Tropical Built Environment Journal. Volume 9, No. 1, 48-59, 2023 www.tbejournal.com
ISSN: 1118-1790

ASSESSMENT OF ENVIRONMENTAL IMPACT OF SAND HARVESTING IN AWKA NORTH L.G.A., ANAMBRA STATE, NIGERIA

[1]Obodoh, D. A*., [1]Okeke, C. E. and [2]Obodoh C. M.

[1]Department of Building, Nnamdi Azikiwe University, Awka Nigeria
[2]Department of Estate Management, Enugu State University of Science and Technology, Enugu Nigeria

*Corresponding author: da.obodoh@unizik.edu.ng

Abstract
Sand harvesting can be described as the process of removal of sand and gravel for the construction of buildings and roads. The nature of its extraction poses some challenges to the environment, which include; erosion, air pollution, and death of aquatic life. The study therefore, examined the environmental impact of sand harvesting in Awka North Local Government Area, Anambra State, Nigeria. with a view to proffering solutions to the negative impacts emanating from such activities. A survey research design was adopted for the study and population of the study was 232,417 based on projected population of the 2006 National Population Census. With a sample size of 400, a stratified random sampling technique was deployed for data selection. A total of 270 correctly filled and returned copies of questionnaire were used for the analysis. The data collected were analysed using frequency tables, percentages and weighted mean. The results showed that, sand harvesting has positive and negative impacts on the host communities. The negative impacts are: high rate of erosion, poor air quality, loss of land, etc.; while the positive impacts include: source of employment, increase in family income and development. The study recommended that monitoring, regulations and licensing of sand harvesters be enforced in addition to carrying out periodic environmental impact assessment on the activities of the sand miners in the area.

Keywords: Construction industry, Environmental impact, Erosion, Pollution, Sand Harvesting

Introduction

The construction industry is one sector that has created huge opportunities for both skilled and unskilled labour in Nigeria and beyond. Sand harvesting happened to be one of the unskilled labour embraced by many youths in some communities as demand for sand increases in the construction industry. Sands are not only found on the world's beaches but also in borrow pit. About 30 billion tons of sands are used to make cement every year (Deutsche, 2017). The demand for sand for the construction of roads and buildings had increased sand prospecting and mining activities, as all new cities require voracious amounts of sands.

Every apartment block, skyscrapers, office buildings, residential buildings and shopping malls built anywhere from Abuja to Lagos, Enugu to Kano is of concrete, which is essentially just sand and gravel glued together with cement. Also every meter of asphalt road that connects those buildings is made with sand (The Guardian, 2017). This no doubt has led to an increase demand for sand mining activities in Nigeria and Anambra state to be precise, with its attendant economic and environmental consequences due to an increase in illegal and unsupervised sand harvesting

Upon the creation of Anambra state in August, 1991 with Awka as its capital, the state's

economy has witnessed a boast in development and growth. This resulted to a tremendous shift in the status of the state from its rural nature to its current state as a bustling growing capital city with a teaming population of more than half a million people (Akanwa and Ikegbunam, 2017) Prior to the development of Awka as the state's Capital Territory, substantial levels of unorganized sand extraction have been predominant for a long time in Awka North, that served as a remote area then. The demand for adequate housing to accommodate its teaming population resulted to high demand for sand to construct both public and private structures, with attendant environmental consequences.

The impact of sand harvesting in Awka North has reached an alarming stage to the extent that something urgent has to be done to address the situation. In Awka North Local Government Area today, buildings develop cracks and collapse with growing number of erosion sites occupying the landmass. The nearness of Umuogbuefi village, Ebenebe to the sand harvesting site has made its road very difficult to access during the rainy season due to the impact of heavy loaded trucks on the load. This created channels of water into people's properties and swept away people's farmland and foundation of buildings. Hence, the need to assess the environmental impact of sand harvesting in the communities in Awka North Local Government Area of Anambra State, Nigeria with a view to proffering possible solutions to those negative impacts.

