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River Basins as Geomorphic Units and Environmental Challenges Associated with their Development in Nigeria

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Abstract

This paper aims at examining the theme "River Basin as a geomorphic units and Environmental Challenges associated with its development in Nigeria". It also examined the environmental problems associated with harnessing their resource potentials in Nigeria. The paper also highlighted a brief history of river basins development in Nigeria, as well as their importance as a geomorphic planning unit. It also attempted a general overview of the problems associated with the development of this unique geomorphic unit. The paper thus advances some deliberate and aggressive environmental management strategies that can provide sustainable environmental management solutions. These strategies can mitigate and ameliorate the challenges associated with its development for the present generation and for posterity, with a view to ensuring a healthy environmental sustainability plan is achieved.

Keywords: River basins, geomorphic, environmental, challenges, development, nigeria.

1. INTRODUCTION

The drainage basin or river basin as the nomenclature implies, is an area of land drained by a river and its tributaries. It is a geomorphic unit from which geographic data is collected, analyzed, and deductions made for the purpose of environmental management and planning. Faniran (1987) observed that such data collected from the river basins cover a wide range of physical and Socio – Economic parameters such as rainfall, run-off, floods, spatial spread of diseases, erosion sediment yield and a host of other environmental factors. The river basin can also be regarded as a geomorphic unit which can be used to study geomorphological and hydrological processes. It is an unambiguous region with natural boundaries which cannot be contested or influenced by political boundaries as a result of trans-bounded nature of the hydrological cycle. Adeoti, (2019) remarked that a major problem confronting river basins/watershed management is the non-implementation of watershed management policies.

The drainage basin or river basin is a concept of development because of its geomorphic inclination. It is also regarded as a system because group of objects are inter connected to perform specific functions in the drainage basin (Leopol, 1934). The concept of river basin is also referred to as a system of interconnected system of water, tributaries that flow towards a single outlet. It is an amalgam of natural processes of precipitation, evaporation, surface and ground water run-offs with man-made features such as dams, reservoirs, hydro-power projects, agricultural, irrigation projects, transportation, residential and other environmental and socio-cultural support services.

Other terms used to describe drainage basins include catchment area, basin catchment, drainage area, basin or water basin. The drainage basin acts as a funnel by collecting all the water within the basin and channeling it to a single point. Each drainage basin is usually separated topographically from adjacent basins by a perimeter; the drainage basin divide makes up a succession of higher geographical features such as ridges, hills, or mountains forming a barrier. Drainage basins are similar in nature but not identical to hydrologic units, which are drainage areas delineated so as to nest into a multilateral hierarchical drainage system. Hydrological units are designed to allow multiple inlets, outlets, or sinks. In a strict sense, all drainage basins are hydrological units but not all hydrological units are drainage basins.

The nature of the river basins and the natural resources they offer attract a lot of human activities within the river basins; that brings about man-environmental interaction within the river basins (Adeoti: 2020). The relationship between these activities of man, the natural landscape, and the environment on which he operates are in most cases antagonistic with adverse hazardous effects on both man and the natural environment. These anthropogenic activities could also have long term effects on both the environment and man (Burton: 2003). The concept of integrated basin management, with the attendant problems associated with the development of river basins has its roots in a collective effort to make river basins and the resources located within the basins to be more productive and economically sustainable for the present generation and posterity (Mody: 2004, Uttah: 2017). See Fig 1.

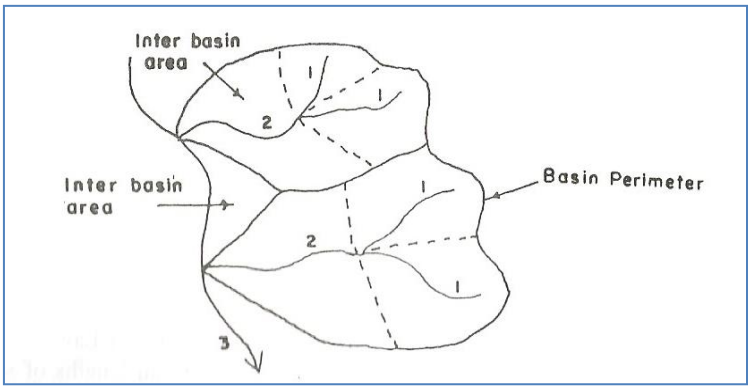

Fig-1: A typical example of stream order in a drainage basin.
Source, R.O Olomo (1997)

