Calls for the Use of Appropriate Technologies and Evolving Sustainable Strategies in Dredging Activities in the Niger Delta Region of Nigeria

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Abstract - *The Niger Delta region of Nigeria is the largest wetland in Africa and third in the world, covering a geographical area of 70,000 km^2, and represents about 12 percent of Nigeria's total surface area. The peculiar location of the region makes its settlements vulnerable to flood and requires sand fillings and reclamations of lands in most parts to achieve areas that are suitable for housing, siting of industries and amenities. Dredging which consists of the excavation of material from a sea, river, or lake bed and the relocation of the excavated material elsewhere. It is commonly used to improve the navigational depths in ports, harbours, and shipping channels, as a tool in water and flood management, creation of new lands and natural habitats, or to win minerals from underwater deposits, thus becomes an indispensable tool for sustainable marine resources management and development in the region. Hence, the calls for the use of appropriate technologies and evolving sustainable strategies in dredging activities in the region is apt and timely as the consequences of the use of obsolete dredging machines should no longer be ignored by stakeholders. This paper therefore calls for the evolution of sustainable strategies such as the ecoshape project, minimizing turbidity, alternative energy, and functionality requirements in the designs and construction of new vessels/dredging machines as well as the adaptation of international best practices in the use of existing equipment.*

Key words: *dredging, Niger Delta region, technologies, sustainable development, water bodies.*

1. Introduction

Dredging could be considered as a mining practice whereby streambed material is excavated from a wetted portion of a water channel and deposited or dumped elsewhere through the use of mechanical, hydraulic, special, and other types of machines known as dredgers. For instance, suction dredgers which are commonly used in most streams, rivers, and channels in the Niger Delta use high pressure water pumps driven by gasoline – powered motor to create suction in a flexible intake pipe [mostly 75-300cm (3-12 inches) in diameter].

However, dredging may vary in area from small excavations to the entire wetted area in a reach and can exceed several meters in depth. Material is commonly dredged from pools and cast over downstream riffle crests. According to Harvey and Lisle (1998), dredging should be of serious concern where it is frequent, persistent, and adds to similar effects caused by other human activities.

It is therefore in the light of the above assertion that the dredging activities in the Niger Delta region of Nigeria is of serious concern to us. Studies on dredging activities indicated that high concentration of suspended sediments can alter survival, growth, and behavior of stream biota (Newcombe and MacDonald 1991) on one hand and the loss of arable land as seen in most dredging sites in the region.

Impacts of suspended sediments can increase with the following: (i) longer exposure time (Newcombe et al 1991), (ii) smaller sediment particle size (Servizi and Martens 1987), (iii) extremes in temperature (Servizi et al 1991), (iv) higher organic content of the sediment (McLeay et al 1987). Extremely high levels of suspended sediment (e.g.> 9,000 mg/L) cab be lethal to aquatic biota, and lethal thresholds may be lower under natural conditions (Bozek and Young 1994) than in the laboratory (Redding at al 1987).

Also, social conflicts have resulted both locally and internationally form the indiscriminate dredging activities by individuals and corporate bodies. Following the dangers posed to the local environment and the outcries of the affected communities, most states in Nigeria like Rivers have banned dredging activities except in cases where necessary permits/licenses have been obtained from the relevant government agencies.

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On the international scene, several developing countries are not left out of this ugly and unwholesome practices orchestrated by greedy businessmen, politicians, and in most cases corrupt government officials. An international Non-Governmental Organization (NGO) – Global Witness based in London that monitors the use of natural resources around the world in its report in 2009 accused sand companies and the Cambodia's regulatory agencies for ignoring national environmental and social safeguards, and international industry best practices. The report said that ignoring these safeguards is in violation of Cambodia's national legislation, international commitments to protect human rights, obligations to conserve biodiversity and best environmental management practices of the dredging industry. It further stressed that livelihoods of local fishermen have been destroyed as fish stocks and crab harvests have been substantially reduced since the arrival of the dredging vessels.

This paper therefore reviews recent developments in the shipping/dredging industry with a view to encouraging operators and those involved in dredging activities in the Niger Delta to adopt modern and appropriate technologies and equipment in their operations as well as develop a sustainable strategy that will minimize the negative environmental impacts and enhance efficient utilization and optimization of available resources considering the rapid population growth in the region.

2.0 The Study Area

The Niger Delta is the largest in Africa and third in the world. It is a geographical area covering about 70,000km^2. It represents about 12% of Nigeria's total surface area. It lies in the southerly part of Nigeria stretching from the Nigeria-Cameroun boundary in the East to Ondo State in the West. The area is bounded in the north by Enugu, Ebonyi, Anambra, Kogi and Ekiti States, while the Atlantic coast forms the southern boundary. The whole area is criss-crossed by dense networks of rivulets, streams, creeks and rivers and consists of several ecological zones, the sandy coastal ridge barrier, brackish and saline mangrove, seasonal and permanent fresh water swamp forest and low land rain forest. The region comprises nine of Nigeria's constituent states; the population as at 2006 was over 28 million. The pattern of settlement in the Niger Delta Region is largely determined by the availability of dry land and the nature of the terrain. Low relief and poor ground drainage are the primary factors responsible for the low number of large settlements in the region. The larger settlements are found in the interior parts of the Delta, which has better drainage conditions and accessibility. In the mangrove swamp zone, the main settlements such as Port Harcourt, Sapele, Ughelli, and Warri, have developed on islands of dry land that intersperse the zone with settlements being located at the head of the navigable limits of the coastal rivers or estuaries. In total, there are 13,329 settlements in the Niger Delta Region. The average population of 13,231 of these (99% of the total) falls below 20,000 people. Settlements of fewer than 5,000 inhabitants constitute nearly 94% of the total number of settlements and only 98 settlements, that is less than 1% of the settlements, can be truly regarded as urban centres according to their population sizes, the predominant settlement type in the Niger Delta is small and scattered hamlets. The vast majority of settlements comprise largely rural communities in dispersed village settlements.

