BRJ BASIC RESEARCH JOURNALS

Basic Research Journal of Soil and Environmental Science Vol. 2(1) pp. 001-009 June 2020
Available online http//www.basicresearchjournals.org

Review

Ecological implications of environmental contaminants on biodiversity and ecosystem services: *The Nigerian Experience*

Bernard B. Meer[1*], Ephraim E. Dishan[1], Damian Ikima[2] and Gabriel O. Ateh[1]

[1*]Department of Forestry and Wildlife Management, Modibbo Adama University of Technology Yola, Nigeria.
[2]Department of Social and Environmental Forestry, Federal University of Agriculture Makurdi, Nigeria.

[*]Corresponding author email: meersbernardo@gmail.com +2347039060249 (BBM)

Acceptance June 15, 2020

ABSTRACT

This paper reviews the implications of environmental contamination on Nigerian biodiversity and ecosystem services aimed at identifying the causes, effects and remediation strategies. Literatures on concept of environmental contamination, biodiversity and ecosystem services were discussed. Environmental contaminants are known to be naturally occurring compounds, but anthropogenic activities introduce them in large quantities in different environmental compartments. This leads to the environment's ability to foster life being reduced as biodiversity become threatened. This occurs due to accumulation of the contaminants in the biosphere as a result of widespread of contaminants and non-degradable state of most them. The paper posits that environmental problems in Nigeria generally are many, diverse in nature and are caused by human interaction with environment for exploits in a number of ways-both in the cities; where industrial activities predominate, and rural areas; where agriculture thrives. The paper observes that these problems are a consequence of environmental contaminants which eventually results to environmental contamination. Remediation of environmental contamination requires special attention to protect all spheres (atmosphere, lithosphere, hydrosphere and biosphere) as a collection. The review proffers possible solutions and recommendations to restore or minimise and prevent further occurrences in Nigeria.

Keywords: Biodiversity; Contamination; Remediation; Ecosystem services; Environmental Contaminants.

INTRODUCTION

Environmental contamination is one of the major environmental problems in the world, posing significant risks to biodiversity and ecosystem services in abiotic environmental compartments (soil, water, air) and in the related biota (e.g., uptake by plants, animals and microbial activities). Chemical contamination has impaired ecosystems, reducing biodiversity and the provisioning of functions and services. This has spurred a movement to restore contaminated ecosystems, develop and implement national regulations that require it (Rohr *et al*., 2016). Environmental contaminants are pervasive and diverse (Gilliom *et al*., 2007; Loos *et al*., 2009).

There are more than 80 000 identified environmental contaminants all over the world (Office of Research and

Development [ORD], 2011). Environmental contaminants, including physical, chemical and biological have reduced biodiversity in many ecosystems (McMahon *et al*., 2012; Beketov *et al.,* 2013). These biodiversity losses often result in reduced environmental health, ecosystem functions and services (Halstead *et al.,* 2014; Rohr *et al*., 2016). Understanding ecological condition is crucial because biodiversity depend on healthy ecosystems. Environmental contaminants can elicit more subtle but nevertheless important and harmful ecological implications (Hellou, 2011). Further, contamination of the environment is certainly not limited to short-term, acute exposures. Effects of long-term, low-level chronic exposures can be equally deleterious, though less obvious for human observers (Saaristo *et al*., 2018). Implications of environmental contaminants on biodiversity and ecosystem services depend on ecological processes, which may influence species-specific responses and lead to indirect effects (Golz, 2019).

Nigeria's well-endowed ecosystems contain one of the highest concentrations of biodiversity on the planet. The biodiversity is considered essential to economic development of the nation. They provide services like climate modification, catchment area protection, ecological integrity, shade, nutrient and water cycling, carbon storage and turnover, regulation of soil structure, resistance to pests and diseases, regulation of above ground diversity, etc (Food and Agricultural Organization [FAO], 2009). They also contribute to environmental stability and sustainability through conservation of ecological processes that link the continuity of life (Meer *et al*., 2019). Unrestricted use of pesticides, insecticides, herbicides and indiscriminate dumping of refuse, industrial activities, excreta and animal dung as well as spillages from refineries, large scale bush burning, widespread of invasive species, etc are perceived as some of the leading factors of environmental contamination in Nigeria (Jande, 2005). Imasuen *et al*. (2013) estimated that Nigeria looses 3000ha of biodiversity vegetation per year through deforestation, bush burning and general desertification. A commitment to ecological sustainability is long entrenched in national policy and has been articulated extensively through the development of most of Nigerian natural resource plans and legislation. Yet, to date these commitments have not succeeded in stopping the decline of biodiversity in Nigeria (Nigeria, 2015).

