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Environmental Impacts of Dredging in the Niger Delta

Options for sediment relocation that will mitigate acidification and enhance natural mangrove restoration

Abstract

Development of oilfield infrastructure in the mangrove areas of the Niger Delta is often preceded by dredging and/or vegetation clearance to create navigable accesses. During dredging, the soil, sediment and vegetation along the right of way (ROW) of the proposed site are removed and typically disposed over bank, and in most cases upon fringing mangroves, and then abandoned. The abandonment of the resulting dredged material has caused a number of impacts including altered topography and hydrology, acidification and water contamination, which has resulted in vegetation damage and fish kills. Consequently, former mangrove areas have been converted to either bare heaps, grassland or freshwater forest after several years of natural weathering. This paper therefore focus on the environmental consequences of abandoned sulfidic dredge materials, extent of abandonment, and options available for their handling and relocation, which will mitigate acidification, restore site topography and hydrology that will enhance natural mangrove re-colonisation. It concludes by recommending sustainable dredging practices including the beneficial uses of dredged materials rather than disposal.

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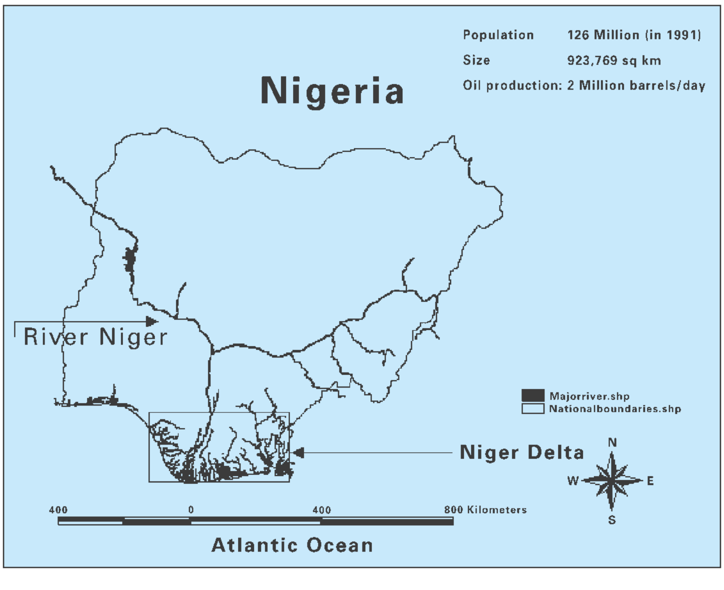
Introduction

The Niger Delta is located in the southern part of Nigeria bordering the Atlantic Ocean. It is a floodplain of over 70,000 sq km. The delta is poorly serviced by roads and is made up of meandering creeks that are highly silted up. The Niger Delta environment has been reported to be highly diverse and sensitive (ERML, 1997), being the home of the largest stands of mangrove in Africa (over 1 million ha) and the fourth largest in the world (Spalding *et al.*, 1997), it is of both regional and global importance (Moffat and Linden, 1995). The Delta is also rich in fishery resources; it provides breeding grounds for various species of finfish, prawns and as habitats for crabs and mollusks (IPIECA, 1993) (Figures 1 and 2).

A number of endangered and potentially vulnerable species are endemic in this area (World Bank, 1995). Mangroves of the Atlantic coast of Africa including the Niger Delta, on account of their gentle gradient of sediment are sensitive/fragile (Blasco *et al.*, 1996). With the result that minor alteration (natural or anthropogenic) could result in a considerable change in the duration of inundation, thereby causing plant mortality and fauna impact (Figure 3).

Figure 1. Location map of Niger Delta.



From left to right: Chief Ebenezer Osoba, chairman of Ebcon Engineeering & Construction Co. Ltd., Nigeria, IADC Award winner Dr. Elijah Ohimain, and IADC Secretary General Constantijn Dolmans (photo courtesy of T. Slinn).

IADC Award 2004

Presented at WODCON XVII, Hamburg, Germany September 27-October 1 2004

In 2004 the IADC Award was presented to Dr. Elijah Ohimain, who is an environmental/petroleum microbiologist focusing mainly on anthropogenic activities affecting the Niger Delta wetlands including mangroves, particularly dredging, spoils management, drilling, oil spills, soil acidification, hyper-salinisation, modification of topography and hydrological regimes. Dr. Ohimain is looking at developing low cost and locally adaptable biotechnologies for wetlands restoration and management of acidic and heavy metal contaminated dredged materials. He holds a PhD degree (2001) in environmental/public health microbiology (University of Benin, Nigeria), post graduate diploma in petroleum engineering (2004) and was recently admitted for a MA degree in sustainable development in Staffordshire University, Stoke-on-Trent, UK. In 2002, Dr Ohimain had a postdoctoral fellowship at the Environmental Sciences Department, Wageningen University, The Netherlands to join a research group studying mangrove soils in the tropical world.