3.0 Materials and Method

Administrative and topographic maps of Nigeria showing the Niger Delta State (scale 1:1000, 000) were acquired. These maps served as base map. Then from the Regional Centre for Training in Aerospace Survey (RECTAS) Ile Ife, Osun State; SPOT 5 satellite image with a resolution of 10m and Shuttle Radar Topography Mission (SRTM) data with a resolution of 30m were acquired. The base maps (which were in analogue form) were scanned and converted into raster image and imputed into ArcGIS version 9.3 geo-referenced to a universal maps were overlaid on settlement and buffer and spatial query was ran for communities at risk which are 500m away from water bodies, 1000m away from water bodies and 1,500m away from water bodies. The maps and imageries produced are presented below.

4.0 Results and Discussion

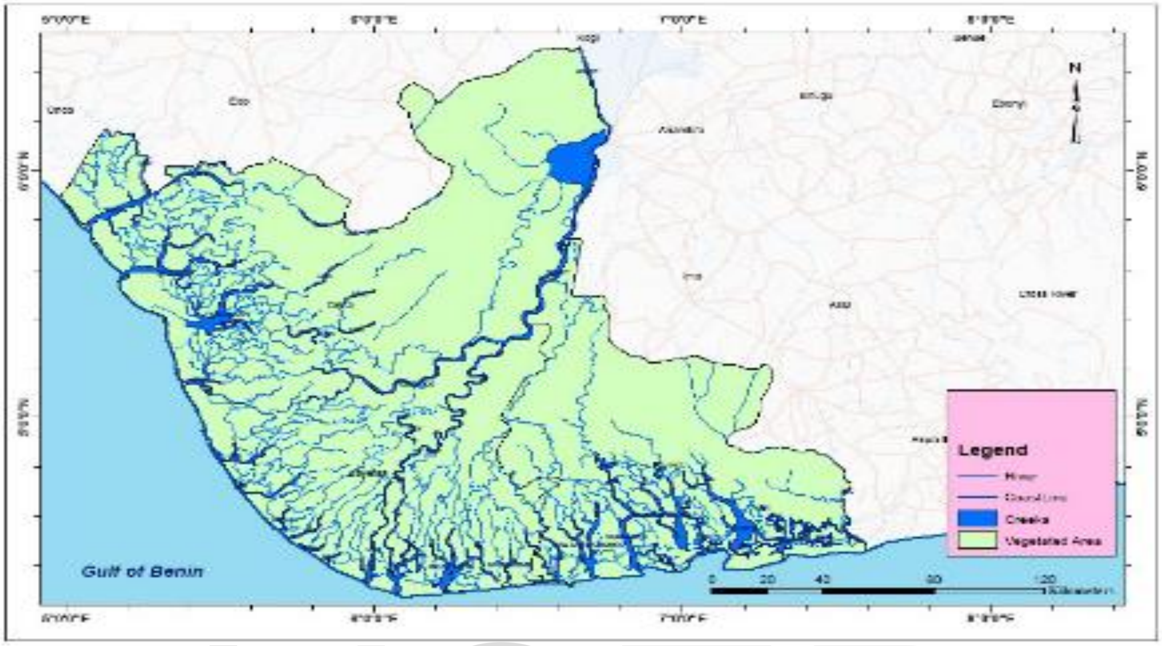

Figure1: Showing the network of water bodies (rivulets, streams, rivers, creeks and the Atlantic Coast)