The Geomorphic attribute of the river basins makes the river basins standout as specific units for planning and development. The river basin as a planning unit is an embodiment of water resources, mineral rich soil resources, vegetal resources, wild life and game reserves and diverse species of flora and fauna. The presence of these important environmental resources makes the river basins active regions of resource development with adverse environment impact especially with little or no priority on, environmental impact assessment (EIA) and social impact assessment (SIA). Ikechukwu and Onu (2013). River basins are physical, cultural, social and economic entities which are ideal for planning purpose. The abundant natural resources found within the river basins are constantly exploited indiscriminately by man for his own benefit at the detriment of nature. These activities have the possibilities of inducing environmental hazards, such as increased sediment yield on water bodies, erosion, and indiscriminate spread of disease amongst others. The aftermath of resource development process within these peculiar geomorphic units "River basins" often pose a hazardous environmental challenge (Auleh: 2015, Murray-Darling Basin Commission: 2010). See fig 2.

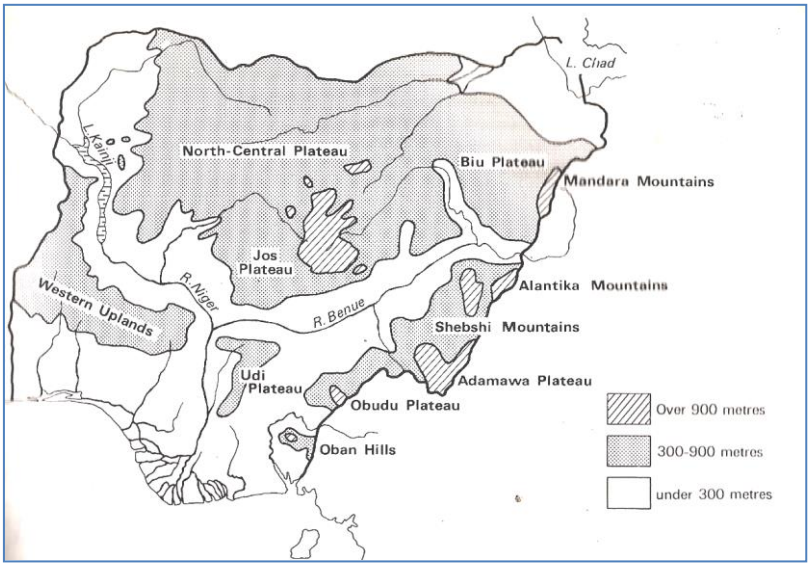

Fig-2: Map of Nigeria showing Kainji Dam. (Source: A New Geography of Nigeria by N.P Ileoje: 1989)

2. MATERIALS AND METHODS

Materials were drawn mainly from in-depth review of existing literature that relates with the theme under consideration. They include maps, tabulated data of river basins development authorities in Nigeria.

3. A Brief History and Rational of River Basin Development in Nigeria

Nigeria's river basins development authorities (RBDA's) were created in 1976 by the Federal Government of Nigeria (UNEP; 2002, William and Nagaraja; 2020). The integral function of the river basins authorities include primarily to harness the country's water resource and to also optimize Nigeria's agricultural resources for food self-sufficiency and security in domestic food production.

The river basins were established to provide water for irrigation, domestic water supply, improvement of navigation, hydro-power generation, recreation facilities, fisheries projects, mineral exploitation, forestry and wild life, and eco-tourism development. They were also expected to bridge the gap between the rural and urban centres by taking development to the grassroots in order to checkmate rural urban migration. These objectives were to be achieved through surface improvement of water by constructing small medium, and large dams which will enable all year round economic activities. They were also to undertake and engender large plantation farming and encourage the establishment of industrial complexes (Akindele and Adebayo, 2004).

