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Environmental Pollution, Water Quality Degradation, and Implications for Fish Production in Nigeria: A Systematic Review

[1]EMMANUEL, John; [2]ADASHOS, Jonathan Adashos; [3]WAMBAI, Fatima Yunusa; [4]TUDAN, Abdulkadir Ahmed; [5]LAMIDI, Owen Andy; [6]OJEH, Vincent Nduka

Ph.D. Scholar, Department of Geography, Taraba State University, Jalingo
[1]johnemmy660@gmail.com: 08068379884 [2]adashosjonathanadashos@gmail.com,,
[3]Teema862000@yahoo.com, [4]abdultudan@gmail.com, [5]Owenz2k3@gmail.com

Correspondence: [6]vinceojehnetwork@gmail.com

ABSTRACT

This paper examines the effects of pollution on water quality and fish production in Nigeria. The study identifies and synthesizes major sources of pollution, assesses systematically the levels of non-biodegradable pollutants, and evaluates the physicochemical parameters of water in selected rivers and lakes. The study was guided by the Ecological Risk Assessment framework developed by the U.S. Environmental Protection Agency (EPA), and adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The study investigated the impact of water quality on fish production levels, the potential health risks associated with consuming fish from polluted water bodies, and the level of pollution management and sustainable fishery practices among artisanal fishermen. Key findings indicated that industrial effluents, agricultural runoff, and domestic waste are significant sources of pollution, leading to high levels of heavy metals, nutrients, and organic pollutants in water bodies. These pollutants negatively affect fish health, reduce fish stocks, and pose health risks to consumers. The study concludes that there exist diverse pollution and pollutants of varying types from different sources, that pose significant danger to human health and aquatic species, and fish production. The study recommends improved pollution management and sustainable fishery practices to mitigate the adverse effects of pollution on water and fish production.

Keywords: water pollution, fish production, sustainable fisheries, Nigeria aquatic ecosystems

1.0 INTRODUCTION

Water is a fundamental resource essential for all living organisms and plays a crucial role in agriculture, industry, tourism, and aquaculture (Aydin, 2018). This central importance of water to existence makes Malik *et al*. (2020), and Sonone *et al*., (2020), to opine that the quality of water directly impacts fish health and productivity; while polluted water can lead to the bioaccumulation of

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toxins within aquatic organisms. This bioaccumulation poses significant risks, as harmful substances accumulate in fish tissues, potentially resulting in mortality when concentrations exceed safe limits (Sonone *et al*., 2020). The rates at which pollutants are taken up and eliminated by fish vary based on the chemical properties of the contaminants and the environmental conditions of the water body (Ali *et al*., 2019). In Southern Taraba State, Nigeria, the water bodies, such as rivers and lakes, are vital for the livelihoods of local communities, particularly those engaged in fishing and farming. Unfortunately, the quality of these water resources is increasingly threatened by various forms of pollution, including agricultural runoff, industrial discharges, and domestic waste (Orobator *et al*., 2020). This situation is exacerbated by inadequate wastewater treatment facilities and weak regulatory enforcement, leading to the degradation of aquatic ecosystems and a decline in fish production (Maton *et al*., 2016).

Water pollution is a major environmental concern with significant implications for aquatic ecosystems, fish production, and human livelihoods (Kosamu, Makwinja, Kaonga, Mengistou, Kaunda, Alamirew & Njaya, 2022). Pollution, whether from industrial, agricultural, or domestic sources, affects the quality of water and the health of aquatic organisms, thereby impacting fisheries and aquaculture productivity (Aydin, 2018). The contamination of freshwater bodies by pollutants such as heavy metals, pesticides, industrial effluents, and organic waste leads to reduced fish stock, disrupted breeding cycles, and increased mortality rates among aquatic organisms (Sonone *et al*., 2020). Empirical evidence suggests a decline in fish stock in both marine and inland waters due to pollution and other anthropogenic factors (Allen, 2017). Despite advancements in fishing technology, catch levels have remained low, highlighting the adverse effects of environmental degradation on fish populations. The consequences of this decline extend beyond ecological concerns, affecting food security and the livelihoods of artisanal fishers and stakeholders in the fisheries sector (Cheung *et al*., 2021).

A key component of pollution assessment in aquatic environments is the study of benthic macro-invertebrates, which serve as indicators of water quality. These organisms respond predictably to pollution stress and can provide insights into long-term changes in water quality (Iyiola & Asiedu, 2020). The absence of pollution-intolerant species often signifies poor water conditions that can have detrimental effects on fish survival and reproduction (Malik *et al*., 2020). Various species of macro-invertebrates, such as worms, mollusks, and crustaceans, play essential roles in the aquatic food web and serve as early indicators of ecosystem health (Manzoor *et al*., 2021).

Several categories of pollutants contribute to water contamination, including degradable organic waste, nutrient-rich fertilizers, chemical pollutants, heavy metals, and thermal pollution (Ayilara *et al*., 2020). Organic pollutants such as sewage, agricultural waste, and industrial effluents deplete oxygen levels in water, leading to hypoxic conditions that threaten fish survival (Bashir et al., 2020). Excessive nutrient loads from fertilizers promote algal blooms, which further deplete oxygen levels and obstruct light penetration, thereby impairing aquatic life (Igwaran *et al*., 2024). Heavy metals and persistent organic pollutants pose long-term toxicity risks to fish and other aquatic organisms due to their non-biodegradable nature (Sharma et al., 2024). Pollution from agricultural activities, quarrying activities, and domestic waste disposal threatens freshwater ecosystems and fish production. The contamination of rivers and streams in this region has led to a decline in fish populations, with implications for local food security and the livelihoods of fishing communities. Given the crucial role of fisheries in sustaining rural economies, understanding the extent of pollution and its impact on fish production is essential for developing effective management and conservation strategies. This study therefore seeks to examine the effects of pollution on water quality and fish production, with a focus on identifying key pollutants, assessing their impact on aquatic ecosystems, and recommending measures for sustainable water and fisheries management.

