Advances in Biological Research 2 (5-6): 97-103, 2008
ISSN 1992-0067

Variations in Heavy Metal Concentrations Following the Dredging of an Oil Well Access Canal in the Niger Delta

[1]Elijah I. Ohimain, [1,2]Gbolagade Jonathan and [3]Steve O. Abah

[1]Biological Sciences Department, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State, Nigeria
[2]Department of Botany and Microbiology, University of Ibadan, Nigeria
[3]College of Medicine, Ambrose Alli University, Ekpoma, Edo State, Nigeria

Abstract: In a study to assess the impact of dredging on heavy metal contamination, surface water was monitored for over one year, from December 1997 to December 1998. Samples were collected twice before dredging, in December 1997 and in June 1998, corresponding to dry and raining seasons respectively. Samples were also collected immediately after dredging in July 1998 and were monitored in August, September and December 1998. Samples were collected analysed from five stations within the study area, station 1-5. Station 1 was in the dredged canal, which was originally a side branch of the Warri River tributary. In the Warri River tributary, Station 2 was 500m upstream and Station 3 was 1000m upstream of the mouth of the dredged canal, whilst Stations 4 and 5 were respectively 500m and 1000m downstream of it. Stations 3 and 5 represented the reference situation to which possible dredging effects could be compared. Prior to dredging, the concentration of heavy metals in the surface water samples of Warri River occurred in traces; lead (0.01-0.28 mg l^{-1}), zinc (0.04-1.02 mg l^{-1}), copper (0.00-0.17 mg l^{-1}), iron (0.22-0.88 mg l^{-1}), chromium (0.00-0.03 mg l^{-1}) and cadmium (0.03-0.14 mg l^{-1}). These values are comparable to values obtained elsewhere in the Niger Delta. But following the dredging of an oil well access canal, the concentration of heavy metals increased in several folds depending on the metal; lead (2.57 mg l^{-1}) zinc (9.56 mg l^{-1}), copper (15.36 mg l^{-1}), iron (229.50 mg l^{-1}), manganese (14.30 mg l^{-1}), chromium (0.27 mg l^{-1}) and cadmium (0.39). The results indicated a significant elevation of heavy metal concentrations over the background values. The percentage increase are as follows; 2333, 2130, 20,750, 51,113, 1960, 1266 and 703% for lead, zinc, copper, iron, chromium, manganese and cadmium respectively. However, 6 months after the dredging, the concentration of heavy metal reduced drastically to 533, 499, 4973, 6013, 480, 328 and 188% for lead, zinc, copper, iron, chromium, manganese and cadmium respectively over the background values. Notwithstanding the effect of tidal dilutions, the impact of dredging on heavy metals is medium to long term.

Key words: Dredging · Heavy metals · Niger Delta · Mangrove · Oil exploration · Warri River · Water quality

INTRODUCTION

Hydrocarbon exploration in the Niger Delta is often constrained by access difficulties due to the meandering wetland of the region. Dredging is often required to make oil exploration sites accessible for drilling and development. During dredging, waterway sediment, soil, creek banks and vegetation along the right of way are typically removed and deposited as dredge spoils at the bank of the newly dredged canal, resulting in a number of environmental impacts including alteration of topography and hydrology [1-3], acidification and water contamination [4-6], which has resulted in vegetation damage [7] and fish kills [6]. Turbidity plumes created as a result of dredging have been reported to cause alteration in the population and diversity of phytoplankton [8] and zooplankton [9, 10]. Benthic invertebrates are also impacted by dredging [6]. In a study carried out by Lewis et al. [11], dredging caused a reduction in numbers of benthic species, increased turbidity, reduction of primary productivity and mobilization and increased bioavailability of sediment trace metals. Dredging has been reported to cause the re-suspension of sediments, which is linked to the

Coressponding Author: Elijah I. Ohimain, Biological Sciences Department, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State, Nigeria.

re-mobilization of contaminants particularly heavy metals and increasing their bioavailability [12]. Re-suspension of sediment causes the oxidation of sediment leading to the mobilization of metals into the water body [13]. It has been variously reported that sediments are sinks for heavy metals and their disturbance through dredging could cause the re-mobilization of metals [14-21].