Nigeria had eleven (11) river basins originally but in 1984 under the General Mohammadu Buhari's military regime, the eleven river basins metamorphosed to eighteen (18) and were designated as River Basins and Rural Development Authorities. However, in 1986, the General Ibrahim Babangida military administration reverted the number to the original eleven (11) river basins. The fundamental factor underlying the establishment of river basins by the Federal Government of Nigeria was to act as a technique and major tool of boosting agricultural food production (Tesfaye, Arnim, Lasisa and Thomas; 2021). Due to the sectorial imbalance in the Nigerian economy created by oil boom. The "Oil Boom" with its sudden and unprecedented wealth seriously undermined the relevance of agricultural productivity and regrettably; succeeded in creating utter neglect for the relegation of agriculture to the background (Saha, 1981). See Table 1 and Fig. 3.

The pre-occupation with the accumulation of oil wealth created a false wealth situation to the detriment of agricultural policies, which inadvertently created structural imbalance in sub-sector growth. The decline in agricultural productivity and its concomitant food crises led to the emphasis that formed the anteceding rationale for the creation of river basin authorities (RBDA'S) in Nigeria.

Table-1: List of River Basins Development Authorities in Nigeria (Ogundele; 2019)

Column 1 Name of Authority	Column 2 Area of Operation	Column 3 Head Quarters
1. Anambra- Imo River Basin Development Authority.	The whole of Anambra and Imo state.	Owerri
2. Benin –Owena River Basin Development Authority	The whole of Edo, Delta and Ondo State excluding those parts of Edo/Delta state drained by the Benin, Escravos, Forcados and Ramos Rivers creek systems.	Benin
3. Chad Basin Development Authority	The whole of Borno State excluding those parts drained by the Jama'are and Misau Rivers Systems but including those parts of Adamawa State drained by the Yedseram and Goma Rivers systems.	Maiduguri
4. Cross River Basin Development Authority	The whole of Cross River State	Calabar
5. Hadejia Jaima'are River Basin Development Authority	The whole of Kano state and those parts of Bauchi and Borno states drained by the Jama'are and Misau Rivers systems.	Kano
6. Lower Benue River Basin Development Authority	The whole of Benue and Plateau state	Makurdi
7. Niger Delta River Basin Development Authority	The whole of Rivers State and those parts of Edo/Delta State drained by Benin, Escravos, Forcados and Ramos Rivers creek system.	Port-Harcourt
8. Upper and Lower Niger River Basin Development Authority	The whole of Kwara and Niger States; the Federal Capital Territory; whole of Kaduna State excluding Katsina State.	Minna
9. Ogun River Basin Development Authority	The whole of Oyo, Ogun and Lagos State	Abeokuta
10. Upper Benue River Basin Development Authority	Those parts of Bauchi State drained by the Adamawa and Taraba River system; the whole of Adamawa and Taraba State excluding those parts drained by the Yedseram River system.	Yola
11. Sokoto-Rima River Basin Development Authority	The whole of Sokoto State and Katsina State	Sokoto