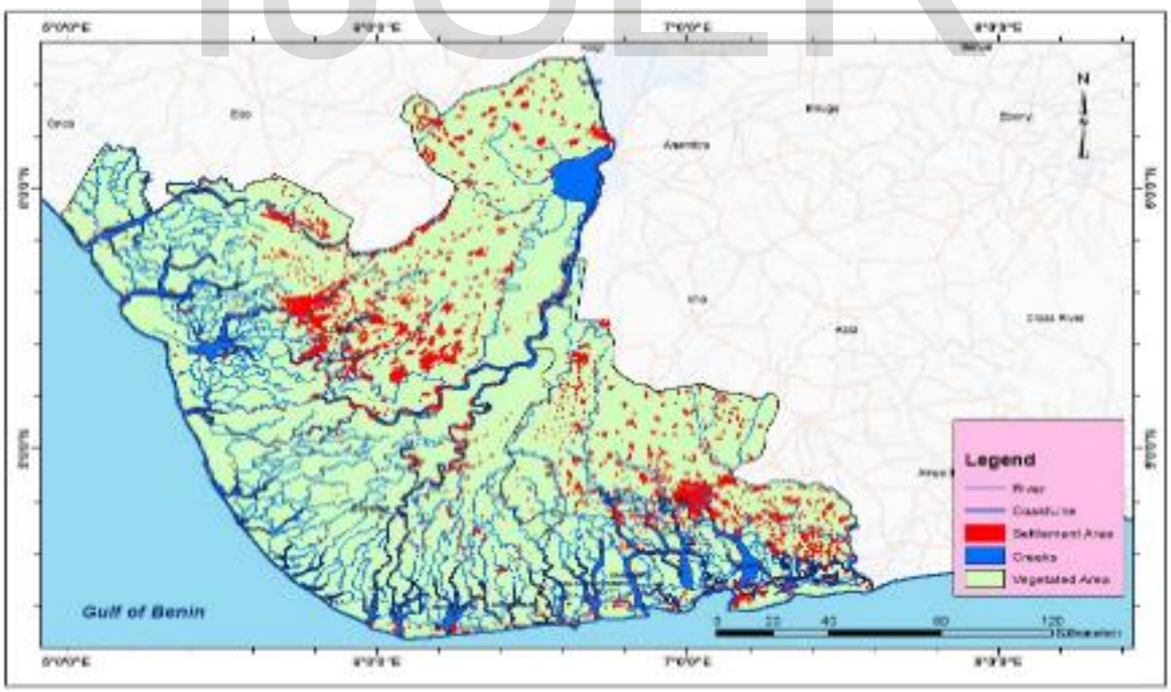

Figure 2: Map of Niger Delta Region showing Water bodies and Settlements

ISSN 2229-5518

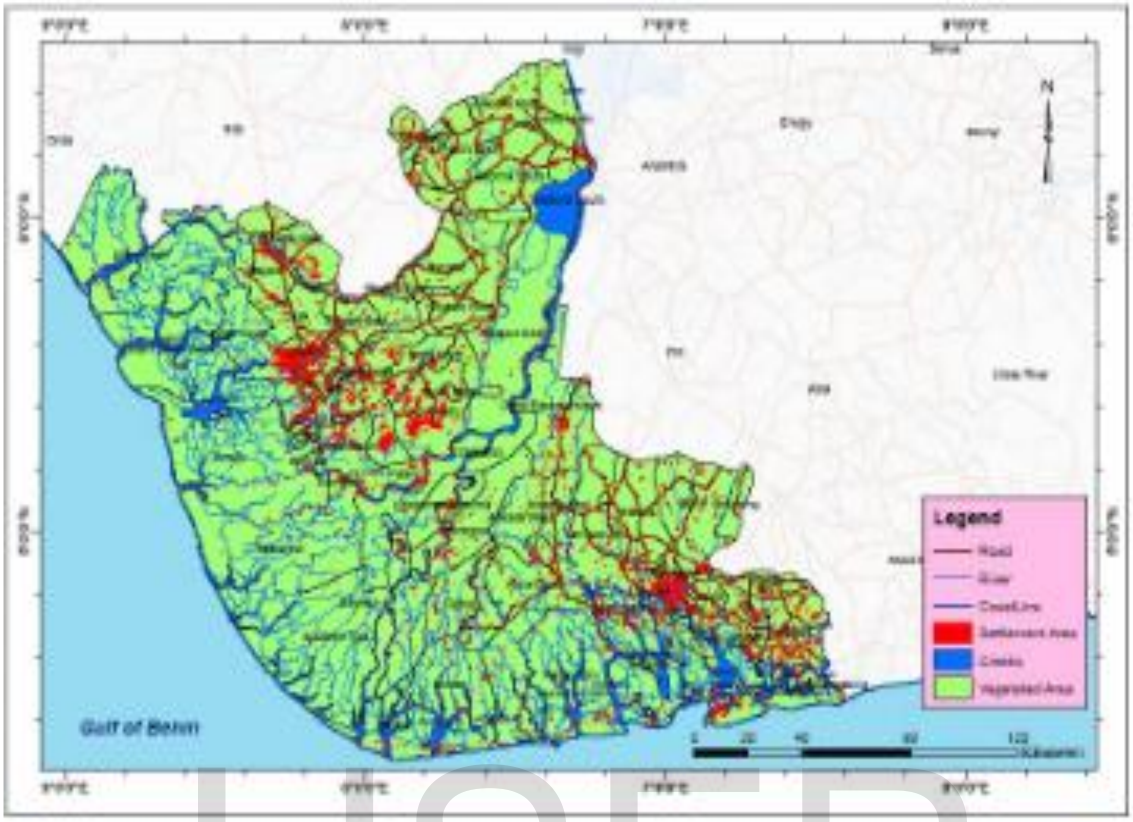

Figure 3: Map of Niger Delta showing networks of Drainage systems, Road networks and Settlement

