrightarrow CO_2 + H_2O$:HC oxidation

$NO_2 + HC \longrightarrow N_2 + H_2O + CO_2$: NOx reduction by HC

$NOx + CO \longrightarrow N_2 + CO_2$: NOx Reduction by CO

Table1: Pollution, causes and symptoms

Category	Major causes	Major symptoms	Examples
Atmospheric pollution	Smoke, dust, exhaust fumes, toxic substances (such as sulfur dioxide and nitrogen dioxide)	Asthma, bronchitis	Photochemical smog, "Yokkaichi Asthma"
Water pollution	Polluted waste water, waste fluids (such as petroleum), sludge, household sewage, sewage discharge, general waste, agricultural chemicals	Noxious odors, poisoning	Minamata Disease, "Itai-Itai" Disease (cadmium poisoning), PCB poisoning
Soil pollution	Arsenic, heavy metals (especially in agricultural chemicals)		Poisoning
Noise	Factories, construction work, road traffic, trains and aircraft, late-night commercial operations, advertising	Headaches, insomnia, depression, hearing loss, impaired development	Osaka Airport noise
Vibration	Factories, construction work, road traffic, trains and aircraft	Dizziness, discomfort, structural damage to homes	Shinkansen (bullet train) vibration
Ground subsidence	Upswelling of groundwater, gravel quarrying, coal mining	Structural damage to buildings	Koto Ward, Tokyo
Noxious odors	Exhaust fumes, river contamination, sanitation facilities, accumulated sewage, livestock farms, etc.	Headaches, discomfort	Sewage in the Sumida River

Source: Based on the Basic Law for Environmental Pollution Control



Smoke from chimney stacks fills the sky (December 1972; photo by Mainichi Shimbun Co. Ltd)

Effect of environmental pollution

The land, water, atmosphere, and biosphere make up the environment. For all pollutants, it acts as a holding tank. The effects on land include the destruction of roofing sheets, the discoloration of cars and vehicles, the death of wildlife, the damage to trees, the littering of

waste surfaces, which results in an offensive stench and poor aesthetics, and poor plant yield due to the infertility of the soil. Specifically, continuous mining reduces soil fertility and production and damages vegetation and soil ecosystems.

(Feng et al.,2019), while other human activities result in landscape damage, such as habitat destruction, soil erosion, animal extinction, and loss of resources, such as wetlands and coastal ecosystems (Vallero and Vallero, 2019). Soil pH decreases as a result of changes in the chemical composition of the soil and the loss of crucial cationic nutrients like calcium, magnesium, and potassium. All of these cause food shortages that can result in famine and even death for both humans and other animals.

Effect on Human Beings

The bulk of human being have been connected to environmental pollution due to the detrimental effects of pollution on health. More evidence is being uncovered by recent studies regarding the link between pollution and a number of serious health issues. The number of these research that concentrate on the negative health impacts of exposure to air pollution is startlingly rising. The The report of the World Health Organization clearly pointed out that indoor air pollution from fires for cooking and heating accounted for 3.8 million deaths (WHO, 2018). The World Health Organization's research (WHO, 2018) made it abundantly evident that 3.8 million deaths were caused by indoor air pollution, specifically fireplaces used for cooking and heating. This figure varied, as predicted, from 10% in middle-class and lower-income nations to 0.2% in high-income nations. Furthermore, according to the Global Burden of Disease report, PM 2.5, a component of ambient air pollution, or outdoor air pollution, was the fifth most significant risk factor for death worldwide in 2015, responsible for 4.2 million deaths and over 103 million lost years of disability-adjusted life (Schraufnagel et al., 2018). Reduced infant telomere length is hypothesized to be related to mother exposures to car PM 2.5, and PM 10.CO, and SO 2 during the third trimester (Song et al., 2019). This implies that we are not only in danger of these pollutants, but also that they pose severe sensitive hazards to the unborn. Sometimes, the effect of pollution on this vulnerable group becomes pronounced and are carried on through the lifetime. It has been discovered that some recalcitrant pollutants such as POPs and PAHs bind with PM, especially PM 2.5 to elicit several types of cardio pulmonary diseases, respiratory diseases, cancer, and non cancer effects on humans. Pollutants that are airborne tend to move a longer distance and wreak more havoc because they get to the

target population either through breathing, settling on drinking water, or exposed foods, thereby contaminating them. Several other health problems associated with pollution may have not been discovered, yet evidence from epidemiological studies is pointing fingers to numerous women's health problems as the aftermath of pollution, particularly air pollution. The literature has indicated that exposure to PM 2.5 and O_3 may cause specific genetic or epigenetic abnormalities and lead to the development of uterine fibroids (Lin et al., 2019

Effects on animal health

While it's possible that there are still unidentified health issues linked to pollution, epidemiological research indicates that a number of women's health issues are directly related to pollution, especially air pollution. According to Lin *et al.* (2019), there is evidence in the literature that exposure to PM 2.5 and O_3 can result in particular genetic or epigenetic abnormalities, which can then produce uterine fibroids.

