Environmental Impacts of Excessive Sand Mining: A Short Review

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Abstract

Purpose – The purpose of this paper is to present an introductive science-based narrative of the negative environmental impacts of unrestrained sand mining and recommend appropriate actions to remediate the adverse situations.

Methodology – Mostly randomly selected published scientific works of literature on the impacts of excessive sand mining were employed in this work.

Findings – The review revealed that although sand mining is a lucrative commercial activity that provides job opportunities for many people in the absence of other means of employment in disadvantaged communities and serves as an indispensable bedrock of resources for the construction and reclamation industries, an excessive form of it is devastating to the environment and must be carefully managed.

Research limitations – This effort is not an exhaustive review of all research works on environmental repercussions of uncontrolled sand mining operations as it mainly focuses on the direct implications of sand mining on the environment. The positive impacts and indirect ones such as those leading to climate change and global warming are not discussed.

Practical implications – This review is a useful introduction to environmental degradation caused by sand mining. It is relevant to future researchers committing to research in environmental fields of studies as it breaks down a complex concept in a succinct but precise presentation. The prospects and recommendations presented in this work provide research opportunities for future studies and could help in the mitigation of the problems associated with sand mining.

Keywords: Sand mining, environmental degradation, pollution, erosion, water quality, biodiversity, ecosystem

1.0 Introduction

Sand mining is an economic activity in which the natural aggregate materials (sand and gravels) are removed from a location to be used as raw materials for construction and other industries. Like any other extractive industry, the recovery of sand has the propensity to impact

the environment and the socioeconomic aspects of the inhabitants. Its occurrence and proliferation are due to the socioeconomic benefits accrued from these undertakings. Extracting natural aggregate materials is the bedrock for the provision of raw materials for construction purposes [1] and with the increasing infrastructural developments currently taking place globally, the demand for sand has skyrocketed as it appears to be nearly indispensable to the construction industry. Sand mining provides many people with job opportunities in the presence of high unemployment rates in some communities. In some cases, it is the primary source of income in the community; hence, many community dwellers partake in sand mining and related commercial activities to earn their livelihood as the sand is an easier accessible resource available to them than most others [2]. An immense contribution of sand mining has to the GDP of some countries (up to 34 %) has been reported [3]. Besides, the employment merits of sand mining, communities have also befitted from the activity via some level of community development projects such as road construction, landfill or reclamation, artificial islands, coastline stabilization and infrastructural and environmental protection projects.

Despite the merits of sand mining activities to their respective communities, they are rapidly becoming a cause of alarm due to the damaging effects they have on the environment. The occurrence of excessive sand mining activities is becoming rampant in many rivers and coastal environments, threatening said environments [4] due to the absence or weak implementation of appropriate government regulations and controls. Unrestrained and excessive removing sand from environments such as water bodies and their immediate vicinities is counterproductive for the general and specific functionality of ecosystems, with an added disorder arising from the technologies and overall methods of extraction [5]. This disruption in the routine natural processes occurring in these environments can occasion severe environmentally devastating physical and biological consequences including loss of habitable and agricultural land and vital infrastructures; destruction of flora and fauna; aesthetic scenery damages, including historical and archeological sites; and air and water quality deterioration [6,7]. Environmental degradation ensues as a result of the extraction rates exceeding the natural replenishment rates [8] leading to disruption to the environment regardless of the size or scale of the extraction[1].

Hence, it can be said that sand mining is a sensitive phenomenon that requires the utmost consideration. It is crucial to the sustenance and livelihood of residents in disadvantaged sand mining communities and the development of these areas. Despite these benefits, it is expedient to emphasize the several ways in which sand mining is detrimental to the environment and suggest solutions to ensure that sustainable sand mining is promoted for the benefit of the inhabitants and the environment. For these reasons, the specific aim of this review is to present a science-based narrative on the adverse environmental impacts of sand mining as reported previously in the literature. The objectives are to analyze, orderly structure, and amalgamate several qualitative data from different sources and provide critical suggestions on how to remediate the environmental degradation caused by excessive sand mining.

2.0 Methodology

In recent years, the volume of written work, published or otherwise, has increased due to the advent of the internet. Data in a substantial number of unpublished works are difficult to verify. To present an unbiased narrative, unpublished papers and papers of non-academic origin were not utilized. Mostly randomly selected published papers from multiple electronic databases were carefully reviewed in obtaining relevant materials required for the above-mentioned topic. The papers referenced in this work are presented in Table 1.