Literature Review

The Nigerian Conservation Foundation (NCF, 2017) defines sand harvesting as the process of removal of sand and gravel for the construction of buildings and roads. The nature of its extraction has become an environmental issue as the demand of sand increases in the construction industry despite the huge opportunities created for both skilled and unskilled labour. Sand play important role in the society in which it acts as a buffer for waves and storms by protecting the infrastructure and communities near the river and oceans. Sand is also used in tourism industries, for fabricated beaches for tourist attraction (Saviour, 2012). The mining of Pit sand can be done on open areas, beaches, inland dunes, mountain sides, while river sand is extracted from riverbeds and banks. Without proper management of mining activities, it increases negative impacts on the environment and water resource, which will result into long term degradation (Mutiso, 2014)). The practice is becoming an environmental issue as the demand for sand as an important mineral resource is increasing in the construction industry.

Although sand mining is expected to be regulated by law in many places, it is still many a time done illegally. It is rapidly becoming an ecological problem as the demand for sand increases in the construction industry. Therefore, proper planning and design before mining is essential to ensure that the negative impacts on the water resource are minimized (Wang, Ding and Yang, 2012). The demand for sand increases as the country is developing, and sand mining has negative environmental impacts. Therefore, the miners and regulators should coordinate to ensure that sand mining happens in a sustainable manner for water resource protection (Kori and Mathada, 2012)

Sand harvesting is a very important activity for economic development in both developed and developing world. Generally, mining disturbs land surface areas, leaving huge open pits which are difficult physically and economically to rehabilitate at the time mining ceases. Excessive mining leads to depletion of resources on both river beds and open lands. There is need for laws across the globe by high level decision makers to enforce solutions to environmental problems.

Sand harvesting operation, undoubtedly has brought wealth, employment opportunities and physical development to many cities, but

simultaneously has led to extensive environmental degradation and most especially threat to human dwellings. Environmental problems associated to sand mining have been felt severely because of the areas fragile geology and ecosystems, and richness of biological and cultural diversity. The indiscriminate sand mining activities, absence of post mining treatment and management of mined areas are making the fragile ecosystems more vulnerable to environmental degradation, leading to threatened buildings and human life

Types of sand harvested for construction purposes

When we think of sand, our mind may instantly jump to the soft surface underneath our toes when we are walking along a beach on holidays or during a picnic (Thompson, 2019). Though, this is true, but there are many different types of sands that are much coarser than beach grains which are utilized for construction. Generally speaking, sand that is used in construction should be clean, neat and free of stones, clay balls and impurities. It is imperative that the sand used has good water retention as well as necessary drainage. Sand can also be washed to remove any excess clay, silt and dust meaning that the grittiness is altered. Sand used for specific construction purposes are classified into three different forms and they are: pit sand, River sand and sea sand.

i. Pit Sand (Coarse Sand): Sharp angular grains which are free from salts. It is coarse sand which is usually used in concreting and has a reddish yellow colour
ii. River Sand: This sand is obtained from banks or beds of rivers. River sand is fine and consists of fine rounded grains. The colour of river sand is almost white and greyish. River sand is usually available in clean condition and is used for plastering.
iii. Sea Sand: This sand is obtained from sea shores. It has fine rounded grains and it is light brown in colour. Sea sand contains salts which attracts moisture from the atmosphere. Such absorption causes dampness and disintegration of work. Sea sand also retards setting action of cement. Due to these reasons, sea sand is generally avoided for engineering purposes. It is used only as a local material for non-structural purposes.

Environmental impacts of sand harvesting

Sand harvesting across the globe have both positive and negative impacts to host communities and the environment. Sand and gravel mining activities have the following positive impacts to the host communities: source of income, creates employment, development and construction of buildings and roads (Tairo, 2013). Other notable impacts from Tairo (2013) include, sand and gravel are useful in landscaping projects which beautify gardens, surrounding Shopping Malls and residential areas. Farmers highlighted that pits left by mining create rain water catchment points for watering livestock. Removal of river sand reduces siltation of rivers which increase s the rate of flowing water

Green Facts (2015) states that the negative impacts on the environment are unequivocal and are occurring around the world. The volumes of sand being harvested have major impact on rivers, deltas, coastal and marine ecosystems resulting in loss of land through river or coastal erosion, lowering of the water table and decrease in the amount of sediment supply. The extraction of sand has impact on biodiversity, water turbidity, water table levels, landscape and climate

Pereira (2012) revealed that sand mining is a threat to water security, resulting from loss of groundwater storage due to lowering of alluvial water table. A lowered water table due to

mining leave drinking water wells dry, and people starving, suspended solids affect domestic water users downstream which increase treatment costs.

