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Nutrients Pollution of the Coastal Marine Ecosystems

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ABSTRACT
Nutrient pollution is one of the most deadly environmental plagues being experienced in our waters globally. This present desktop study aims to add to the already existing knowledge provided by various researchers on nutrient pollution and effects on the coastal marine ecosystems. The study looks at the nutrients involved, their common sources, effects on the coastal ecosystems and possible solutions to the menace. Nitrogen and Phosphorus are identified as the major predictors or the nutrients that results to nutrient over enrichment when in excess supply in the coastal water bodies. The sources of nutrient pollution spans from agriculture, animal husbandry, aquaculture, urban and industrial pathway, storm water runoff to fossil fuel combustion. Among the consequences of nutrient pollution are ecological changes (biological diversity crisis), hypoxia and anoxia (oxygen problem), harmful algal blooms (HABs), sea grasses and coral reefs destruction. Control and preventive measure advocated in this study includes improvements in human dietary consumption, nitrogen emissions coupling, nitrogen and phosphorus removal from the waste water, embracing or switching to renewable energy sources, optimal and efficient fertilizer usage and manure management, restriction to livestock movement along waterbodies' banks, deployment of ultrasound bloom treatment technology, avoidance of cleaning detergents and soaps that made of phosphates for washing and cleaning at homes, hotels and sanitation firms and stoppage of open/bush human defecations.
Keywords: Nutrients Pollution, Coastal, Marine, Ecosystems

INTRODUCTION

Coastal water is a critical habitat for many marine species and is the basis for many important economic activities which includes tourism, coastal recreation and fishing, as well as property values. Coastal habitats or ecosystem include estuaries, bays, lagoons, deltas, coastal wetlands, seagrass meadows, coral reefs, mangroves, kelp forests, and upwelling areas (US EPA, 2003). Being interface between terrestrial environments and open oceans, coastal waters encompass the above unique habitats and serve important human needs. It provides support for many fish species and habitats for many other organisms such as marine mammals, corals, sea turtles, and submerged aquatic vegetation. Most of the world's densely population cities are in the coastal regions.

Estuaries and coastal areas are regions of high population density and intense human activities. They comprise approximately 7% of the surface area of the world's ocean, while accounting for 30% of the total net oceanic primary production (Alongi, 1998; Gattuso et al., 1998; Dürr et al., 2011). The rapid increase of human activities has increased nutrient transport from land to sea in the past decades, resulting in environmental deterioration and changes to biogeochemical processes (Seitzing et al., 2005; Halpern et al., 2008; Qu and Kroeze, 2010). According to Yule et al., 2010; Smith et al., 2012, tropical estuaries are the most biogeochemically active zones, and are more easily affected by anthropogenic nutrient loading than estuaries at higher latitudes.

Nutrients are chemicals needed by organisms to survive, grow, and reproduce. Autotrophs are organisms needing only inorganic nutrients, such as water, carbon dioxide, nitrate, and phosphate, plus the energy from

sunlight and photosynthesis to make the organic molecules that compose cell parts and enable growth and reproduction (Stevenson and Esselman, 2013).

Algae and aquatic plants are autotrophs in rivers. In contrast to autotrophs, heterotrophs need organic molecules for energy and for nutrition. Fungi and most bacteria, other than cyanobacteria, are heterotrophs that require organic molecules as an energy source and a wide diversity of inorganic and organic chemicals for nutrition. The combination of chemicals needed by these microbes depends upon the species. Animals require organic molecules as a source of energy and nutrition. Thus, the basic supply of inorganic nutrients and sunlight regulate how rapidly organisms grow in an ecosystem, and often the biomass of organisms that occur.