Each year at selected conferences, the International Association of Dredging Companies grants awards for the best papers written by younger authors. The winner of an IADC Award receives € 1000 and a certificate of recognition and the paper may then be published in *Terra et Aqua*.

Nearly 50 years ago, oil and gas deposits were discovered in geological structures in the Delta. This has been the cause of anthropogenic influences particularly dredging and dredged material disposal. Dredging is often carried out to create accesses for oil exploration, marine/coastal transportation and other water borne commerce. Dredging in sensitive environments is often accompanied by ecological impacts including damage to flora and fauna, alteration of coastal topography and hydrology, impairment of water quality etc. (Ade Sobande & Associates, 1998). Dredging virtually affects all components of the environment including zooplankton (Ohimain *et al.*, 2002a), phytoplankton (Ohimain *et al.*, 2002b), benthic invertebrates (Ohimain *et al.*, 2002c) and vegetation (Fagbami *et al,* 1988).

Dredging has also been associated with widespread hydrological changes (Ohimain, 2003a), which has been reported to be the cause of the observed coastal retreat (Eedy *et al.*, 1994). Dredging may disrupt the dynamic interrelationship between environmental components and socio-economic functions of these coastal areas, thus creating an imbalance in the ecosystem.

Dredging in sensitive ecosystems may have serious impacts if not well managed, but handling/management of the resultant dredged materials is of greater concern in the Niger Delta (van Dessel and Omoku, 1994). Typically, the materials are placed adjacent to the canal being dredged, mostly upon fringing mangrove vegetation, and then abandoned (Figure 4). The subsequent poor spoil management practices have led to a number of environmental impacts through direct burial and destruction of fringing mangroves and associated fauna, siltation of navigable canals, flooding and suffocation of mangroves, degradation of water quality, habitat fragmentation and alteration of vegetation and land use (Ohimain, 2003a, 2003b). Dredging with placement of dredged materials as canal banks caused alterations in the sediment distribution pattern along the coastline (Awosika *et al.*, 1993). The cumulative effects of these impacts are the loss of wetlands.

In this paper, the impacts of dredged material abandonment in relation to changes in topography, hydrology, land use and estuarine acidification are discussed. These impacts/constraints causes mangrove dieback and prevent natural mangrove restoration. The paper also looks at available options for sediment relocation to mitigate impacts and encourage natural/volunteer mangrove re-succession.

Environmental Impacts

The impacts arising from dredged material management are discussed using an abandoned dredged