Saviour (2012) in his study opined that sand harvesting leads to water pollution as a result of some physio-chemical and biological parameters which characterize degradation of water quality by colouration when it turns from brown to reddish orange, lowering PH and increasing electrical conductivity. This is due to high concentration of ions of sulphate ((SO), Iron (Fe) and other heavy toxic metals such as zinc, nickel, copper and low dissolved oxygen (DO).

Bindhusri and Arunachalam (2015) in their study stated that by removing the alluvial soil or sand, the river geomorphology will change because it can bring the river banks under unstable conditions. Sand mining reduces the amount of food, shelter, and spawning and breeding habitat available for aquatic and terrestrial animals. Daniel, Kamau and Mbagua (2017) also discovered that water from sand harvesting areas have high turbidity, dissolved solid, hardness and electrical conductivity which are above World Health Organization's (WHO's) recommended values.

Sand mining has negative impacts on coastal and inland erosion and it occurs largely from direct sand removal from beaches, mostly through illegal sand mining. Erosion can also occur indirectly as a result of near shore marine dredging of aggregates or as a result of sand mining in rivers. Damming and mining have reduced sediments delivery from rivers to many coastal areas, leading to accelerated beach erosion. According to Lawal (2011), the complete removal of vegetation and destruction of the soil profile destroys habitats above and below the ground as well as within the aquatic ecosystem, resulting in the reduction in faunal population. Also, there is disturbance of landscape and distortion of topography as a result of excessive sand mining in Nigeria (Lawal, 2011).

According to Green Facts (2015), sand mining has several negative impacts on habitats and can have effect on pollution and change the level of water acidity (PH). Lawal (2011) also stated that, there is loss of valuable fertile land and timber as well as habitat alterations which disrupt ecosystems and destroy native species. Increase in turbidity affect aquatic species, a major impact to fauna. Therefore, there is need for preliminary investigations into the type of vegetation occurring and possible impacts before mining.

Besides compacting land, heaving vehicles are a source of pollution to the villages near mining sites. Lawal (2011), also states that noise and air pollution occur as dust accumulates from gravel roads which are a reality to villages near mining areas. Air pollution caused by dust particles can be a health hazard causing respiratory disorders such as asthma and irritation of lungs (Saviour, 2012)

Economic impacts of sand harvesting

Sand is an important natural resource in economic development worldwide, but the continuous removal has adverse effects on the environment. Negative environmental impacts seem to outweigh positive effects in mining worldwide. It has been observed that different negative impacts exist in countries like United States of America, India, etc., due to in-stream mining occurring in rivers and streams (Green Facts, 2015).

Tourism may be affected through beach erosion. Sand is often removed from beaches to build hotels, roads and other tourism-related infrastructure. In some locations, continued construction is likely to lead to an unsustainable situation and destruction of the main natural attraction to visitors, the beaches themselves (Green Facts, 2015). Loss of lives had also been recorded in India which impacted tourism, agriculture and fishing potentials.

Both traditional and commercial fishing can be affected through destruction of benthic fauna, and agriculture could be affected through loss of agricultural land from river erosion and lowering of the water table.

The insurance sector is affected through exacerbation of the impact of extreme events such as floods, droughts, and storm surges through decreased protection of beaches. The erosion of the coastal areas and beaches affects houses and infrastructure as a decrease in bed load or channel shortening can cause downstream erosion, including bank erosion and the undercutting or undermining of the engineering structures such as bridges, side protection walls and structures for water supply (Green facts, 2015).

