



Water pollution: A menace to aquatic eco-diversity and human health: A review

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Abstract

Water is a well-known natural endowed resources of life form on earth planet and recognized in industrials. However, indiscriminate introduction of hazardous substances into the environment causes undesirable effects on aquatic eco-diversity, human health and biodiversity at large. Water pollution and concentration in the aquatic ecosystem is now an undeniable fact and is one of the main environmental, social and economic issues, with more than 70% of the earth's surface covered water. Aquatic pollutants ranges from industrial effluents, agriculture runoffs in addition to municipal sewage that are dumped in the river, gradually transferring water to be ineligible for human consumption and survival by aquatic life forms. Adoption of efficient use of potential pollutants, awareness creation, recycling, government intervention, stricter enforcement and monitoring policies will help to minimize the threats pose on aquatic ecosystem and human health. This review covers the major causes of water pollution, effects on aquatic eco-diversity and human health and mitigation strategies.

Keywords: Aquatic, biodiversity, environment, water pollution, pollutants

Introduction

The essential roles of water, contributing to continuing life on the earth planet and prosperity of the industries have been recognized over time (Khan *et al.*, 2020) ^[19]. Water is often separated from other environmental components mainly as a source of life that cannot be substituted (Zeyneb *et al.*, 2021) ^[33]. However, the depletion of potable water sources across the world, especially the rural areas has led to increases demand and scarcity of potable water (Zubaidi *et al.*, 2018; Fenu and Mallocci, 2020) ^[34, 13]. Environmental quality attainment and sustainability of resources are considerable challenges faced by most developing countries. Although these countries found laws and policies to control, monitor and reduce environmental pollution, such as water pollution; but they fail to enforce them to protect the environment (Laheab *et al.*, 2021) ^[22].

Water pollution occur by the presence of excessive amounts of a hazard (pollutants) in water making it unsuitable for drinking, bathing, cooking or other uses. While Pollution is the introduction of a contamination into the environment. Water pollutants are containments or substance which when introduced into environment causes undesirable effects or spoils resources. Water pollution has gained an international recognition owing to hazardous materials into water body and the effect on the health of the people, resulting from continuous population growth, increase economic movement and other factors (Hasan *et al.*, 2019; Bassem, 2020) ^[15, 6]. These has led to spoilage of water bodies, threatening aquatic biodiversity and the whole ecosystem at large. Water pollution is one the main environmental issues, with more than 70% of the earth's surface covered water.

Water pollution has caused several environmental, social and economic issues for communities and aquatic diversity, it is also considered a great problem facing freshwater and marine environment (Bassem, 2020) ^[6]. Pollutants are derived from chemical, organic (biological), or physical areas, which affects aquatic animals' immune system either directly or indirectly by changing water quality (Fenu and Mallocci, 2020) ^[13]. Aquatic pollutants ranges from industrial effluents, agriculture runoffs in addition to municipal sewage that are dumped in the river, gradually transferring water to be ineligible for human consumption.

Globalization and Industrialization have engulfed the whole world. Starting from developing nations to developed nations, resulting in the discharge of various pollutants in to the aquatic environment, threatening the health of the population and damaging the quality of the environment.

About 80% of the world's population is facing threats to water security and quality (Owa, 2013) ^[27]. Large quantity of domestic sewage is drained in to river and most of the sewage is untreated. The accumulation of water pollutants into the aquatic ecosystem is a threat. Developing countries like Nigeria contributes more to water pollution due to lack of effective management policies, governance system, capacity and infrastructure to keep pace with urban growth and economic development. Water pollutants recovery and recycling system are also not well established to control the menace. The need for a well-coordinated effort in controlling devastating effects of water pollution on aquatic fauna and human health is required.

Review of literature

History, Origin and Status of Water Pollution

Water as one of the natural endowed resources is the core of life that help our existence and survival (Singh *et al.*, 2020) ^[32]. However, when the water got contaminated by various toxic, inorganic industrial and other sources of pollutants, it became unsafe for consumption for humans' other purposes. This leads to water scarcity because it limits its availability for humans and ecosystem. Water pollution is the main crisis within and around water quality.

The water pollution intensity is subject to pollutant's abundance and ecological impact, and the level of water use (Singh *et al.*, 2020) ^[32]. Major drivers of pollutants are chemical, biological or physical action. In the same vein, natural occurrence such as volcanic eruptions and evaporation can sometimes cause water pollution. More so, human actions and activities on land are the major cause of pollution.