Threat posed by contaminants is large (Crain *et al*., 2008) and environmental contamination is one of the least studied stressors in ecosystems management (Lawler *et al*., 2006). Research on environmental contaminants conventionally recorded a limited range of endpoints, most commonly by studying mortality following exposure in the laboratory or by testing the implication of a single contaminant on a single species under standardized laboratory conditions. These approaches are logistically tractable and repeatable but are criticized for their simplicity, particularly when such experiments neither take chemical nor biological complexity into account (Saaristo *et al*., 2018).

Biodiversity is under threat worldwide. Many scientists consider that the Earth has now entered a global biodiversity extinction crisis (United Nations Environment Programme, [UNEP] 2007). That is, they believe that many of the biodiversity today are under threat of rapid extinction. In response to this crisis, as a nation Nigeria needs to transform the management of biodiversity by placing the conservation and sustainable use of Nigerian biodiversity at the centre of human thoughts and actions.

Biodiversity is among the providers of ecosystem services and as such the links between biodiversity, ecosystem functions and services are very important to study. Biodiversity-ecosystem services relationships are influenced by environmental conditions (Hooper *et al*., 2012) including contaminants. However, there has been far less emphasis on the direct implications of environmental contaminants on biodiversity and ecosystem services. Therefore, a comprehensive understanding of how environmental contaminants directly affect biodiversity and ecosystem services is necessary to develop sound and efficient management strategies that protect biodiversity and ecosystem services. The aim of this paper review is to investigate the ecological implications of environmental contaminants on biodiversity and ecosystem services, ranging from causes to effects and remediation endpoints.

Environmental contamination

An environment can be contaminated. Contaminants pose detrimental implications on the environment. From literature, Contamination can be defined as the presence of elevated concentrations of substances in the environment above the natural background level for the area and for the organism. Therefore, environmental contamination can be referred to as undesirable and unwanted change in physical, chemical and biological characteristics of abiotic component (air, water and soil) which is harmful for biotic component (plants, animal and microorganisms). Contamination can take the form of chemical substances or energy, such as noise, heat or light (Wong, 2012; Masindi and Muedi, 2018).

Types of environmental contaminants

Environmental contaminants can be naturally occurring compounds or foreign matter which when in contact with the environment cause adverse changes. Irrespective of contaminants falling under different categories, they all

receive considerable attention due to the implications they introduce to the environment. There are different types of contaminants which include the following (El-Shahawi, *et al*., 2010; Wong, 2012).

Inorganic environmental contaminants

Industrial, agricultural and domestic wastes contribute to environmental contaminations which cause adverse harm to biodiversity health. From such sources, inorganic contaminants are released. Inorganic contaminants are usually substances of mineral origin with metals, salts and minerals being examples (Wong 2012). Studies have reported inorganic contaminants as material found naturally but have been altered by human production to increase their number in the environment (Masindi and Muedi, 2018).

Organic environmental contaminants

Organic contamination can be briefly defined as biodegradable contaminants in an environment. Some of the common organic contaminants which have been noted to be of special concern are human waste, food waste, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), pesticides, petroleum, herbicides and organochlorine pesticides (OCPs (El-Shahawi, *et al*., 2010).

Biological environmental contaminants

Biological contaminants are described as contaminants which exist as a result of human actions. This type of contaminants includes bacteria, viruses, moulds, mildew, animal dander and cat saliva, house dust, mites, cockroaches and pollen (Masindi and Muedi, 2018).

Sources of environmental contaminants

Environmental contaminants can emanate from both natural and anthropogenic processes and end up in different environmental compartments (soil, water, air and their interface). The sources of environmental contamination are naturally found but anthropogenic activities have also been contributing to their intensive production.

Natural processes

Many studies have documented different natural sources of contaminant. Under different and certain environmental conditions, natural emissions of chemical compounds occur. Such emissions include volcanic eruptions, sea-salt sprays, forest fires, rock weathering, biogenic sources and wind-borne soil particles. Contaminants can be found in the form of hydroxides, oxides, sulphides, sulphates, phosphates, silicates and organic compounds. The most common contaminants are lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), zinc (Zn) and copper (Cu). Although the aforementioned contaminants can be found in traces, they still cause serious health problems to biodiversity (Herawati *et al.,* 2000).

Anthropogenic processes

Industries, agriculture, wastewater, mining and metallurgical processes and runoffs also lead to the release of contaminants to different environmental compartments. Contaminants naturally emitted in wind-blown dusts are mostly from industrial areas. Some important anthropogenic sources which significantly contribute to the environmental contamination include automobile exhaust which releases lead; smelting which releases arsenic, copper and zinc; insecticides which release arsenic and burning of fossil fuels which release nickel, vanadium, mercury, selenium and tin (He *et al*., 2005).

Concept of biodiversity and ecosystem services

Biodiversity is defined as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” The importance of this definition is that it draws attention to many dimensions of biodiversity. It explicitly recognizes that every biota can be characterized by its taxonomic, ecological, and genetic diversity and that the way these dimensions of diversity vary over space and time is a key feature of biodiversity. Thus, only a multidimensional assessment of biodiversity can provide insights into the relationship between changes in biodiversity and changes in ecosystem functions and services (Millennium Ecosystem Assessment [MEA], 2005).