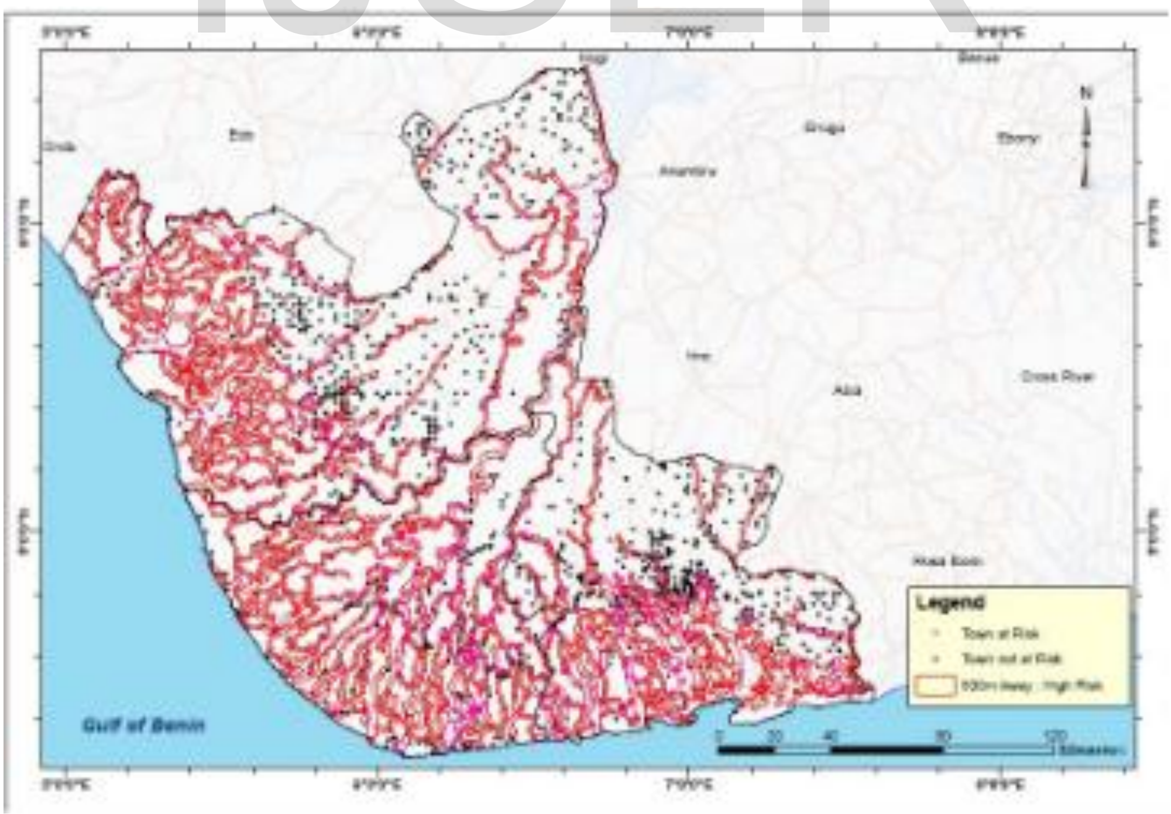

Figure 4: Map showing towns that can be flooded within 500m of the water bodies

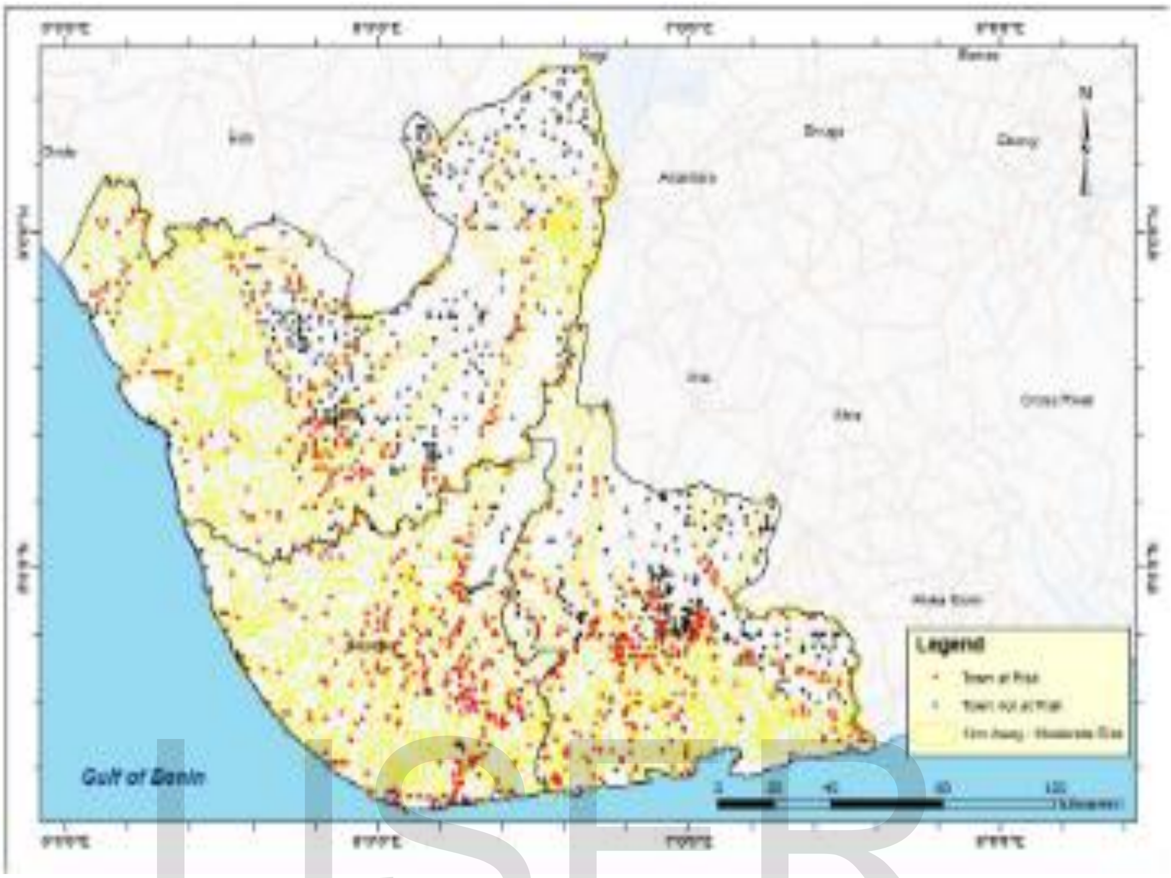

Figure 5: Map showing Communities at risk of flood within a 1000m from River systems

Figure 1shows the network of water bodies such as rivulets, streams, rivers, creeks and the Atlantic Coast around the Niger Delta region; figure 2 shows water bodies and settlements in the region; figure 3 networks of drainage systems, roads and settlements; while figure 4 shows towns that can be flooded within 500m of the water bodies; and figure 5 shows communities at risk of flood within a 1000m from river systems. This therefore brings to the fore the inevitability and imperative of dredging activities in the Niger Delta region of Nigeria the calls for the use of modern and appropriate technologies in carrying out such operations in order to alleviate the adverse environmental and socio-economic consequences emanating from these activities.

4.1 The Dredging Process

The dredging process consists of the following three elements:

1. Excavation: this process involves the dislodgement and removal of sediments (soils) and / or rocks from the bed of the water body. A special machine – the dredger – is used to excavate the material either mechanically or hydraulically or by combined action.
2. Transport of excavated material: transporting materials from the dredging area to the site of utilization, disposal or intermediate treatment.

3. Utilization or disposal of dredged material: In construction projects, dredging is driven by the demand for dredged for materials. In navigation and remediation dredging, the project is driven by the objective of removing the material from its original place.

Types of Dredging

Maintenance Dredging: Is the activity of keeping existing watercourses, harbor basins, etc, at the required nautical and / or hydrological depth by removing siltation. The environmental effects of such an operation are in general of minor importance and limited to the effects of the extraction operation itself and the relocation operation when no beneficial use of the dredged material is available. Environmental issues increase in importance when the material to be dredged is polluted.

Capital Dredging: Is the activity of creating new civil engineering works by means of dredging, such as harbor basins, canals, etc, and the deepening of existing waterways, approach channels. Capital dredging is carried out in virgin soil, which is general is unpolluted. The effects on the environment are limited to the actual working site(s), where the existing habitat or ecosystem is (temporarily) removed.

Mineral Dredging: The activity of extracting minerals with an economic value from underwater deposits. Minerals dredging takes place to mine for instance gold, diamonds, tins, so-called minerals sands (ilmenite, rutile, zircon), phosphates; but also for sand, clay and gravel. The non-valuable fractions dredged along with mined mineral(s) are in general dumped back in the mined area. The environmental effects of minerals dredging are comparable with capital dredging, the resulting "landscape" however might cause other environmental problem (e.g. with deep gravel pits).

Environmental Remedial Dredging: Is the activity of removing polluted sediments from rivers, harbor basins, etc. environmental dredging therefore often will be a special type of maintenance dredging. The removal of polluted sediments just because their presence might cause a hazard to public health has created a net type of project and ecosystems. Environmental aspects must be taken into account during all phases of the execution of environmental dredging works.

Type of Dredgers

Dredging equipment, classified according to the methods of excavation and operation, cab be grouped into the following main categories: Mechanical dredgers, Hydraulic dredgers, Special, low-impact dredgers; and others types of dredgers.

The selection of dredging equipment for a particular project will depend upon a combination of factors, including: the type of physical environment; the nature, quantity and level of contamination of the material to the dredged; the method of placement; and the distance to the placement site.