In Niger Delta, following the dredging of a tributary of the Warri River to enable the drilling of an oil well has led to a number of impacts including impairment of benthic invertebrates [6], algal bloom [8] and destruction of zooplankton [9]. Ohimain *et al*. [22] revealed that changes in the physico-chemical environment arising from the dredging may have contributed to the observed impacts. The study revealed that while some parameters decreased such as dissolved oxygen, others increased including turbidity, suspended solids, BOD_5 and sulphate following the dredging. The alteration of these water quality parameters were thought to contribute to the observed impacts, but the contribution of heavy metals have not been reported. Kwon and Lee [23] reported that heavy metals are toxic and exert chronic and lethal effects on aquatic animals and plants. Obiajuwa et al [24] reported heavy metal pollution around hydrocarbon production facilities elsewhere in the Niger Delta. Hence, this study is aimed at assessing the impact of dredging on the dynamics of heavy metals of the Warri River system over a one year period.

MATERIALS AND METHODS

This study was carried out in and near a dredged canal (5°31”N, 5°31”E) leading off a tributary of the Warri River in the mangrove swamp of the Niger Delta about 20km from Warri in Delta State, Southern Nigeria (Figure 1). The vegetation here is typical of mangrove swamp dominated by *Rhizophora* species. The area is characterized by high relative humidity (80-92%) and annual average rainfall exceeding 2800mm. Although, there are two seasons (wet and dry), measurable precipitation occurs in all the months of the year. Notwithstanding, the period of April to October is often regarded as raining season, while November-March is regarded as dry season. Atmospheric temperature ranged between 27°C to 29°C [25].

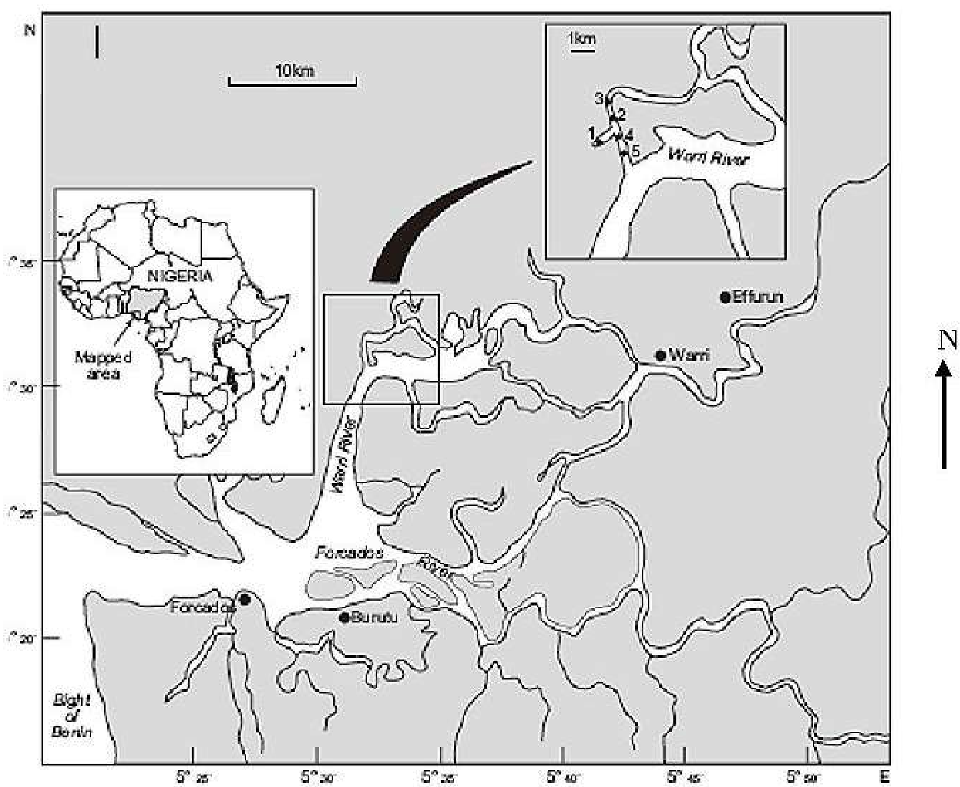

Fig. 1: Map of Warri River showing the study area

The surface water of the study area was monitored for over one year, from December 1997 to December 1998. Samples were collected from five stations within the study area, station 1-5. Station 1 was in the dredged canal, which was originally a side branch of the Warri River tributary. In the Warri River tributary, Station 2 was 500m upstream and Station 3 was 1000m upstream of the mouth of the dredged canal, whilst Stations 4 and 5 were respectively 500m and 1000m downstream of it. Stations 3 and 5 represented the reference situation to which possible dredging effects was compared. From each station, samples were collected twice before dredging, in December 1997 and in June 1998, corresponding to dry and raining seasons respectively. Samples were also collected immediately after dredging in July 1998 and were monitored in August, September and December 1998.