Biodiversity include all ecosystems (managed or unmanaged ecosystems). It is the foundation of ecosystem services to which human well-being is intimately linked. No feature of Earth is more complex, dynamic, and varied than the layer of living organisms (i.e. biosphere) that occupy its surfaces and its seas (MEA, 2005). Biodiversity contributes directly (through provisioning, regulating, and cultural ecosystem services)

and indirectly (through supporting ecosystem services). It represents the foundation of ecosystems that, through the services they provide, affect human well-being. These include provisioning services such as food, water, timber, and fiber; regulating services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfilment; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005).

There are many measures of biodiversity; species richness (the number of species in a given area) represents a single but important metric that is valuable as the common currency of the diversity of life but it must be integrated with other metrics such as Shannon Winner's diversity index, important value index, etc to fully capture biodiversity. Variability, dynamics, trophic position, and functional attributes of many species are poorly known. Ecological indicators are scientific constructs that use quantitative data to measure aspects of biodiversity, ecosystem condition, services, or drivers of change. Ecological indicators form a critical component of monitoring, assessment and decision-making and are designed to communicate information quickly and easily to policy-makers (MEA, 2005).

The main threats to biodiversity in Nigeria

Nigeria (2015) records showed that 70-80% of Nigeria's original forest has disappeared and presently the area occupied by forests is reduced to 12%. In the period between 2000 and 2005, Nigeria lost about 2,048ha of forest (FAO, 2005). Although Nigerian government established several forest reserves for conservation of forest resources, these forest reserves have been seriously neglected and received little or no improvement in terms of investment and management (Prasad and Freitas, 2003). The implication of these losses is that many plants and animals, including many potentially valuable species are on the fast track to extinction. The United States Agency for International Development [USAID] (2012) report on Biodiversity and Tropical Forestry Assessment recorded that there are many environmental threats in Nigeria affecting Biodiversity. A National Assessment (Nigeria, 2015) confirmed the reality of high rise and fast tracked increase in biodiversity loss in Nigeria.

Understanding the ecological implications of environmental contaminants

The presence of contaminants in the environment leads to a number of adverse ecological implications. Such implications affect all spheres of the environment (i. e. hydrosphere, lithosphere, biosphere and atmosphere). Until the effects are dealt with, health and mortality challenges on biodiversity will continue to persist (Masindi and Muedi, 2018). Contaminants in the environment can look and smell pretty nasty, but their implications go beyond just aesthetics. Some of the contaminants resist breakdown and accumulate in the food chain. These contaminants can be absorbed or consumed by primary producers or consumers respectively who in turn may be eaten by secondary and tertiary consumers. Contaminants can also get into sediments, implicating large coastal areas, threatening human health, and reducing the economic well being of regions that depend on a healthy coastal environment (National Oceanic and Atmospheric Administration, 2017).

Effects of recognized and emerging contaminants

Environmental contamination is becoming a serious issue of concern around the world as it has gained momentum due to the increase in the use and processing of contaminants. Soil, water and air are the major environmental compartments which are affected by environmental contaminants. It is often inferred that the loss of biodiversity will negatively affect ecosystem function (Cardinale *et al*., 2012; Hooper *et al*., 2012).

Effects on Soil (Litho spherical effects)

Emissions from different sources of contaminants lead to soil contamination. Soils have been noted to be the major sinks for contaminants (e.g. heavy metals) released into the environment. Most heavy metals do not undergo microbial or chemical degradation because they are non-degradable and consequently their total concentrations last for a long time after being released to the environment (Lepp, 2012). The presence of heavy metals in soils is a serious issue due to its residence in food chains, thus destroying the entire ecosystem. There are various ways through which contaminants present risks to biodiversity and ecosystem services. Such ways include direct ingestion, absorption by plants, food chains, consumption of contaminated water and alteration of soil pH, porosity, colour and its natural chemistry which in turn implicate the soil quality (Wong, 2012; Masindi and Muedi, 2018).

Effects on water (Hydrological effects)

Contaminants can be found in traces in water sources and still be very toxic and impose serious health problems to aquatic biodiversity and other ecosystems. Food chains and food webs symbolise the relationships

amongst organisms. Therefore, the contamination of water actually affects all organisms (Masindi and Muedi, 2018). Coastal waters are generally nitrogen limited, excessive nitrogen leads to excess production of algae, decreasing water clarity and reducing concentrations of dissolved oxygen, a situation referred to as eutrophication (Pearl *et al*., 2006). Eutrophication can be accompanied by massive blooms of nuisance and toxic algae, habitat loss for fish and shellfish, alteration of food webs, degradation and loss of sea grass beds, and the loss of biological diversity (Howarth *et al*., 2003). Fresh waters are generally not nitrogen limited, the addition of nitrogen does not lead to excessive eutrophication as it does in coastal waters. However, nitrate leaching from terrestrial systems to fresh waters leads to acidification effects.