Increasingly strict environmental regulations have led to significant developments in dredging equipment. These include automatic control positioning systems and degassing systems. These innovations aim to reduce potentially adverse environmental impacts.

Mechanical Dredgers

Three main sub-groups of mechanical dredgers can be identified: Bucket-ladder dredgers, Backhoe dredgers; and Grab dredgers.

These dredgers are well-suited for removing hard-packed materials or debris and to working in confined areas.

Mechanical means are used for exaction – dislodging the material and then raising it to the water surface – in a way similar to dry land excavation methods. Mechanically dredged sediments are generally transported by barges. Cohesive sediments dredged and transported this way usually remain intact, with large pieces retaining their in-situ density and structure through the whole dredging placement process.

Hydraulic Dredgers

Three main sub-groups of hydraulic dredgers are: Stationary suction dredgers, Cutter suction dredgers; and Trailing suction hopper dredgers

These dredgers use hydraulic centrifugal pumps to provide the dislodging and lifting force and remove the material in a liquid slurry form. They usually work well in loose unconsolidated silts, sans, gravels and soft clays. In more cohesive materials teeth or waterjets may be applied for breaking-up the materials.

Special Low-Impact Dredgers

It is increasingly important to dredge contaminated sediments in an environmentally acceptable manner, in particular ensuring that contaminants are not re-mobilized and / or released in to the water column where they may detrimentally affect aquatic life. A new range of equipment has therefore been developed with the aim of increasing precision, i.e. reducing over-dredging, and minimizing the suspension of bed materials. In some cases existing dredger types have been modified; in some other cases completely new dredgers have been designed. Examples include the following: encapsulated bucket lines for bucket chain dredgers; closed buckets for backhoes; closed clamshells for grab dredgers, auger dredger disc cutter, scoop dredger and sweep dredger (all modified cutter dredgers).

Other Types of Dredgers

There are a number of dredging machines which do not readily fit into the above categories. Many of them comprise specialized tools developed for specific purposes. Of particular note are hydronamic dredging techniques that do not raise dredged materials above the water surface e.g. water injection dredgers.

4.2 International Best Practices

Both dredging and disposal are now carefully regulated. In addition to national and regional legislation and policies, the most widely applicable international regulatory instrument is the London Convention 1972 (LC 0- 72) which covers the marine waters of the whole world. LC-72 adopted the Dredged Material Assessment Framework (DMAF), a widely reviewed and accepted approach to the assessment of suitability of dredged material for disposal at sea. The contracting parties to the Convention, some 90 counties, are now expected to adopt the DMAF accordingly. There are also regional conventions such as the Oslo and Paris Convention, the Helsinki Convention and the Barcelona Convention.

Legislation controlling placement on land (and in inland water) is based on national regulatory systems often involving a great variety of laws prepared for various waste materials, e.g. sewage sludge, agricultural and industrial waste. Some counties are now developing regulations specifically for dredged materials.

Management Alternatives for Dredged Materials

These can be grouped into the following five main categories: sustainable relocation, beneficial use**,** open-water disposal**,** confined disposal**,** and treatment

Sustainable Relocation- Marine or fluvial sediment normally contributes to the sustainability of natural ecosystems. Their role in river, estuarine and coastal zone processes should be respected wherever possible. In environmental assessment, therefore as a first option the relocation of estuary in the natural environment should be considered.

Beneficial Use- Dredged material is increasingly regarded as a resource rather than as a waste. More than 90 per cent of sediments from navigation dredged comprise unpolluted, natural, undisturbed sediment, which is considered acceptable for a wide range of use. The DMAF recognizes this and requires that, as a first step in examining dredged material management options, possible beneficial uses of dredged material be considered. Beneficial use may be defined "any use which does not regard the material as a waste". A great variety of options are available, and the main types can be distinguished as follows:

coastal protection e.g. beach nourishment, onshore/offshore feeding, managed retreat; agriculture, horticulture, forestry; habitat development or enhancement, e.g. aquatic habitats, bird habitats, mudflats, wetlands ; amenity development or enhancement e.g. landscaping; raising low-laying land; land reclamation e.g. for industrial development, housing, infrastructure; production of construction materials e.g. bricks, clay, aggregates; construction works, e.g. foundation fill, dikes. Operational feasibility, that is, the availability of suitable material in the required amount at a particular time, is a curial aspect of many beneficial uses.

Open-Water Disposal - Open-water disposal means that dredged material is placed at designated sites in oceans, rivers and lakes such that it is not isolated from the adjacent waters during placement. Placement is generally via release from pipelines, barges and hoppers.

Open-water sites can be either dispersive or non-dispersive (retensive) depending on whether the sediments is transported out of the site or remains within the designated boundaries. Generally, clean or mildly contaminated materials can also be considered with appropriate control measures.

Variants of open-water disposal include:

Unrestricted placement on waterbeds in the form of mounds; placement with lateral containment in natural or man-made depressions; placement with lateral containment behind constructed beams.

Confined Disposal - Confined disposal means that the dredged material is placed in an engineered- containment structures, that is, within dikes or bunds, or in natural or constructed pits, or borrow pits. This isolates the material from surrounding waters or soils during and after placement. Other terms used in the literature for this type of placement include "confined disposal facility (CDF)", "diked disposal site", and "containment area". CDFs may be constructed in open waters (known as island CDFs), at near – shore sites or on land.

The function of CDFs is to retain the dredged materials solids whilst releasing the carrier water. For facilities receiving contaminated material, an additional objective is to provide th efficient isolation of contaminants from the surrounding area.

To achieve this, depending on the degree of intended isolation. CDFs may be equipped with a complex system of control measures such as surface covers and lines, treatment of effluent, surface run-off and leachate.

Treatment - Treatment is defined as the processing of contaminated dredged material to reduce its quantity or to reduce the contamination. Treatment methods range from separation techniques, in which contaminated mud is separated from relatively clean sand, to incineration. Some techniques are well developed but others are still in the early staged of development. The problem is scale: treatment is often expensive, so the treatment of small volumes of contaminated material is more likely than that of large volumes.