Table 1 Information of Papers referenced in this work

Reference number	Type of paper	Type of ecosystem	Main Country covered	Journal/publisher
1	Original	Riparian	Ghana/Iceland	Land Restoration Training Program, Keldnaholt
2	Original	Riparian	Nigeria	Albanian Journal of Agricultural Sciences/Agricultural University of Tirana
3	Original	Riparian	Botswana	Citeseer/Pennsylvania State University College of Information Sciences and Technology
4	Original	Riparian	China	Water Science and Engineering/Elsevier
5	Original	Riparian	South Africa	IACSIT Press
6	Original	Coastal	Ghana	Singapore Journal of Tropical Geography/Wiley Online Library
7	Review	Riparian/coastal	India	International Journal of Environmental Science and Technology/Springer
8	Original	Riparian	India	International Journal of Emerging Technology and Advanced Engineering
9	Original	Coastal	Tanzania	Third World Planning Review/Liverpool University Press
10	Original	Other	India	Environmental international/Elsevier
11	Original	Coastal	Indonesia	Journal of Coastal Development
12	Original	Riparian	Turkey	Environmental Earth Sciences/Springer

Reference number	Type of paper	Type of ecosystem	Main Country covered	Journal/publisher
13	Original	Riparian	Malaysia	Journal of Sustainable Science management/University of Malaysia, Terengganu
14	Original	Coastal	Netherland	The North Sea Foundation, Utrecht
15	Original	Riparian	Sri Lanka	International Water Management Institute (IWMI), Sri Lanka
16	Original	Riparian	India	University of Agricultural Sciences, Bangalore
17	Original	Other	Tanzania	American Journal of Applied Chemistry/Science Publishing Group
18	Original	Riparian	India	VSRD International Journal of Technical & Non-Technical Research/ Visual Soft India Pvt. Ltd.
19	Original	Riparian	Nigeria	Journal of Environment and Geology/Pulsus
20	Original	Riparian	India	Environmental Geology/Springer
21	Original	Coastal	USA	Contract
22	Original	Riparian	Nigeria	Journal of Geomatics and Geoscience
23	Review	Coastal	Morocco	White Paper

3.0 Review and discussion

The dangers of excessive sand mining to the environment are numerous. Not only that there are many direct environmentally adverse impacts of sand mining but also these impacts generate a considerable number of secondary effects. However, this paper focuses on the direct adverse environmental impacts of sand mining and their consequences. The physical, chemical, and biological environments are greatly impacted by sand mining activities and although the terms are complex, they are interlinked concepts. For this reason, the discussion will be based on the air, water, and land ecosystems.

3.1 Air

The air is a primary component of the environment that is greatly impacted by sand mining operations. The predominant air quality issue with sand mining is dust particles resulting from the use of machinery to facilitate drilling which aroused dust particles in the air and the use of industrial minerals such as silica flux and very fine gypsum leading to exacerbation of respiratory disorders such as asthma and irritation of the lungs and bronchial passages including mucus membrane [9,10].

3.2 Water

The predominant aspect of the environment that is impacted by sand mining is water. Sand is generally found in abundance in and around aquatic environments. Most environmental pollutants end up in the water ecosystem thereby changing their physical and chemical makeup affecting aquatic life. The impact and consequences are interlinked and made be placed under multiple categories. Several impacts of sand mining on water bodies are discussed in the following paragraphs.

3.2.1 Water quality deterioration and Water pollution

Sand mining activities introduce substances into the water body, resulting in pollution. For example, water turbidity increased from 7.4 NTU in 1997 to 22 NTU in 2002, and water transparency decreased from 4.2 m in 1995 to 1.95 m in 2002 [11]. According to one study on the Hars River [12], the unlawful extraction of natural aggregates such as sand and gravels from the river coupled with wash-water discharge influences the quality of water in the river. Surface water quality deterioration was observed at the mining site, for example, as a result of the sediment status changes occurring via the introduction of materials from mining machinery and other mining accessories [12]. A similar decline in water quality was detected in a research on the Kelantan River [13], which revealed an extraordinarily significant rise in some physicochemical parameters such as TSS, turbidity, and nitrate concentration exceeding the Malaysian Interim National Water Quality Standard (INWQS) requirements as a result of sand mining activities. Due to the complexity of mining activities, other harmful substances are also deposited in water. For instance, heavy metal contaminants that may be generated during sand mining are thought to be present in the top layer of river sediments [14]. The increased deterioration of water quality can undoubtedly raise the cost of water treatment.

Sand mining can have a range of other effects on water quality, in addition to the ones described above. Farmers in one Sri Lankan area, for example, have claimed that sand mining has impacted their crop cultivations due to seawater intrusion along the riverbank [15]. River irrigation users also reported a water shortage and a rise in river salinity. Groundwater depletion and saltwater intrusion have all been documented as a result of sand mining. In irrigation wells along the Uttara Pinakini River's riparian zones, groundwater loss due to unrestrained sand mining was detected [16]. Sand mining turns riverbeds into vast, deep pits, lowering the groundwater table and

drying out the drinking water wells along the river banks. Increased salinity or concentrations of dangerous contaminants can result from a decline in the volume of water in wells. Fluoride values of 3.09, 2.59, and 1.01 mg/L were discovered in three water samples collected from tube wells in an Indian region [7]. Fluoride is hazardous to both animals and humans in high levels, and those who consume water containing more than 1.5 mg/L of fluoride develop fluorosis [17].