Effect on Animals

Animal life and marine organisms are susceptible to sublethal health impacts from oil spills that occur during exploration, refining, and transportation on land, through pipelines, and/or aboard marine boats.These creatures suffer detrimental effects to their respiratory, circulatory, and digestive systems 426 Microbes for a Healthy Environment and Well-Being when they breath in or ingest petroleum products containing harmful substances. Seabirds and other marine mammals are faced with the dangers of oil slicks that tend to foul their skin or feathers leading to retarded movement, inability to secure sufficient food, and inability to run from predators resulting to their death. Seabirds are severely impacted by oil spills and often go unreported. Studies have shown that birds are dying due to oil-fouling. Even though some oil-fouled birds are discovered and reported when they die, the number of unreported deaths due to effects from oil spills is high (Walker *et al.*, 2019).

The problems posed by plastics in the environment are more considerable. According to Barboza *et al.,* (2019), it negatively impacts ecosystems, reduces biodiversity, and may eventually have an impact on the lives of mostly birds, fish, crabs, turtles, and other marine species. Plastics cause direct or secondary harm to animals. According to Barnes (2019), direct hazards include ingestion stress issues that can cause internal damage, lacerations, and lesions; choking and entanglement of aquatic organisms; hindered growth and photosynthesis in primary food producers like algae; and effects on the development and reproduction of crustaceans. Not only can an animal die instantly, but it can also get

injuries or have its movement restricted, which could cause it to starve to death or make it harder for it to flee from predators. Even more so, these organisms are impacted by certain additives used in making plastics, such as plasticizers and other organic pollutants, that cause changes in metabolic processes and behaviors. Furthermore, pollution impacts on genetic variability and biodiversity of the natural population. Studies have indicated that genomes in fish inhabiting polluted environments possess highly complex ribosomal sequences. A systematic increase in the number of copies of the ribosomal DNA is observed, which occurs in response to variations in environmental conditions. This happens because these sequences are involved primarily in the maintenance of genome integrity (Araújo da Silva et al., 2019).

Effects on microorganisms

The nutrient cycle and energy transfer in aquatic food webs depend heavily on microscopic populations found in flowing water habitats, such as zooplankton (Xiong et al., 2019).Thus, biotic reactions of tiny organisms to their surroundings could be a reliable indicator of environmental degradation in aquatic ecosystems.However, pollution has had a major impact on how zooplankton biodiversity is distributed geographically, which has decreased their effectiveness.This occurs due to the fact that these sequences are mostly involved in maintaining the integrity of the genome (Araújo da Silva et al., 2019).

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Remediation of pollution

Environmental remediation concerns the quality of the environment, and how to support decision making to decide on how to handle it. Research into exposure pathways has illustrated the dangers of pollutants, such as fine dust, heavy metals or volatiles exuded from former petrochemical sites.

Treatment Technologies to Remove Environmental Pollutants (Remediation)

According to Prabhukumar G. *et al.*, (2004) Reducing hazardous materials into benign forms and then developing efficient risk management plans to mitigate the negative consequences of persistent, highly toxic, and challenging-to-treat pollutants are necessary for the economical treatment of environmental pollutants. innovative waste treatment procedures that are more successful in lowering economically viable contamination levels than currently available techniques have been addressed through the use of several innovative methodologies. Better waste treatment options could come from using nanotechnology to remove the smallest pollutants from air and water (less than 50 nm and 300 nm), as well as creating "smart materials" or "reactive surface coatings" that are engineered to be specific to a particular pollutant and that can immobilize, destroy, or change harmful compounds. Because of their improved surface and other unique changes in their physical, chemical, and biological properties brought about by size effects, nanomaterials have been the subject of growing study in the field of environmental remediation. Because conventional technologies are typically unable to reduce wastewater concentrations to acceptable regulatory requirements, there has been significant research into the creation of innovative materials with higher affinity, capacity, and selectivity for heavy metals, a major source of pollution. The capacity of commercially available ion-exchange sorbents, like Duolite GT-73, Amberlite IRC-718, Dowex SBR-1, and Amberlite IRA 900X, to remove heavy metal pollutants is restricted, and they are frequently insufficient for the majority of applications. The newest techniques for creating nanoscale materials that are perfectly controllable at the molecular level. Targeted removal of toxic waste is now possible because to the development of recombinant DNA techniques, which allow for the creation of "artificial" protein polymers with fundamentally novel molecular organization capabilities.

Conclusion

An outline of pollution, causes, Impacts, and Remediation strategies have been provided in this work. Air pollution appears to be the most researched and investigated sort of pollution. Increased morbidity and an earlier mortality rate linked to air pollution may be the cause of this. Pollution is a shared responsibility between developed and developing

countries, but it is borne primarily by the latter because of insufficient laws, low awareness, and extreme poverty.

Vulnerable groups in middle- and low-income nations are disproportionately impacted by pollution. To make it possible to remediate an already impacted environment, awareness of the risks associated with pollution must be increased and all hands must be mobilized to prevent acts that contribute to environmental pollution.

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