Environmental pollution poses a significant threat to water quality and fish production. The indiscriminate discharge of agricultural chemicals, industrial effluents, and untreated sewage into water bodies contributes to the deterioration of aquatic ecosystems, which in turn affects fish health and productivity (Umar, 2020). Due to extensive anthropogenic activities along river banks, many water sources in the region are contaminated with both organic and non-organic pollutants, leading to fluctuations in fish stocks and increased health risks for communities relying on these resources. Despite the importance of fisheries for food security and economic sustainability, there is a lack of comprehensive data on the extent and effects of pollution, making it essential to investigate these issues systematically.

2.0 LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 The Concept of Pollution

Pollution is a major environmental issue that poses significant threats to ecosystems, biodiversity, and human health. The study of pollution spans multiple disciplines, including environmental science, ecology, toxicology, and public health. Saravanan *et al*. (2021) define pollution as "the introduction of harmful substances or energy into the environment at a rate that surpasses the ecosystem's ability to assimilate and neutralize them." This definition underscores the disruption caused when pollutants overwhelm an ecosystem's natural recovery mechanisms. Similarly, Edo *et al*. (2024) describe pollution as "an undesirable alteration in the physical, chemical, or biological characteristics of air, water, and land, leading to harm to living organisms and degradation of human life." This definition highlights pollution's far-reaching impacts on various environmental components.

Okoye *et al*. (2022) conceptualize pollution as "the accumulation of synthetic chemicals and toxic substances in the environment, causing long-term ecological disturbances and health hazards." This perspective draws attention to the persistent and often hidden consequences of pollution. Meanwhile, the World Health Organization (WHO, 2018) defines pollution as "the presence of substances in the environment that, due to their quantity, nature, or persistence, may cause harm to human health, biodiversity, or the ecosystem." This definition links pollution directly to public health concerns and sustainability challenges. Similarly, the United Nations Environment Programme (UNEP, 2020) characterizes pollution as "the contamination of air, water, and soil by chemical, physical, or biological agents, resulting in adverse environmental and health effects." This broad definition encompasses various forms of pollution and their wide-ranging impacts.

According to Ukaogo *et al*. (2020), pollution refers to "negative alterations in environmental components, whether caused entirely or partially by human activities, disrupting the natural equilibrium that existed before human intervention. These changes manifest as energy fluctuations, variations in radiation levels, and undesirable biological, physical, and chemical modifications within the biosphere, affecting all living organisms directly or indirectly through food, air, water, and agricultural products." This definition emphasizes the diverse sources of pollution and its complex consequences on ecological balance. Similarly, Al-Taai (2021) defines pollution as "the quantitative and qualitative changes, both accidental and intentional, that affect one or more environmental elements, ultimately harming organisms and diminishing the ability of ecosystems to sustain productivity." Therefore, pollution is a multifaceted environmental problem with serious ecological and health implications. Its various definitions reflect its complexity, highlighting the need for effective mitigation strategies to protect both the environment and human well-being

2.1.2 Fish Production

Fish production plays a crucial role in ensuring food security, supporting livelihoods, and fostering global economic growth. This sector encompasses both capture fisheries, where wild fish are harvested, and aquaculture, which involves the farming of fish. Together, these practices contribute significantly to global nutrition and employment opportunities. According to the Food and Agriculture Organization (FAO, 2018), fish production is defined as "the total quantity of fish obtained through capture fisheries and aquaculture, including both marine and freshwater species harvested for human consumption and industrial use." This definition captures the breadth of fish production methods, encompassing both natural processes and those managed by humans. Gebremedhin *et al*. (2021) further elaborate on this concept, describing fish production as "the biological and economic process of harvesting and managing fish stocks for sustainable exploitation." This perspective highlights the critical balance necessary between fish extraction and sustainability, emphasizing the importance of responsible management practices to ensure the long-term viability of fish populations.

In addition, Quiñones *et al*. (2019) define fish production as "the rate at which fish biomass is generated, harvested, and utilized, considering ecological and environmental constraints." This definition integrates the natural growth of fish populations with the practices employed by humans in harvesting these resources. It underscores the need to consider ecological factors and the environmental impact of fishing activities. Elhetawy *et al*. (2023) take a broader view, characterizing fish production as "the systematic exploitation of aquatic resources, including wild fish capture and controlled breeding in aquaculture systems." This definition acknowledges the dual nature of fish production, encompassing both the harvesting of wild stocks and the cultivation of fish through aquaculture, which is increasingly vital for meeting global demand.

Finally, Hernández-Barrero *et al*. (2022) define fish production as "the yield of fish from aquatic ecosystems per unit area over time, influenced by environmental conditions, fishing pressure, and management practices." This perspective emphasizes the dynamic interplay between environmental factors, human activities, and effective management strategies in determining fish production outcomes. Fish production is a multifaceted process that is essential for food security and economic stability worldwide. These definitions help highlight the importance of sustainable practices in both capture fisheries and aquaculture, ensuring that this vital resource can be preserved for future generations.

Fish production is a crucial component of global food security, economic stability, and cultural heritage. Boyd *et al*. (2022) note that the primary types of fish production include capture fisheries and aquaculture (fish farming), both of which contribute significantly to the global supply of fish. Each type has distinct characteristics, challenges, and sustainability considerations that influence their impact on local economies, ecosystems, and food systems.

Capture Fisheries: Capture fisheries involve the harvesting of wild fish from natural water bodies such as oceans, rivers, lakes, and reservoirs (Ainsworth *et al*., 2023). This method encompasses a wide range of fishing activities, from small-scale operations to large commercial fleets.