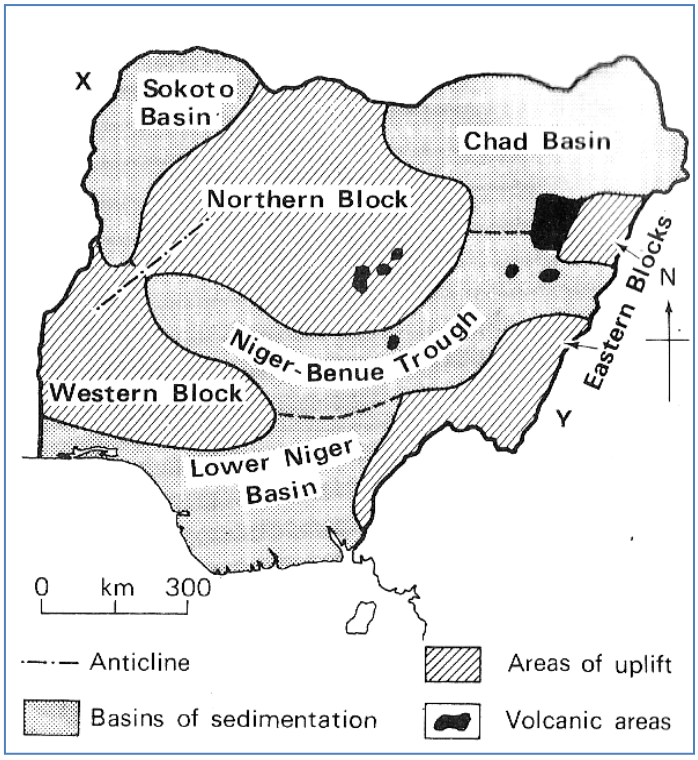

Fig- 3: A Map of Nigeria showing some River Basins in Nigeria
Source: A New Geography of Nigeria, by N.P Ileoje: 1989

All the activities that transpire within the river basins are specific activities that demand proper environmental monitoring in terms of Environmental Impact Assessment (EIA's) and Social Impact Assessment (SIA's) Environment. UNICEF (2020) noted that development processes take place within most river basins, these anthropogenic activities do not in most cases, take cognizance of the environmental implication of indiscriminate resource exploitation within the river basins.

All the activities that takes place in river basins needs proper planning, evaluation and monitoring, to ensure sustainability of the environment. Eze and Joel (2017), identified five approaches to river basins development using the following five (5) concepts.

i. Single Purpose Development Concept
ii. The Multi-purpose Development Concept
iii. The Basin Wide Programme.
iv. Comprehensive River Basin Development
v. Unified Basin Administration.

3.1 The Single Purpose Development. This is when the developmental strategy of a river basin is aimed at one major output e.g. water supply, or when an urban centre is threatened by imminent hazardous flooding, the single purpose development basin will then be charged with the single and sole responsibility of flood control infrastructures such as provision of Dykes, levees, and flood forecast stations etc. This approach is usually aimed at one objective to remedy a specific environmental problem within the river basin. This strategic plan is imperative as there have been disastrous flooding hazards, especially recalling the October-December 2012 flood in Nigeria.

3.2 Multi – purpose storage concept: In this strategy, a single project can be designed to encompass various purposes that could meet diverse needs. For example, a dam may be constructed within a river basin to provide portable water for the residents within, and the advantage of the held water could be used for hydro electricity power (HEP). A dam may also be built for the purpose of irrigation but could be eventually converted for fishing, transport and irrigation. E.g Kainji Dam in Niger state in Nigeria, Akosombo dam in Ghana, Zambezi dam in the river Zambezi.

3.3 Basin wide programme: This is a deliberate attempt at developing a drainage basin to extend development to every nook and corner of the basin, with a view not to over exploit or under exploit the natural resources within the basin area. The major aim of the basin wide programme is to mitigate environmental degradation, through the introduction of adaptive and mitigation instruments.

3.4 Unified Basin Administration: This is the situation where the development of the river basin is placed on a specific administration to monitor all

processes that are taking place within the river basin. In this case, there are central governing bodies for the basin that are responsible for the monitoring of all geomorphic, climatic water supply, irrigation, agricultural processes and other activities that take place within the river basin. All the processes are under the control of a central administration within the river basin. This is the case of the river basin development authority in Nigeria as they are all controlled by the Federal Government.

3.5 Comprehensive River Basin Development: This is the last stage in river basin development. It is most popular in Europe, France and other sophisticated nations of the world where technological known how is not handicapped. It is also referred to as development at its peak in river basin development studies.

The five approaches enumerated above, are popular approaches for the development of river basins, Arnimi, Lalisa, and Thomas (2021) noted that while any of the above approaches will be adopted for development of river basins, there should be adequate planning, remediation, and management strategies to avert environmental degradation in the river basins because once the natural resource base is depleted due to anthropogenic activities, its regeneration could be difficult to achieve (Oya: 2010).