Water Pollutants

About 1500 substances have been listed as pollutants in freshwater ecosystems and a generalized list of pollutants

includes acids and alkalis, anions (sulphide, sulphite, cyanide), detergents, domestic sewage and farm manure, food processing water, gases chlorine, ammonia, heat, metals (cadmium, zinc, lead), nutrients (phosphates, nitrates), oil and oil dispersants, organic toxic wastes (formaldehydes, phenols), pesticides, polychlorinated biphenyls and radionuclides, in addition to oxidizable materials, domestic sewage contains detergents, nutrients, pathogens and a variety of other compounds (Dwivedi, 2017) ^[11]. While others are natural sources (weathering of soil and rock, erosion, forest fires and volcanic eruptions), domestic wastes (sewage and laundry wastes), agricultural chemicals and industrial wastes (Hassan et al., 2017; Khatun et al., 2017) ^[16, 20].

The history of water pollutants can be examined during the Ancient Times, Medieval Time, After World War-II and the present day.

During Ancient Times: Water forms like rivers, lakes and streams were in the major source of drinking water. However, human waste was deposited in the same water bodies and they became so polluted that in order to obtain clean drinking water, these ancient cultures needed to build aqueducts (Fuhrman, 1984) ^[14].

Medieval Times-1800s: During this time, people were unaware of what was good for them and what was bad. Mercury was frequently dumped into water and was allowable to run freely into lakes and streams from most of the humans and farm waste. Most people living in metropolises just dumped their waste and garbage onto the street that smelled very bad. However, civilization made many great strides during the latter half of this period, frequently to the damage of the ecosystem. Individuals even consumed chemicals at that time as they thought, it's good for their health. For the benefit of industry, the Industrial Revolution of the 1800s saw little care for the ecological impact. Many chemical substances have been dumped into the rivers. At that time, people were not concerned about the environmental impact of their inventions (Helmer *et al.*, 1997) ^[18].

After World War-II: Besides contaminants such as human waste, composts, leather tanning and slaughtering waste, the development of industries and factories had also resulted in much water pollution problems. As waste from industries dumped into river freely without care about the environment were affecting ecology and humans, including flora and fauna (Kidd, 1983) ^[21].

Present Day: Many people still do not know how to guard themselves against chemical toxins and waterborne diseases, even with this act. Many cleanups on a large scale have been going on for years (Dwivedi, 2017) ^[11].

Origin and Status of Water Pollutants

The origin of water pollutants can be traced to their fundamental occurrence on earth, the development of natural products by transformation, and their man-made synthesis. Most of the pollutants are products of domestic, agricultural or industrial use by concentration and transformation of naturally occurring compounds. The generation of sewage and waste waters comprising agrochemicals, pesticides, petrochemicals hydrocarbons, heavy metals, and radio nuclides are some important examples of pollutants (Singh *et al.*, 2020) ^[32].

Many of the chemicals do not occur in the nature and the pollution they cause is entirely manmade. For example, the synthesis of various pesticides, surfactants, plastics and petrochemicals has created a large number of chemicals in the environment that have created serious environmental problems.

Sources/Causes of Water Pollution

The source(s) of water pollution; whether it's direct or indirect, often results to death of aquatic creatures and also bring ill health to both animals and human that drink from it. Water pollution is one of the major today's environmental problems and the most vulnerable in terms of pollution, thus, water must be preserved and protected from all types of pollutants.

The common sources of water pollution can vary from wholly natural to manmade sources, which include the following;

- i. Natural sources and runoff: This occur when entry of pollutants is emptied in water reservoirs through; rain water, atmosphere (dust, storms), underground rocks and volcanoes, natural run off and surrounding vegetation (fallen leaves, twigs etc) and saltwater intrusion (occurs naturally but some human activities like pumping of fresh groundwater also increase it)
- ii. Domestic sewage: These comprises of waterborne wastes of the public and contains about 99% of water and 1% of solids. Of the solids existing in sewage, 70% are organic and 30% are inorganic in nature. Sewage produces odors and spread of enteric diseases besides organic pollution which leads to oxygen depletion and aquatic-kill (Mahar and Datta, 2001) ^[25].
- iii. Agricultural Wastes: Is the waste that originate generally from run-off from cultivated arenas and animal farms. In the recent time, for promoting the growth of fruits and vegetables, farmers add various kinds of agrochemicals (pesticides and herbicides) that cause many kinds of pollution problems. Their leaching also pollutes ground water and can cause toxicity to aquatic life also (Savci, 2012) ^[31].
- iv. Industrial Wastes: Is a waste that possess the potential for polluting water reservoirs directly. Nature of industrial waste can vary from industry to industry and also on time as it depends on the usage and type of raw materials used, different processes and also operational factors. It is mentioned that industrial wastes are rich in organic matter (Dwivedi, 2017) ^[11]. Hazardous chemical waste may be in solid, liquid or in gaseous form. The characteristics which make material hazardous are corrosively, Ignitability, toxicity and reactivity (LCWGM, 2016) ^[23].