Aquaculture (Fish Farming): Aquaculture, or fish farming, is the controlled breeding, rearing, and harvesting of fish in artificial or semi-controlled environments (Piate & Orok, 2024). This practice has gained prominence as a means to supplement fish supply and reduce pressure on wild fish stocks.

Subsistence Fishing: Subsistence fishing is a specific subset of capture fisheries focused on small-scale practices primarily aimed at local consumption. This type of fishing is particularly prevalent in rural and coastal communities, where access to commercial food sources may be limited.

Commercial Fishing: Commercial fishing represents a larger-scale approach to fish production, focusing on harvesting fish for sale and profit. Operational scale fishing can vary from medium-sized enterprises to massive industrial operations that deploy large fleets equipped with advanced technology.

Fish production plays a vital role in global food security, economic stability, and cultural heritage. While capture fisheries continue to be a significant source of seafood, the growing demand for fish has led to the expansion of aquaculture as a sustainable alternative. However, both capture fisheries and aquaculture face environmental and regulatory challenges that require innovative management strategies.

2.2 Sources of Water Pollution

Water bodies, particularly inland waters such as rivers, lakes, and reservoirs, are increasingly threatened by pollution from multiple sources. These include industrial effluents, agricultural runoff, municipal wastewater discharge, and domestic waste disposal (Umar, 2020; Pericherla *et al*., 2020). The contaminants introduced into these ecosystems vary in composition and concentration, ranging from heavy metals and nutrients to pharmaceuticals, pesticides, and emerging pollutants such as microplastics (Amoatey & Baawain, 2019). The widespread pollution of freshwater ecosystems not only disrupts aquatic biodiversity but also poses severe environmental and public health risks, particularly in developing nations where regulatory frameworks and treatment facilities are inadequate.

Industrial Effluents: Industries release a variety of hazardous chemicals, including heavy metals (lead, mercury, cadmium), organic solvents, hydrocarbons, and synthetic compounds into water bodies (Umar, 2020).

Agricultural Runoff: Agricultural activities significantly contribute to water pollution through the use of chemical fertilizers, pesticides, herbicides, and livestock waste (Pericherla *et al*., 2020). Excess nutrients, particularly nitrate and phosphate, enter water bodies through surface runoff, leading to eutrophication, a process characterized by excessive algal growth that depletes oxygen levels and results in fish kills and biodiversity loss.

Municipal Wastewater and Domestic Discharges: In many urban and rural areas, untreated sewage and domestic waste find their way into rivers, streams, and lakes, introducing pathogens such as bacteria (*Escherichia coli*, *Salmonella*), viruses, and protozoa that can cause waterborne diseases, including cholera, dysentery, and typhoid fever (Umar, 2020).

Emerging Contaminants: Recent studies have highlighted the presence of pharmaceutical residues, endocrine-disrupting chemicals (EDCs), personal care products, and microplastics in water bodies (Amoatey & Baawain, 2019). These contaminants originate from hospitals, households, and industries, and their long-term ecological and health effects are still under investigation.

2.3 Level of Non-Biodegradable Pollutants on Water Bodies in Nigeria

The contamination of surface waters by chemicals such as pesticides, pharmaceuticals, per-fluorinated alkylated substances (PFAS) or personal care products and POPs are now widely recognized (Folorunsho *et al*., 2023). Every year, large volumes of pharmaceuticals are produced and consumed. However, not all acquired medications by consumers are used. Unused and expired medications which can be potentially toxic substances when they accumulate in different matrices like water and soil are indiscriminately disposed in Nigeria. There is also sparsity of information on the disposal methods and protocols used by community pharmacists in the disposal of expired drugs in Nigeria (Kayode-Afolayan *et al*., 2022). The weak national guideline for medication disposal and poor compliance to same is feared to increase the potential risk of contamination of the environment and increases the risk of ingesting toxic pharmaceutical wastes by humans and animals. The crave for civilization and modern technology with the inability to afford same has led to massive importation of sundry electronics from developed countries into Nigeria (Afolabi *et al*., 2023). As a major destination of used electrical and electronic equipment from these developed countries, at least 60,000 tonnes of these used electrical and electronic equipment are imported annually. With very poor recycling infrastructure to manage the electronic waste (E-waste), there is heavy reliance on informal sectors to employ crude dismantling and artisanal recycling techniques and uncontrolled open burning of cables to recover wires (Nnorom and Odeyingbo, 2020) and consequently pollute the soil, water and air with the following substances, brominated flame retardants, non-dioxin-like polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PBDF) and dioxin-like polychlorinated biphenyls (DL-PCB) (Nnorom and Odeyingbo, 2020; Afolabi *et al*., 2023). All these crude activities create mountains of E-waste often dumped in agricultural farm lands and water bodies (Nnorom and Odeyingbo, 2020; Afolabi *et al*., 2023).

2.4 Physicochemical Parameters of Rivers and Lakes

The physicochemical parameters of these water bodies are essential indicators of their health and suitability for various uses, including drinking water, agriculture, and industrial activities. To evaluate the extent of pollution, researchers employ physicochemical and biological indicators of water quality. These include:

Temperature: Studies have shown that the temperature of Nigerian rivers and lakes varies significantly across different regions and seasons. For instance, Oyebode *et al*. (2018) reported that the temperature of the Niger River ranged from 24.5°C to 31.5°C during the dry season, while the wet season saw temperatures between 22.5°C and 28.5°C. Similarly, in Lake Chad, temperature variations were observed to be influenced by climate change, with an average increase of 0.5°C per decade (Onyekwelu *et al*., 2019).

pH: Most Nigerian rivers and lakes have a pH range that is generally considered suitable for aquatic life, typically between 6.5 and 8.5. A study by Adeyemo and Olaniran (2017) found that the pH of the Ogun River varied from 6.8 to 7.5, indicating a neutral to slightly alkaline condition. However, urban and industrial pollution has led to pH fluctuations in some water bodies. For example, the pH of the Oshun River near industrial areas was reported to be as low as 5.0, indicating acidic conditions (Adeyemo and Olaniran, 2017).