3.6 Anthropogenic Activities in River Basins

The developmental strides taken by man to bring about improved standard of living, which eventually leads to the manipulation of the environment, includes deforestation through farming, industrialization, building of dams or artificial lakes, road construction, peasant farming, and mechanized agriculture. It also includes water project development for both industrial and domestic uses, hydroelectric power projects and fishing. All these result to ecological transformation. These activities are intended towards getting maximum output from the environment; however, they are not devoid of hazardous effects on the environment irrespective of the potential gains.

This is in tune with the theory of Environmental possbilism propounded in the 19th century by Lucien Febvre which states that man has the ability to manipulate the environment to his own advantage and his own ends. This is against the backdrop of the deterministic theory which suggests the activities of man to the dictates of the environment.

4.0 Environmental Challenges Associated with River Basin Authority Development in Nigeria (The Kanji Dam Example).

As it is characteristic of all natural systems, if any of the components of an ecosystem is distorted, there is an immediate reaction in the output of the whole system to reflect the ecological disturbance (Murray – Darling, 2010). This is the situation with the activities of River Basin Development Authority in Nigeria (RBDA). The construction of the Kainji Dam in the upper course of the river Niger for the provision of water and Hydro-electricity and harnessing of water for local and industrial uses had serious negative ecological implication on the landscape and the environment, both at the upstream and the downstream levels. Some of the challenges associated with the River Basin Development are highlighted below.

4.1 Dynamic Change in Ecosystem Structure

The construction of a dam across a river holds back water that spreads over the land. The resultant effect of the lake is that since it has to spread into the forest, the structure of the forest ecosystem changes from terrestrial to aquatic.

This eventually leads to loss of flora and fauna and a remarkable decline in species diversity (Eze and Joel: 2017). During the early period of the construction of the Kainji Dam, the decaying vegetation and terrestrial animals served as a source whereby nutrients were added to the lake and this eventually led to the higher output of fish at the early years when the dam was built, but in recent time, the quantity and quality is declining as well as deteriorating, because there is no decaying vegetation. The level of water in a dam fluctuates between seasons. During the annual floods regime (wet season), the lake spread far and wide but during the dry season, it decreases in area extent. The implication is that the area of land occupied by the lake varies according to season. In dry season, the area formally occupied by the lake varies according to season. During the dry season, the area formally occupied by water is exposed to vagaries of environmental limitations such as excessive evaporation and soil erosion. The Jabi Dam, in Jabi River and the earth Dam are situated in Abuja, Nigeria. And they also experience seasonal fluctuation in water volume which usually pose as seasonal environmental hazard and limitation. It is also susceptible to increase in sediment yield, in water bodies which will also encourage silting up of water bodies and growth of water hyacinth.

4.2 Irrigation Problems and the Spread of Water-borne Disease

The spread of water borne disease from the resultant lake is a common problem to the communities that live downstream in such areas. In recent a study of the spread of diseases in the upper Imo river Basin, as highlighted in Njoku; (2017) and Uttah (2017), states

that Onchocercicsis (river blindness) and micro filarial skin worms and Guinea worms are severe and debilitating parasitic infection of global concern. The authors decried the gross under- reporting of the scourge. The study which assessed the prevalence and intensity of river blindness and the micro filarial skin worm in the Imo river basin pointed out that these infectious disease are migratory in nature tracing its source from the Udi-Enugu-Okigwe axis from where some rivers and their tributaries supporting black-fly (simolium fly) breeding have their origin. These include Oji River, Ajali, Mamu, Adada and Imo rivers. Communities around the Lake Kainji Dam also suffered health hazards that are connected to infectious diseases such as Guinea Worm and River Blindness.

One indisputable fact about watersheds/ river basins is that we all live downstream from someone and upstream from someone else. Anything released into the water bodies or atmospheric course can come down again, nearly or thousands of miles away. To understand the safety of water quality in a stream, whether it is devoid of vector and other disease carrying organisms, one must examine the entire area it drains. There is interconnectivity of communities by watersheds that do not respect natural or social political boundaries, as geomorphic units, they in fact, encompass several cultural, national, and economic boundaries. What happens in one country's part of the watershed upstream will also impact on the people downstream.

