JOURNAL OF TRANSLATIONAL PUBLIC HEALTH RESEARCH (JTPHR)
Vol 3 Issue 1 - 2026 (**EISSN** 3121-9284)
https://journals.chroniva.org/index.php/JTPHR

ENVIRONMENTAL CHEMISTRY AND THE MANAGEMENT OF ENVIRONMENTAL POLLUTION IN NIGERIA: SOURCES, EFFECTS AND SUSTAINABLE CONTROL STRATEGIES

By

Isidi Peter Adigwe.
Sci education chemistry option.
University of Delta State Agbor.
Orcid num 0009000592234342
peter.isidi@unidel.edu.ng

Abstract

Environmental chemistry is an important branch of science that examines the chemical composition of the environment, the movement and transformation of chemical substances in nature, and the effects of these substances on humans, animals, plants and ecosystems. Its importance has increased because of growing environmental pollution arising from industrial activities, oil exploration, agricultural practices, transportation, urbanisation, poor waste disposal and the indiscriminate use of chemicals. In Nigeria, environmental pollution is a major concern, particularly in communities experiencing oil spills, gas flaring, contaminated water, poor sanitation, air pollution and the accumulation of solid and hazardous waste. These problems affect public health, agricultural productivity, biodiversity and sustainable economic development. This paper examines environmental chemistry and its relevance to the management of environmental pollution in Nigeria. It discusses the meaning of environmental chemistry and environmental pollution, the major sources and forms of pollution, the chemical processes responsible for environmental contamination, the effects of pollution and practical strategies for controlling it. The paper argues that environmental pollution cannot be effectively managed without understanding the chemical behaviour of pollutants, their sources, pathways and effects. It therefore emphasises environmental monitoring, enforcement of environmental laws, cleaner industrial production, proper waste management, public education, remediation of contaminated sites and the adoption of environmentally friendly technologies. The paper concludes that environmental chemistry should be given greater attention in Nigeria's educational, industrial and environmental management systems because scientific understanding is essential for protecting natural resources and achieving sustainable development.

Keywords: Environmental chemistry, environmental pollution, chemical contaminants, environmental management, sustainable development.

1.0 Introduction

The environment provides the natural resources that support human survival and economic activities. Water, air, soil, forests, minerals and other natural resources are essential for food production, industrial development, transportation, energy generation and human health. However, the increasing demand for these resources has placed considerable pressure on the environment. Industrialization, population growth, urban expansion, agricultural activities and technological development have increased the quantity of waste and chemical substances released into the natural environment. When these substances are released without adequate treatment or control, they can contaminate air, water and soil and create serious environmental problems. Environmental pollution is not simply the presence of unwanted substances in the environment. It also involves the concentration, movement, persistence and chemical transformation of pollutants and the harm they may cause to living organisms and natural systems. Some pollutants break down relatively quickly, while others remain in the environment for many years. Certain chemicals can accumulate in the tissues of living organisms, move through food chains and eventually reach humans through the consumption of contaminated food and water. Understanding these processes requires knowledge of environmental chemistry.

Environmental chemistry is concerned with the chemical processes occurring in the atmosphere, hydrosphere, lithosphere and biosphere. It examines how natural and human-made chemicals enter the environment, how they react with other substances, how they move from one environmental compartment to another and how they affect living organisms. For example, environmental chemistry helps explain how sulphur dioxide and nitrogen oxides released from industries and vehicles contribute to acid deposition; how pesticides move from agricultural land into rivers; how petroleum hydrocarbons contaminate soil and groundwater; and how heavy metals such as lead, mercury and cadmium can persist in the environment and pose risks to human health.