Dissolved Oxygen (DO): Studies have shown that DO levels in Nigerian rivers and lakes are generally within acceptable limits but can be affected by pollution. A study by Oyebode *et al*. (2018) found that the DO levels in the Niger River ranged from 4.5 to 7.5 mg/L, which is sufficient for most aquatic life. However, in polluted areas, such as near industrial discharges, DO levels were observed to be as low as 2.0 mg/L, posing a risk to aquatic organisms (Oyebode *et al*., 2018).

Electrical Conductivity (EC): High EC levels can indicate the presence of pollutants and can affect the taste and quality of water. A study by Onyekwelu *et al*. (2019) reported that the EC of Lake Chad ranged from 200 to 500 µS/cm, which is considered moderate. However, in some industrial areas, EC levels were found to be as high as 1000 µS/cm, indicating significant pollution (Onyekwelu *et al*., 2019).

Total Dissolved Solids (TDS): High TDS levels can affect the taste and quality of water and can be an indicator of pollution. A study by Adeyemo and Olaniran (2017) found that the TDS levels in the Ogun River ranged from 100 to 300 mg/L, which is within acceptable limits. However, in areas affected by industrial discharge, TDS levels were as high as 500 mg/L, indicating significant pollution (Adeyemo and Olaniran, 2017).

Nutrients (Nitrate, Phosphate, and Ammonium): Studies have shown that nutrient levels in Nigerian rivers and lakes are influenced by agricultural and urban runoff (Edegbene et al., 2022; Andem et al., 2022). A study by Oyebode *et al*. (2018) found that the nitrate levels in the Niger River ranged from 0.5 to 2.0 mg/L, while phosphate levels ranged from 0.1 to 0.5 mg/L. However, in areas with intensive agricultural activities, nitrate levels were as high as 5.0 mg/L, indicating a risk of eutrophication (Oyebode *et al*., 2018).

Heavy Metals: Heavy metals such as lead, cadmium, and mercury can be toxic to aquatic organisms and can accumulate in the food chain (Sonone et al., 2020). A study by Onyekwelu *et al*. (2019) found that the lead levels in Lake Chad ranged from 0.01 to 0.05 mg/L, while cadmium levels were as high as 0.02 mg/L. In the Oshun River, mercury levels were found to be as high as 0.01 mg/L, indicating significant pollution (Onyekwelu *et al*., 2019).

2.5 Effect of Water Quality on Fish Production

Fish production is a vital component of Nigeria's economy, contributing significantly to food security, employment, and income generation (Olaifa et al., 2022; Odioko & Becer, 2022). However, Anani *et al*. (2022) noted that the quality of water in aquatic ecosystems, including rivers, lakes, and ponds, plays a crucial role in fish production. Pollution exerts profound negative effects on aquatic ecosystems, affecting water quality, biodiversity, and human health. Nutrient pollution from fertilizers and sewage leads to harmful algal blooms (HABs), which block sunlight, consume dissolved oxygen, and release toxins, creating dead zones where aquatic life cannot survive (Lan et al., 2024; Umar, 2020). Toxic pollutants, such as heavy metals and pesticides, disrupt fish reproduction, impair immune systems, and lead to the decline of sensitive aquatic species, altering ecosystem balance (Pericherla *et al*., 2020). Water quality is a critical factor in fish production in Nigeria. Physicochemical parameters such as temperature, pH, DO, EC, and TDS, as well as nutrient levels and heavy metal contamination, can significantly impact fish health and productivity (Abdul-Azeez & Muhammad, 2024; Chris et al., 2023). Microbial contamination and algal blooms further complicate the issue, leading to reduced fish growth and increased mortality.

2.6 Health Risks Associated with Consuming Fish from Polluted Water Bodies

Fish consumption is a significant part of the diet in many Nigerian communities, providing essential nutrients and protein. However, the increasing pollution of water bodies in Nigeria poses a serious threat to the health of consumers. Water pollution in Nigeria is primarily attributed to industrial discharges, agricultural runoff, and domestic waste (Adeyemi *et al*., 2018). Industrial activities, such as mining and oil exploration, release heavy metals and chemicals into water bodies, while agricultural practices contribute pesticides and fertilizers (Okereafor *et al*., 2020). Domestic waste, including sewage and household chemicals, further exacerbates the problem (Adeyemi *et al*., 2018). Heavy metals, such as lead, mercury, and cadmium, are common pollutants in Nigerian water bodies. These metals can accumulate in fish tissues, posing significant health risks to consumers (Oyegoke *et al*., 2019).

Studies have shown that fish from polluted waters in Nigeria contain elevated levels of heavy metals, which can lead to various health issues, including neurological disorders, kidney damage, and cancer (Eze *et al*., 2020). Exposure to pesticides and other chemicals used in agriculture and industry can result in acute and chronic health effects, including liver and kidney damage, hormonal imbalances, and reproductive issues (Ajibola *et al*., 2024). A study by Ogunfowokan *et al*. (2017) found that fish from the Niger Delta region contained high levels of organochlorine pesticides, which are known to be persistent and bioaccumulative. Similarly, domestic and industrial waste often contain pathogens, including bacteria, viruses, and parasites, which can contaminate water bodies and fish. Consuming fish contaminated with these pathogens can lead to gastrointestinal illnesses, such as cholera and typhoid fever (Adeyemi *et al*., 2018). A study by Eze *et al*. (2020) reported a high prevalence of fecal coliforms in fish samples from polluted rivers in Nigeria, indicating a significant risk of microbial contamination.