Effects on air (Atmospherically effects)

Industrialisation and urbanisation, due to rapid world population growth, have recently made air contamination a major environmental problem around the world. The air contamination was reported to have been accelerated by dust and particulate matters (PMs) particularly fine particles such as PM 2.5 and PM 10 which are released through natural and anthropogenic processes. Natural processes which release particulate matters into air include dust storms, soil erosion, volcanic eruptions and rock weathering, while anthropogenic activities are more industrial and transportation related (Masindi and Muedi, 2018).

Effects on biodiversity and ecosystem services (Biospheric and Ecological Effects)

Documented effects of environmental contamination on flora species include visible foliar damage, decreased chlorophyll content, accelerated leaf senescence, decreased photosynthesis, increased respiration, altered carbon allocation, water balance changes and epicuticular wax and other physiological processes. These can lead to changes in canopy structure, carbon allocation, productivity, and fitness of the species (Karnosky *et al*., 2006).

Both direct and indirect contamination affects wildlife. Indirect contamination threatens the habitat of animals. According to (www.marinebio.org)"The use of synthetic chemicals to control pests, principally insects, weeds and fungi, became an integral part of agriculture and disease control after World War II."Dichloro Diphenyl Trichloroethane (DDT), a pesticide that was widely applied between the 1940s and 1960s, mainly for mosquito abatement, is one example of a synthetic chemical known to be highly destructive to animals. However, by the end of the 1960s, it was clear that DDT was found to contaminate different species of animals causing reproductive system failures, and neurological effects which calls for its ban in many countries. In aquatic ecosystems, contaminants-induced effects are mediated by changes in water chemistry which in turn can cause increased mortality in sensitive species, changes in community composition, and changes in nutrient cycling and energy flows (Driscoll *et al*., 2003). Some contaminants (e. g. Lead poisoning) in sub-lethal doses can damage the brain, the nervous and reproductive systems and cause kidney disease, birth defects, miscarriage and nerve disorders in mammals www.marinebio.org.

Contaminants that are cellular poisons inhibit both microbial growth and activity that is responsible for the major cycling of elements in the environment. Any impairment of microbial growth will necessarily have negative effects on microbial activity. Major transformations, such as nitrogen fixation, nitrification and carbon mineralization may be impaired as a result of contaminant effect. It should also be remembered however, that microorganisms also often use Contaminants as nutrient sources, a fact that can lead to major, often unchecked and uncontrolled growth of microbial biomass (Wainwright, 1999).

Biodiversity in contaminated sites in Nigeria

The physicochemical properties of contaminated site tend to inhibit soil forming processes and affect the area's biodiversity by exerting a strong selective pressure on fungi and plants (Ceci, *et al.,* 2012). The biodiversity of Nigerian ecosystems is increasingly being destroyed or depleted by persistent threat of environmental contaminants. Nationally, there are thousands of contaminated sites of varying size and significance in settings ranging from abandoned buildings in inner cities to large areas contaminated with toxic materials.

Evidences of environmental contamination in Nigeria

Evidences of environmental contamination in Nigerian communities can be discussed under the following headings:

Farming

The agricultural activities of farmers in Nigeria have far reaching effects on the environment and its inhabitant. Empirical evidences have shown that primitive farmers use fire to clear parcels of farm land, modify the soil by ploughing, alter the drainage by irrigation and introduce

or breed new animals and crops. These activities no doubt alter the natural vegetation of the environment (Ityavyar and Tyav, 2015). Livestock farming popularly referred to as domestication of animals which is commonly practiced in Northern and North central regions of Nigeria also has a major contaminating implication on the land surface. Over grazing have leads to soil erosion by wind and water in different parts of northern Nigeria and the deliberate removal of forest to create new agricultural lands in north central Nigeria is seriously reducing the normal functions and services rendered by the forest ecosystem in the zone (Ityavyar and Tyav, 2015) thereby, causing serious environmental problems.

Deforestation and overexploitation

The main source of water contamination in Nigeria has to do with forestry activities. These activities have increased the magnitude and frequency of flooding, soil erosion, sediment loads in rivers, slopes instability and degradation of adjacent lands in southern, western and eastern Nigeria (Ityavyar and Tyav, 2015). The highest concentration of severe gully erosion in Nigeria is found in five Eastern states of Anambra, Enugu, Abia, Imo, and Akwa Ibom Anambra is famous with its Agulu-Nanka-Oko Ekwulobia gullies. Gullies of about 120m depth and 2km width have been recorded in this area. According to recent media reports, over 70 percent of land in Anambra state is ravaged or threatened by erosion at various levels (Obi and Okekeogbu, 2017).