Nutrient Pollution and Eutrophication: widespread ecological problem in Nigeria as well as the entire universe. Numerous point and nonpoint pollution sources, involving waste disposal, atmospheric nitrogen oxides, chemical fertilizers used in agriculture and fossil fuel uses, contain Nutrients. Nitrogen and phosphorus are the major nutrient elements to cultivate aquatic plants. However, overgrowth of these organisms, consequence to the increment of nutrients, is destructive to water. This is called "Eutrophication" which means well-nourished water by nutrients (see figure 5). The eutrophication drive towards a rapid overgrowth of aquatic plants – especially the phytoplankton plants which they grow on the surface of the water - which affect the water sanitation, hinder the food chain cycle which adversely affect the fish population and health, increase the turbidity of water, and prevent the necessary solar transmission for emergent vegetation growth.

Table 1: Some Sources of water pollutants with their effects and corresponding solution

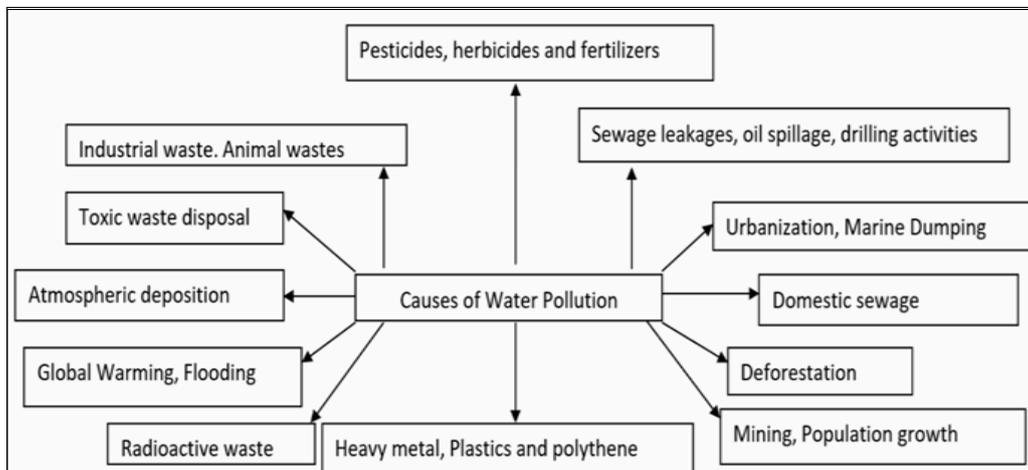
Sources	Components/pollutants and their effects	Solutions
Agricultural run-offs and mill-waste	NO ₃ – and PO _{3_4} (in fertilizers) • Excess amount results to eutrophication	Control its use by (a) using only when crops are growing (b) not using on bare fields (c) not applying when there is a prediction of rain (d) not disposing in river
	Herbicide and pesticide residues • Accretion of pesticides and herbicides have lethal effects on organisms in the water and also, to the humans • Level of pesticides start to build up as it passes over the food chain • High dose of pesticides may collect in the tissues of ultimate consumers that are mostly carnivores	• Use pesticides that are biodegradable • Use methods to control biological pest • Plant must be genetically modified so that it can resist attacks by pests as this may reduce the need of chemical insecticides
Untreated sewage consisting mainly of human faeces and domestic waste	Suspended solids • Reduced penetration of light • If suspended solids are biodegradable, microorganisms can decompose them and their processes require a high oxygen requirement	• Before entering rivers, treat sewage • Help to stop the farm slurry (liquid manure) from entering into rivers and ponds
Domestic waste includes detergents and food waste	Detergent • ‘Hard’ detergents create foam that reduces oxygen supply to water-borne organisms • Soft detergents are biodegradable but it may contain high phosphate levels that can sometimes give rise to eutrophication	• Use low-phosphates biodegradable detergents
Animal waste from farm	Microorganisms such as bacteria and protozoa • If water would be used to drink, perhaps it will cause waterborne diseases namely cholera to be properly treated	Drink water that is properly treated and boiled
Effluents from industries • Electronic and electroplating plants • Food and beverage processing industry • Rubber product processing industry	Heavy metals such as Cu, Hg, Zn and Cr • Highly toxic accumulation through the food chain in the organism • Mercury can cause acute human nervous disorder. Waste water contains numerous contaminants, including sulphide of hydrogen	• Treat effluent before discharging it into bodies of water • File a law suit against hazardous waste dumping
Underground pipes	Lead • Lead is highly poisonous heavy metals that could build up in living organism tissues • Lead may affect children’s mental capability	• Use copper pipes in plumbing rather than lead pipes