This is one of the explainable trends in the spread of disease and common occurrence of such disease among communities that share the same basins or watersheds. The interconnectivity of the larger bodies of water to smaller bodies of water enhances the spread of water borne diseases and water pollutant materials such as indiscriminate disposal of solid and liquid waste (industrial effluents) which are also injurious and inimical to human health and the environment.

4.3 Irrigation and Hydro-Electric Power

One of the major aims of river Basins development in Nigeria is to supply water to farmlands especially in the drier zones through irrigation network, as well as concentration of water at specific points for hydro-electric power development Continuous irrigation of the farmland leads to the development of certain water weeds and snails that are vectors of disease such as Biliharziasis, and river blindness as mentioned earlier. The farmers that wade through the canals hardly realize that the canals are infested with diseases until they fall sick.

The stagnant water of the dams and the canals are also ideal breeding grounds for mosquitoes which is the causative agent for malaria parasite. Other common diseases result from the animals reared in the basin. Their wastes are usually passed indiscriminately around the basin. These include cows, sheep, goats which are carriers of tape worm and liver flukes. These animals waste find their way into the irrigation canals and dams where they develop through their life cycles. This is one of the major justifications of increase in water borne diseases around the areas where river basin development activities take place.

4.4 Eutrophication

This is commonly referred to as undue accelerated growth of weeds in water bodies occasioned by modern usage of artificial fertilizers, containing nitrogen, phosphorus, and potassium. This can affect the mouths of river basins through modern agricultural activities in the river basins. The minerals introduced specifically will be transported by the drainage basin and accumulate there, this results to ecological disturbance in the natural mineral balances. This is a major caurse of eutrophication in river basins. Eutrophication can also accelerate the growth and spread of water hyacinth which is a major challenge of rivers transport in Nigeria and African water ways, as the growth of such water weeds impedes navigation and water transport.

4.5 Global Warming

Global warming which is both an issue of local and international concern is one of the resultant effects of river basin development activities (Cohen 1995, UNEP 2002). The watersheds exposure to sun affects temperature evaporation and transpiration (water used by plants). Soil moisture is more rapidly lost by evaporation, evapotranspiration and transpiration on steep slopes facing the sun. Slopes exposed to the sun usually support different plants than those facing away from the sun. Orientation with regard to the prevailing winds has similar effects.

Deforestation which is one of the principal activities in the river basins exposes the land environment to direct vagaries of the element of weather and climate. Due to excessive reduction of vegetation cover this will increase the earth's temperature with far reaching hazardous effects (Auleh, 2015). The natural trend of elements of weather and climate is also hampered with attendant environmental hazards such as, flooding, erosion, soil desiccation and others.

4.6 Destruction of Natural Aquifers

When water from precipitation infiltrates the soil, it percolates through permeable rock into ground water storage called aquifers. Natural ground water discharge is a major source of water for many streams. Aquifers are rapidly depleted through the activities of river basins development. Pumping water from an aquifer for industrial, irrigation or domestic use reduces

the aquifer's volume unless withdrawals are modified or ground water recharge is increased, the aquifer will eventually be depleted. A drained aquifer can collapse from the setting of overlying lands. Collapsed underground aquifers no longer have as much capacity to accept and hold water because the soils settle and condense resulting in lesser water hold capacity. Recharge is difficult, volume is less, and yields are considerably reduced. Springs once fed from the water table also dry up. It is on this note that William and Nagaraja (2020), opined that since groundwater has a huge potential, to ensure future demand for water, it is important that human activities on the surface do not negatively affect the source (Okoro, *et al*, 2009), (UNESCO, 2017) emphasized on the importance of groundwater globally as a source for domestic and industrial consumption, reduction in quantity with subsequent change in quality can undoubtedly pose a serious environmental threat to humans and livestock, in the Sahara region, water crises is gradually setting in as a result of the shortage of the resources.