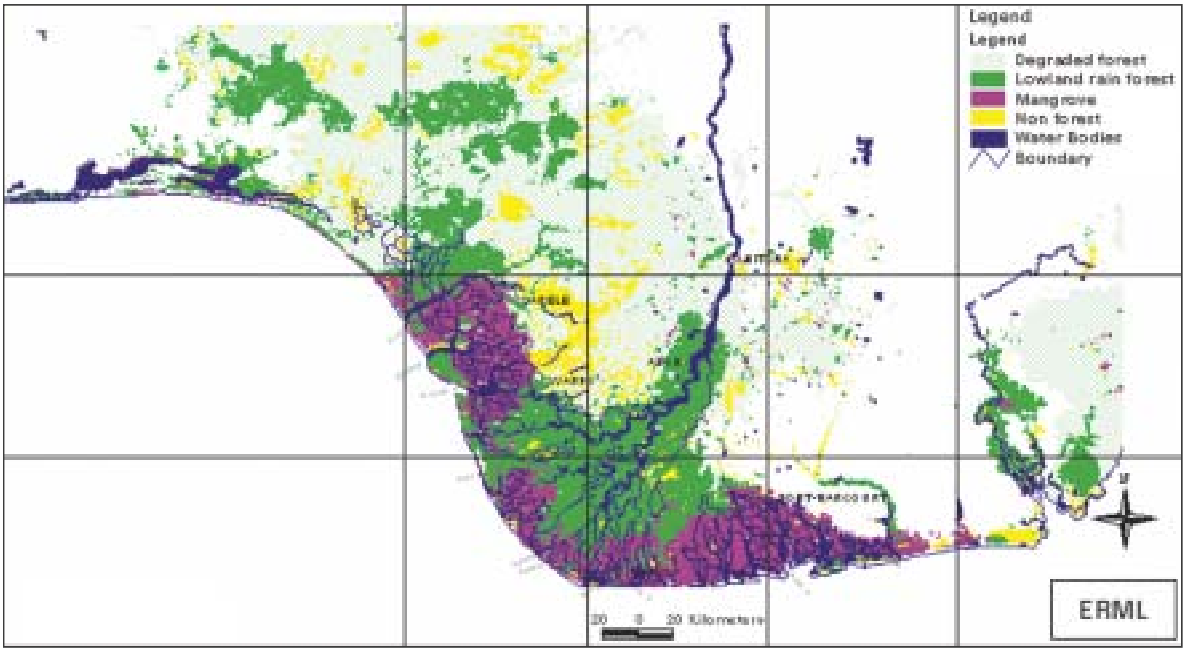


Figure 2. Ecological zonation of the Niger Delta based on vegetation type.

material heap within the drainage area of Escravos River as a case study.

Impacts on topography

Topographic profile of the study area was carried out at low tide using Nikon automatic level model AE-7 using a beacon located at Escravos bar, Ugborodo as reference point. Measurements were made along three transects across the dredged canal starting from an undisturbed mangrove habitat through a dredged material heap (canal bank), across the dredged canal and terminating at an undisturbed mangrove swamp on the other side of the canal. Soil surface elevations were taken at 10 m intervals.

Results presented in Figure 5 shows that the soil surface elevation of the mangroves was in the range of 1.10 – 1.17 m above the lowest low water spring tide datum (LLWS), with a mean of 1.14 m LLWS (n =13). Within the heap, soil surface elevation was in the range of 1.10 – 2.05 m, with a mean of 1.51 m (n = 22). Therefore, the topographic elevation difference between the mangrove soil and the abandoned dredged material heap is 37 cm. This micro-topographic difference, though minor has resulted in important changes in the ecosystem. ERML (2003) similarly recorded a 100 cm topographic difference between soils supporting healthy mangroves and dredged material heap within the study area. The direct impact of canal banks is the conversion of mangrove wetlands to uplands or man-made levees (Turner and Streever, 2002).

The elevated soil surface prevents tidal water from inundating the site; hence mangrove propagules are unable to reach the heap and a few years later non-

Figure 3. Mangroves in the Niger Delta are environmently sensitive and fragile. Shown here are tall red mangrove (rhizophora racemosa) and dwarf red mangrove (rhizophora mangle).

Figure 4. Canalisation and managing the resultant dredged material is a serious challenge.