During sampling, water samples were collected into 100ml bottles and preserved with concentrated sulphuric acid to pH <2. Buck Scientific Atomic Absorption Spectrophotometer model 200A was used for heavy metal analysis according to APHA [26]. A correlation study was carried out with the results of physicochemical parameters (temperature, pH, alkalinity, turbidity, chloride, conductivity, TDS, TSS, DO, BOD, COD, hydrocarbons, ammonia, nitrate and sulphate) obtained from a previous study in the same location and of the same samples [22] in order to explain the origin of the heavy metals.

RESULTS AND DISCUSSION

Prior to dredging, the concentration of heavy metals in the surface water samples of Warri River occurred in traces; lead (0.01-0.28 mg l^{-1}), zinc (0.04-1.02 mg l^{-1}), copper (0.00-0.17 mg l^{-1}), iron (0.22-0.88 mg l^{-1}), chromium (0.00-0.03 mg l^{-1}) and cadmium (0.03-0.14 mg l^{-1}) (Fig. 2). These values are comparable to values obtained elsewhere in the Niger Delta [27-29]. But following the dredging of an oil well access canal, the concentration of heavy metals increased in several folds depending on the metal; lead (2.57 mg l^{-1}) zinc (9.56 mg l^{-1}), copper (15.36 mg l^{-1}), iron (229.50 mg l^{-1}), manganese (14.30 mg l^{-1}), chromium (0.27 mg l^{-1}) and cadmium (0.39). The results indicated a significant elevation of heavy metal concentrations over the background values. The percentage increase are as follows; 2333, 2130, 20,750, 51,113, 1960, 1266 and 703% for lead, zinc, copper, iron, chromium, manganese and cadmium respectively. However, 6 months after the dredging, the concentration of heavy metal reduced drastically to 533, 499, 4973, 6013, 480, 328 and 188% for lead, zinc, copper, iron, chromium, manganese and cadmium respectively over the background values. Action of tidal dilution is partly responsible for the reduction in heavy concentrations, but the presence of the unconfined sulfidic dredged materials deposited adjacent to the canal that is leaching into the canal may have helped to sustain acidification and heavy metal mobilization through pyrite oxidation [30]. It has been variously reported that the reason for the prolonged effect of dredging was attributed to the washing of leachates into the river from unconfined spoil dumps [31-33]. Elevated levels of heavy metals have been variously reported to be associated with oil development activities in the Niger Delta [34-38] and there are indications of heavy metals bioaccumulation [27-42].

In an attempt to understand the source of the elevated metals, a correlation studies between the heavy metals and 15 physicochemical parameters [22] was carried out. Out of the 15 physicochemical parameters, only 10 exhibited significant relationships with the metals, these are presented in Table 1. From the results of the correlation studies, it appears that there are at least three factors/mechanisms contributing to the heavy metal re-mobilization, they include sulphate acidity/conductivity/TDS, turbidity and oxygen/organic carbon systems. From the correlation analysis, it appears that acidity play a major role in the elevation of the water heavy metal concentrations following the dredging operations. For instance, pH correlated negatively with all the metals with correlation coefficients > 9.3 except for iron where it is 0.828. Similarly, sulphate concentrations had a strong positive correlation with all the metals with correlation coefficients > 9.3. It has been previously reported that soils and sediments of the mangrove ecosystem of the Niger Delta is high in non-bioavailable forms of heavy that are bound to the sediments/ soils as metal sulphides [1, 30, 43-45]. The dredging may have caused the re-suspension of anoxic sediments leading to their oxidation, which resulted in the formation of sulphuric acid causing the lowering of the pH and the release of heavy metals. According to Peltola and Astrom [46], dredging results in the oxidation of the reduced sulphur in the sediments resulting in a lowering of pH, which in turn leaches metals. Conductivity and TDS showed similar strong positive relationship with all the metals, suggesting that the acidification following the oxidation of the sediments may have caused the mobilization of sediment bound metals into the water column.