Forest clearing leads to vegetational removal which increases infertility of land and subsequently desertification and drought (Ityavyar and Tyav, 2015). The Northern part of Nigeria especially the frontline states comprising of Bauchi, Gombe, Borno, Yobe, Jigawa, Kano, Katsina, Sokoto, Zamfara and Kebbi which lie roughly North of latitude 12^0N face serious threats of desertification occasioned by over exposure of the fragile environment mostly through improper farming techniques, overgrazing by livestock and occurrence of frequent fires and drought (Omijeh, 2008).

Floodlist (2019) reported that flood has affected several states including Lagos and Rivers over the last few days. Continued heavy rain in September 2019 increased levels of the Niger and Benue rivers, causing flooding in Cross River, Kogi, Benue, Adamawa, Taraba and Niger states. Torrential rainfall and flash floods hitting the BAY (Borrno, Adamawa, Yobe) states have had a devastating implication on the host communities and biodiversity (Office for the Coordination of Humanitarian Affairs, 2019). Following heavy rains on 26-27 October 2019, a large number of people have been displaced in Adamawa State of Nigeria. Most of the farmlands have been submerged in water leading to a heavy loss of farm produce, livestock, biodiversity and other valuable items worth millions of Naira destroyed (Displacement Tracking Matrix, 2019).

Poaching

Hunting is also one of the human activities that often result to bush burning and the use of chemicals in our streams, rivers and seas in search of game in Nigeria. Many hunters in Nigeria use dogs, traps, spears, arrows, guns, knives, fire, etc to hunt for plant and animal species. The methods employed create a lot of negative implications on the environment. For instance, the rural Tiv people of North central Nigeria use bush burning to hunt for rats and other fauna species. The result of this is that sometimes it destroys both the biotic and abiotic components of the environment especially when the fire is out of control (Ityavyar and Tyav, 2015).

Oil spillage and gas flaring

Oil is the primary base of Nigeria's economy and is also the cause of major environmental problems in the Niger Delta region of Nigeria. Over the years, oil exploration, production, and refinement in Nigeria has resulted in various environmental and ecological problems that range from oil spills, gas flares, habitat destruction, air and water contamination as well as land degradation. Also, a major cause of oil contamination in that same region is also to a great extent from the activities of illegal oil bunkering and illegal refineries operated by the indigenes and some highly placed individuals in government. The chemical properties of spilled oil often affect the productiveness of soil and contaminate water bodies, thereby causing irreparable damage to agricultural lands as well as aquatic bodies (Ogbonna and Ekweozor, 2000). According to the assessment conducted by United Nations Environment Programme (2011), the public health of Ogoni communities has been seriously threatened. The water bodies of these communities are contaminated with high levels of hydrocarbons.

Domestic and industrial waste

This has also constituted a major source of environmental contamination in Nigeria. The improper disposal and ineffective management of municipal solid waste and industrial waste creates major environmental and aesthetic problems in most of Nigeria's urban areas. Gbehe (2004) pointed out that most of the environmental challenges in Nigeria take their origins in the developmental processes. The environment is highly contaminated in the process of execution, processing and

disposal of minerals, these activities dominate in Nigerian cities such as Lagos, Enugu, Ibadan, Kano, Port Harcourt, Benin, Warri, Kaduna, Yandev-Gboko, thereby injecting contaminants into the environment. The contaminants released into the air due to execution, processing and disposal of minerals deplete the ozone layer (Ityavyar and Tyav, 2015) which in turn cause climate change that affects Nigerian biodiversity and ecosystem services.

Housing

Ityavyar and Tyav, (2015) observed that unplanned housing projects with inadequate sewage system constitute a major source of water contamination in Nigeria, especially in urban environments. Scientific evidence has shown that residents also litter the environment with polythene bags, empties of canned foods and drinks, sachet water bags and so on. This development combined with solid waste generated in households which are also dumped in water channels, streams and rivers in some cases blocked the courses of these channels, streams and rivers resulting to flooding. In 2012 Lagos floods rendered most residents homeless in some parts of Victoria Island Ajegunle etc in Lagos-homeless. Also in Benin city, Gbehe (2004) observed that the Ikpoba River which flows along the fringe of the city was so contaminated in certain portions of it that it may be mistaken for a cesspool.

Mechanisms of remediation strategies

Remediation goals and objectives are fundamental components of any successful ecological restoration. There are several ecological theories and disciplines that can inform and guide the remediation of contaminated sites, thus improving the cost-effectiveness and success of restoration programs. Environmental remediation is an important focus of the green economy. Sites that are contaminated due to the release of contaminants must be remediated in order to redevelop the environment or return it to its natural state. Remediation projects usually begin with a site assessment to determine the costs of the project, as well as the technology that would be the most appropriate for the particular site. It is carried out on various environmental media including lithosphere (soil and sediment), hydrosphere (ground water and surface water) and the atmosphere (soil surface). Soil and water remediation may be conducted separately or together, depending on the type and extent of the contamination (Société Générale de Surveillance [SGS], 2019).