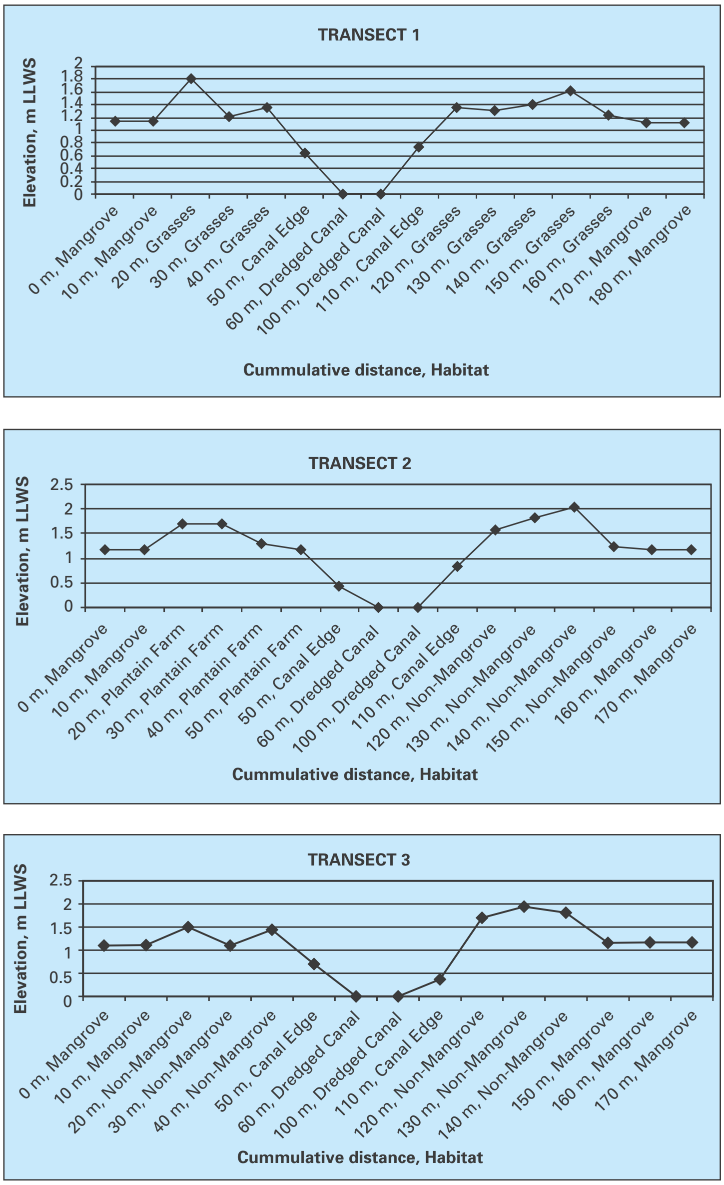


Figure 5. Microtypographic changes in a dredged material disposal area.

mangroves begin to re-colonise the heap, thus causing a shift in the vegetation structure and floristic composition. The dredged material heap that was initially bare, i.e., devoid of vegetation including mangroves, are now being colonised by non-mangroves especially grasses, shrubs and trees as a result of altered soil physico-chemical properties. This is expected because it has been recognised that the distribution of mangrove species is determined by soil chemical properties such as pH, salinity and redox potential (Nickeson and Thibodeau, 1985; Mckee, 1993; Komiyama *et al.*, 1996). ERML (2003) recorded marked changes in the chemical properties of abandoned heaps relative to that of adjacent mangroves, the salinity of the heap being several orders lower than that of the intact mangroves.

The reduced salinity may have encouraged the growth of invasive species in preference to mangroves. This is plausible because the period of inundation per day is relatively shorter and in most times non-existent at higher soil surface elevation. Elsewhere in Japan an elevation difference of only 35 cm affected seedlings survival. The survival rate of mangrove seedlings showed a clear relationship with the microtopography, with the results that seedlings performed poorly at higher elevations (Komiyama *et al.*, 1996). It therefore follows that the physical change in soil topography is linked to the chemical and biological changes in the environment.

Impacts on hydrology

The hydrology of wetlands, particularly mangroves, is the most important force determining their biotic and physical characteristics. Through the action of tides, waves, river flows and surface runoff, erosion and sediment deposition determine the morphology and soil composition of wetlands. Hydrology is a key determinant of species distribution, wetland productivity, and nutrient cycling and availability (Mitsch and Gooselink, 2001). It has been recognised that the hydrology of tidal wetlands is very sensitive spatially to small changes in topography and associated tidal regime (Hughes, 1998). Though, the dredging of canals has caused widespread hydrological changes in the Niger Delta (Figure 6), the abandonment of dredged material as canal banks compounded the problem (van Dessel and Omoku, 1994). The abandoned heap forms barrier to surface drainage/inundation, resulting in ponding of the backswamp. Mangroves are known to be tolerant to seasonal and tidal flooding, but are quite sensitive to permanent flooding (Kathiresan and Bingham, 2001). The canal banks become less accessible to tidal water with increasing elevation. The high rainfall within the delta (>2500 mm annually) contributes to the reduction in salinity, which encourages the emergence of invasive species. On the other hand, there were instances where canalisation has resulted in saltwater intrusion into freshwater swamps (Human Rights Watch, 1997; Ashton-Jones, 1998).

About 200 sq km of wetland was impacted as a result of dredging induced hydrological changes (Fagbami *et al.*, 1988). This along with other factors has been reported to be responsible for coastal erosion and retreat in the Niger Delta (Ebisemiju, 1988; Ibe, 1988; Eedy *et al.*, 1994; World Bank, 1995; Ashton-Jones, 1998). Turner and Lewis (1997) reported several cases in other parts of the world where mangrove dieback was caused by modification of hydrology. The authors presented evidence linking wetland loss to topographic, hydrologic and habitat alterations arising from dredging activities.

Impacts of acidification

The sediments and soils of the mangrove zone have been reported to contain reduced iron sulphides particularly pyrite (Anderson, 1966). When present in the natural anoxic and undisturbed state under mangrove cover, sedimentary pyrites are known to be innocuous, but their disturbance through dredging and dredged material disposal often initiates a series of oxidative reactions leading to estuarine acidification (Sammut and Lines-Kelly, 2000) (Figure 7). Estuarine sediment acidification has been reported to cause the death of vegetation (Ohimain, 2003a, 2003c), fish/aquatic biota (Dublin-Green, 1995; Sammut *et al.*, 1995), change in water quality (Sammut and Lines-Kelly, 2000) and heavy metal contamination (Petersen *et al.*, 1997; Ohimain, 2001). Following the dredging of an oil well access canal within the Benin River drainage area, leachates that were trapped behind a dredged material backswamp were found to have a pH of 2.3. The deposited dredged materials prevented tidal flushing, and a few months after several hectares of mangrove vegetation were killed followed by fish mortality (Ohimain, 2003a).