Sand and gravel mining in stream channels can damage public and private property. Channel incision caused by gravel mining can undermine bridge piers and expose buried pipes and other infrastructure. Several studies have documented the bed degradation cause by in-stream mining. Head-cutting mobilizes substantial quantities of stream-bed sediments which are then transported downstream to deposit in the excavated area and locations further downstream.

Sand act as a reservoir to charge ground water wells, so when removed, wells have to be dug deeper which increases water costs (Pereira, 2012). Generally, there is loss of employment to farm workers as agricultural land is destroyed to pave way for mining, while there are human rights violations to farmers. Still in India, Pereira (2012) recognized that, there is destruction of mangrove forests due to illegal construction of storage docks, roads, infrastructure for beach mining, storage and transportation of sand from rivers. This has increased the vulnerability of land to floods in Mumbai. Aromolaran (2012) noted land degradation in agrarian community, by destroying the soil surface and structure as well as declining the nutrients status of agricultural land.

According to Bagchi (2010), there is contamination of and aquifer water due to formation of ponds as harvesters tend to dig on areas with thick sand bed, creating water ponds. Water accumulates in ponds combined with biodegradable materials from flora and fauna wastes causing contamination.

The possible solutions that can aid the control of the environmental impact of sand harvesting include: -

i. Reducing the consumption of sand: By optimizing the use of existing buildings and infrastructure, recycling of building and quarry dust materials, concrete rubbles and glass bottles can reduce sand consumption.
ii. Setting Taxes on Aggregates Extraction to Create Incentives on Alternatives: The current situation will continue unless sand extraction is correctly priced and taxed so that other options become economically viable.
iii. Mitigating against the negative consequences of extraction: This involves minimizing the extent of mining, repairing and rehabilitation of mines as well as replacement of resources
iv. Regulating Initiatives should be applied to manage the issues

Methodology

The survey research design was adopted for the study. The study was carried out in Awka North Local Government Area of Anambra State. The communities in the local government are Awba Ofemili, Ugbene, Ebenebe, Achalla, Urum, Amanasa, Amanuke, Isu aniocha, Mgbakwu and Ugbenu. Data for study were collected through questionnaire distributed to the selected samples from the communities and

field observations were also carried out. The population of Awka North according to 2006 census is 112,192 (National Population Commission, 2006). According to the NPC in UN-HABITAT (2009), Awka North LGA has an annual growth rate of 5.34%. This estimates a population of 232, 417 by the end of 2020. A sample size of 400 was determined using Taro Yamane formula. The computation is as follows in equ. 1:

$$n = \frac{N}{1 + N(e)^2} \quad \text{equ. 1}$$

Where n = sample size
N = Population size
e = Level of precision or sampling error
I = Constant

Substituting the values in the formula, where e = 5%, We have,
N = 232,417

$N = 232417/ (1 + 232417 (0.05)^2) = 399.3$, approximately = 400 respondents

The data for the research were collected through questionnaires and personal field observations, and analysed using Statistical Package for Social Science (SPSS, version 17). In the analysis, a mean score of 3.00 was determined as the minimum acceptable for an informed decision in the study based on average of the 5 – point Likert Scale used in the data collection instrument.

Results and Discussion

Availability of sand for harvesting in the study area

The results of the data generated from 270 correctly filled and returned questionnaires were presented and analysed in Table 1.

Table 1 shows the analysis of the respondents' ratings on the availability of sand for harvesting in the communities.