4.3 Environmental Impacts of Dredging

Direct or indirect environmental and socio-economic impacts may be associated with any element of the dredging process – excavation, transport and disposal. The effects may be positive or negative, short term or long term and may include amongst others impacts on: water quality, e.g. increase in suspended solids concentration potentials Release of contaminants during dredging or disposal; leaching of contaminants from disposal sites; habitats and natural areas, e.g. habitat enhancement or creation, removal or destruction of benthos, smothering; local communities, e.g. the effects of noise; increased labour opportunities; changes to bathymetry or topography; physical processes, e.g. waves, currents, or drainage and hence erosion or deposition; archeological assets, e.g. shipwrecks; recreation, e.g. sailing, swimming and beach use; economic activities, e.g. commercial fishing; improved infrastructure; excessive dredging may lead subsidence i.e. movement /shift in the interior of the earth or adjacent land/riverbanks.

Figure 6: Dredging activities along the Tombia-Agudama River in Bayelsa State

4.4 Socio-Economic Benefits of Dredging

Dredging is vital to social and economic development. In particular, dredging is vital to the construction and maintenance of much of the infrastructure upon which our economic prosperity and social well-being depend. These include among others: deepening of rivers and canals (aquatic highway) in order to provide adequate access to ports and harbours; to create underwater foundations; to facilitate the emplacement of pipelines or immersed tunnel elements; to construct flood control structures such as dams, dikes or levees; to ensure flood defenses (by improving or maintaining the discharge capacity of watercourses); to create or maintain storage capacity in water supply reservoirs; for land reclamation; for construction materials – sands, gravels; for mining precious metals like gold; use of dredged materials for beach replenishment; to remove contaminated sediments, thus improving water quality and restoring the health of aquatic ecosystems.

Figure 7: Impacts of dredging activities along the Tombia-Agudama River in Bayelsa State

4.5 Evolving Sustainable Technological and Innovative Strategies in Dredging

The environmental impact of dredging activities has been an issue of great concern in recent times and more emphasis is now put on sustainability by various stakeholders in answer to the effects of pollution, shortage of resources and stress on ecosystems. Therefore, it is our responsibility to combine sustainability requirements with the ever increasing demands on dredging applications. Up till now, dredging equipment has been designed from an economical point of view. The challenge however is to balance this design philosophy with ecological requirements, without compromising economy. In other to achieve this objective, instruments like the Environmental Impact Assessment and other legislations have been used or are being developed as they remain veritable drivers for the balance with ecology, though, execution of dredging projects in a more sustainable way can also present important social and economic benefits.

EcoShape Project

According to the Central Dredging Association (CEDA) (2008), the Dutch dredging community, guided by Boskalis and Van Oord took up this challenge by announcing the start of their "EcoShape: Building with Nature" programme (www.ecoshape.nl). As a major dredge designer and builder, IHC Merwede also participates in this initiative in order to be able to use the results in their own development programmes for more sustainable dredging technology. It is noteworthy that only incremental adaptations will not be sufficient to develop really sustainable products which require more challenging innovative steps. Product innovation will allow more accurate and better controlled dredging, minimize and if possibly eradicate the negative effects of dredging on the environment and optimize its profitability. Further to supporting the EcoShape programme, IHC has defined its own long term development programme which should result in "green" dredging technology and equipment that will meet the future requirements on sustainable dredging equipment. This must assist the dredging world to cater for the required sustainable ways of operation. IHC's long term programme called "Sustainability and dredging" commenced in October 2007 to look at all sustainability issues within the dredging industry and identify the consequences for the requirements of their future products. In the past two decades, IHC Merwede has made adaptive and innovative progress on development of sustainable dredging to fortify its market leading position, including techniques, equipment and management aspects of dredging.

According to CEDA (2008), critical research was carried out in close cooperation with governments, leading research institutes, environmental consultants, and dredging contractors resulting to advanced knowledge been successfully implemented which lead to the state of the art of 'green' dredging equipment and techniques. Driven by a number of global trends of growing economy, migration towards coastal zones, high demand for energy and other natural resources, dredging projects become more demanding and sensitive. These changes require extensive innovative dredging projects, which challenged IHC to take incremental steps towards innovative equipment, systems and components. Most important improvements involve deeper dredging, larger capacities, higher accuracy and efficiency improvement.

Minimizing Turbidity

CEDA (2008) opined that turbidity minimization has been achieved through incremental steps. The main incremental steps of the last decades focused on dredging process, equipment and construction, thus incremental steps to reduce turbidity include careful adaptation of dredging equipment and procedures. For example, to minimize the development of turbidity clouds, screen undersize discharge is placed underneath the keel of the vessel of a gravel dredger. Most recent solutions for turbidity reduction include: strong, cone shaped overflow control valves; automatic starting and stopping of the dredge pump only when the drag head suction pipe is near the bottom; hopper dredgers with variable volume to cater for silt dredging; and the reduction of direct impact of dredging activities has also been achieved by improving accuracy of the dredging activities. Optimized hull design of the stem (bulbous bow) and stern (twin gondola design) has also led to a significant reduction of the resistance and improved inflow, increasing the efficiency of the propulsion system. An increase of the hull width at equal length and draught boosted carrying capacity, further improving transport capacity of the dredger. This relatively small draught makes these vessels extremely suitable for beach nourishments as they can access beaches much easier, saving on pumping distance. Energy saving is also achieved by development of high efficiency pumps, that require less power than comparable standard pumps. As society becomes increasingly aware of the importance of the development of sustainable products and sustainable production, the industry must take the responsibility to blaze the trail in the development of sustainable dredging equipment, balancing economy, ecology and society, and these have been defined in the following three spearheads of the sustainability programme: turbidity control; energy issues and emission control, and sustainable design and construction methods involving the whole chain. During dredging activities, concern for turbidity and suspended sediment impacts increases if ambient water conditions are usually clear. Submerged aquatic vegetation, corals and other species requiring clear water habitats are especially vulnerable. These species may be adversely affected by changes in light penetration or by thin layers of fine suspended sediment. Also, during dredging, increases in the level of suspended sediments will particularly occur as result of the excavation process, vertical transportation, overflow losses, pumping poor mixture overboard and underwater disposal. In the dislodging process, the cohesion of the in-situ material is broken and part of the material can be brought into suspension by the cutting movement. During vertical transportation, dredged material sediment in direct contact with the surrounding water (in an open bucket for instance) dilutes, resulting in an increase in suspended sediment content in the surrounding water. The overflow of excess water from the hopper without precaution measures to the overflow system inevitably brings sediment into the water. Dumping material through the bottom doors at relocation sites causes results in dispersion during the fall from surface to sea floor. Turbidity control is principally defined by the dredging process and equipment adaptation and innovation of technology plays a pivotal role as posited by CEDA (2008).