The importance of environmental chemistry is particularly clear in Nigeria. The country faces several environmental challenges associated with oil and gas operations, industrial activities, agricultural chemical use, open waste burning, poor sewage disposal, mining and rapid urbanization. Oil spills and petroleum-related contamination have affected parts of the Niger Delta, while inadequate waste collection and disposal have contributed to environmental degradation in many urban centres. Air pollution from vehicles, generators, industries and the burning of solid waste also affect environmental quality. The World Health Organization (2021) identifies air pollution as a major environmental risk to human health, with exposure associated with respiratory

and cardiovascular diseases. This demonstrates that pollution is not only an environmental issue but also a public health and development concern. Chemical contamination of water and soil is equally important. Untreated industrial effluents, sewage, agricultural runoff and improperly disposed chemicals can introduce harmful substances into rivers, streams, groundwater and agricultural land. These contaminants may reduce water quality, damage aquatic organisms, affect soil fertility and enter the human food chain. The United Nations Environment Programme (2019) has also highlighted the need for improved environmental governance and stronger management of pollution and waste as part of the global effort to protect ecosystems and human well-being.

In Nigeria, the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act 2007 provides an institutional framework for enforcing environmental standards and regulations, while the National Oil Spill Detection and Response Agency (NOSDRA) Act 2006 provides a framework for detecting and responding to oil spills in the petroleum sector. These laws show that environmental protection requires scientific knowledge, institutional responsibility and effective enforcement. However, the existence of environmental laws alone does not guarantee a clean environment. Effective implementation, regular monitoring, public participation and access to appropriate pollution-control technologies are also necessary. Environmental chemistry therefore provides a scientific foundation for understanding environmental problems and developing appropriate solutions. It helps environmental officers identify pollutants, laboratory scientists analyze contaminated samples, industries improve production processes, farmers manage agricultural chemicals and policymakers establish evidence-based environmental standards. It also supports the development of cleaner technologies and the restoration of polluted environments. This paper examines environmental chemistry and its relevance to the management of environmental pollution in Nigeria. It explains the major concepts, discusses the sources and effects of environmental pollution, examines the contribution of environmental chemistry to pollution control and presents practical strategies for improving environmental management in the country.

2.0 Conceptual Terms

Concept of Environmental Chemistry

Environmental chemistry is the branch of chemistry that studies the chemical composition of the environment and the chemical reactions and processes that occur in air, water, soil and living organisms. It focuses on the sources, movement, transformation, distribution and effects of chemical substances in the environment. Manahan (2017) explains environmental chemistry through the chemical processes operating within the environment and the relationships between chemical substances and natural systems. The field considers both naturally occurring substances and chemicals introduced through human activities. It therefore helps explain how pollutants behave after they are released into the environment.

Baird and Cann (2012) describe environmental chemistry as an area of chemistry concerned with the chemical principles and processes that determine the composition and behaviour of environmental systems. This includes the study of air pollution, water contamination, soil chemistry, toxic substances and chemical reactions that influence environmental quality. The United States Environmental Protection Agency (EPA) also approaches environmental protection through the identification, measurement and control of chemical and other contaminants in environmental media. This practical approach demonstrates the importance of chemical analysis in identifying pollution sources and assessing environmental risks. In simple terms, environmental chemistry helps us understand what chemicals are present in the environment, where they come from, how they behave, how long they remain and the possible harm they may cause. For instance, when petroleum spills on farmland, environmental chemistry helps determine the types of hydrocarbons present, how they spread through the soil, whether they reach groundwater and what treatment methods may be suitable. Environmental chemistry is therefore important in environmental protection because it provides the scientific information needed to prevent pollution, monitor environmental quality, assess chemical risks and restore contaminated environments.

Concept of Environmental Pollution

Environmental pollution refers to the introduction of harmful substances or forms of energy into the environment in quantities or concentrations that cause, or are likely to cause, damage to humans, animals, plants, natural resources and ecosystems. Pollution may affect the air, water, soil and other components of the environment. The World Health Organization (2021) identifies environmental pollution, particularly air pollution, as a major threat to human health. Exposure to polluted air can contribute to serious respiratory and cardiovascular conditions. This shows that pollution can affect human health directly through breathing and indirectly through its effects on food, water and the wider environment.