2.7 Level of Pollution Management and Sustainable Fishery Practices

Artisanal fishing, a crucial livelihood for millions of people globally, faces significant challenges from pollution and unsustainable practices. Globally, artisanal fisheries contribute significantly to food security and local economies. However, they are often characterized by limited access to technology and resources, making them vulnerable to environmental degradation (FAO, 2018). Pollution, including plastic waste, oil spills, and chemical runoff, poses a substantial threat to fish populations and marine ecosystems (Borja *et al*., 2019). Sustainable practices, such as the use of selective fishing gear and the establishment of marine protected areas (MPAs), are essential for mitigating these impacts (Carneiro & Martins, 2022). In Africa, artisanal fishing is a vital source of protein and income for coastal communities. However, the sector is plagued by overfishing, habitat destruction, and pollution (Sall, 2024). The lack of regulatory frameworks and enforcement mechanisms exacerbates these issues. However, community-based management (CBM) has shown potential in improving resource governance and reducing overfishing (Hamelin *et al*., 2024). Nigeria, with its extensive coastline and numerous inland water bodies, has a significant artisanal fishing sector. However, the sector is under threat from pollution, particularly from oil spills and industrial waste (Oluwakayode-Oluyi *et al*., 2025). The Niger Delta region, a major oil-producing area, has experienced severe environmental degradation, affecting fish populations and the livelihoods of local fishermen (Odubo & Odubo, 2024).

2.9 Empirical Review

Gundi (2016) explored the effects of water pollution on fish health. The study used secondary sources relying on articles and journals that provide adequate information about water pollution and its effects on fishes. It was identified that water pollution disrupts the growth of the fishes and decreases the quality of them. The percentage of fish population decreases as well as the percentage of fish decline also increases due to water contamination. As a result, it is identified that water pollution disrupts the growth of the fishes and decreases the quality of them. The percentage of fish population decreases as well as the percentage of fish decline also increases due to water contamination. The present article will examine the effects of water pollution on fish population and fisheries sector.

Akinsulire *et al*. (2018) assessed the potential impacts of fish farm effluents throughout a production life cycle on receiving coastal ecosystems in Southwestern Nigeria. Physicochemical characteristics of fish pond effluents collected from nine fish farms, surface water and sediments from two sites 50 meters apart downstream (SI) and upstream locations (1 SII) along a potential contamination gradient of receiving coastal ecosystem were determined using standard volumetric procedures and methods described in American Public Health Association (APHA). The results show that water and sediment obtained from downstream (SI) and upstream (SII) adjacent Lagoons showed no significant variation ($P < 0.05$) in mean values of pH, dissolved oxygen, conductivity, biochemical oxygen demand, chemical oxygen demand, SO_4, NO_3 and total organic matter. However, the concentrations of PO_4 (3.90 ± 1.04), total organic carbon (6.01 ± 0.29), total dissolved solids (96.63 ± 11.78) and total suspended solids (6.25 ± 1.98) downstream of receiving coastal ecosystems were relatively higher than the levels observed in fish ponds (PO_4 - 1.45 ± 0.25, total organic carbon - 5.92 ± 0.31, total dissolved solids - 71.62 ± 4.10 and total suspended solids - 3.95 ± 0.49) suggesting potential impact from fish farms.

Ajibade *et al*. (2024) analysed the effect of marine pollution and selected climatic variables on artisanal fish capture in Nigeria over 1980-2019. Analytical tools employed include unit root test, co-integration, and the error correction mechanism. The study found that the sea surface temperature, wind speed, current year marine litter plastic waste, and magnitude of marine litter plastic wastes from the previous year negatively influenced the artisanal fish capture quantity in the period under review ($p<0.05$). The study concluded that climate change and marine plastic pollution are major issues with negative impacts on artisanal fish capture in Nigeria. It was therefore recommended the need to draw up strategies towards cleaner aquatic environment through the improvement of waste disposal system in Nigeria alongside concerted ocean clean-up exercises.

Utete *et al*. (2018) assessed the historical fish catches, species composition, and investigate the effects of climatic variability and catchment dynamics in periurban Lakes Chivero and Manyame in Zimbabwe. The Mann-Kendall test was used to analyse time series trends in fisheries and climatic data. Multiple regression analysis was used to assess relations between fish catches and climate data for Lakes Chivero and Manyame. Fish catches have significantly declined in Lakes Chivero and Manyame over the periods considered with a shift towards a monospecies dominance in the fish community. Peri-urban lakes are characterised by highly adapted, relatively large sized fish species which have an ability to utilise a directional environmental disturbance such as hypereutrophication. Climatic factors have significant effects in fish catches in Lake Chivero. Despite the potential negative socioeconomic consequences inferred from declining fish catches, water pollution, gross underreporting, poor recording and preservation of fisheries statistics remains a massive threat to the survival of inland peri-urban fisheries in Lakes Chivero and Manyame.

Umar (2020) assessed literature on major source and effect of pollution in inland water bodies of Nigeria through published and unpublished materials as well as browsing of related issues on the internet. The result shows that sources of pollution account for several point sources of water pollution, while developed nations adopt stringent water quality requirements to control river pollution from point and non-point sources, the situation is different in most developing countries like Nigeria. Waste water treatment in Nigeria is not given the necessary priority it deserves and therefore, industrial waste discharged into receiving water bodies without treatment and the effect of these include, among others, river pollution, loss of aquatic life, uptake of polluted water by plants, disease burden and shorter life expectancy. It was recommended that the federal, state and local governments in Nigeria should ensure that industrial wastes, agricultural, pesticides, petroleum, particularly effluents are pre-treated before discharging them into the environment.