Table 1: Sand availability for harvesting in the communities

S/No	Sand availability for harvesting	N	Min	Max	Mean	SD
1	River sand is available for harvesting in the community	270	2	5	3.61	1.197
2	Pit sand (croscone) is available for harvesting in the community	270	2	5	3.87	1.187
3	There is sea sand available for harvesting in the community	270	1	3	2.12	1.267
4	Coarse sand is available for harvesting in the community	270	1	3	2.72	1.187
5	Laterite is harvested in the community	270	1	3	2.83	1.415
6	Gravel and crushed stone are harvested in the community	270	1	5	2.63	1.415
7	Soils are harvested from more than one site in the community	270	1	5	3.87	1.187
8	Soils harvested from different sites are of different colour and texture	270	2	5	4.27	0.721

Table 1 shows the soils available for harvesting in the communities in Awka North Local Government of Anambra State. The results from the respondents indicate that there are different soils especially pit sand (croscone) which has a mean score of 3.87, and river sand with mean score of 3.61 are being harvested. The results indicate that most other soils are not available for harvesting in the communities since they have a mean score less than 3.00. The results also show that there are different sites for sand harvesting in the communities and the soils harvested from different sites differ in colour and texture.

Positive impact of sand harvesting in the communities in Awka north L.G.A.

Table 2 shows the analysis of the ratings of the positive impacts of sand harvesting in the communities.

Table 2: Positive impact of sand harvesting in the communities

S/No	Positive impact	N	Min	Max	Mean	SD

1	A large amount of sand harvesting is carried out in the community	270	2	5	3.58	0.766
2	Sand harvesting is one of the major and lucrative businesses in the community	270	2	5	3.16	0.762
3	Sand harvesting provides employment for community members	270	2	5	3.80	0.709
4	Sand harvesting is a major source of income for families in the community	270	1	5	3.32	0.926
5	Sand harvesting in the community makes the price of sand for construction cheaper for the community members	270	2	5	3.83	0.975
6	Sand harvesting helps to speed up development in the community/LGA.	270	1	5	3.59	0.905

Table 2 shows the positive impacts of sand harvesting in the communities. The respondents agreed that the above mentioned impacts are real in their communities, since they all recorded a mean score of above 3.00.

Negative impact of sand in the study area

Table 3 shows the analysis of the ratings of the negative impact of sand harvesting in the study area.

Table 3: Negative impacts of sand harvesting in the communities

S/No	Negative impact	N	Min	Max	Mean	SD
1	Fish and aquatic life in water bodies are drying off	270	1	5	3.47	0.921
2	Clear water bodies the area are getting dirty and polluted	270	1	5	3.52	1.528
3	A large amount of waste is generated	270	1	5	3.19	1.197
4	Current and abandoned sites result in higher erosion	270	1	5	3.67	0.961
5	Air pollution occurs due to raising of dust particles and smoke from trucks and machinery	270	1	5	3.77	1.284
6	Noise pollution from harvesting, transportation and machinery	270	2	5	3.98	0.812
7	Lowering of water level in rivers, wells, streams and other water bodies	270	1	5	3.43	0.871
8	Water pollution from spillage of oils and other chemicals discharged by machinery	270	1	5	3.45	0.965
9	Loss of land due to widening of rivers and other water bodies	270	1	5	3.44	0.908
10	Destruction of infrastructure due to exposure of critical foundation components	270	1	5	3.13	1.013
11	Deforestation and destruction of landscape in and around sites.	270	1	5	4.01	0.844

Table 3 shows the negative impacts of sand harvesting in the communities. The respondents agreed that the mentioned impacts are experienced in their communities, since all recorded a mean score of above 3.00. The impact that rated highest is deforestation and destruction of landscape in and around the sites, followed by noise pollution from harvesting and transporting process by machinery, Air pollution due to raising of dust particles and smoke from trucks and machinery, etc.

Strategies for minimizing the negative impacts of sand harvesting in the study area

Table 4 shows the analysis of the ratings for the Strategies for Minimizing the Negative Impacts of Sand Harvesting in the Communities in Awka North LGA.

Table 4 shows the possible strategies to minimize the negative impacts of sand harvesting in the communities in Awka North Local Government Area. The respondents agreed that the mentioned strategies will go a long way in minimizing the negative impacts of sand harvesting in the area, since all have a mean score of approximately 4.00.

Table 4: Strategies for minimizing the negative impacts of sand harvesting in the communities.