The United Nations Environment Programme (2019) explains that pollution and waste are connected to unsustainable production and consumption patterns. Poor management of chemicals and waste can contaminate natural resources, damage ecosystems and undermine human well-being. Environmental pollution can be caused by natural events such as volcanic eruptions, wildfires and dust storms. However, many of the serious pollution problems experienced today are associated with human activities. These include industrial discharge, oil spills, mining, excessive pesticide use, vehicle emissions, improper waste disposal and the release of untreated sewage. In practical terms, environmental pollution occurs when human activities introduce substances into the environment in ways that reduce its quality or make it harmful to living organisms. For example, discharging untreated industrial wastewater into a river may introduce toxic chemicals

and heavy metals. Burning plastics and other waste materials may release harmful gases and particles into the atmosphere. Applying excessive fertiliser to farmland may cause nutrients to enter nearby rivers and contribute to eutrophication. Environmental pollution is therefore a major environmental, health and development challenge that requires scientific understanding, effective laws, responsible human behaviour and sustainable management practices.

3.0 Discussion: The Role of Environmental Chemistry in Understanding and Managing Environmental Pollution

Identification of the Major Sources and Types of Environmental Pollution

One of the important contributions of environmental chemistry is that it helps identify the sources and types of pollution affecting the environment. Pollution does not come from one source alone. It may originate from industrial production, petroleum exploration, agricultural activities, transportation, mining, domestic waste, construction and other human activities. Identifying the source is the first step towards controlling pollution because it helps environmental managers determine what has been released, where it has been released and what measures are required to prevent further contamination. Environmental pollution can be classified into different forms according to the environmental component affected. Air pollution: Air pollution occurs when harmful gases, particles and other substances enter the atmosphere in concentrations that may affect human health and the environment. Common air pollutants include carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ground-level ozone (O_3) and particulate matter such as $PM_{2.5}$ and PM_{10}. These substances may be released through vehicle exhausts, industrial operations, fuel combustion, open burning and the use of generators. The World Health Organization (2021) identifies particulate matter, ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide as major pollutants requiring air-quality monitoring and control.

Water pollution: Water pollution occurs when harmful chemicals, microorganisms, organic waste or other contaminants enter rivers, streams, lakes, oceans and groundwater. Industrial effluents, untreated sewage, oil spills, agricultural runoff and poorly managed waste disposal are common sources. Chemical pollutants such as petroleum hydrocarbons, pesticides, nitrates, phosphates and heavy metals can reduce water quality and threaten aquatic organisms. In Nigeria, the UNEP (2011) assessment of Ogoni land documented extensive petroleum contamination of land and groundwater, demonstrating how oil-related chemicals can affect water resources and community health.

Soil pollution: Soil pollution occurs when harmful substances accumulate in the soil and change its chemical composition or reduce its ability to support plant and animal life. Pesticides, petroleum products, industrial chemicals, heavy metals, batteries, electronic waste and improperly disposed solid waste may contaminate soil. Some contaminants remain in the soil for long periods and may

be absorbed by crops or transported into groundwater. This can affect agricultural productivity and expose people to harmful substances through food and water.

Noise and other forms of environmental pollution: Environmental pollution also includes noise, excessive heat and radioactive contamination. Although these forms are not all chemical pollutants, they are important in broader environmental management. Environmental chemistry is particularly relevant where pollution involves radioactive materials, toxic chemical releases and the chemical substances associated with industrial and transportation activities. The identification of pollution sources and categories enables environmental scientists to select appropriate sampling methods, laboratory tests and control measures. It also prevents the use of general solutions for problems that require specific scientific treatment.

Understanding the Movement, Transformation and Persistence of Chemical Pollutants

Environmental chemistry helps explain what happens to chemical substances after they enter the environment. A chemical released into the environment does not necessarily remain where it was deposited. It may dissolve in water, evaporate into the atmosphere, attach to soil particles, move through groundwater, break down into other substances or accumulate in living organisms. The scientific study of these processes is often described as the environmental fate and transport of pollutants. The United States Environmental Protection Agency (EPA) explains that the fate of a contaminant concerns what happens to it after release, while transport refers to how it moves through the environment. Some contaminants degrade quickly, while others persist for long periods. For example, when petroleum is spilled on farmland, some of its lighter chemical components may evaporate into the air, while heavier hydrocarbons may remain in the soil. Rainwater may also carry some contaminants into nearby streams or groundwater. The extent of contamination depends on the chemical properties of the petroleum, soil composition, rainfall, groundwater conditions and other environmental factors.