Orobator *et al*. (2020) evaluated water quality from selected aquaculture ponds in Benin City, Nigeria. Water samples were collected from deep concrete pond, white plastic tank, black plastic tank, black tarpaulin pond, earthen pond and surface concrete pond. Standard procedures were adopted to analyze the selected physicochemical parameters of water. The analyzed results were subjected to WHO (2009) and FEPA (1993) permissible limits for aquatic water quality. Pond D (black tarpaulin pond) had the highest concentrations of EC, Total suspended solids (TSS), Total dissolved solids (TDS), turbidity, Sulphate, Biological oxygen demand, NO4, P, Ca, NH4, Mg, Na, K, Zn, Cu, Cr, Pb and Cd. Pond D was more acidic and had the lowest alkalinity, Chemical Dissolved Oxygen (COD) and Dissolved Oxygen (DO) values than other fish ponds. COD and P contents in all the fish ponds were above their permissible limits. The status of TSS, TDS, and turbidity, Zn, Cu, Cr, Pb and Cd showed that these water indices were not toxic. The study recommends that fish pond water as well as water holding facilities should be monitored periodically. It also suggests that Pond D (black tarpaulin pond) should be least considered when setting up aquaculture system.

Tumwesigye *et al*. (2022) assess the effect of water quality on aquaculture productivity in Ibanda District, Uganda. The specific objectives were to examine the status of water quality parameters (temperature, turbidity, pH, alkalinity, Ammonia content, hardness, Carbon dioxide content, and Iron content) and assess their effect on fish pond productivity. Using data from fish farmers and water samples taken from 25 restocked fish ponds in ten sub-counties, the study revealed that of the eight water quality parameters examined only four (average turbidity, alkalinity, hardness, and Carbon dioxide content) were within the acceptable ranges, while Ammonia content, temperature, pH, and Iron content were slightly outside the recommended ranges. In addition, the study revealed that water quality parameters such as temperature, pH, and Ammonia Carbon dioxide, and Iron content had a significant effect on the weight and size of both tilapia and catfish. The study concluded that certain water quality parameters have a detrimental effect on fish farming.

Bilewu *et al*. (2022) assessed physicochemical parameters in selected water bodies in Oyo and Lagos States. Water samples were collected from frequently used water bodies at Awba Dam and National Horticulture Research Institute (NIHORT) in Ibadan, Oyo State and the Ogun River in Lagos State. The locations were selected based on surrounding population and activities. Sampling was done in the months of April and June, 2021. The physicochemical parameters analysed were pH, electrical conductivity (EC), salinity, total dissolved solids (TDS), chloride, biochemical oxygen demand (BOD) and dissolved oxygen (DO). Average salinity value ranged between 0.2675 ± 0.14 mg/L (UI) and 0.6735 ± 0.22 mg/L (Berger). These values are quite high and significant when compared to the threshold level of 0.0000001 mg/L. Of the three sampling points, the samples obtained from Awba

Dam at the University of Ibadan seem to have the better quality in relative terms. This follows from the BOD and TDS values of 3.75 ± 0.28 mg/L and 259.7 ± 156.89 mg/L respectively. The study concludes that the mismanagement of waters through unrestrained and unrestricted dumping of contaminants has caused these water bodies to have poor quality.

Uzomah *et al*. (2021) reviewed available data on the concentrations of polycyclic aromatic hydrocarbons (PAH), persistent organic pollutants, metals, and microplastics in freshwater and marine fish in Nigeria with reference to international maximum levels for contaminants in food and the potential risk to human health. The findings suggest that the consumption of smoked *Ethmalosa fimbriata* poses a higher potential carcinogenic risk than the other fish species that were investigated. Most of the other studies on PAHs in smoked fish are focused on the smoking method, and little information is available on the initial level of PAHs prior to the smoking process. Metal contamination in fish appeared to be affected by mineral deposits in the environment and industrial effluents.

Naluba and Bob-Manuel (2021) investigated the impact of marine pollution on productivity of fish and sea food companies in Port Harcourt Metropolis, Rivers State. The study adopted a descriptive and experimental research design and it is a census study. Primary source of data was generated through self- administered questionnaire. The target population of interest for the study comprised of 266 managers and supervisors of 20 selected fish and sea food companies in Port Harcourt Metropolis. Primary data for the research was collected through the administration of a structured questionnaire. Also, laboratory analysis was conducted on the three water bodies which were utilized by shipping and marine food companies' operation. Data generated were analyzed and presented using both descriptive and inferential statistical techniques. The hypotheses were tested using the Spearman's Rank Order Correlation Statistics. The findings revealed that there is a significant relationship between oil waste from marine pollution and the productivity of fish and sea food companies in Rivers State [(P =.000) $p<0.05$]; there is significant relationship between solid waste discharged from marine pollution and the productivity of fish and sea food companies in Rivers State [(P =.000) $p<0.05$]; amongst others. The finding was further substantiated with the laboratory results which strongly affirmed the above findings.

Ehiemere *et al*. (2022) determined the concentrations of heavy metals in surface water and in fish pond water, sediments and farmed fish (*Clarias gariepinus*) from a fish farm cluster with the view of assessing its pollution level and associated human health exposure risk through fish consumption. Samples were digested with aqua regia and metal concentrations were determined with an atomic absorption spectrophotometer equipped with an air acetylene flame. The pollution studies showed that lead, cadmium and chromium contaminated the surface water samples. Sediment from all sites showed low to considerable contamination by the heavy metals. The human exposure risk assessment of the metals showed that the total hazard index was less than one which indicates no probable adverse health effect from the consumption of fish from the ponds, although this case is different for Pb since there is no estimation of oral reference dose (RfDo) for lead according to EPA.

Osuagwu and Olaifa (2018) examined the effect of oil spills on fish production in the Niger Delta of Nigeria from 1981-2015 using an estimable model based on a Cobb Douglas production function. The variables included in the model are captured fish production, number of fishers, loan to fishery, oil spills and oil production. The findings suggest that oil spill and oil production negatively affects fish production, while farm labour has a positive effect on fish production. On the other hand, fishery loan exerts a negative effect on fish production and this could be ascribed to the bottlenecks in trying to access these loans. The Pairwise Granger Causality test result shows that the number of times oil is spilled to the environment affects the level of fish production negatively. The study corroborates the findings in recent literature and proposes a cautious approach to oil exploration activities for sustainable economic development.