Inorganic nutrients occur naturally in ecosystems, originating from rocks dissolution, the bacterial process of nitrogen fixation in which atmospheric nitrogen (N2) is converted to ammonia (NH3), and from decomposition of dead organisms by bacteria and fungi (Stevenson and Esselman, 2013). Nitrogen is one of the limiting nutrients during photosynthesis. It enters into the system through rainfall, in-situ N2 fixation, river run-off, and diffusion from sediments. Nitrogen is largely controlled by redox reactions mediated by phytoplankton and bacteria. The processes include remineralization, ammonification, nitrification, denitrification and fixation.

Phosphorus (P) is found in the form of inorganic and organic phosphates (PO4) in natural waters.

Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically-bound phosphates. Phosphorous is a limiting nutrient needed for the growth of all plants- aquatic plants and algae alike (Philminaq, 2020). The macronutrients nitrogen and phosphorus are important among all the nutrients in aquatic ecosystems, because they are usually in shortest supply compared to the others ((Stevenson and Esselman, 2013).. When they are in limited supply, they limit the rate at which algae and plants can grow. Phosphate, nitrate, and ammonia are the forms of phosphorus and nitrogen used by algae and plants. Generally, terrestrial and marine ecosystems tend to be more limited by nitrogen than phosphorus, and freshwater ecosystems tend to be more limited by phosphorus than nitrogen. Research during the past decade confirms that N is the chief culprit in eutrophication and other impacts of nutrient over-enrichment in temperate coastal waters, while P is most problematic in eutrophication of freshwater lakes.

Primary productivity is often controlled by nutrients in marine systems (Whitall, Mason, and Pait, 2012). Most often, photosynthetic productivity in these systems is controlled by nitrogen (N), though at certain times of year some systems can be co-limited by both nitrogen and phosphorus. Though not basically a pollutant, silica distribution can also have impacts on diatom communities because diatoms need silica for frustule growth (Whitall, Mason, and Pait, 2012). In saline waters, nitrogen is usually the key nutrient involved in eutrophication, but phosphorus may also be important in some estuarine situations (Environment Agency, 2019). These nutrients are not without deleterious consequences when in excess, hence the problems of nutrients pollution.

The pollution from the nutrients Nitrogen and Phosphorus represents the largest source of degradation in the coastal waters, which include some of the richest and most productive habitats in the oceans (Howarth et al 2000,). About half of the global fisheries catch occurs in or is dependent upon coastal waters of the world.

Nutrient pollution is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer, causing excessive growth of algae. It is a form of water pollution, and refers to contamination by excessive inputs of nutrients.

Nutrient pollution in some cases results from natural processes such as rocks weathering and the mixing of ocean currents and is also commonly caused by human activities such as soil erosion from agriculture, stormwater runoff in cities discharging into the water bodies, and from operations in industrial facilities (Clarke, 2022).

Nutrient Pollution can be categorized into point source and non point source. Point source nutrient pollution refers to pollution type attributed to specific point, and is easily quantifiable such as effluents discharge pipes from power plants and coastal factories. Non point source nutrient pollution refers to pollution whose origins are difficult to pinpoint such as urban areas surface runoffs, precipitation, agricultural runoffs.

Common Sources of Nutrient Pollution

Sources of nutrient pollution to the inland waters (freshwater) and coastal areas are multifarious, and include agriculture, aquaculture, septic tanks, urban wastewater, urban stormwater runoff, industry, and fossil fuel combustion (Selman and Greenhalgh, 2010). Nutrients are released into the aquatic ecosystems through the air, surface water, or groundwater pathways (Table 1).

Table 1: Primary Sources and Pathways of Nutrients (Selman and Greenhalgh, 2010).

	Pathways		
Sources	Air	Surface Water	Ground-water
Sewage treatment plants		✔	
Industry	✔	✔	
Septic systems		✔	✔
Urban stormwater runoff		✔	
Agricultural fertilizers	✔	✔	✔
Livestock operations	✔	✔	✔
Aquaculture		✔	
Fossil fuel combustion	✔		

Agriculture

The global population is projected to reach 9.8 billion people by 2050 (UNDESA, 2017) Population growth and changes in consumption patterns, including new dietary preferences require the production of more (and more diverse) food. This, in turn, is driving agricultural expansion and intensification and bringing new environmental externalities, including impacts on water quality.