S/No	Strategies	N	Min	Max	Mean	SD
1	Sand harvesting should be monitored and regulated by appropriate agencies	270	2	5	4.49	0.698
2	Licenses should be given to legal sand harvesters by government	270	3	5	4.32	0.688
3	Consideration for existing wild and aquatic life should be put into consideration before determining mining sites	270	3	5	4.58	0.557
4	Erosion control should be taken into consideration before and during sand harvesting	270	3	5	4.47	0.543
5	Environmental impact assessment should be done regularly to guide sand harvesters	270	2	5	4.42	0.793
6	The government should increase taxes on sand harvesting to discourage regular harvesting of sand.	270	1	5	3.84	0.982
7	There should be alternatives to reduce the need and consumption of sand for construction	270	3	5	4.12	0.727
8	Sand harvesting sites should be located far away from residential areas	270	3	5	4.26	0.587
9	More modern and safer methods of sand harvesting should be adopted	270	4	5	4.54	0.501

Field observations in some sand harvesting sites.

Plates 1 to 5 show sand harvesting sites, negative impacts and harvesting mechanism.



Plate 1: Various sites for sand harvesting in the communities of Awka North LGA



Plate 2: Pollution of water bodies



Plate 3: Effect of erosion in the area

Plate 2 shows where sand is harvested close to where the villagers fetch water and wash. The activity of sand harvesting there makes the water unfit for use by the villagers.

Plate 3 shows the effect of erosion on the access road to Umuogbuefi village, Ebenebe and the farmland. Almost half of the road has been swept off by the erosion and the farm ridges were also affected.



Plate 4: Clay plaster sand harvested in a rice farm

Plate 4 shows where clay plaster sand is harvested in somebody's rice farm. This results to stagnant water collecting point during the rainy season



Plate 5: Sand harvesting mechanism on the site

Plate 5 shows sand harvesting operation going on in a river in the study area.

Discussion

Table 1 represents the soil available for harvesting in the communities. The results show that the majority of the residents believe that there are abundant and various soils available from different sources for harvesting. The results from the respondents indicate that there are different soils harvested in the communities especially pit sand (croscone) and river sand which have mean greater than 3. 00. It can be deduced that, there is large amount of different sands harvested in the communities from various sites/locations with differing properties.

Table 2 shows the positive impacts of sand harvesting in the communities and they all had a mean value above 3.00. The positive impacts include; major business, source of income and employment for the residents. It also aids the development in the LGA and reduces the cost of sand used in construction

There evidence of negative impacts of the practice of sand harvesting in the communities

(Table 3). The respondents agree that sand harvesting has negative impact on the communities, as all the listed negative impacts had a mean value above 3.00 this shows that the negative impacts on the environment affect the aquatic life, water bodies, air quality, forestation and existing infrastructure. It also leads to the generation of noise, waste, high rate of erosion and loss of useful land.

The possible strategies to mitigate the negative impacts of the practice of sand harvesting in the communities were shown in Table 4. The respondents strongly agree with almost all the suggested possible solutions, as they had a mean score above 4.00 except one which is government increase in taxes to discourage regular/illegal harvesters.

Conclusion and Recommendations

Sand harvesting is a very important activity for development in both developed and developing economies. Sand and gravel mining activities have the following positive impacts to the host communities: source of income, creates employment, development and construction of buildings and roads. There is serious presence of sand harvesting in some communities in Awka North Local Government Area of Anambra State, Nigeria. The river sand and pit sand (croscone) are the most common sand harvested in the communities. The communities experience environmental degradation, accidents, wastes generated and general damage to the environment. Generally, the activity of sand harvesting disturbs the land surface, leaving huge open pits which are difficult physically and economically to rehabilitate at the end of the day. Excessive and indiscriminate sand harvesting leads to depletion of resources on both riverbeds and open lands. The negative impacts of sand harvesting outweigh the positive impacts. The communities are willing to embrace possible solutions to eliminate or reduce these negative impacts. The research justified that there are both positive and negative environmental impacts of sand harvesting in the communities in Awka North Local Government Area of Anambra State. It can be concluded that majority of the respondents are not happy with the environmental degradation, accidents caused, waste generated, threats and general damage to the communities' environment.