Environmental chemistry also explains processes such as:

1) Dissolution: The process through which a substance dissolves in water or another liquid.

2) Adsorption: The attachment of chemical substances to the surface of soil, sediment or other materials.

3) Chemical degradation: The breakdown of a chemical substance into other compounds through chemical reactions.

4) Biodegradation: The breakdown of certain substances by microorganisms.

5) Volatilisation: The movement of a chemical substance from a liquid or solid state into the air as vapour.

6) Bioaccumulation: The gradual accumulation of certain substances in the tissues of living organisms.

7) Biomagnification: The increase in the concentration of certain persistent contaminants at higher levels of a food chain.

These processes are important because the original pollutant may change into another substance, and the resulting product may still be harmful. A contaminant may also move away from its original source and expose people who do not live close to the pollution site. Understanding these processes helps scientists determine where to collect samples, how to assess exposure and which remediation methods are appropriate.

Monitoring and Analysis of Environmental Quality

Environmental chemistry contributes to pollution management through the collection, testing and interpretation of environmental samples. It is difficult to control pollution effectively without knowing the nature and concentration of the substances present in the environment. Environmental monitoring provides the scientific evidence required to determine whether air, water and soil are safe or contaminated. For water-quality monitoring, environmental scientists collect samples from rivers, streams, boreholes, wells and industrial discharge points. They analyze parameters such as pH, turbidity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, electrical conductivity, nitrates, phosphates, heavy metals and petroleum hydrocarbons. These tests help determine whether water is suitable for drinking, irrigation, industrial use or aquatic life. Air-quality monitoring involves measuring particulate matter and gases such as carbon monoxide, Sulphur dioxide, nitrogen dioxide and ozone. The results help identify pollution hotspots and assess whether emissions are within applicable standards. The WHO (2021) air-quality guidelines provide health-based reference levels for key pollutants and support the development of air-quality policies. Soil samples can be tested for pH, organic matter, nutrient content, petroleum hydrocarbons, pesticide residues and heavy metals such as lead, cadmium, chromium and mercury. These analyses help determine the extent of contamination and whether the soil can safely support agriculture or other land uses. In Nigeria, environmental monitoring should be strengthened around industrial areas, mining communities, oil-producing regions, major highways, landfills and locations where hazardous waste is handled. Universities, research institutes, environmental agencies and accredited laboratories should work together to improve the quality of environmental data. The UNEP (2011) Ogoni land assessment provides a useful Nigerian example: the investigation analyzed more than 4,000 samples from over 200 locations and used soil and groundwater investigations to establish the extent of petroleum contamination. Environmental monitoring should not be conducted only after pollution incidents. Regular testing is necessary to identify contamination early, track changes in environmental quality and evaluate whether control measures are working.

Protection of Human Health and Ecosystems from Chemical Contamination

Another important contribution of environmental chemistry is its role in protecting human health and natural ecosystems. Many environmental pollutants can affect people through inhalation, ingestion or direct contact with contaminated materials. The seriousness of the effect depends on the type of chemical, its concentration, duration of exposure, route of exposure and the vulnerability of the exposed person. Air pollutants such as fine particulate matter can penetrate deep into the respiratory system. Carbon monoxide interferes with the ability of blood to transport oxygen, while some other pollutants contribute to respiratory and cardiovascular diseases. The WHO (2021) identifies air pollution as a significant risk to human health and provides guidelines for controlling exposure to major air pollutants. Chemical contamination of water can also create serious health risks. For example, excessive exposure to lead can affect the nervous system, while mercury can cause neurological and developmental harm. Certain pesticides can affect the nervous system or other body systems, depending on the chemical involved and the level of exposure. Nitrate contamination of drinking water is another concern, particularly for infants. These examples show why water-quality testing must go beyond checking whether water looks clean. Environmental chemistry also helps protect ecosystems. When untreated wastewater containing organic matter enters a river, microorganisms may use up dissolved oxygen while breaking down the waste. If oxygen levels fall too low, fish and other aquatic organisms may die. Excessive nutrients from fertilizers and sewage can also encourage the rapid growth of algae, a process known as eutrophication. When the algae die and decompose, oxygen depletion may further damage aquatic life. The effects of chemical pollution are not limited to the location where the pollutants are released. Contaminated water can affect downstream communities, pollutants can move through food chains, and damaged soil can reduce agricultural productivity. UNEP's (2011) investigation in Ogoni land demonstrated the relationship between petroleum contamination, groundwater quality, ecosystem damage and risks to local communities. Environmental chemistry therefore supports public health protection by identifying harmful substances, assessing exposure pathways, determining contamination levels and providing scientific evidence for preventive action.