The need for more food production for the increasing human population and for industrial raw materials has led to use of artificial fertilizers. Agricultural systems have expanded and intensified in the last century, along with using nitrogen and phosphorus fertilizers in response to the ever-increasing demand for food. In clear terms, land clearing and agricultural expansion have contributed to higher pollutant loads in water, but probably the biggest impacts have been caused by certain unsustainable patterns of agricultural intensification (Mateo-Sagasta et al., 2017).

Figure 1. Agricultural Systems Expansion and Intensification (Mateo – Sagasta, et al., 2017).

The agrochemicals usage, overuse and misuse, water, animal feeds and drugs designed to increase productivity have resulted in higher pollution loads in the environment, including rivers, lakes, aquifers and coastal waters. Production of crops entails the massive usage of chemical fertilizers or animal manure containing nitrogen and phosphorus. Inasmuch as the fertilizers result to increased crop production the overuse of these fertilizers can lead to an excess of nutrients in the soils. Heavy rainfall event will lead to nutrient-rich soils leaching into contiguous watercourses, eventually running into the sea. An excess of nitrogen and phosphorus stimulates rapid growth of algal colonies resulting in algal blooms and consequent eutrophication. Nitrogen lost to the atmosphere in the process of ammonia volatilization can pollute water bodies via atmospheric deposition.

Animal Husbandry (Livestock production)

Livestock production accounts for 70 percent of all agricultural land and 30 percent of the land surface of the planet (FAO, 2006). The livestock sector is one of the major three contributors to the most severe environmental problems, including water-quality degradation, at every scale from local to global In livestock production, feedlots are often located on the banks of watercourses so that (nutrient-rich) animal waste (e.g. urine) can be released directly into those watercourses.

Figure 2. A Livestock Farm (Howarth, et al., 2000).

Animal wastes may be the largest single source of N that moves from agricultural production to coastal waters, either directly via overland flow (runoff) or indirectly through volatilization and deposition of atmospheric nitrogen

Aquaculture

Demand for fish and shellfish for food, feed and other products has grown faster than for any other agricultural commodity in the last several decades. Total global aquatic animal production reached 167 million tonnes in 2014 (FAO, 2016b), of which an estimated 146 million tonnes was consumed directly by humans. Aquaculture operations (farms) lead to nutrient pollution, with surplus fertilizer, wastes, and leftover foods causing masses of nitrogen and phosphorus to be discharged into coastal waters. If not properly managed, aquaculture operations can have severe impacts on aquatic ecosystems as nutrient wastes are discharged directly into the surrounding waters. High nutrient loads can cause the eutrophication of lakes, reservoirs, ponds and coastal waters, leading to algae blooms that suppress other aquatic plants and animals. For each ton of fish, aquaculture operations produce between 42 and 66 kilograms of nitrogen waste and between 7.2 and 10.5 kilograms of phosphorus waste (Strain and Hargrave 2005).

Urban and Industrial Sources

Municipal wastewater treatment plants and industrial wastewater discharge facilities are some of the urban and industrial sources of nutrient losses. These sources are considered "point sources" of nutrient pollution because they make direct discharge of nutrients into surface water bodies or groundwater through conduit pipes or other discrete conveyance system. They are controllable sources of nutrients and are often monitored and regulated in advanced countries. Human sewage is the most prevalent urban source of nutrient pollution. In developed countries, the sewage treatment system is very efficient unlike in the developing countries. In developing countries, less than 35 percent of cities have any form of sewage treatment (UNEP and WHRC 2007), and when sewage is treated, it is just primary treatment aimed at getting rid of solids, not nutrients. Where households are not connected to municipal wastewater treatment plants, Septic systems are often used in developed countries. Septic systems are designed to purify waste by leaching it through soils. The Municipal sewer and septic tank systems lack the capability to discard nutrients such as nitrogen and phosphorus from

urban waste. This has led to the discharges of untreated or not properly treated nitrate and phosphorus laden wastes into the watercourses (figure 2). Dietary choices could have a crucial impact (Howarth et al. 2002). The consumption of meat protein/products is special concern with respect to nitrogen pollution. Nitrogen excreted as part of human faeces from the meat consumed by the people is discharged into the sewers. Bush toilets and defecation systems used in the country sides of developing countries cause significant release of Nitrogen into the contiguous water bodies via surface runoffs.