Figure 6. Hydrologic modification — notice the dredged material canal banks and the oil wellheads.

Impacts on land use and vegetation succession
The usual practice of placing unconfined sediments continuously along the canal bank beyond tidal inundation has led to the creation of artificial levee (Figure 6). In the process, several kilometers of undulating heaps now characterise the once low-lying inter-tidal landscape. The resultant change in the topography and hydrology of the area often prevent site re-colonisation by native mangrove species. After several cycles of natural weathering, the dredged materials often become relatively lower in salinity and acidity, and are then colonised by acid and metal tolerant invading species. Factors, which restrained mangroves from re-colonising the area such as altered topography and hydrology that prevented tidal water and mangrove seedlings from reaching the site, favour the growth of non-mangrove/invasive species. Grasses (*Paspalum vaginatum* and *Mariscus ligularis*) are usually the first to colonise the sites, followed by shrubs mostly Alchornia cordifolia and the Siam weed (*Chromolaena odoranta*), and as conditions becomes more favorable other non-mangrove plants become established. Woody trees such as Alstonia boonei (*stool wood*), Musanga cecropioides (*umbrella tree*) and Anthoclesta vogelii (*cabbage tree*) are now common on abandoned/weathered dredged material heaps in the delta (Ohimain and van Mensvoort, 2003).

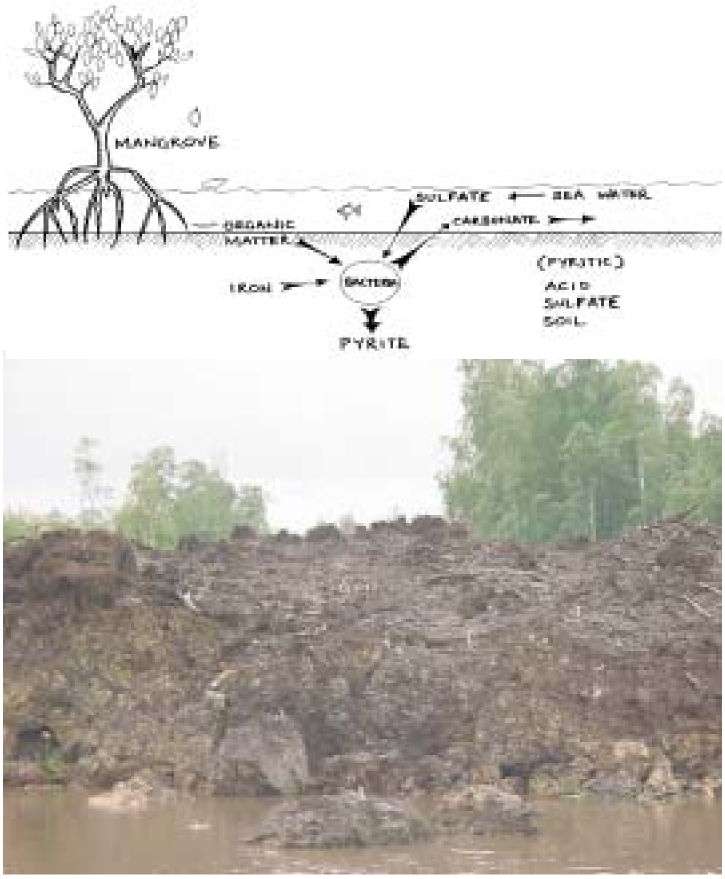


Figure 7. Dredged material disposal and abandonment: Under estuarine conditions sedimentary pyrites are innocuous, but when disturbed by dredging may lead to acidification.

Because of the limited dry lands in the area, elevated dredged material disposal sites become attractive to the natives for the establishment of fishing camps and home gardens and in the process reside dangerously close to oil infrastructure (Figure 8). In a study carried to assess the spatial risk associated with the proximity of emerging settlements to oil facilities shows that 42% of 51 communities are within a distance of less than 1 km to oil installations, which was classified as having high vulnerability (Onwuteaka, 2002). In most cases, the size of the emergent settlements appears to be limited only by the size of the available dredged material heap (Ohimain and van Mensvoort, 2003). Therefore, the abandonment of dredged material may have contributed to the change in human demography of the Niger Delta among other factors. Plantain (*Musa sp*) commonly grows well on dredged material heaps (Figure 9). Although this is a positive impact,

Figure 8. Land use change for human habitation can be highly vulnerable. Shown here, a well-established community built upon an abandoned dredged material adjacent to an oil flow station.