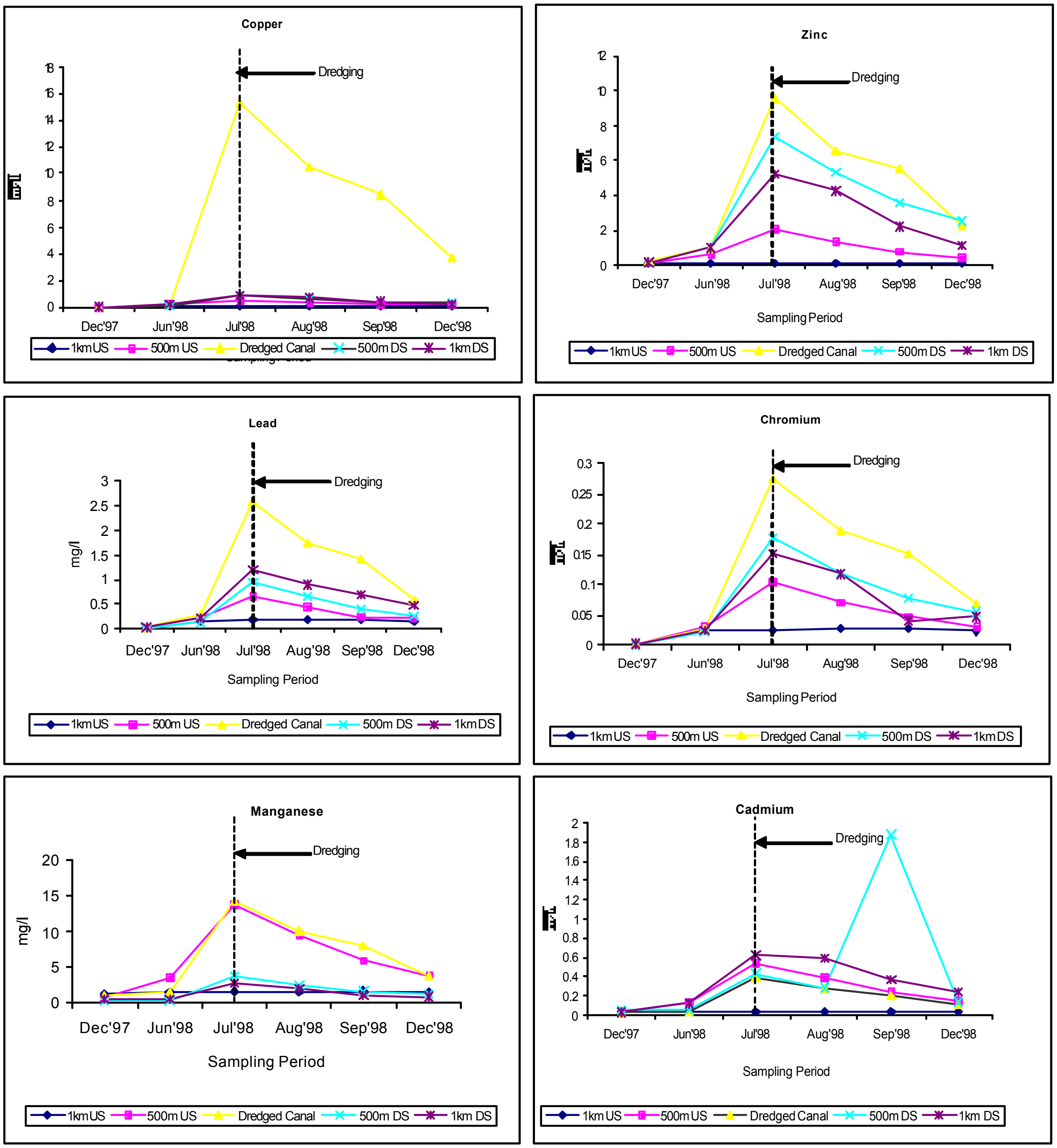

Fig. 2: changes in heavy metal concentrations following dredging

Table 1: Correlation coefficients of heavy metals with physico-chemical parameters following the dredging of Warri River