Detergents used for cleaning and laundry are known to contain nitrogen and phosphorus, and these are discharged into the water bodies. For industrial sources of nutrient pollution, certain industries are larger sources than others. Pulp and paper mills, food and meat processing, agro-industries, and direct discharge of sewage from maritime vessels are some of the larger sources of industrial nutrient pollution.

Figure 3. Sewage Effluent – Nutrients transfer pathway (Nixon and Fulweiler, 2009)

Storm water Runoff

Rainfall events remove nutrients from residential lawns and impervious surfaces into near water bodies. Heavy rainfall in urbanized areas can overwhelm sewage and waste systems. Fertiliser usage in lawns, pet and wildlife waste, and industrial discharge contribute to urban runoff. This runoff from roofs, roads, and pavements contain large amounts of nutrients (nitrogen and phosphorus), so aquatic ecosystems can be devastated when storms occur in some metropolitan cities, combined sewer overflow (CSO) systems exacerbate stormwater runoff problems (Selman and Greenhalgh, 2010). CSOs are designed for the collection of rainwater, domestic wastewater, and industrial wastewater in the same conduit pipe. During heavy rain or snowmelt events, wastewater volume can exceed the capacity of the CSO system, as well as that of the wastewater treatment plant receiving the flow. As a result, the excess wastewater, including raw sewage

containing nitrogen and phosphorus, is discharged directly into nearby streams and rivers, and later into the coastal water bodies.

Fossil Fuels

Anthropogenic nitrogen through man's activities finds its way into the coastal marine environments by the combustion of organic matter to release energy from biomass, coal, oil and natural gas (Galloway et al. 2002). Fossil fuels are combusted to release energy for electricity, transportation, and industrial processes. The burning of the fossil fuels releases nitrogen oxides or ammonia into the atmosphere, which can then be atmospherically deposited as nitrogen ions directly into waterways or onto terrestrial land masses and subsequently leached off into water.

Nitrogen oxides lead to the formation of smog and acid rain. This through precipitation is deposited back to the land and washed into nearby water bodies through rain and snow (wet deposition), or can settle out of the air through dry deposition process. The primary sources of nitrogen oxides are coal-fired power plants and exhaust from cars, buses, and trucks. Atmospheric deposition is the process by which particles (often pollutants) in the form of dust aerosols, gases or precipitation from the atmosphere enter water systems. Extensive atmospheric nitrogen deposition results to nitrogen saturation of the watersheds and further exportation of nitrate to streams, lakes, and coastal water bodies. In the Chesapeake Bay, atmospheric deposition accounts for 30 percent of all nitrogen inputs. In some areas, such as in the U.S. North Atlantic, atmospheric deposition of nitrogen can exceed riverine nitrogen inputs to coastal areas (Spokes and Jickells 2005). In the Baltic Sea, atmospheric deposition, primarily from burning fossil fuels, accounts for 25 percent of nitrogen inputs (HELCOM 2005).

Consequences of Nutrient Pollution

The popular saying that anything in excess is bad, applies to nutrient release to the coastal ecosystem. There is every tendency of increased primary production for the overall good of the aquatic organisms with increased nutrients into the system. When the nutrients are in excess, deleterious consequences are imminent. The effects of nutrient pollution or nutrient over enrichment are diverse and among other include ecological changes (biological diversity crisis), hypoxia and anoxia, harmful algal blooms, sea grasses and coral reefs destruction.