3.2.2 Lateral channels erosion and instability, waterways siltation, and uncertainty of the slope

By mobilizing huge amounts of streambed sediments, which are then transported downstream and deposited in the excavated region and neighboring locations, sand and gravel mining in stream channels can cause lateral channel erosion and slope instability [18]. This can also happen if the flow capacity of the channel is enhanced by increasing the local flow depth and breadth. As a result, water from the stream beneath the mining site picks up more silt, expediting bed erosion. The silt can then be deposited in the waterways. However, increased stream bank erosion and channel extension, as well as vertical instability in the channel bed, are all consequences of channel incision [18]. As a consequence of channel enlargement, the streambed is shallowed, which enhances sediment movement downstream. All of these actions can then lead to changes in hydrological functions such as a change in water flows, flood regulation, and marine currents[18]. For instance, dredging caused an alteration in the discharge distribution flow waters in a river system in Nigeria resulting in a higher frequency of floods and longer retention time in the subsequent years [19].

3.2.3 Effects of increased sediment disturbance and turbidity on aquatic life

Sand mining involves a lot of earthmoving and soil breaking activities which loosen the soil into fine particles thereby increasing the turbidity and altering the chemical nature of the adjoining water bodies. The chemical composition of the water is crucial to the sustainability of its life forms [13]; therefore, sand mining operations upstream have a profound impact a considerable distance downstream due to the flow of the water. The combination of organic and mining discharges that are introduced into rivers are some of the causes of the turbidity and alteration of the chemical species in the water [20]. The added chemical species cause a redistribution of fine particles in the water [14] and can alter its nutrient parameters [13]. According to Ambak et al, [13], if any factors surpass the optimum or approach harmful limits, aquatic animals' survival and overall health will be jeopardized.

Sedimentation and soil erosion have long-term and short-term effects on the community structure of the river. For example, small-scale alluvial mining and commercial extraction of sand are carried out along the Rivers Ankobra and Birim in Ghana with the immediate impact of the turbidity being the reduction of sunlight reaching the plant population thereby reducing the food making process of photosynthesis in plants [20]. This decrease in photosynthetic activity in plants, together with the resulting eyesight impairment caused by increasing turbidity, results in a decrease in fish feeding activities [13,20]. Over time, fish life becomes essentially non-existent in some areas

below mine discharge sites where water pollution is obvious [20]. Reduced sunlight penetration and oxygen levels have a significant impact on aquatic animal activity, including phytoplankton composition. The respiratory activities of animals are also affected by the low level of oxygen giving them respiratory distress. The low oxygen level is due to much more of it being used to disintegrate the added organic pollutants in the water. As water holds less oxygen, organisms compete for the available oxygen, leading to their reduction or in severe cases a radical change of biodiversity.

Sand dredging, another type of sand mining, can ruin benthic habitats. When sediment flows through the feeding and respiratory systems of suspension feeders like sponges, bryozoans, and hydrozoans, they might get obstructed or disturbed [13]. Some species, like barnacles, may be influenced by sedimentation because the increased suspended material may have an impact on zooplankton by reducing the number of food particles caught and inhibiting the feed intake mechanism [11,21]. Sand mining operations have a significant impact on fish spawning and hatching [20,21], as the mating process is hampered and eggs may be destroyed by not only being brought to the surface but also due to the increased deposition of sediment. The cumulative effects of these mining activities on aquatic organisms include a rise in infections, a greater risk of death, and a reduction in the population of aquatic animals.

3.3 Soil and land

Although the level of harm done to the water ecosystem by illicit and unregulated sand mining is immense, sand mining has equally severe consequences for the soil and land. It is worth mentioning that sand mining has a positive cyclic feedback loop on both land and aquatic environments, meaning that the impact on one increases the influence on the other. For example, the deepening of riverbeds is one result of instream sand mining, which diminishes slope stability and promotes erosion of adjoining land. When the soil erodes, more harmful elements are transferred to water environments, causing problems for aquatic organisms.