Management of Agricultural Chemicals and Prevention of Water and Soil Pollution

Agriculture is essential to food security and economic development in Nigeria. However, agricultural activities can contribute to environmental pollution when fertilizers, pesticides, herbicides and other chemicals are used improperly. Farmers apply these substances to improve crop production and control pests, but excessive application, inappropriate storage and poor disposal practices can expose the environment to chemical contamination. Fertilizers commonly contain nitrogen, phosphorus and potassium. These nutrients are necessary for plant growth, but excessive quantities can be washed from farmland into nearby rivers and lakes through surface

runoff. Nitrates may also leach through the soil into groundwater. When too much nitrogen and phosphorus enter surface water, they can promote excessive algal growth and contribute to eutrophication.

Pesticides also require careful management. They are designed to control insects, weeds and other pests, but some may affect non-target organisms such as fish, beneficial insects, birds and soil microorganisms. The Food and Agriculture Organization of the United Nations (FAO) and UNEP (2022) explain that pesticides and fertilizers can create environmental and health risks when their use, handling and disposal are not properly managed. Environmental chemistry helps farmers, agricultural extension officers and environmental agencies understand how agricultural chemicals behave in soil and water. It provides information about the persistence, mobility, toxicity and degradation of pesticides and fertilizers. This knowledge can guide decisions about the type of chemical to use, the quantity to apply, the timing of application and the necessary precautions. For example, farmers should avoid applying fertilizers immediately before heavy rainfall because runoff may carry nutrients into nearby water bodies. Pesticides should be applied according to approved instructions, and empty chemical containers should not be reused for drinking water or household purposes. Buffer zones of vegetation along rivers and streams can also reduce the movement of soil and chemicals from farmland into water bodies. Sustainable agricultural practices, including integrated pest management, appropriate fertilizer application, soil testing, organic soil improvement and responsible chemical storage, can reduce pollution while supporting agricultural productivity.

Treatment of Industrial Waste and Remediation of Contaminated Environments

Industrial activities generate wastewater, gases, solid waste and chemical residues. These wastes may contain acids, alkalis, solvents, petroleum products, heavy metals and other substances that can harm the environment if they are released without treatment. Environmental chemistry provides the scientific basis for selecting appropriate treatment and remediation methods. Industrial wastewater treatment may involve physical, chemical and biological processes. Physical methods include screening, sedimentation and filtration. Chemical methods include neutralization, coagulation, precipitation and oxidation. Biological methods use microorganisms to break down biodegradable organic pollutants. The method selected depends on the type and concentration of contaminants in the wastewater. For example, acidic industrial wastewater may require neutralization before discharge. Wastewater containing certain dissolved metals may be treated through chemical precipitation, which converts dissolved metals into less soluble forms that can be separated from the water. Organic pollutants may require biological treatment or advanced oxidation, depending on their chemical properties and resistance to degradation. Remediation is the process of cleaning up or reducing contamination in polluted soil, water or other environmental media. One method is bioremediation, which uses microorganisms to break down or transform

certain pollutants. Another is phytoremediation, which uses plants to remove, stabilize or reduce the availability of certain contaminants. Other methods include soil washing, excavation and safe disposal, containment and groundwater treatment. The Nigerian experience in Ogoni land illustrates the scale of work that may be required to restore a polluted environment. UNEP (2011) recommended a comprehensive clean-up and restoration programme following its assessment of petroleum contamination. The report demonstrated that environmental remediation requires detailed investigation, scientific planning, long-term monitoring and cooperation among government, industry and affected communities. Industries should therefore treat their waste before discharge, maintain pollution-control equipment, conduct environmental audits and comply with approved standards. Environmental remediation should be based on laboratory evidence rather than assumptions, because different pollutants require different treatment approaches.