Ecological Changes – Biological Diversity Crisis

Nutrient pollution causes ecological changes that result to biological diversity crisis/loss. There is a drastic reduction or loss in the variety of living organisms in the ecosystem. Moderate addition of nutrients such as nitrogen and phosphorus to the waterbodies will definitely lead to increased primary productivity - that is, the production of algae (phytoplankton) that forms the base of the aquatic food web, but their excessive inputs will result to eutrophication. Eutrophication has both desirable and undesirable effects on the species inhabiting the aquatic environments. Besides, the floral and faunas have different sensitivities to the effects of nutrient over-enrichments. Some species, such as blue-green algae, thrive from eutrophication, while, other species are in danger of disappearing from the sea. The preponderance of algae population (algal bloom) in the water bodies makes the water murkier especially when they die and decompose resulting to oxygen depletion otherwise known as hypoxia and anoxia. This condition has severe detrimental effects on the ecological communities in the ecosystem. Also these massive colonies of algae species block sunlight which is vital for photosynthesis from penetrating the water bodies and this has a disastrous consequences. These changes in nutrients, light, and oxygen favor some species over others and cause shifts in the structure of phytoplankton, zooplankton, and bottom-dwelling (benthic) communities (Howarth, et al., 2000). This can cause increase in the harmful algal blooms (HABs) such as red and brown tide organisms as they become more frequent and extensive, sometimes resulting in human shellfish poisonings and deaths of marine mammals.

This condition can also results to shifts in the species composition of the phytoplankton and changes in the types of plants that support the ecosystem (Turner, 2002). The changes in the species and composition of the phytoplankton can have deleterious consequences on the grazing benthic and water column animals (Olsen et al, 2006, Wolowicz et al, 2006.) As a result of nutrient over enrichment, a vital species such as the bladderwrack, seaweed can be lost completely which would be incredibly obnoxious to the ecosystem. Since

the seaweed is an essential habitat for many invertebrates and young fishes and is a food source for several animals, it would lead to the decline of many other species. Therefore, the biological diversity would be affected with the decline in the bladderwrack (Voice of the ocean, 2019 – 2023). Poisonous toxins from algal blooms will harm fish assemblages, and invasive species will be better adapted to high-nutrient environments and drive out the original species, which may lead to a loss in ecosystem functionality.

Hypoxia and Anoxia (The Oxygen Problem)

Nutrient pollution or over enrichment leads to changes in the structure of ecological communities through the process of indirect oxygen depletion and direct increased nutrient concentrations. Macroalgae and phytoplankton that resulted from nutrient enrichment do produce oxygen just as the land plants do but this happens only in the day time when the plants are actively growing. This makes the surface waters to be saturated with oxygen due to light availability (Nixon and Fulweiler, 2009). During the night, when there would no oxygen production, and also the oxygen produced during the day is lost through diffusion. The oxygen levels may become very low if the respiration demands exceed the rate at which oxygen can diffuse back into the water from the air. The macroalgae and phytoplankton when they die sink into the deep water and decompose or eaten by grazing animals and are excreted as faecal pellets. This organic matter in a stratified system stimulates respiration in isolated bottom water and sediments, which depletes bottom water oxygen levels. The aquatic organisms have varying sensitivities to the environmental conditions. Hypoxia and anoxia can alter the composition of a community by killing off more sensitive or less mobile organisms/sedentary ones, reducing suitable habitat for others, and changing interactions between predators and their prey (Howarth, et al., 2000). Oxygen depletion can cause fish kills and create dead zones in water with little or no oxygen, where aquatic life cannot survive. It is known as hypoxia, these areas (dead zones) are caused by algal blooms consuming oxygen as they die and decompose. This can result in the massive deaths of aquatic life. As a result, the area around the algal blooms will be a dead zone with dead animals and plants life alike. The resulting foul smell may affect the rest of the aquatic life, sending them further away from the area.