Figure 9. Farming, such as this plantain plantation, can be done on abandoned dredged material, but the toxicology of the crops needs to be ascertained.

there is the need to carry out toxicological studies to ascertain the safety of crops cultivated in these areas, as plants are known to bio-accumulate heavy metals when grown on contaminated dredged soils/sediments (Bramley and Rimmer, 1988; Delaune and Smith, 1985; Tam *et al.*, 1995).

Extent of Impacts

The extent of impacts arising from dredging in the delta has not been documented. Ohimain and van Mensvoort (2003) reported that the type and nature of oil field development activity could be used to estimate the extent of impact. For instance, approximately 2 ha of mangrove forest was loss during the dredging of an access slot leading to a well head, but an additional 2.4 ha was lost due to dredge material deposition (UNICALCONS, 1994). Dredged materials generated from dredging canals leading to multiple wellheads are often larger and in the order of 1.9 – 8 ha (ERML, 2003). However, dredged materials generated from the construction of flow stations, compressor stations, gas plants are larger, whereas those generated from the construction of major installations such as terminals could be extensive (Ohimain and van Mensvoort, 2003).

Materials generated from trunk/pipelines right of way (ROW) although relatively narrow [ERML (2003) recorded a width of 25 m], could also be extensive and perhaps running into hundreds of kilometers. Several hectares of mangroves fringing most of the creeks where dredging has taken place were killed likewise.

A major oil producing company operating in the delta generated approximately 20 million cubic metres of dredged materials between 1990 and 1996 (Ade Sobande and Associates, 1998). It is expected that the amount of abandoned materials may have increased considerably taking into account the activities of other oil companies, the nearly 50 years of such operations in the delta and the observed high sedimentation/siltation rates which often necessitates frequent maintenance dredging. And following the recent directive by the Federal Government to stop routine gas flaring, many oil industry operators have initiated gas gathering and utilisation projects, which also involve dredging for access creation and dredged material placement.

Options for Mitigating Environmental Impacts

There have been several previous attempts to manage sulfidic dredged materials including proper handling, restoration of mangroves and rehabilitation to alternative use (Ohimain, 2002d, 2003b). Proper handling techniques are based on the premise that environmental factors, which control the growth of acidithiobacilli, also influence acidification (Rose and Cravotta 1998; Ohimain *et al.*, 2004). Such factors include water, air and the presence of pyrite. Hence, proper handling to prevent or control acidification is focused on techniques that selectively prevent either air or water from reaching the materials, neutralise acidity or inhibit acid-forming bacteria (Perry *et al.* 1998; Ohimain 2002d). Commonly used handling techniques and their mechanism of action can be found in Ohimain *et al.* (2004). However, the emphasis here is placed on sediment relocation and backfilling with the intention of reversing the consequences of documented cause-and-effect relationships between topographic/hydrologic changes and mangrove impacts caused by continuous dredged material deposits along dredged canals.

Prior to relocation, the materials need to be quantified upfront and a survey carried out on potential areas for use/placement. Such areas may include disused canals leading to derelict /unsuccessful prospects, eroding beaches and some natural depressions. These sites are common in the delta. Ibe (1988) reported that the entire 900 km Nigerian coastline is threatened by coastal erosion and are therefore potential sites for sediment relocation.

In Louisiana, canal backfilling has been used to mitigate wetland impacts arising from oil and gas access canal dredging (Neil and Turner, 1987). Turner and Lewis (1997) showed that restoration of hydrology by removing tidal restrictions and impoundments caused by dredged material placement restored wetland vegetation. They also acknowledged that the failure of most restoration efforts is usually related to hydrologic parameters including salinity and tidal flooding patterns as well as the interaction between topography and channel functions. Therefore to permit natural/volunteer mangrove recruitment, the restoration of normal tidal exchange and residence time, site topography and drainage, and freshwater inputs are necessary (Kaly and Jones, 1998). This will require site excavation (and grading to pre-disposal elevation) and backfilling into disused canals (Turner and Streever, 2002).