Oruonye et al. (2023) examined challenges of livelihood sustainability from artisanal inland water fishing activities in Ibi LGA, Taraba State, Nigeria. The study used descriptive survey, and purposive sampling in selecting 406 respondents from 12 communities in 6 political wards. Descriptive statistics was used to analyse 401 questionnaires retrieved. Findings of the study reveal decline in daily fish catch from three baskets 10 years ago to only one basket presently. Also, income from fishing has declined from ₦150,000 ($192) monthly 10 years ago to less than ₦50,000 ($64) presently. Factors responsible for decline in fish catch include rising water level, temperature increase, pollution, climate change, seasonality and unsustainable fishing practices. The unsustainable fishing practices include use of chemicals, small size nets and mosquito nets in fishing. In addition, the fishermen engaged in non-fishing activities, fish farming and construction of fishing ponds along the floodplain as a way of achieving livelihood sustainability. Challenges of livelihood sustainability include seasonality of fishing activities, decline in fish stocks, use of traditional fishing methods and unsustainable fishing practices among others.

2.10 Theoretical Review

Ecological Risk Assessment (ERA)

The Ecological Risk Assessment (ERA) Framework was developed as a systematic and structured approach by the U.S. Environmental Protection Agency (EPA) in the 1990s to evaluate the potential risks posed to ecological systems by various pollutants and environmental stressors (Paustenbach, Langenbach, & Wenning, 2024). This framework emerged from the growing recognition of the need to protect not only human health but also the integrity of ecosystems, which are vital for sustaining biodiversity and providing essential services to society. While no single individual is credited with "propounding" the ERA theory, its development reflects a collaborative evolution shaped by contributions from various interdisciplinary fields, including toxicology, ecology, environmental chemistry, and regulatory science. Researchers and practitioners from these fields worked together to create methodologies that could effectively assess the impact of contaminants on ecological health. This collaborative effort was crucial in addressing the complexities of environmental interactions and the multifaceted nature of ecological risks (Carriger & Parker, 2021). The ERA Framework is designed to provide a comprehensive assessment of the potential adverse effects that pollutants may have on ecosystems, encompassing flora, fauna, and their habitats. It involves several key steps, including problem formulation, exposure assessment, effects assessment, and risk characterization. Each of these components serves to systematically evaluate the likelihood and severity of ecological harm resulting from environmental contaminants.

- **Problem Formulation:** This initial stage involves defining the scope of the assessment, including the specific ecological concerns, the contaminants of interest, and the ecosystems or species that may be affected.

- **Exposure Assessment:** This phase evaluates how organisms in the ecosystem are exposed to pollutants, considering factors such as concentration levels, duration of exposure, and the pathways through which exposure occurs (e.g., water, soil, air).

- **Effects Assessment:** In this stage, the potential ecological impacts of the identified pollutants are analyzed. The goal is to ascertain the nature and degree of harm that may result from exposure.

- **Risk Characterization:** The final step involves synthesizing the information gathered in the previous phases to provide an overall assessment of ecological risk.

The ERA Framework has become an essential tool for regulatory agencies, environmental consultants, and researchers, enabling them to make informed decisions about environmental protection and resource management (Awewomom et al., 2024). Its interdisciplinary foundation ensures that assessments are thorough and consider a wide range of ecological factors, thereby enhancing the framework's credibility and applicability in real-world scenarios. Elsharkawy and Sharkawy (2025) in their study reported that whether in dealing with prospective risks or retrospective assessments of past environmental damage, ERA provides a means to balance ecological protection with economic and social considerations. Rohr et al. (2016) reported that no single level of biological organization may serve as the ideal basis for ERA; instead, a dual approach that integrates insights from both bottom-up and top-down methodologies is essential. Mwinyihija (2011) used Ecological Risk Assessment (ERA) as a tool in evaluating hazards and risks, concluded that results using ERA were very successful which yielded a tangible pathway to manage both the pollution generation and waste management. Ibezim-Ezeani and Ihunwo (2023) used ERA in analyzing Cd, Cr, Ni and Pb metals in sediment sampled from an estuary (Sambreiro River) in the Niger Delta Region of Nigeria, and concluded that Cd has the highest degree of ecological risk index for the studied river. Egbueri and Enyigwe (2020) employed the ecological risk assessment and found that 100% of the sampled water pose very high ecological risks. Zou et al. (2025) applied the ERA framework to the Yangtze River Trunk Line Wuhan–Anqing Waterway Regulation Project and provided a replicable tool for the Waterway Management Authority to address the complex sustainability challenges in global waterway development projects.

As environmental challenges continue to evolve, spurred by factors such as climate change, habitat destruction, and pollution, the importance of the ERA Framework in guiding effective management strategies cannot be overstated. It serves as a critical mechanism for safeguarding ecosystems and ensuring that human activities do not compromise the health and resilience of the natural environment.

RESEARCH METHODOLOGY

A systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

The following databases were searched: PubMed, Scopus, Web of Science, and Google Scholar. The search terms included "pollution," "water pollution," and "fish production." Only studies published within a defined five-year window (i.e. 2020 to 2025) were considered in this work. The inclusion criteria included peer-reviewed articles, focus on pollution and fish production, and availability of study in English.

. The quality of the studies was assessed using the Critical Appraisal Skills Programme (CASP) checklist.

FINDINGS

Major Sources of Pollution

Industrial activities discharge hazardous substances—including heavy metals such as lead, mercury, and cadmium, as well as organic solvents, hydrocarbons, and synthetic compounds—into water bodies (Umar, 2020). Additionally, the extensive use of chemical fertilizers, pesticides, herbicides, and the improper disposal of livestock waste significantly contribute to water pollution, often resulting in eutrophication and fish mortality (Pericherla *et al*., 2020). The release of untreated sewage and household waste introduces pathogens that can trigger waterborne diseases (Umar, 2020). Moreover, pharmaceuticals, endocrine-disrupting chemicals (EDCs), personal care products, and microplastics are increasingly detected in aquatic ecosystems (Amoatey & Baawain, 2019).