Many active remediation projects of contaminated sites restore biodiversity by *Ex-situ*/translocating (moving from elsewhere) or *In-situ*/reintroducing (taking a local stock, replicating it in "captivity," and introducing at the same general location where it was found). There is a rich history of attempted translocations and reintroductions that have provided guidance on how to successfully restore biodiversity using these approaches (Rohr *et al*., 2016). Some of the available remediation mechanisms include the following:

***In situ* techniques**

Bioremediation, natural attenuation, bio venting, bio sparging, permeable reactive barriers, soil vapor extraction and injections (SGS, 2019). Ecosystem device or organisms that can create, significantly modify, maintain, or destroy a contaminated habitat can be important tools for remediation (Byers *et al*., 2006). The most well-known examples are those involving phytoremediation, or the use of plants to remove concentrated contaminants from soil, sediments, or water. Phytoremediation has been used to clean up sites contaminated with metals and certain organic compounds, facilitating natural recovery (Meagher, 2000). Although the plant communities associated with phytoremediation might represent novel or hybrid communities and thus an undesirable restoration endpoint (Hobbs *et al*., 2009), in many cases, the historical community can be restored after these plants are harvested. Like phytoremediation, microbial/myco remediation or the use of microbes to accelerate contaminant breakdown, has also proven to be a valuable use of ecosystem managers for remediation purposes (Kang 2014).

Ex-*situ* techniques

Pump and treat with on-site treatment of pumped water (separators, stripping towers, activated carbons), land farming and ground treatment by mobile units (SGS, 2019). Maintaining and breeding of endangered plant and animal species under partially or wholly controlled conditions in specific areas like zoological and botanical gardens, nurseries, gene banks, etc (Iyyappan *et al*., 2018).

Off-site techniques

Excavation of contaminated ground and assessment by a treatment centre (biological, physico-chemical, thermal) and by incineration treatments and much more (SGS, 2019).

Prevention techniques

The best mechanism of environmental remediation strategies is prevention. For example, above ground

storage tanks can be used to contain considerable amount of harmful waste and to prevent it from ever leaking in the environment. Econotanks and other above ground mechanisms can be set up quickly. It may be possible to set up a tank even as an emergency is developing. Depending on the situation, environmental contaminants may be isolated before they seep into the environment. Environmental contaminants with additional liners and walls can provide additional protection. If hazardous materials are at risk of leaking into the environment, moving it into a safe storage system will reduce risks (Lal and Stewart, 1990).

CONCLUSION

Environmental contaminants are threatening biodiversity and ecosystem services and are caused by natural and anthropogenic processes on environment. Environmental contaminants have the potential to greatly affect the biodiversity and ecosystem services as well as the benefits provided by these systems. The overall assessment of all implications on biodiversity loss is unprecedented leading to geometric decline in biodiversity and ecosystem services. This poses a serious threat to sustainable development. The understanding of environmental contaminant effects on environment will remain patchy until direct measures of remediation are undertaken. Integrated responses that address both environmental contamination and sustainable use of natural ecosystems could be further strengthened.

Environmental contamination has remained active in Nigeria, leading to a significant decline of biodiversity composition and structure. The contiguous rise of recognized and emerging contaminants in Nigeria, many of which are designed to exert adverse effects on biodiversity and ecosystem services, it is important to update existing frameworks for studying their short and long-term consequences. The rapid decline of biodiversity in Nigeria could be reversed if there are sound remediation mechanisms based on ecological awareness. This should be determined on the basis of sound scientific evaluations of the existing resources and the carrying capacity of the ecosystem. Each contaminated site requires its own strategy and site-specific designs for decontamination. The contamination of Nigerian communities warrants emergency action ahead of all other remediation efforts. This calls for need to prioritize areas for remediation.

RECOMMENDATIONS

- The functional endpoints such as productivity and respiration, ecological studies, routine toxicological studies and ecological risk assessment should be adopted.
- Legislation and guidelines to ensure that criteria for minimizing significant adverse implications of environmental contaminants on biodiversity and ecosystem services should be put in place as part of the basis for contamination prevention and control measures. Nigerian government should enact and implement environmental laws.
- Afforestation and reforestation programs can be adopted in bare areas (savannah zones) to reduce and absorb runoff, climate change, erosion, and improve habitat
- Proper dispose of waste, industrial and household contaminants should be encouraged
- New institutions should be established in Nigeria to support a comprehensive environmental restoration exercise
- Select or screen out bacteria, fungi and plants that can survive on different contaminants and use them for bioremediation.
- Sustainable programs and practices such as windbreaks, shelterbelts, alley farming, taungya system, woodlots, home garden, protein bank, apisilviculture, agroforestry system, introduction of multi-purpose trees, fodder trees and fuel wood species, prescribed burning and introduction of nitrogen-fixing species are the various techniques that can be employ to restore, regenerate and conserve biodiversity and ecosystem services thereby, reducing the adverse effects of environmental contaminants.