Source: Adopted from Briggs (2003); Haseena *et al.* (2017) [17].

Major causes of Water Pollution

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual) (Badejo *et al.*, 2017) [5]. A body of water at all level being it a lake, stream, river,

pond, ocean and even the water underground in the soil, can become polluted when it's contaminated by any source of water pollutants (Anny *et al.*, 2017) [3]. When water is polluted, it becomes unsafe for human consumption owing to the dangerous or toxic substances and disease-causing bacteria and organisms, it also affects aquatic fauna.



Source: Abdel-Raouf *et al.* (2017) [1].

Fig 1: Major causes of water pollution



Source: Olufunke (2022)^[26].

Fig 2: Agriculture pesticides spray in Nigeria



Source: Hasan (2010).

Fig 3: Washing Gold, Kebbi, Nigeria 2004 (mining pollution)



Source: Field Observation, 2022.

Fig 4: Industrial waste in Wurukum (River Benue), Nigeria



Source: Hasan (2010).

Fig 5: Nutrient pollution in Oloshi River, Imo State, Nigeria



Source: Babatunde (2020)



Fig 6a and b: Oil spill in the village of Ikarama, Bayelsa State, Nigeria



Source: Field Observation, 2022.

Fig 7: Drinking of river water at Nagi, Benue State, Nigeria (Major cause of waterborne disease)

Types of Water Pollutants

Pollutants may be of different types and having different properties like Stock pollutants which include non-biodegradable plastics, synthetic chemical and heavy metals (have no or very little absorptive capacity). The pollutants could be of point or non-point source. Point source pollution- When source of water pollution is known or pollutants that are entering into water are from identifiable source like ditch, pipe industry, storm drain and sewage treatment plants (Claudia, 2016)^[10]. Non-point source pollution- When source of water pollution is not known or pollution does not come from single discrete source (Brian, 2008)^[8]. It is very difficult to control and may come from different sources like pesticides, fertilizers industrial wastes. The Non-point source pollution is the main and leading cause of water pollution.

There are various types of pollutants categorized as: Organic Pollutants, Inorganic Pollutants, Radioactive Pollutants, Suspended Solid, Pathogens, Nutrients and Agricultural Pollutants and Thermal Pollution.

- i) **The Organic Pollutants:** They consists of carbon, hydrogen, oxygen, nitrogen and Sulphur. Organic compound emitted from sewage, urban waste water, industrial wastewater and agricultural waste. Example is Oleic acid, Palmitic acid, Dodecanoyl chloride and Docosanoic anhydride (Ekevwé *et al.* 2018)^[12].
- ii) **The Inorganic Pollutants:** Consist of nitrite, ammonium nitrate and heavy metals in drinking water. The high levels of inorganic nitrogen pollutants (nitrate, nitrite, ammonium) and inorganic phosphates in river water resulting from draining water from agricultural fields,

releasing municipal/industrial sewage, etc. lead to many health problems. Nitrite is carcinogenic in nature, which increases the risk of stomach, liver and esophageal cancer and can lead to high levels of ammonium in the body (Rekha *et al.* 2016)^[30].