Onwuagbuche (1993), also emphasized the need for the protection of aquifers in the Imo River Basin Nigeria, effective management strategy will avert further ecological catastrophies in River Basins that will promote a healthy, and safer environment which is one of the major goals of sustainable development and environmental management.

4.7 Increases in Flooding

Dams are usually built for flood control and other uses. When a dam is built in a river basin and the watershed ecosystem is permanently changed, it could lead to a significant modification of the flood plain. When a river is dammed, the flood plain no longer serves the ecological function it once performed for the communities that are situated around the flood plain. This ecological modification arising from River basin activities may eventually force people to move into the most flood prone land, believing that they will be protected from all floods. The dams may reduce the frequency of floods, but does not prevent the biggest, most damaging floods from occurring the end result is more hazardous and expensive damages from floods than ever before.

A number of factors affect the likelihood of flooding in river basins such factors are topography, soil type, and landslide destruction of vegetation, dam construction in upstream and its consequences on the downstream. All these are usually summed up as topographical and catchment factors, climate change and others. A combination of the above mentioned factors accounted for the unprecedented 2012 flooding of the upper and lower Niger Basin in Nigeria between October and December 2022.

4.8 Problem of Resettlement

The problem of resettlement is usually an imminent problem in river basin development especially in the area of dam construction (Auleh, 2015). The choice of the dam site may result to the relocation of some aboriginal settlers to some other places and this may affect the economy and also alter their socio-cultural life style. This was the case of Kainji Dam in Niger State, Nigeria, when the settlers of Bussa were relocated to new Bussa by the reason of the sitting of the Lake Kainji Dam. At Bussa Settlers were reluctant to adapt to new lifestyle, at the New Bussa settlement with modern architectural designs which do not conform to their traditional architecture.

5.0 Remediation Strategies for Ameliorating Environmental Problems Associated with River Basins Development Authorities in Nigeria,

Since river basin development activities are specially carved out geographical/hydrological units to bring about development, deliberate attempts must be made to forestall any form of lopsided development. Vladirmir and Somlyody (2013) articulated the relevance of remediation and effective management of river basins to mitigate adverse environmental degradation. Akindele and Adebayo (2004) pointed out that though these units have been delimited to serve specific developmental purposes, their activities seem to be dwindling and little or no attention has not been accorded the existing problems resultant from the basin development. While it is not just enough to identify the problems, this paper has also evolved the following ameliorative strategies to mitigate the environmental problems that have emanated from indiscriminate negative resource extraction over the years.

5.1 Provision of Adequate Health Facilities around the River Basins

Since the problem of water borne diseases is still acute, in this regards, the rural communities should be well equipped with adequate health facilities and competent medical personnel, constant health talks, and other strategies that could lead to the eradication of diseases such as river blindness and frequent outbreak of water borne epidemic such as cholera. Provision of portable and clean drinking water is paramount. In 2021, Cholera is still ravaging in seventeen states in Nigeria (NCDC; August 2021).

5.2 Re-aforestation

Soil erosion problems can be mitigated through intensive tree planting. Planting of cover crops and afforestation progrmmes that will prevent silting up of water bodies should also be encouraged. This will prevent intensive isolation from the sun's radiation that could also accelerate global warming and ozone layer depletion.

5.3 Pollution Control

Environmental protection agencies responsible for pollution control should enact laws on environmental protection and impose sanctions on offenders especially on the aspect of indiscriminate waste disposal of solid and industrial waste. Scientific laboratory test should also be carried out on regular basis to ensure the safety of water and soils. Ikechukwu (2018) emphasizes the role of ground water management in River Basins in Nigeria as an adaptive measure for environmental protection.

5.4 Protection of River Basins

The river basins should be well protected in the context of sustainable development. This will go a long way to improve human wellbeing. River basins are essential geographical units and also a beehive for planning developmental activities. While these activities are taking place, adequate care must be ensured to avert any form of ecological catastrophe through proper environmental protection and monitoring mechanism such as Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) (UNEP, 2002, World Bank, 2004).