Concerned stakeholders should provide environmental education and alternative domestic energy/livelihood in order to avoid abuses such as deforestation and over exploitation to encourage high composition, population structure and density of biodiversity.

REFERENCES

Beketov MA, Kefford BJ, Schafer RB, Liess M (2013). Pesticides reduce regional biodiversity of stream invertebrates. Proc Natl Acad Sci USA, 110:11039–11043.

Byers JE, Cuddington K, Jones CG, Talley TS, Hastings A, Lambrinos JG, Crooks JA, Wilson WG (2006). Using ecosystem engineers to restore ecological systems. *Trends Ecol Evol*. 21:493–500.

Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P (2012). Biodiversity loss and its implication on humanity. Nature, 486, 59–67.

Ceci A, Maggi O, Pinzari F, Persiani AM (2012). Growth responses to and accumulation of vanadium in agricultural soil fungi. *Applied Soil Ecology*. 58:1-11.

Crain CM, Kroeker K, Halpern BS (2008). Interactive and cumulative effects of multiple human stressors in marine systems. *Ecology Letters*, 11, 1304–1315.

Displacement Tracking Matrix (2019). Nigeria - Flood In Adamawa State Flash Report. *Displacement.iom.int,* 29 October 2019. P 1.

Driscoll CT, Driscoll KM, Mitchell MJ, Raynall DJ (2003). Effects of acidic deposition on forest and aquatic ecosystems in New York