- iii) **Radioactive Pollutants:** Naturally radioactive material comes from earth crust and dissolves in surface drinking water. Anthropogenic radioactive material emitted from nuclear power plant, nuclear weapons testing and manufacture and application of radioactive material. Generally, radionuclide appeared in drinking water have series of uranium thorium and aluminum and with naturally occurring materials of radium, uranium and the radioactive gas radon. These contaminants cause dangerous effect on human being. Radium causes bone cancer. Uranium also causes cancer in bone and toxic effect on kidney (Bonavigo *et al.*, 2009)^[7].
- iv) **Suspended Solid:** are the pollutants municipal and industrial wastewater treatment plants and sewage treatment plants. There are three different types of suspended solid are found (a) sand and other material at washing steps (b) organic content that cannot used for final product (c) suspended solid in the wastewater (Dwivedi, 2017)^[11].
- v) **Pathogens:** are small microbes that cause disease, including bacteria, viruses, pillows, and certain parasites. Viruses generally present in wastewater are Hepatitis and Norwalk virus and a common fungus is Candida. A salmonella bacterium causes food poisoning whereas Vibrio cholera is the pathogen that causes cholera.
- vi) Parasites such as Cryptosporidium and Schistosoma can cause diarrhea and all wastewater pathogens can lead to serious gastrointestinal illness (Dwivedi, 2017)^[11].
- vii) **Nutrients and Agricultural Pollutants:** large quantities of chemical fertilizers in agriculture causes so many environmental problems as some fertilizers contain heavy metals (e.g. cadmium and chromium) and high radionuclide concentrations. Non-organic fertilizer contains salts of phosphate, nitrate, ammonium and potassium. Manufactured fertilizer industry contains excess heavy metals such as Hg, Cd, As, Pb, Cu, Ni, and Cu. Heavy metal fertilizer is deposited in the soil and plant system. Plants absorb fertilizers through the soil; they can enter the food chain that contaminates the water (Savci, 2012)^[31].
- viii) **Thermal Pollution:** The temperature alteration in water bodies, as a result thermal pollution occurs. The thermal power plants discharge causes raise in temperature of aquatic system of 10 °C. Therefore, very serious effect on aquatic life due to global warms by thermal effect. Use of wind and solar energy in place of thermal energy. Thermal pollution decreases by plantation and reduce the emitting of carbon dioxide in environment (Rao, 2015)^[29].

Effects of Water Pollution on Aquatic Eco-diversity and beyond

- i. Nutrient deficiency in aquatic ecosystem: Population of decomposing microorganisms like bacteria and fungi decline in acidified water which in turn reduces the rate of decomposition of organic matter affecting the nutrient cycling. The critical pH for most of the aquatic species is 6.0. The diversity of species declines below this pH whereas the number and abundance of acid tolerant species increases.
- ii. Deaths and diseases are caused due to water pollution and approximately 14000 people die every day due to water pollution (Letchinger, 2000; Pink, 2006)^[24, 28]. In humans,

drinking or consuming polluted water in any way has many disastrous effects on our health. It causes typhoid, cholera, hepatitis and various other diseases

- iii. Polluted water and water sources have intolerable smell and contains less flora and fauna: Reduced the population/survival rate and diversity of the species (Olufunke, 2022)^[26].
- iv. As a result of increased water pollution, the growth of plants is adversely affected; the minerals needed for photosynthesis cannot be obtained and forests cannot grow. Mixing wastes with sewage water that causes pollution causes serious pollution.
- v. Dirty water also causes bacterial, viral and parasitic diseases in human body.
- vi. The free circulation of toxic waters in nature poisons the soil and especially pollutes the groundwater causing damage to the soil, thus threatening the lives of living things in the region.
- vii. Destruction of Ecosystems: Ecosystems are extremely dynamic and respond to even small changes in the environment. Water pollution can cause an entire ecosystem to collapse if left unchecked.
- viii. Eutrophication: Chemicals in a water body, encourage the growth of algae. These algae form a layer on top of the pond or lake. Bacteria feed on these algae and this decreases the amount of oxygen in the water body, severely affecting the aquatic life there.
- ix. Effects the food chain: Disruption in food chains happens when toxins and pollutants in the water are consumed by aquatic (Fish, shellfish, animals etc) which are then consumed by humans (Abonyi, 2020)^[2].

Pollution and Prevention Measures

Water pollution has become a global problem that demand evaluation and policy to counter this problem. The ecosystems, wildlife and oceans need to be restored to a healthy state and change the world into one with no or minimal waste. The following are some of the measures to be taken for prevention of pollution.