	Physico-chemical parameters									
	PH	Turbidity	TDS	TSS	DO	BOD_5	COD	Organic carbon	Conductivity	Sulphate
Lead	-0.930	0.808	0.918	0.810	-0.897	0.978	0.954	0.965	0.927	0.973
Zinc	-0.933	0.803	0.911	0.804	-0.901	0.978	0.956	0.966	0.920	0.969
Copper	-0.954	0.789	0.882	0.791	-0.904	0.989	0.969	0.977	0.891	0.968
Iron	-0.828	0.944	0.921	0.945	-0.740	0.917	0.848	0.871	0.920	0.927
Chromium	-0.939	0.798	0.912	0.800	-0.903	0.982	0.962	0.972	0.921	0.977
Manganese	-0.942	0.801	0.904	0.803	-0.886	0.990	0.961	0.972	0.911	0.970
Cadmium	-0.944	0.802	0.902	0.804	-0.885	0.991	0.962	0.973	0.910	0.972

The second system affecting heavy metal mobilization is turbidity and suspended solids. Both parameters had a strong positive relationship with the studied heavy metals. This is plausible because the dredging may have caused the re-suspension of sediments, which increased water turbidity, suspended solids and the concentrations of the heavy metal associated with the sediment phase. It has been reported that heavy metals bounded to sediments, play a major role in the pollution of the river system [47, 48].

The third system affecting heavy metal mobilization is oxygen and carbon systems. Dissolved oxygen had a strong negative correlation with all the metals, while organic carbon, COD and BOD had a strong positive relationship with the metals (Table 1). The re-suspension of the sediment may have exerted an oxygen demand causing the depletion of oxygen, which is utilized for the oxidation of metal sulphides to their sulphate forms, thus mobilizing metals into solution.

CONCLUSION

In conclusion, the dredging of an oil well access canal caused the elevation of heavy metals in Warri River. The result of the six month post dredging monitoring shows that the concentration of heavy metals reduced considerably, however, the presence of unconfined spoil banks adjacent to the canal tends to prolong the impacts. It is therefore concluded that the impacts of dredging on heavy metal is medium to long term.

ACKNOWLEDGEMENT

We wish to express our gratitude to Dr(Mrs) M.O. Benka-Coker for supervising the PhD research of the first author.

REFERENCES

1. Ohimain, E.I., 2003a. Environmental Impacts of oil mining activities in the Niger Delta mangrove ecosystem. Proceedings of the International Mine Water Association (IMWA) conference held in Johannesburg, South Africa (October 2003), Mine Water and the Environment Armstrong, D., de Villiers, A. B. Kleinmann, R. L. P., McCarthy, T. S. and Norton, P. J. (Editors), pp: 503-517, International Mine Water Association (IMWA), Sandton, South Africa
2. Ohimain, E.I., 2003b. Preservation of Niger Delta Wetland Resources Through Proper Handling and Rehabilitation of Abandoned Waste Sulfidic Dredge Spoils. Environmental Science and Technology. Uzochukwu, G. A., Schimmel, K., Reddy, G. B., Chang, S. Y. and Kabadi, V. (editors), pp: 3-12 Battelle Press, Columbus, Ohio, USA.
3. Ohimain, E.I., 2004a. Available options for the bioremediation and restoration of abandoned pyritic dredge spoils causing the death of fringing mangroves in the Niger delta. In: Biohydrometallurgy; a sustainable technology in evolution (Tsezos, M., Hatzikioseyian, A. and Remoudaki, E., eds.). National Technical University of Athens, Zografou, Greece. pp: 475-481.
4. Ohimain, E.I., 2004b. Environmental impacts of dredging in the Niger Delta; options for sediment relocation that will mitigate acidification and enhance natural mangrove restoration. Terra et Aqua, 97: 9-19.
5. Ohimain E.I., 2001. Bioremediation of heavy metal contaminated dredged spoil from a mangrove ecosystem in the Niger Delta. PhD thesis University of Benin, Benin City, Nigeria
6. Ohimain, E.I., M.O. Benka-Coker and T.O.T. Imoobe, 2005. The impacts of dredging on macrobenthic invertebrates in a tributary of the Warri River, Niger Delta. African J. Aquatic Sci., 30: 49-53.
7. Fagbami, A.A., E.J. Udo and C.T.I. Odu, 1988. Vegetation damage in an oilfield in the Niger Delta of Nigeria. J. Tropical Ecol., 4: 61-75.
8. Ohimain, E.I and T.O.T. Imoobe, 2003. Algal bloom in a newly dredged canal in Warri, Niger Delta. Nigerian J. Sci. Res., 4: 14-21.
9. Ohimain, E.I., T.O.T. Imoobe and M.O. Benka-Coker, 2002. Impacts of dredging on zooplankton communities of Warri River, Niger Delta. African J. Environ. Pollution and Health, 1: 37-45.
10. Toumazis, A.D., 1995. Environmental impact with dumping of dredged material at sea: A case study of the Limasol Port extension works. Wat. Sci. Technol., 32: 9-10.
11. Lewis, M.A., D.E. Weber, R.S. Stanley and J.C. Moore, 2001. Dredging impact on an urbanized Florida bayou: effects on benthos and algal-periphyton. Environmental Pollution, 115: 161-171.
12. Perin, G., R. Fabris, S. Manente, Robello-Wagener, C. Hamacher and C. Scotto, 1997. A five year study on the heavy metal pollution of Guanabara Bay sediment (Rio De Janeiro, Brazil) and evaluation of metal bioavailability by means of geochemical speciation. Water Research 31(12): 3017-3028.