Sand mining has profound effects on soli quality. For instance, it decreases soil quality and contributes to soil erosion. A reduction in groundwater levels due to deterioration of soil quality can cause many fertile and productive agricultural regions to become barren. The rapid continuation of sand mining on the Bharathapuzha riverbed has significantly lowered water tables, to the point where wells are almost perpetually dry, and land that was once known for its abundant rice harvest now faces water scarcity, destruction of agricultural land, the loss of farmworkers jobs, and the threat to their livelihoods [7]. Furthermore, sand mining has increased the levels of dangerous substances in the soil. According to Ako et al.[22] Pb, As, Cu, Ni, Cd, Hg, Ag, and Zr levels at sand mining activity sites in a region of North Central Nigeria were all significantly above the accepted soil limits, resulting in soil degradation. Furthermore, sediments transferred to aquatic bodies by soil erosion can pollute watercourses, marshes, and lakes.

The negative environmental implications of excessive sand mining include the well-known floral population destruction, landscape disturbance, infrastructural instability, and the little-known mine-induced seismicity. For example, Saviour[7] observed that large-scale denudation of forest cover is one of the concerns associated with sand mining, while Ako et al[22], reported that results from field surveys revealed that one of the physical repercussions of sand and gravel mining in Luku, Ghana is the reduction of farmlands and grazing areas. This is because, to remove sand and gravel, overburden and waste rock are scrapped off, which destroys vegetation. The removal of the overburden can have a substantial impact on the landscape's morphology and stability, as it leads to deforestation and severe surface erosion. Furthermore, sediment flow downstream as a result of channel enlargement and streambed shallowing removes sediments from upstream and deposits them downstream. This process continues upstream, and it may eventually reach the stream's tributaries. Bridges, for example, can lose their stability and be destroyed as a result.

In addition to infrastructure damage, beach sand has been lost in coastal locations. Coastal sand mining, like inland sand mining, has significant land-based environmental impacts. Beaches all around the world are being mismanaged and degraded, notably with the advent of unscientific beach sand mining for several reasons, resulting in higher erosion rates. Erosion is the principal source of land loss in coastal locations where sand mining is practiced. According to studies, coastal property in some parts of Ghana is eroding at a rate of almost 2 m per year, resulting in the loss of both private and community holdings, including farmlands, as well as land disputes between landowners and contractors [6]. Sand mining operations in Morocco have increased both mined and unmined coastline erosion rates, posing a direct and indirect hazard to coastal archaeological artifacts [23]. It is predicted that approximately 7 million m^3 of sand will be required for coastal protection in the Netherlands in a few years to replenish sand loss in regions prone to erosion [14].

4.0 Recommendation

With the detrimental environmental consequences of excessive sand mining just discussed, critical steps must be taken for effective environmental remediation and sustainable sand mining operations. To protect the rivers and coastal settings from illicit and unrestrained sand mining, the following actions are recommended:

1. the provision and incentivization of employment opportunities in other sectors such as agriculture and fishing;
2. the intensification and encouragement of population control methods;
3. the crafting and rigid implementation of government policies and regulations concerning sustainable sand mining operations;
4. the use of appropriate substitute materials for the construction industry and the encouragement and practice of recycling and reuse of construction materials; and

5. the minimization of the environmental degradation caused by previous mining activities via the use of vegetation and reforestation, pit filling, construction of dikes and sea walls, and other reclamation and protection projects.

5.0 Conclusion and prospects

This paper summarizes the direct environmental impacts caused by excessive sand mining. Sand mining has many socioeconomic benefits; however, if unchecked, it can be extremely devastating and leads to environmental degradation. Sand mining affects both the physical, chemical, and biological aspects of the environments with occurrences such as loss of biodiversity, destruction of infrastructures, loss of vegetation, air, water, and land pollution, loss of arable land, and other adverse phenomena. Although many studies have been carried out on the environmental impacts of sand mining, many unsolved problems and challenges must be overcome before sand mining can be a lucrative, viable but environmentally friendly and sustainable industry. Steps leading to remedying this situation entail addressing some of the gaps and research challenges. To achieve this will require several scientific research works, some of which are suggested here:

1. that a systematic investigation involving geological simulations be conducted to determine natural rates of replenishment of sand for the provision of a guide for the volume of sands that can be removed at any given time, preventing rapid and excessive sand mining and avoiding permanent damage to the environment;
2. that a complete scientific assessment and evaluation of the total impacts of sand recovery be implemented to arrive at appropriate data for mining operation site reclamation;
3. that multi-disciplinary Studies be executed on the level of environmental degradation and biodiversity loss to be able to quantify biological environmental impact;
4. that an assessment study on self-regulation and support capacity of the ecosystem be carried out in determining sustainable management of the ecosystem services at sand mining operations; and
5. that intensive research focusing on developing alternative materials for the construction industry be implemented.

This review has endeavored to present an evidence-based introduction to the environmental impacts of sand mining. It is anticipated that this analysis will provide a brief but precise overview of the phenomenon to foster sustainable and environmentally friendly sand mining operations.

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