- i. **Reuse:** Reusability refers to the use of materials more than once in their original form instead of throwing away after each use especially plastic pollutants.
- ii. **Reduce:** In order to reduce pollution, there is need to reduce our usage of the raw materials in the manner that will create pollution. This translates to changing our daily attitudes and avoiding the use when there is a better alternative to it. Today, shops are seen offering products such as cereals, nuts, beans and pasta without packaging. Instead, reusable bags or jars are used.
- iii. **Recycle:** Recycling of products such as plastic involves collection of plastic waste and reprocessing it into new products, in order to reduce the amount of plastic in the waste stream.
- iv. **Educate Businesses:** Education is an important solution in order to increase awareness and behavioural/attitudinal change. People need to be guided and advised on waste disposal so as to prevent the occurrence of pollution. There is need to speak to operators/owners of local restaurants and businesses about that the alternatives that they can divert to for stoking, packaging items.
- v. **Government Intervention:** The lawmakers and government need to arise and get involved in the prevention of pollution so as to allow strict adherence to prevention measures to take place. Awareness and sensitization be on continuous bases.
- vi. Pick up litter and throw it away in a garbage can.

- vii. Blow or sweep fertilizer back onto the grass if it gets onto paved areas. Don't put fertilizer on the grass right before it rains. The chemicals will wash into storm drains and waterways.
- viii. Wash your car or outdoor equipment where it can flow to a gravel or grassy area instead of a street.
- ix. Never clean up a spill by hosing it into a storm drain. Place kitty litter, sand, or another absorbent on the spill. Once the liquid becomes solid - sweep it up and throw it in a garbage can.

Conclusion and Recommendations

Water pollution and concentration in the aquatic ecosystem is now an undeniable fact. Though water is vital in all natural and human activities. However, misuse of water coupled with growing population size, industrialization, change in climate, and urbanization has increased the shrink in aquatic ecosystem and human health. Water pollutants can be traced from ancient times, medieval time, After World War-II and the present day, while its origin can be traced to their fundamental occurrence on earth, the development of natural products by transformation, and their man-made synthesis. Major sources of water pollution are discharge of domestic wastes, agriculture wastes, industrial wastes, excessive use of pesticides and fertilizers and urbanization. Bacterial, viral and parasitic diseases are spreading through polluted water and affecting both human health and aquatic fauna. Thus, water from all sources should have some form of purification and control measures against pollutants.