5.5 Periodical Evaluation of Drainage Basin Characteristics

It is also important to monitor and evaluate the drainage basin characteristics periodically to ascertain if there is any digression from the normal trend of basin activities. This could be achieved through Environmental Impact Assessment and Social Impact Assessment UNESCO (2017) recommended periodic environmental monitoring and data collection banks in the river basins to mitigate probable environmental hazards. It is expedient for hydrologists and fluvial geomorphology experts to take periodic inventory of the drainage basin characteristics and where priority attention should be given.

Drainage basin characteristics could be grouped as follows;

1. Areal characteristics
2. Linea characteristics
3. Topographic characteristics

5.5.1 Areal Characteristics

Basin shape

Form factor (F) = $\frac{A}{L^2}$ ------Equation (1)

Where A is Drainage Area
L is basin length

Basin Circularity (RC)

RC = $\frac{\text{Area of Basin}}{\text{Area of Circle of the same perimeter}}$

Lemiscale (K) K = L = $\frac{L^2}{4^A}$ ------Equation (2)

Where L is Basin Length
A is Basin Area

5.5.2 Linear Characteristics

a) Stream order
b) Average length of streams in each order
c) Total length of streams in each order
d) Drainage density

That is $\frac{\sum L}{Ad}$ ------Equation (3)

Where ∑L is cumulative of rivers
Ad is the total drainage area.

e) Bifurcation ratio that is $\frac{n}{n+1}$ ------Equation (4)

Where n is the number of streams in each order

f) Sinuosity ratio.
g) Average distance of travel from the divide to the center of the basin
h) Length of overland flow
i) Length of the main stream

5.5.3 Topographic Characteristics

i. Average gradient of streams in each other
ii. Mean gradient – this is the average gradient of all the streams in the basin
iii. Mean basin slope

That is = $\frac{DN}{\sum 1}$ ------Equation (5)

Maximum basin relief (H) this is the difference between the highest and lowest points in the basin.

Ruggedness number

HPd where H - is maximum relief
Dd - is drainage density

Relief ratio; (Rh)

Rh = H/L where H is the maximum basin relief
L is the horizontal distance along the longest dimension of basin parallel to the principal drainage line

6.0 Summary of Environmental Changes from River Basin, development Activities

- Deforestation reduces the soil's capability to hold as much water, greatly increasing run off into local streams and rivers as well as increase in sediment yield.
- Increased siltation from deforested slopes changes the shape of river bed and banks, which can lead to changes in the flood regime within the river basin.
- Activities of River Basins drain wetlands, which are the kidneys of the ecosystem, thus removing the watershed's natural sponges which absorb runoff and drains, as well as filtration of pollutants. This could also affect the flood regime of the River Basin.
- Urbanization leads to paved roads, more buildings and less open space, all these activities negate

infiltration and also create micro climatic environments that could lead to global warming.

- As land pressure increases, more people build permanent structures in the river flood plain, thus increasing pressure on control floods with Dams.

7.0 CONCLUSION

All over the world, the activities of River basin development generate ecological problems. But it is pertinent to note that the degree of the environmental impact varies from one country to the other. In many advanced nations in North America and Europe, environmental problems associated with the activities of River Basin are not as severe as they affect developing countries such as Nigeria. This is as a result of the gap in technological known how. UNEP (2018), emphasized sustainable development along river basins in the interest of present generation and posterity. The incidence of the 2012 flooding of the upper and lower Niger is still fresh in mind. There are already projections and forecasts of a likely incidence of flooding in subsequent years if preventive measures are not put in place to checkmate the catastrophic effects of flooding (Erunke; 2021).

Though, man has been quite reckless in the way he uses the environment, this is however, not to say that the man-environment relationship has not been cordial in some parts of the world. There are situations especially in Northern Nigeria where man has embarked on re-aforestation and other activities with a view to conserving and improving the quality of the environment to ensure a positive relationship between man and the environment. The disturbing factor is that the rate of replenishment or repair is not commensurate to the rate of depletion.

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