From Figure 5, the topographic height of the healthy mangrove stand ranged from 1.1 to 1.17 m, with a mean of 1.14 m, whereas the mean soil elevation difference between the healthy mangroves and non-mangroves is 37 cm. This amount of material will therefore be relocated from the canal banks and back filled into disused canals in order to restore the topography and hence the hydrology. As the site becomes tidally inundated once again, it will permit the removal of acidic oxidation products and restoration of soil chemical properties (Neil and Turner, 1997). This is plausible because the brackish water of the Niger Delta is well buffered with pH ranging from neutral to slight alkaline (7.0 – 8.4) (Ohimain, 2003c), the acidity is therefore expected to decline afterwards (Indraratna *et al*., 2002). Tidal inundation will permit the soils return to anoxic condition found in natural undisturbed mangroves (Kaly and Jones, 1998) and encourage the growth of estuarine microorganisms particularly sulphate reducing bacteria (SRB) that will mediate the reduction of sulphate to metal sulphide; thus reducing acidity and heavy metal availability (Ohimain, 2003c). White *et al*. (1997) also suggested the rehabilitation of wetlands by re-flooding. Ainodion *et al*. (2002) used restoration of soil surface topography to successfully re-establish mangroves within the Escravos River drainage area (Figure 10).

Figure 10. Restoring the topography and thus the hydrology can result in mangrove restoration.

Sustainable Dredging Practices

The cumulative impacts of the intricate network of artificial canals have never been studied, however, there is increasing trend towards the application of precautionary principle to proactively protect sensitive environment including natural resources and bio-diversity. The principle provides for actions to avert risks of serious or irreversible impacts to the environment in the absence of scientific certainty about the impact (Cooney, 2003). Therefore, in view of the myriad of potential impacts arising from dredging in a sensitive environment, it became necessary to modify the dredging process with a view of suggesting more sustainable practices and improving the selection of mitigation measures/alternatives.

Both hydraulic and mechanical dredgers are generally used in the Niger Delta. Hydraulic pipeline dredges are mostly used for reclamation and maintenance dredging, and in few cases where dredged material placement is at some distance from the dredging site. Mechanical dredgers such as buckets, draglines, swamp buggies and such are mostly used for the creation of new accesses. Such dredgers typically place the materials at near in-situ densities close to the dredging area primarily upon fringing mangroves and are then abandoned. Such practices should be discouraged and beneficial uses supported. Areas where the current dredging practices could be modified sustainably are discussed below.

Beneficial uses

Prior to dredging, the volume of the expected dredged material should be estimated upfront and, thereafter, options for their utilisation identified. As a first line of action, the owner of the lease should consider using the materials for site filling and upgrading during site preparation. This option is very unlikely as the materials are usually silty clay with low bearing capacities and are therefore poor construction materials. To the contrary, more of these spoils are produced during site preparation. The lessee should therefore consider using the dredged spoils to backfill disused canals especially those leading to derelict or unproductive wellheads and other areas where the company does not plan to return to in the very near future. Canal backfilling has been variously tested and found to be effective in mitigating dredged material impacts and wetland loss (Neil and Turner, 1987; Turner *et al.*, 1994; Turner and Streever, 2002) as this has encouraged natural mangrove restoration.

Next is to seek host community needs, and if the materials are required for the creation of farm and habitable lands, this will be followed by screening of available areas/suitable places for material disposal. Areas that may be suitable are natural depressions, which do not ordinarily support mangroves, or previously degraded areas. Such areas should not be close to oil installations or pipeline ROW or major dredged canals that are frequently maintained to ease oil related transportation.

A majority of the coastal communities are fishing villages, and they largely depend on an external food supply even in the mist of lush mangrove vegetation. The dredged materials could therefore be used to support farming in addition to accommodation needs, but not as currently being practiced. Only crops that have been documented to strive well in mangrove areas (acid sulphate soils) should be encouraged. Such crops include rice (Anderson, 1966; Sylla *et al.*, 1995), yam, pineapple and cassava (Minh *et al.*, 1997; Stevenson *et al.*, 1999), and sugarcane (Nga *et al.*, 1993). In the Niger Delta, plantain grows very well on mangrove sediments/soil (Figure 8) and should therefore be encouraged. Other crops could still be cultivated in the heap after several cycles of leaching that would permit the reduction of acidity, heavy metals and salinity. But toxicity tests need to be carried out to assure the public of the safety (or otherwise) of the crops.

If the host community does not need part or all of the materials, the next line of action is to consider using the dredged material to counter erosion problems in the delta. It has been reported by several authors that the entire 900 km long Nigerian coastline is being threatened by coastal erosion (Ibe, 1988, Awosika *et al.*, 1993; Eedy *et al.*, 1994). Such areas are potential sites for the disposal of dredged materials. Such a management option has the twin advantages of meeting the coastal protection /stabilisation needs while safely disposing the waste materials.