Level of Non-Biodegradable Pollutants

The widespread production and consumption of pharmaceuticals in Nigeria lead to the improper disposal of unused and expired medications, which exacerbates pollution levels (Kayode-Afolayan *et al*., 2022). Additionally, the country imports large volumes of used electrical and electronic equipment, much of which is dismantled and recycled through informal methods. This practice contributes significantly to the release of persistent pollutants (Nnorom & Odeyingbo, 2020; Afolabi *et al*., 2023).

Physicochemical Parameters of Water

Water temperature ranges from 24.5°C to 31.5°C during the dry season and 22.5°C to 28.5°C in the wet season (Oyebode *et al*., 2018). The pH generally remains within the range of 6.5 to 8.5, suitable for aquatic life, though urban and industrial pollution can cause fluctuations (Adeyemo & Olaniran, 2017). Dissolved oxygen levels typically fall between 4.5 and 7.5 mg/L but may drop to as low as 2.0 mg/L in highly polluted zones (Oyebode *et al*., 2018). Electrical conductivity ranges from 200 to 500 µS/cm, with higher values observed in industrial areas (Onyekwelu *et al*., 2019). Total dissolved solids (TDS) range from 100 to 300 mg/L, also increasing in polluted environments (Adeyemo & Olaniran, 2017). Nutrient levels, particularly nitrates, are elevated in areas of intensive agriculture, reaching up to 5.0 mg/L (Oyebode *et al*., 2018). Heavy metals such as lead, cadmium, and mercury are present at harmful levels in some water bodies, posing serious ecological and health risks (Onyekwelu *et al*., 2019).

Effect of Water Quality on Fish Production

Nutrient pollution leads to the formation of harmful algal blooms (HABs), which block sunlight, deplete dissolved oxygen, and release toxins, thereby creating aquatic dead zones (Umar, 2020). The accumulation of heavy metals and pesticides disrupts fish reproduction, compromises immune responses, and reduces the populations of sensitive species (Pericherla *et al*., 2020). In addition, microbial contamination and recurring algal blooms hinder fish growth and increase mortality rates (Umar, 2020).

Health Risks Associated with Consuming Fish from Polluted Water Bodies

Toxic metals such as lead, mercury, and cadmium accumulate in fish tissues, potentially causing neurological damage, kidney dysfunction, and carcinogenic effects in humans (Oyegoke *et al*., 2019; Eze *et al*., 2020). Exposure to pesticides and chemical residues through fish consumption may result in liver and kidney damage, endocrine disruption, and reproductive health issues (Ajibola *et al*., 2024). Moreover, fish from water bodies contaminated with domestic and industrial waste may carry pathogens that cause gastrointestinal illnesses (Adeyemi *et al*., 2018).

Level of Pollution Management and Sustainable Fishery Practices

Artisanal fisheries in Nigeria face substantial challenges from pollution and unsustainable exploitation, often operating with limited technological and financial resources (FAO, 2018). The adoption of selective fishing gear and the creation of Marine Protected Areas (MPAs) are critical strategies for mitigating environmental impacts (Carneiro & Martins, 2022). Community-Based Management (CBM) approaches have shown promise in enhancing local governance, promoting resource sustainability, and curbing overfishing (Hamelin *et al*., 2024).

CONCLUSION

This study highlights the profound negative impacts of pollution on water quality and fish production in Nigeria. Industrial discharges, agricultural runoff, and domestic waste are identified as the primary sources of pollution, introducing heavy metals, excess nutrients, and organic contaminants into aquatic systems. These pollutants compromise fish health, reduce population levels, and pose significant health hazards to consumers. Addressing these challenges requires a multifaceted approach, including stronger regulatory enforcement, the expansion of wastewater treatment infrastructure, and the promotion of community-based and sustainable fisheries management. Such efforts are essential for safeguarding the country’s water resources and ensuring the long-term viability of its fishery sector. The review emphasizes the need for improved pollution management and sustainable fishery practices to mitigate these adverse effects. Strengthening regulatory frameworks, enhancing wastewater treatment facilities, and promoting community-based management are crucial steps towards ensuring the sustainability of water and fish resources.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are proposed:

1. Regulatory frameworks should be implemented and strictly enforced on industrial and agricultural waste disposal to reduce pollution. Strengthening these regulations will help pinpoint and control the primary sources of pollution, ensuring accountability among industries and farmers, thereby protecting local water bodies from harmful contaminants.
2. Investment in advanced wastewater treatment facilities should be prioritized to ensure that effluents are treated before discharge into water bodies. Upgrading treatment technologies can significantly reduce the levels of non-biodegradable pollutants, thereby improve the overall health of aquatic ecosystems and preserve biodiversity.
3. Regular monitoring of water quality and fish health should be conducted to identify and address emerging pollutants and their impacts. Implementing systematic water quality

assessments will provide vital data on physicochemical parameters, enabling timely interventions to mitigate pollution and protect aquatic life.

4. The use of selective fishing gear should be encouraged, and marine protected areas should be established to promote sustainable fishery practices. These measures will help mitigate the adverse effects of declining water quality on fish populations, ensuring sustainable yields and the long-term viability of fisheries.
5. Communities should be educated on the importance of proper waste disposal and the risks associated with consuming fish from polluted water bodies. Raising awareness will empower local populations to make informed choices regarding fish consumption, ultimately promoting public health and safety.
6. Community-based management initiatives should be promoted to ensure sustainable fishery practices. Engaging local fishermen in the management process will foster a sense of ownership and responsibility, encourage the adoption of environmentally friendly practices and enhance community resilience against pollution.

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