Promotion of Cleaner Production, Environmental Laws and Sustainable Development

Environmental chemistry also supports cleaner production and sustainable industrial development. Cleaner production involves preventing or reducing pollution at the point where it is generated rather than waiting until waste has already contaminated the environment. It encourages industries to use raw materials efficiently, reduce hazardous substances, conserve energy and water, recycle materials and adopt safer production processes. For example, a manufacturing company can reduce pollution by replacing a highly hazardous chemical with a safer alternative, improving equipment to prevent leaks, reusing process water and installing systems to capture harmful emissions. A food-processing factory can reduce the pollution load of its wastewater through improved production practices and treatment before discharge. These measures can protect the environment while also reducing waste and operating costs. Environmental chemistry provides the scientific knowledge needed to evaluate whether a proposed substitute is genuinely safer and whether a production process creates harmful by-products. It therefore supports informed decisions about chemicals, raw materials, production methods and waste management. In Nigeria, environmental protection is supported by laws and institutions. The National Environmental Standards and Regulations Enforcement Agency (NESREA) is responsible for enforcing environmental laws, regulations and standards. Its regulatory framework covers areas such as sanitation and waste control, industrial pollution, chemicals and pesticides, healthcare waste, plastics and other environmental concerns. The National Oil Spill Detection and Response Agency (NOSDRA) also has an important role in oil-spill detection and response. These institutions need adequate funding, skilled personnel, laboratory facilities, monitoring equipment and effective cooperation with state and local authorities. Environmental regulations are most effective when industries are regularly inspected and violations attract appropriate sanctions. The United Nations Environment Programme (2019) emphasizes that environmental protection and human well-being are closely connected to sustainable production, responsible consumption and effective environmental governance. Cleaner production should therefore be seen not as an obstacle to economic

development but as a way of achieving development without unnecessarily damaging the natural resources on which future generations depend.

4.0 Solutions for Improving Environmental Chemistry and Pollution Management in Nigeria

The following measures are important for strengthening environmental protection and applying environmental chemistry to pollution management in Nigeria.

Strengthening Environmental Education

Environmental chemistry should receive greater attention in secondary schools, colleges, polytechnics and universities. Students should understand the sources of pollution, the chemical behaviour of pollutants, the effects of environmental contamination and practical methods of prevention. Environmental education should also be connected to everyday activities such as waste disposal, water use, agricultural practices and energy consumption.

Improving Environmental Monitoring Laboratories

Government should invest in well-equipped environmental laboratories across the country. These laboratories should have modern instruments and trained personnel capable of analyzing water, soil, air and industrial waste samples. Universities and research institutes should also receive support to conduct independent environmental studies and publish reliable findings.

Enforcing Environmental Laws and Regulations

Environmental agencies should strengthen inspections and enforce existing environmental laws. Industries, mining operators, petroleum companies and other organizations should be held accountable when their activities contaminate the environment. Enforcement should be consistent and transparent, irrespective of the size or ownership of the organization involved. NESREA's published regulations provide an existing legal foundation for several areas of pollution control.

Promoting Proper Waste Management

Government at all levels should improve waste collection, sorting, recycling, treatment and safe disposal. Open dumping and uncontrolled burning of waste should be discouraged. Hazardous waste, medical waste, batteries, electronic waste and industrial chemical residues require appropriate handling because they may contain substances that can contaminate soil, water and air.

Encouraging Cleaner Industrial Production

Industries should adopt technologies and production methods that reduce the release of pollutants. They should install appropriate wastewater treatment systems, control industrial emissions, prevent chemical leaks and reuse materials where possible. Environmental audits should be conducted regularly to identify weaknesses in pollution prevention.