Harmful Algal Blooms (HABs)

The application of Nitrogen and phosphorus fertilizers to soils causes faster, larger, and greater yields in plants. The same will happen when these nutrients are discharged into contiguous watercourses and this when in excess will cause algal colonies to increase swiftly in population and form what is called 'algal blooms' on the surface of the water body(Figure 1). Algal blooms are known to be mainly composed of bio-toxins and are characterized by a distinct discoloration of water due to a large number of pigmented algae cells. The colors range from green, red, brown, and yellow. The major types of algal blooms are cyanobacteria (blue-green algae) and red tides (red algal blooms).

Algal are known to produce powerful toxins that can cause harm to human beings, fisheries resources and coastal ecosystems as well. The deleterious effects among others include mass mortalities of wild and farmed fish and shellfish, human poisonings from contaminated fish or shellfish, alterations of marine food webs through damage to larval or other life stages of commercial fisheries species, and death of marine mammals, seabirds, and other animals (Howarth et al., 2000). When being consumed by small fish and shellfish, these toxins move up the food chain and can impact larger animals like sea lions, turtles, dolphins, birds and manatees (Rinkesh, 2023). Algal blooms can negatively impact aquatic life by blocking out sunlight and clogging fish gills. Algal blooms can block sunlight penetration to deeper layers of the ocean, leading to the decline of producer populations.

Figure 4. Harmful Algal Blooms (HABs) (https://www.conserve-energy-future.com)

These producer populations often form the foundation of aquatic ecosystems and provide oxygen and a stable food source at the base of the food chains. Therefore, a decline in producer populations will not only result in limited oxygen availability (eutrophication) but also cause a reduction in food resources at many trophic levels. Predators will also be affected by algal blooms as they cannot locate their prey efficiently.

Algal blooms produce toxins that reduce the suitability of water for human consumption. Their large presence on the water and their well propagating sequences leads to quick contamination of water, thus posing a health hazard to humans. Strong irritation, itching, and even skin diseases are experienced when such contaminated water comes into contact with the human skin.

Nutrient pollution and the Coral reefs and Seagrass

Coral reef and seagrass are vital parts of the coastal marine ecosystems. They play crucial roles in general functionality of the ecosystem wellbeing. They provide habitats among other things for the benthic zooplankton species and food for the other grazing populations. Coral reefs are among the most diverse ecosystems in the world, and also among the most sensitive to nutrient pollution (Howarth et al., 2000).

The major coral reef ecosystems on earth are seen in naturally nutrient starved surface waters in the tropical and subtropical regions. Recent studies have shown that nutrient rich waters are obnoxious to the growth of coral reefs against the previous belief that corals thrive or blossom in regions of high nutrient upwelling.

Fig. 5. Coral Reefs- Nutrient Sensitive Coastal Marine Ecosystem (Nixon and Fulweiler, 2009)

Results of some studies have shown algal turfs or seaweeds dominance and overgrowth on the reefs due to the high nutrient levels are deleterious to the coral reefs and also led to shifts away by corals and the coralline algae that help build the reef structure. The impacts of nutrient over enrichment on the corals are made serious as the population of the fishes, sea urchins and other animals that forage on the algae and help to keep the coral clear are reduced through diseases or over exploitation. Seaweed coverage on the reefs has ecological impacts. The seaweed blooms can result to oxygen deficiency on the reef surface as the seaweeds die and decompose, and this cause habitat degradation required to supporting coral reef organisms high diversity and potential important foragers (Howarth, et al., 2000). Nutrient over enrichment often leads to the degradation or complete elimination of seagrass beds.

Besides the fact that growth of plants in the beds are light limited, nutrient pollution can reduce the available light by causing phytoplankton growth, epiphytes growth on the leaves of the seagrass, and ephemeral seaweeds(macroalgae) blooms that cover both seagrasses and perennial seaweeds like kelp. Nitrogen over-enrichment can lead to nuisance blooms of ephemeral seaweeds which can have deleterious impacts on seagrass beds and coral reefs.