It should however be noted that the cost of dredging and overall site preparation would increase with increasing distance to the disposal site. But when viewed along with the risk/disadvantages associated with creek bank abandonment and the advantages of sound dredged materials management practices, the benefits are likely going to outweigh the costs.

Routing to avoid acidification hotspots

Projects could also be routed away from potential acidification hotspots. The author in collaboration with other researchers from Wageningen University and Research Centre, The Netherlands are currently developing geostatistical techniques to predict acidification hotspots across the entire Niger Delta. Future projects can be then be routed away from potentially high-risk areas.

Backfilling

This is the returning of material to a canal to mitigate alteration of site topography and hydrology. The aim of backfilling is to decrease the elevation of canal banks while increasing the elevation of dredged canals to restore site hydrology, which is a pre-requisite for natural mangrove restoration. Dredged materials should never be deposited continuously as canal banks. A sustainable way of handling canal banks is by breaching the levees to re-establish tidal access into the backswamp, which will prevent the accumulation of acidic by-products. Best practices for pipeline projects incorporate backfilling and restoration of site hydrology/topography as integral parts of pipeline installation. This is currently being practiced in the Niger Delta, but the excess materials after pipelaying and backfilling still pose a major challenge.

Thin layer placement

This is the deposition of dredged materials in thin uniform layers over wetland vegetation or open bay bottom (Turner and Streever, 2002). Spray hydraulic dredgers are usually used for this purpose. Thin layer placement provides an alternative to the current practice of forming elevated dredged material heaps. In the event that dredged materials are to be disposed close to the site, it is recommended that natural depressions or derelict canals be sorted for; otherwise a thin layer placement should be done. This has the potential of preventing acidification with minimal impacts on mangroves. The inherent disadvantage here is that large expanse of land will be required. In the context of restoration, thin layer placement can also be used to maintain and nourish subsiding wetlands, or raise sediment surface elevation of open water sufficiently to permit re-colonisation by emergent/volunteer wetland vegetation (Turner and Streever, 2002).

Mitigation banking

Another sustainable practice that could be encouraged is mitigation banking. This is a situation whereby an already despoiled/impacted area is restored to compensate for the area that is to be dredged. In practice, seedlings and mangrove propagules are salvaged from the dredging area and used to re-vegetate an already impacted site. A major oil producing company operating in the Escravos area successfully used this technique to minimise wetland impacts (ERML/LES, 2000; Ainodion *et al.*, 2002).

Management plans
When it becomes practically impossible not to disturb mangrove soils, an acid sulphate soil management plan (ASSMP) should be developed to mitigate the attendant impact. The management plans should among other things outline the strategies to manage the potential impacts of activities that are likely to disturb acid sulphate soils. The ASSMP needs to specify all potential environmental impacts, performance criteria, and mitigation strategies together with relevant monitoring and reporting requirements, and where an undesirable impact or unforeseen level of impact occurs, the appropriate corrective action (Department of Environment, 2003). The ASSMP should be structured to address the key elements of environmental management onsite and the performance criteria for all elements determined.

Legal framework
Until recently, there were no regulations guiding the placement of dredged materials in wetlands of Nigeria. Enforcement of regulations is very weak, hence there were cases where dredging was carried out across wildlife sanctuaries, cultural sites and other protected areas. The Department of Petroleum Resources (DPR, 2002) mandated that it is the responsibility of the lessee to manage the dredged materials generated during exploration and production activities and recommended an Environmental Impact Assessment (EIA) studies for any dredging activity exceeding a cumulative area of 500 m^2. Ideally, if these provisions were strictly followed, what to do with the waste dredged materials would have been adequately addressed in the EIA. Unfortunately, because of the subjectivity of impact assessment/evaluation process (Steinemann, 2001), dredged material management is still largely unaddressed in most EIA reports.

Conclusion and Recommendations

The environmental impacts of dredging in the Niger Delta are presented here using a case study. Dredging impacts virtually all components of the environment, but the impacts are often compounded by the abandonment of the resultant dredged materials over bank, causing alteration in the topography and hydrology and acidification. Impacts arising from these alterations include water contamination, vegetation damage, fish kills and change in land use. The altered topography among other factors prevents natural mangrove re-succession.

The paper takes a look at options for handling contaminated dredged materials and sediment relocation, with potentials to restore topography, hydrology, mitigate acidification and encourage natural mangrove re-colonisation. The paper concluded by highlighting sustainable dredging practices that has the potential to minimise impacts. It also provide means of improving dredged materials management alternatives especially when dredging in a sensitive environment

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