Alternative Energy

Concerned stakeholders in the shipping industry like IHC are also evaluating alternative energy needs. Ships use lower grade fuels as energy source. On worldwide scale these fuels are merely considered a bi-product of the refinery process. These low grade fuels could be upgraded, although at high costs. Primary global energy streams would be disrupted if all ships turned to other, hydrocarbon based, energy sources such as light distillates. As a result, stakeholders agreed, until recently, the dangerous emissions in the exhaust gases of the ships' prime movers that resulted from use of these lower grade fuels. In April 2008, a new text of Marpol Annex VI was agreed upon by the IMO's Marine Environmental Protection Committee in London [MEPC, 2008]. Implementation of this legislation will have a dominating impact on the development of propulsion systems in the near future. Annex VI demands a significant reduction of the emissions of Nitrogen Oxides and Sulphur Oxides.

In Sulphur Emission Control Areas (SECA) only light distillates will be accepted from 2010 onwards. Only diesel fuel used in cars is sufficient. To reduce NOX emissions with the required 80% in 2016, only two potentially feasible solutions are available at this moment. TNO in the Netherlands is developing a plasma assisted gas cleaning process. This process is claimed to remove about 50% of the NOX emissions, while the target is a reduction of 70%. Selective Catalytic Reduction (SCR) potentially reduces NOX emissions by 90%. Wärtsilä has already successfully tested out SCR on a paper carrier. Though this system has a lot of potential, IHC still sees problems blocking implementation on a large scale. The reduction of SOX to acceptable levels requires reduction of sulphur in the fuel before burning it in the diesel engine, or removal of sulphur from the exhaust gasses. On board sea water scrubbers could be used and this process potentially removes up to 75% of SOX from the exhaust gases. As a positive effect of the scrubbing process, particular matter (PM) in the exhaust gasses is reduced (claims are up to 80%). The sea water disposed after the scrubbing process has a reduced pH of approximately 6.5. An alternative is to remove sulphur from HFO in the refinery but it is expensive to adapt the refineries for sulphur removal from HFO, both in price and in man-hours and it is not expected that oil companies will be willing to provide shipping with HFO without sulphur. Shipping could also turn away from use of HFO, and only use light distillates. This will have a significant impact on oil prices. HFO consumption by ships amounts approximately 9.4% of the worldwide oil production. Shifting to light distillates will further stress the market of these fuels. HFO demand will drop. The impact on prices and availability are significant. This is not a desirable option. All these considerations discard the real sustainability problem. At the end of the line use of oil as energy source is not sustainable. World oil reserves are finite and sooner or later we will have to consider other energy sources. LNG is certainly a potential solution, particularly on short sea shipping. Gas production is much higher than gas consumption, and the excess production is more than sufficient to supply all ships with energy. For energy conversion we could use either a dual-fuel diesel-engine, or a gas turbine. Especially the latter solution has a very high power density, saving space and weight. Disadvantages are the space requirements of the gas tanks and the strict requirements imposed on such ship by the authorities. Batteries are a potential solution, but at this moment far too expensive and too heavy to be a feasible alternative. Fuel cells may form an alternative in the future. At this moment, the largest available units provide about 20 kW. In the future, we could consider fuel cells as alternative for auxiliary or port generators. Wind energy could be an option for auxiliary too. As main energy source, wind energy is not a feasible option. A large wind mill produces about 1000 kW of power. About 20 large wind mills are required to supply energy to a large dredger, such as HAM 318. As auxiliary energy source for remotely located consumers, small windmills could be an option. Solar cells currently produce too little energy per square meter (approximately 120 W/m^2). Current generation solar cells could only be used for small, remotely located consumers. Contrary to wind mills, solar cells may be strongly improved in the future. This would make solar cells a potential auxiliary energy source (MTI, 2008).

Functionality requirements

According to CEDA 2008, IHC is also addressing the re-design of its products starting at the level of functionality requirements, instead of only improving existing products, which allows for a careful choice of materials and production processes, which in turn, should result in more sustainable products. An integral life cycle perspective that addresses the more important issues in each phase of the product's life cycle can also lead to significant improvements in the equipment's sustainability and optimizes the effective and profitable use of dredging equipment. Design for dismantling has been identified as a potentially important issue. Guiding principles are improvement of maintainability and maximization of re-use of parts and materials. Further development of LCCA (Life Cycle Costing Analysis) tools will lead to progress in this direction together with the introduction of controlled dismantling facilities for dredging equipment. Such facilities stimulate re-use and recycling; create local jobs at the dismantling sites and decreases risk of accidents and spills. Additional advantages are control of the destination of key technology components (avoiding unauthorized use/copy) and reduction of old, low efficiency, more polluting dredging equipment in a controlled way. This also eliminates unwanted competition for direct customers by third parties with the use of second-hand or even third-hand equipment. Lastly the issue of maintenance: with dredging vessels being often used intensively and under extreme conditions, the design for maintenance has an important impact on the minimization of equipment downtime. This includes design for assembly (e.g. shortest possible replacement time of wear parts such as cutting tools, dredge lines and centrifugal pumps), and optimizing maintenance activities. Improvement of the wear-resistance of materials and monitoring critical wear components will further reduce maintenance costs and down-time. The future dredging equipment should both keep its quality and profitability, and have a positive contribution to the environment and society during its entire life cycle (CEDA, 2008).

Adaptation of modern technology

A company known as Aquamec Limited based in Finland has introduced the concept of One Versatile Machine for various shallow water applications called Watermaster Classic. Watermaster Classic is an excellent solution for accurate dredging. It can remove an exact layer of sediment from the bottom. Its excellent moving and anchorage capabilities enable efficient dredging in places where dredging has to be done in several different areas of the river. Watermaster Classic does not need external help to move from one place to another. Precision dredging is especially needed when exact hydrometrical modeling has been done. Watermaster Classic ensures the results which are effective and long lasting (PLANC 2009).