Figure 6. Blooms of ephemeral seaweeds (macroalgae) (Howarth, et al., 2000).

According to Howarth, et al., (2000), nutrient over enrichment generally lowers the seagrass and kelp communities bio- diversity, because these plant communities provide food and shelter for a rich and diverse array of marine animals, the degradation of seagrasses and kelp or their replacement by nuisance seaweed blooms brings marked changes in the associated animal life. These ecosystems are important as spawning sites and breeding/nursery grounds for fish species. Water clarity is impaired as a result of sediments released to the water column when the seagrasses coverage is lost. Also as the sediments are let go the attached nutrients find their way into the system and cause additional algal blooms.

Nutrients Pollution and Preventive Measures

Eutrophication is an excessive supply of nutrients to an ecosystem, while a decline or decrease in the supply of nutrients is known as Oligotrophic (Nixon, in press). When nutrients are in moderate supply, primary productivity is bound to increase but the reverse becomes the case when there is an over enrichment. This then poses a threat to the aquatic ecosystems, especially in the high population density regions. So, caution must be taken to control or prevent whatever activities that will lead to this problem. Some of the control or preventive measures are discussed hereunder. Improvements in the human dietary consumption through enlightenment can help reduce nutrient pollution. According to Hutchinson (1969), human population becomes eutrophic by consuming less meat and animal fat and by this the coastal environments would be protected from eutrophication. Diet options could have a significant impact (Howarth et al. 2002). The consumption of meat protein is of particular concern in terms of Nitrogen pollution not just because N is excreted by meat eating people, the N is released in sewage. The N in the diet is ultimately excreted into the environment.

Atmospheric deposition is a good pathway through which nitrogen enters the coastal ecosystem, there should be advanced technology which help uncouple the emissions of nitrogen from combustion. Advanced waste water treatment technologies geared towards nitrogen removal and that of phosphorus removal from detergents causing declines in phosphorus loading have helped in tackling the problems associated with nutrient pollution (Nixon et al. 2008). Embracing renewable energy sources such as solar, geothermal, and tidal power should be

globally advocated. This will have a considerable impact on reducing nutrient pollution that is as a result of fossil fuels usage.

There should be optimal and efficient use of fertilizers and manure management. This has the capacity to reduce nutrient pollution from the sources. There should be improved management of animal wastes to avoid nutrient release from the manure. Livestock movements should be avoided along the riparian corridors or water bodies' banks. The use of Ultrasound Bloom Treatment should be recommended (Rinkesh, 2023). This technology employs the ultrasonic sound waves in water bodies to look for algal blooms and to control the growth. It has the capacity to reduce algae growth by 90%, causes no harm to the aquatic organisms and is 100% environmentally friendly and cost effective. This is used to monitor large water bodies and is capable to detect the presence of algal threat. These waves are sent over the top layer of the water bodies to counter the buoyancy, making them sink and disable photosynthesis. The algae eventually die due to the lack of light. Phosphate free cleaning detergents and soaps should be avoided at homes, hotels and sanitation firms. The use of these detergents should be with caution or sparingly so as to avoid excess quantities being released into the sewages which later got discharged into the water bodies. Open human/bush feces should be discouraged as this is very significant source of nutrients which eventually got discharged into the waterbodies.

CONCLUSION

Geomorphologically speaking, nutrients or the solutes emphasized in this study are nitrogen and phosphorus. These nutrients can result primarily from rocks weathering and ocean current mixing (already dissolved nutrients in the water) which got discharged into our waters – both surface and ground water bodies. Their moderate supply will lead to increase in primary productivity, but when in excess supply brings about deleterious consequences to the coastal marine ecosystems. The consequences are hydra headed. The resulted harmful algal blooms produce toxins that affect the ecological habitats, the organisms (both flora and fauna), and humans that consume the sea foods. Control and preventive Measures proffered if adhered to will drastically reduce or put to an end the menace of nutrient pollution or over enrichment.

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