The study recommends the following to eliminate or minimize the impacts of sand harvesting in the study area: The government of Anambra State should enact laws to regulate and monitor sand harvesting in state, Sand harvesters should be licensed by the appropriate authorities,, Existing wild life, aquatic life and erosion control should be taken into consideration while determining sand harvesting sites, Environmental Impact Assessment (EIA) should be done regularly in the communities where sand harvesting activities are carried out, reduction on sand consumption by providing alternatives, and increase in taxes for sand harvesting to discourage regular and excessive harvesting of sand.

References

Akanwa, A. O and Ikegbunam, F. I. (2017). Adverse effects of unregulated aggregates exploitation in South Eastern Nigeria. *EPRA International Journal of Research and Development,* 2(3), 167 - 177.

Akanwa, A. O. and Ikegbunam, F. I. (2017). Environmental crises associated with san harvesting in Awka. *EPRA International Journal of Research and Development*. 2(3), 130 133.

Aromolaran, A.K. (2012). Effects of sand mining activities on land in Agrarian Communities of Ogun State. *Continental Journal of Agricultural Science,* 6(1), 41 – 49.

Bagchi, P. (2010). Unregulated sand mining threatens Indian rivers. *The Journal India Together*, 21, 7 – 9.

Bindhusri, A. and Arunachalam, M (2015). Environmental impact of sand mining in Tamiraparani River, South Tamilnadu. Conference paper. Available online at https://www.researchgate.net/publication/280739460. accessed April 2020.

Daniel, I. K., Kamau, G. N. and Mbugua, J. K. (2017). Assessment of the effects of sand harvesting on river water quality: case study of Luuma River, KIvaa Ward, Machakos County. *MOJ Proteomics Bioinform*, 6(1), 195 – 200.

Deutsche, W. (2017). Sand mining decimates African Beaches. (Online). Available at http://www.dw.com/en/sand-mining-decimates-african-beaches/a-37546330. Accessed March, 2020.

Green facts. (2015). The mining of sand, a non-renewable resource. (Online). Available at https://www.greenfacts.org/en/san-extraction/index.htm#1.Acessed April, 2020.

Kori, F. and Mathada, H. (2012). An assessment of environmental impacts of sand and gravel mining in Nzhelele Valley, Limpopo Province, South Africa. *Third International Conference on Biology, Environment and Chemistry*. DOI: IPCBEE. 46(29).

Lawal, P. O. (2011). Effects of sand/gravel mining in Minna Emirate Area of Nigeria on stakeholders. *Journal of Sustainable Development*.4(1), 193 – 199.

Mutiso, K. (2014). Impacts of instream sand harvesting in water supply: a case study of River Thwake, Makueni County. Research project, Department of Environmental Planning and Management, Kenyetta University, Nairobi Kenya.

Nigerian Conservation Foundation (2017). "Nigerian Conservation Foundation expresses concern over Sand Mining in Lagos State" *Punch Newspapers Nigeria*. Published 6th March, 2017.

Pereira, K. (2012). Sand Mining: The unexamined threat to water security. Available online at: https://www.ismenvis.nic.in. Accessed April 2020.

Saviour, N. M. (2012). Environmental impacts of soil and sand mining: A review. *International Journal of Science, Environment and Technology*, 1(3), 125 -134.

Tariro, M. (2013). Case studies of environmental impacts of sand mining band gravel extraction for urban development in Gaborone. Master of Science Thesis submitted to the Department of Environmental Management, University of South Africa.

The Guardian. (2017). Sand Mining: The global environment crisis you have probably never heard of. The Guradian Newspapers. published February 27th, 2017.

Thompson, W. M. and Sons. (2019). The various grades of sand used in construction. Available online at: https://1660ca12.multiscreensite.com/the-various-grades-of-sand-used-in-construction . Accessed April, 2020.

Wang, Z.F, Ding, J.Y and Yang, G.S. (2012). Risk analysis of slope instability of

levees under river sand mining conditions. Institute of Engineering, Hohai University, China. *Water Science and Engineering*, 5(3), 340 349.