5.0 Conclusion and Recommendations

It is evident that the Niger Delta environment would be better managed and enhanced if the operators and stakeholders in the shipping and dredging industry adapt modern technological and innovative strategies that have been advanced in this paper. The widespread marine pollution witnessed in the region now arose mostly from the use of obsolete equipment, non-adherence to international best practices, lack of new investments in terms of equipment upgrade in line with current development in the international market as well as the inordinate desires of actors for excessive profit-making without due regards to the marine ecosystem.

We therefore call on relevant authorities in Nigeria to rise to the occasion by enforcing all necessary laws and international treaties regulating dredging operations and practices with a view to protecting the environment by reduction of the destruction done to aquatic habitats, triggering new investments in this sector through the promotion of technological advances as well as creating more jobs through adherence to international best practices.

References

Boulton, A.J., Stibbe, N.B. Grimm, and **S.G. Fisher.** 1991. Invertebrate recolonization of small patches of defaunated hyporheic sediments in a Sonoran Desert stream. Freshwater Biol.26:267-277

Bzek, M.A., and **M.K. Young.**1994. Fish mortality resulting from delayed effects of fire in the Greater Yellowstone Ecosystem. Great Basin Nat.54:91-95

CEDA 2008. CEDA secretariat. www.dredging.org

DHI Solution. 2014 Managing sediment spill from dredging works – minimizing environmental impact and securing environmental compliance. Retrieved on March 19, 2014, sedimentspill@dhigroup.com

Dietrich, W.E., and **J.D. Smith**. 1984. Bedload transport in a river meander. Water Resour. Res. 20:1,355-1,380.

Dredging: The facts. 2014. Retrieved on March 19, 2014 www.iadc-dredging.com , www.toaconst.co.jp/eng/Rand D/soil/

Gallardo, A., J. Prenda and **A. Pujante.** 1994. Influence of some environmental factors freshwater macroinvertebrates distribution in two adjacent river basins under Mediterranean climate. II. Mollusks. Arch. Hydrobiol. 131:449-463.

Green, R.H. and **R.C. Young.** 1993. Sampling to detect rare species. Ecol. Appl. 3:351-356.

Griffith, J.S. and **D.A. Andrews**. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. N. Am. J. Fish. Manage 1:21-28.

Harvey B. C. 1986. Effects of suction gold dredging on fish and invertebrates in two California streams. N. Am. J. Fish. Manage. 6:401-409.

Harvey B. C. and **Lisle T.E.** 1998. Effects of suction dredging on streams: a Review and an Evaluation Strategy. Fisheries Habitat, Vol. 23, No. 8.

Harvey B. C. and **A.J. Stewart.** 1991. Fish size and habitat depth relationships in headwater streams. Oecologia 87:336-34.

Holtby, B.C.and **M. C. Healey.** 1986. Selection for adult size in female coho salmon (Oncorhynchus Kisutch). Can. J. Fish. Aquat. Sci. 43:1,946-1,959.

http//www.bayelsa.gov.ng/portal/Bayelsa/about Bayelsa. Retrieved on March 24, 2014.

http//www.enropean-dredging.eu/definitions.Retrieved on March 25, 2014.

Mackay, R.J. 1992. Colonization by lotic macroinvertebrates: a review of processes and patterns. Can. J. Fish. Aquat. Sci. 49:617-628.

McAllister, M.K., and **R.M. Peterman**. 1992. Experimental design in the management of fisheries: a review. N. Am. J. Manage. 12:1-18.

McLeay, D.J. I. K. Birtwell, G.E Hartman, and **G. L. Ennis**. 1987. Responses of arctic grayling (Thymallus arcticus) to acute and prolonged exposure to Yukon placer mining sediments. Can. J. Fish. Aquat. Sci. 44:658-673.

MTI Holland B.V. (2008). A presentation at the CEDA Dredging Days Conference held in October 2008 in Antwerp.

Nelson, J. M. and **J.D. Smith.** 1989. Flow in meandering channels with natural topograghy. Pages 69-102 in S. Ikeda and G. Parker, eds. River meandering. American Geophysical Union Water Resources Monography 12. Washington, DC.

Newcombe, C.P and **D.D. MacDonald.** 1991. Effects of sus-pended sediments on aquatic ecosystems. N. Am. J. Fish Mange. 11:72-82.

Nielsen, J. L. T.E. Lisle, and **V Ozaki.** 1994. Thermally stratified pools and their use by steelhead in northern California Stream. Trans. Am. Fish. Soc. 123:613-626.

PLANC (2009). Dredging Management Practices for the Environment: A structure selection approach. Report no. 100, Brussels, Belgium.

Redding, J. M. C. B. Schreck, and **E.H. Everest.** 1987. Physio-logical effects on coho salmon and steelhead of exposure to suspended sediment. Trans. Am. Fish. Soc. 116:737-744.

Servizi, J.A. and **D.W. Martens.** 1987. Some effects of suspended Fraser River sediments on sockeye salmon (Oncorhynchus Nerka). Pages 254-264 in H.D. Smith, L. Margolis and C.C. Wood, eds. Sockeye salmon population biology and future management. Canattdian Special Publications in Fisheries and Aquatic Sciences 96. Ottawa, Canada.

Sos Kem. 2012. Sand mining along Cambodia's coastline is negatively impacting the country's economy and environment. Retrieved on March 19, 2014 http//www.khmerservice.org.

Stevenson, R. J. 1991. Benthic algal community dynamics in a stream during and after a spate. J.N. Am. Benthol. Soc. 9:277-288.

Stevenson, R. J. and **C. G. Peterson.** 1991. Emigration and immi-gration can be important determinants of benthic diatom as-semblages in streams. Freshwater Biol. 26:279-294.

Thomas, V G. 1985. Experimentally determined impacts of a small, suction gold dredge on a Montana stream. N. Am. J. Fish. Manage. 5:480-488.

Thorne, S.D. and **D.J. Furbish.** 1995. Influences of coarse bank roughness on flow within a sharply curved river bend. Geo-morphology 12:241-257.

Wolman, M. G. and **R. Gerson**. 1978. Relative scales of time and effectiveness of climate in watershed geomorphology. Earth Surf. Proc. 3:189-208.