13. Saulnier, I. and A. Mucci, 2000. Trace metal remobilization following the re-suspension of estuarine sediments; Sagueney Fjord, Canada. Applied Geochem., 15: 203-222.
14. Ouyang, Y., J. Higmann, J. Thompson, T. O'Tool and D. Campbell, 2002. Characterization and spatial distribution of heavy metals in sediments from Cedar and Ortega Rivers. Journal of Contaminant Hydrology, 54: 19-35.
15. Stephens, R.S., B.J. Alloway, A. Parker, J.E. Carter and M.E. Hodson, 2001. Changes in the leachability of metals from dredged canals sediment during drying and oxidation. Environmental Pollution, 114: 407-413.
16. Stephens, R.S., B.J. Alloway, J.E. Carter and A. Parker, 2001. Towards the characterization of heavy metals in dredged canal sediments and an appreciation of availability: two examples from the UK. Environmental Pollution, 113: 395-401.
17. Delaune, R.D. and C.J. Smith, 1985. Release of nutrients and heavy metals following oxidation of freshwater and saline sediments. J. Environ. Qual., 14: 164-168.
18. Gambrell, R.P., 1994. Trace and toxic metals in wetlands. A review. J. Environ. Qual., 23: 883-891.
19. Gambrell, R.P. and J.B. Wiespape, W.H. Patrick and M.C. Duff, 1991. The effect of pH, redox and salinity on metal release from contaminated sediment. Water Air Soil Pollut, 57: 354-367.
20. Khalid, R.A., R.P. Gembrell, M.G. Verloo and W.H. Patrick, 1977. Transformations of heavy metals and plant nutrient in dredged sediments as affected by oxidation-reduction potential and pH. Vol. 1. USAGE/ WES, Vicksburg, pp: 53.
21. Perterson, W., E. Willer and W. Williamowski, 1997. Remobilization of trace element from polluted anoxic sediments after resuspension in oxic water. Water Air Soil Pollut, 99: 515-522.
22. Ohimain, E.I., T.O.T. Imoobe and D.D.S. Bawo, 2008. Changes in water physico-chemical properties following the dredging of an oil well access canal in the Niger Delta. World J. Agric. Sci., 4 (6): 752-758.
23. Kwon, Y.T. and C.W. Lee, 1998. Application of multiple ecological risk indices for the evaluation of heavy metal contamination in a coastal dredging area. Sci. Total Environ., 214: 203-210.
24. Obiajunwa, E.I., D.A. Pelemo, S.A. Owolabi, M.K. Fusasi and F.O. Johnson-Fatoku, 2002. Characterization of heavy metal pollutants of soil and sediments around crude oil production terminal using EDXRF. Nuclear Instruments and Methods in Physics Research B., 194: 61-64.
25. Egborge, A.B.M., 1994. Water Pollution in Nigeria Biodiversity and Chemistry of Warri River. Ben miller Books Nig. Ltd., Warri, pp: 331.
26. American Public Health Association, 1995. Standard Methods for the Examination of Waste and wastewater. A.P.H.A/AWWA/WPCF, Washington DC., pp: 946.
27. James, M. and P.O. Okolo, 2003. Variation of heavy metal concentrations in water and freshwater fish in the Niger Delta waters. A case study of Benin River. Pakistan J. Sci. Industrial Res., 46(6): 439-442.
28. Davies, O.A., M.E. Allison and H.S. Uyi, 2006. Bioaccumulation of heavy metals in water, sediment and periwinkle (*Tympanotonus fuscatus* var radula) from the Elechi Creek, Niger Delta. African J. Biotechnol., 5(10): 968-973.
29. Obire, O., D.C. Tamuno and S.A. Wemedo, 2003. Physicochemical quality of Elechi Creek in Port Harcourt, Nigeria. J. Appl. Sci. Environ. Mgt., 7(1): 43-49.
30. Ohimain, E.I., W. andriesse and M.E.F. van Mensvoort, 2004. Environmental Impacts of Abandoned Dredged Soils and Sediments: Available Options for their Handling, Restoration and Rehabilitation. Journal of Soils and Sediments, 4(1): 59-65.
31. USEPA/ USACE., 1998. Evaluation of Dredged Material Proposed for Discharge in Waters of the US. Inland testing manual Report No. EPA-823-398-004. pp: 391.
32. USEPA/USACE., 1992. Evaluating Environ. Effects of dredged material management alternatives: a technical framework. pp: 96.
33. Turner, R.E., 1997. Wetland loss in the Northern Gulf of Mexico multiple working hypothesis. *Estuaries*. 20: 1-3.
34. Kakulu, S.E. and O. Osibanjo, 1988. Trace metal pollution studies in sediments of the Niger Delta area of Nigeria J. Chem. Soc. Nigeria, 13: 9-15.
35. Kakulu, S.E. and O. Osibanjo, 1992. Pollution studies of Nigerian rivers: trace metal levels of surface water in the Niger Delta area. Int. J. Environ. Stud., 41: 287-293.
36. Kakulu, S.E., O. Osibanjo and S.O. Ajayi, 1987. Trace metal content of fish and shell fishes of the Niger Delta area. Environ. Int., 13: 247-251.
37. Iwegbue, C.M.A., F.E. Egobueze and K. Opuene, 2006. Preliminary assessment of heavy metals levels of soils of an oil field in the Niger Delta, Nigeria Int. J. Environ. Sci. Tech., 3(2): 167-172.