State. Environmental Pollution 123:327-336.
El-Shahawi MS, Hamza A, Bashammakhb AS, Al-Saggaf WT (2010). An overview on the accumulation, distribution, transformations, toxicity and analytical methods for the monitoring of persistent organic contaminants. *Talanta*. 80:1587-1597.
Floodlist (2019). Nigeria – Floods Hit Lagos, Situation Worsens in Niger and Adamawa States. *Copernicus*, the Europe's eyes on earth. Pp 1-2.
Food and Agriculture Organization (FAO) (2005). *Global forest resources assessment*. Food and Agriculture Organization of the United Nations, Rome.
Food and Agriculture Organization (FAO) (2009) *State of the World's Forests 2009*. FAO, Rome.
Gbehe NT (2004). "Land Development in Nigeria: An Examination of Environmental Degradation Associated with land use Types. Conference Paper at the Department of Geography Benue State University (B.S.U.) Makurdi. January, 2004.
Gilliom RJ, Barbash JE, Crawford CG, Hamilton PA, Martin JD, Nakagaki N, Nowell LH, Scott JC, Stackelberg PE, Thelin GP (2007). The quality of our nation's waters—pesticides in the nation's streams and ground water, 1992–2001. US Geological Survey; Reston, (VI). Available from: http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291.pdf
Golz AL (2019). *Role of ecological processes in determining effects of contaminants in aquatic ecosystems*. Stockholm University, Sweden. Pp 1-46.
Halstead NT, McMahon TA, Johnson SA, Raffel TR, Romansic JM, Crumrine PW, Rohr JR (2014). Community ecology theory predicts the effects of agrochemical mixtures on aquatic biodiversity and ecosystem properties. Ecol Lett. 17:932–941.
He ZL, Yang XE, Stoffella PJ (2005). Trace elements in agroecosystems and implications on the environment. *Journal of Trace Elements in Medicine and Biology*.19 (2–3):125-140.
Hellou J, (2011). Behavioural ecotoxicology, an 'early warning' signal to assess environmental quality. Environ. Sci. Pollut. Res. 18, 1–11.
Herawati N, Suzuki S, Hayashi K, Rivai IF, Koyoma H (2000). Cadmium, copper and zinc levels in rice and soil of Japan, Indonesia and China by soil type. Bulletin of Environmental Contamination and Toxicology. 64:33-39.
Hobbs RJ, Higgs E, Harris JA (2009). Novel ecosystems: Implications for conservation and restoration. Trends Ecol Evol. 24:599–605.
Hooper DU, Adair EC, Cardinale BJ, Byrnes JEK, Hungate BA, Matulich KL (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature, 486, 105–129.
Howarth R, Marino R, Scavia D (2003). Nutrient pollution in coastal waters: Priority topics for an integrated national research program for the United States. National Oceanic and Atmospheric Administration, National Ocean Service.10-56.
Imasuen OI, Oshodi JN, Onyeobi TUS (2013). Protected areas for environmental sustainability in Nigeria. *J. Appl. Sci. Environ. Manage*. 17 (1). 53-58.
Ityavyar EM, Tyav TT (2015). Environmental pollution in Nigeria: The need for awareness creation and sustainable development. *Journal of research in Forestry, wildlife and environment*. 4 (2). 1-14.
Iyyappan J, Ayyam V, Chandrakasan S (2018). *Biodervisity conservation: Issues and strategies for the tropical Islands*. Acadamic Press. 525-552.
Jande GG (2005). Legal Mechanisms for the control of Pollution on the high seas. Afri. J. Environ. Law Dev. Stud. Vol 1. Part 1. Pp.1 – 13.
Kang JW (2014). Removing environmental organic pollutants with bioremediation and phytoremediation. Biotechnol Lett. 36:1129–1139.
Karnosky DF, Skelly JM, Percy KE, Chappelka AH (2006). Perspectives regarding 50 years of research on effects of tropospheric ozone air pollution on US forests. Environmental Pollution. 147:489-506.
Lal R, Stewart BA (1990). Soil degradation. Springer-Verlag, New York.
Lawler JJ, Aukema JE, Grant JB, Halpern BS, Kareiva P, Nelson CR (2006). Conservation science: a 20-year report card. Frontiers in Ecology and the Environment, 4, 473–480.
Lepp NW (2012). *Effect of heavy metal pollution on plants. Metals in the Environment, Pollution Monitoring Series,* Applied Science Publishers. Department of Biology. Liverpool, United Kingdom: Liverpool Polytechnic. P 2.
Loose R, Gawlik BM, Locoro G, Rimaviciute E, Contini S, Bidoglio G (2009). EU-wide survey of polar organic persistent pollutants in European river waters. *Environ Pollut*. 157:561–568.
Masindi V, Muedi KL (2018). *Environmental Contamination by contaminants (Heavy Metals)*. Open Access books. 1-21.
McMahon TA, Halstead NT, Johnson S, Raffel TR, Romansic JM, Crumrine PW, Rohr JR (2012). Fungicideinduced declines of freshwater biodiversity modify ecosystem functions and services. *Ecol Lett*. 15:714–722.
Meagher RB (2000). Phytoremediation of toxic elemental and organic pollutants. Curr Opin Plant Biol. 3:153–162.
Meer BB, Tella I, Saka MG, Nyiputen I, Gbande S, Chapman H (2019). Sustainability, Population and Structure of Woody Species Composition of Taraba State Forests. *Asian J. Res. Agric. Forest*. 1 (4) 1-13.
Millennium Ecosystem Assessment (MEA) (2005). Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC. 1-51.
National Oceanic and Atmospheric Administration (NOAA) (2017). Contaminants in the Environment. US department of commerce. P 1.
Nigeria (2015). Fifth National Biodiversity Report. 1-89.
Obi NI, Okekeogbu CJ (2017). Erosion problems and their implications in Anambra State of Nigeria. A case study of Nanka community. *Intern. J. Environ. Pollut. Res*. 5(1), pp 24-37.
Office for the Coordination of Humanitarian Affairs (2019). Nigeria: Floods in Borno, Adamawa and Yobe. Situation Report No. 2.*United Nations*. P 1.
Office of Research and Development (ORD) (2011). *UE. Framework for an EPA Chemical Safety for Sustainability Program*. Office of Research and Development, USEPA; Washington (DC).
Ogbonna EA, Ekweozor P (2000). *The Adverse Effects of Crude Oil Spills in the Niger Delta*. Urhobo Historical Society.
Omijeh EJ (2008). Strategies for the control of desertification in northern Nigeria. *FUTY J. Environ*. 3(1), pp 1-12.
Paerl HW, Valdez LM, Peierls BL, Adolf JE, Harding LW (2006). Anthropogenic and climatic influences on the eutrophication oflarge estuarine ecosystems. *Limnology and Oceanography* 51(1, part 2):448-462.
Prasad MNV, Freitas H (2003). Metal hyperaccumulation in plants - Biodiversity prospecting for phytoremediation technology. *Elect. J. Biotechnol*. 6: 275-321.
Rohr JR, Farag, AM, Cadotte MW, Clements CH, Smith JR, Ulrich CP, Woods RR (2016). Transforming Ecosystems: When, Where, and How to Restore Contaminated Sites. Integr Environ Assess Manag. 12(2): 273–283.
Saaristo M, Brodin T, Balshine S, Bertram MG, Brooks BW, Herman SM, McCollum ES, Sih A, Sundin J, Wong BM, Arnold KM (2018). Direct and indirect effects of chemical contaminants on the behaviour, ecology and evolution of wildlife. Proc. R. Soc. B 285: 20181297. P.o. 1-10.
Société Générale de Surveillance (SGS), (2019). Environment: Contaminated land studies. SGS Inspection Services Nigeria Limited. P 1.
United Nations Environment Programme (UNEP) (2007). *Global Environment Outlook: (GEO4 environment for development)*, UNEP.
United Nations Environment Programme (UNEP) (2011). Environmental Assessment of Ogoniland. Relief web. P 3.
United States Agency for International Development (USAID) (2012). Biodiversity conservation and Tropical Forestry assessment. International Resources Group 1211 Connecticut Avenue, NW, Suite 700 Washington, DC.
Wainwright M (1999). An introduction to environmental biotechnology. Kluwer Academic Publishers. 1-2.
Wong MH (2012). Environmental Contamination: Health Risks and Ecological Restoration. United States of America: Taylor and Francis Group.