References

1. Abdel-Raouf AEM, Maysour EN, Farag KR, Abdul-Raheim M. Wastewater Treatment Methodologies. *Int. J. Environ. Agri. Sci.*, 2019;3(1):1-26.
2. Abonyi NN. Environmental pollution and associated health hazards to host communities (case study: Niger Delta region of Nigeria). *Central Asian Journal of Environmental Science and Technology Innovation* 2020;1(1). <https://www.cas.press.com/article_95591.html>Accessed 4 January 2022
3. Anny FA, Kabir MM, Bodrud-Doza M. Assessment of surface water pollution in urban and industrial areas of Savar Upazila, Bangladesh. *Pollut.* 2017;3(2):243-259.
4. Babatunde AO. How oil and water create a complex conflict in the Niger Delta; University of Ilorin, 2020. <<https://www.google.com/url?sa=t&source=web&rct=j&url=https://theconversation.com/amp/how-oil-and-water-create-a-complex-conflict-in-the-niger-delta>>
5. Badejo Ibrahim B, Abdulrahman KA, Dali JZ, Badgal BE. Assessment of physicochemical parameters of river Yobe, Gashua, Yobe State, Nigeria. *Int. J Fisheries Aquat. Stud.* 2017;5(2):93-98.
6. Bassem SM. Water pollution and aquatic biodiversity. *Biodiversity Int J.* 2020;4(1):10-16. DOI: 10.15406/bij.2020.04.00159
7. Bonavigo L, Zucchetti M, Mankolli H. Water radioactive pollution and related environmental aspects. *Journal of International Environmental Application & Science.* 2009;4:357-363.
8. Brian M. Water Pollution by Agriculture (PDF). *Phil. Trans. Royal Society.* 2008;B 363:659-666.
9. Briggs David. Environmental pollution and the global burden of disease. *British Medical Bulletin.* 2003;68:1-24.
10. Claudia C. Clean Water Act Section. United States, 2016.
11. Dwivedi KA. Researches in Water Pollution. *Int. Res. J. Natural Appl. Sci.* 2017;4(1):118-142.
12. Ekevwé AE, Isaac A, Baertholomew G, Aroh O. Review of organic pollutants in wastewater along the Course of River Gwagwarwa and River Rafin Malam in Kano State-Nigeria. *Journal of Biotechnology and Bioengineering.* 2018;2:36-39.
13. Fenu G, Mallocci FM. Lands DSS. A decision support system for agriculture in Sardinia. *HighTech and Innovation Journal.* 2020;1(3):129-135. <https://doi.org/10.28991/HIJ-2020-01-03-05>.
14. Fuhrman RE. History of water pollution control. *Journal (Water Pollution Control Federation).* 1984;56:306-313.
15. Hasan MK, Shahriar A, Jim KU. Water pollution in Bangladesh and its impact on public health. *Heliyon.* 2019;5(8):e02145. <https://doi.org/10.1016/j.heliyon.2019.e02145>
16. Hassan T, Parveen S, Bhat NB, Ahmad U. Seasonal Variations in Water Quality Parameters of River Yamuna, India. *Int. J Curr. Microbiol. App. Sci.* 2017;6(5):694-712.
17. Haseena M, Malik MF, Javed A, Arshad S, Asif N, Zulfiqar S. Water pollution and human health. *Environmental Risk Assessing Remediation.* 2017;3(1):16-19.
18. Helmer R, Hespanhol I, Supply W. *Water pollution control: A guide to the use of water quality management principles.* London: E & FN Spon, 1997.
19. Khan U, Haque MI, Khan AM. Environmental sustainability awareness in the Kingdom of Saudi Arabia. *The Journal of Asian Finance, Economics, and Business.* 2020;7(9):687-695. <https://doi.org/10.13106/jafeb.2020.vol7.no9.687>
20. Khatun R. Water Pollution: Causes, Consequences, Prevention Method and Role of Wbphed with Special Reference from Murshidabad District. *Int. J. Sci. Res. Publ.* 2017;7(8):269-277.
21. Kidd DE. The history and definition of water pollution: A teaching unit. *Bulletin of Science, Technology & Society.* 1983;3:121-126.
22. Laheab Al-Maliki A, Sabeeh Farhan L, Ihsan Jasim A, Sohaib Al-Mamoori K, Nadhir Al-Ansari. Perceptions about water pollution among university students: A case study from Iraq. *Cogent Engineering.* 2021;8:1:1895473. DOI: 10.1080/23311916.2021.1895473.
23. Laboratory Chemical Waste Management Guidelines (LCWMG). Environmental Health and Radiation Safety University of Pennsylvania, 2016.
24. Letchinger M. *Pollution and Water Quality, Neighbourhood water nquality assessment.* Project oceanography, 2000.
25. Mahar PS, Datta B. Optimal identification of ground-water pollution sources and parameter estimation. *Journal of Water Resources Planning and Management.* 2001;127:20-29.
26. Olufunke KA. Water Pollution in Nigeria and its Effect on Agriculture: A Case Study of Niger Delta, *Research and Science Today.* www.rstjournal.com. 2022;1(23):3-13.
27. Owa FD. Water pollution: sources, effects, control and management. *Mediterranean Journal of Social Sciences.* 2013;4:65-8.
28. Pink DH. Investing in tomorrow's liquid gold. *World Journal of Analytical Chemistry.* 2006;2:42-46.
29. Rao DS. Thermal pollution-Impact on living organisms. *International Journal of Engineering Research and Sports Science,* 2015, 2.
30. Rekha Kathal VC, Kumar L, Puri A, Baishya R, Uniyal PL. Pollution Status of Yamuna River, India-A national

- concern. *International Research Journal of Environment Sciences*. 2016;5:1-6.
31. Savci S. An agricultural pollutant: Chemical fertilizer. *International Journal of Environmental Science and Development*. 2012;3:73.
32. Singh J, Ashok P, Priyanka Y, Vishal M. Water Pollutants: Origin and Status, 2020, 5-19. <https://www.researchgate.net/publication/336816995>
33. Zeyneb K. Water Pollution: Causes, Negative Effects and Prevention Methods, Istanbul Sabahattin Zaim University, *Journal of the Institute of Science and Technology*. 2021;3(1):129-132. <https://doi.org/10.47769/izufbed.862679>
34. Zubaidi SL, Dooley J, Alkhaddar RM, Abdellatif M, Al-Bugharbee H, Ortega-Martorell S. A novel approach for predicting monthly water demand by combining singular spectrum analysis with neural networks. *Journal of Hydrology*. 2018;561:136-145. <https://doi.org/10.1016/j.jhydrol.2018.03.047>.