38. Howard, I.C., M. Horsfall, I.A. Spiff and S.C. Teme, 2006. Heavy metals levels in surface waters and sediments in an oilfield in the Niger Delta, Nigeria. Global J. Pure App. Sci., 12(1): 79-83
39. Etim, L., E.R. Akpan and P. Muller, 1991. Temporal trends in heavy metal concentration in the clam *Egeria radiata* from the Cross River, Nigeria Rev., Hydrobiol., 24(4): 327-333.
40. Chindah, A.C., A.S. Braide and O.C. Sibeudu, 2004. Distribution of hydrocarbons and heavy metals in sediment and a crustacean (*Penaeus notialis*) from the Bonny River/New Calabar River Estuary, Niger Delta. African J. Environ. Assess. Mgt., 9: 1-17.
41. Hart, A.D., C.A. Oboh, I.S. Barimalaa and T.G. Sokari, 2005. Concentrations of trace metals (lead, copper and zinc) in crops harvested from oil prospecting locations in Rivers State, Nigeria. African J. Food Agric. Nutri. Dev., 5: 1-22.
42. Agbozu, I.E., I.K.E. Ekweozor and K. Opuene, 2007. Survey of heavy metals in catfish Synodontis clarias. Int. J. Environ. Sci. Tech., 4(1): 93-97.
43. Horsfall, M. and A.I. Spiff, 2002. Distribution and partitioning of trace metals in sediments of the lower reaches of the New Calabar River, Port Harcourt, Nigeria. Environmental Monitoring and Assessment. 78: 309-326.
44. Anderson, B., 1966. Report on the Soils of the Niger Delta Special Area. Niger Delta Development Board, Port-Harcourt Nigeria.
45. Ohimain, E.I., 2002. Sustaining stakeholders' values through proper handling and restoration of abandoned waste dredge spoils in the Niger delta. A paper presented at the Department of Petroleum Resources' Health, Safety and Environment (HSE) conference to be held in Abuja, Nigeria (9^{th}-11 th December 2002). http://www.nigeriaoilandgas-hse.org/conf2002/script_42.asp.
46. Peltola, P. and M. Astrom, 2002. Concentration and leachability of chemical elements in estuarine sulphur-rich sediments, W. Finland. The S. Total Environ., 284: 109-122.
47. Gibbs, R.J., 1973. Mechanism of trace metal transportation in rivers. Sci., 71-73.
48. Forstner, U. and G.T.W. Wittman, 1981. Metal Pollution in the Aquatic Environment. Second Edition. Springer Verlag Publishers, Berlin.