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Oil Pollution and Water Quality in the Niger Delta: Implications for the Sustainability of the Mangrove Ecosystem

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Oil Pollution and Water Quality in the Niger Delta: Implications for the Sustainability of the Mangrove Ecosystem

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I. Introduction

The Niger Delta as historically defined comprises the present Delta, Bayelsa and Rivers States in south-south Nigeria (Dike 1956; Willinks *et al.,* 1958; Akinyele 1998). The total area is 25,640 km^2; Low Land Area 7,400km^2, Fresh Water Swamp 11,700 km^2, Salt Water Swamp 5,400 km^2 and Sand Barrier Islands 1,140 km^2 (Ashton-Jones. 1998). The Niger Delta mangrove ecosystem is the largest in Africa and second largest in the world (Awosika, 1995). It is one of the world's most fragile ecosystems (NDES, 1997) and the area with the highest fresh water fish species in West Africa (Ogbe 2005).

Oil activities started in the Niger Delta in 1908. However, commercial oil production began at Oloibiri, Bayelsa State in 1956 but oil exportation started in 1958. Presently, oil accounts for over 80% of state revenues, 90% of foreign exchange earnings and 96% of export revenues (Ohiorhenan 1984; Ikelegbe 2005; UNSD, 2009). About 2.45 million barrels is produced daily that earns the country an estimated $60 billion annually (Ploch, 2011). Over 85% of oil is produced in the Niger Delta (SPDC, 2008) mostly from the mangrove ecosystem. However, oil activities impact adversely on the marine environment (Lee and Page, 1997; Snape *et al.,* 2001; Liu and Wirtz, 2005), with allied severe socio-economic effects (Ibeanu, 1997; Roberts, 1999, 2005; Omoweh, 2005). Oil extraction impacts on ecosystems in a variety of ways; impacts related to climate change, (Fischlin *et al.*, 2007) physical impacts (Swer and Singh, 2004), chemical impacts (Banks *et al.*, 1997) and biological impacts (Meyer *et al.*, 1999).

In the Niger Delta, this has been exacerbated by the oil companies' impunity of operations with no regard for the environment. As, such, oil operation have entailed recurrent oil spillages and massive gas flaring. The impunity of oil operations in the Niger Delta is exemplified by the fact that Shell operations in Nigeria that accounts for just 14% of its oil production worldwide, accounts for a staggering 40% of its oil spills worldwide (Gilbert, 2010). Oil spills records obtained from the Department of Petroleum Resources (DPR) showed that between 1976 and 2005, 3,121.909.80 barrels of oil was spilled into the Niger Delta environment in about 9,107 incidents. Independent researchers have however argued that the volume and incidents of oil spills are under reported (Green Peace, 1994; Banfield, 1998; Iyayi, 2004).

Three main mangrove species exists in Nigeria; R. Racemosa, R. mangle and Rhizophora harrisonni (Adegbehin, 1993). Two others of less abundance, Avincennia germinans and Laguncularia racemosa are also present. The mangrove is a highly productive biotope with a vigorous, rich and endemic wildlife, supporting a wide and varied group of mobile organisms ranging from birds that nest in the trees to fishes that feed and live among submerged prop roots (Odum *et al.,* 1982). Mangroves are the most sensitive of all coastal ecosystems (Hayes and Gundlach, 1979). Hydrocarbons are major threat to mangroves (Hanley, 1992; Kadam, 1992; Tarn and Wong, 1995), as high proportions of heavy metals are retained in mangroves sediment (Tarn and Wong, 1995). The mangrove forests and creeks constitute the main areas of oil exploration and exploitation activities in the Niger Delta.

II. Materials and Method

Water samples were collected for two years from three (3) swamp locations within the crude oil prospecting areas of the mangrove ecosystems two with high oil activities (Nembe and Okrika) and one devoid of oil activities (Okpare). The samples were collected, in January and July and analysed for their physical and

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chemical parameters. The samples for chemical analysis were collected in labelled sterilised plastic bottles, following APHA, 1998 (standard procedures) and transported in an ice chest to the laboratory. The samples for total hydrocarbon content (THC) analysis were placed in pre-labelled glass containers and sealed with aluminium foil. Temperature was recorded in situ using the mercury-in-glass thermometer, pH was determined using a pH meter, while dissolved oxygen (DO) and biochemical oxygen demand (BOD) were determined using the modified Winkler method and the 5 day BOD test respectively (APHA, 1998). Nitrate and salinity were determined using the Brucine and ascorbic acid methods respectively, while phosphate was determined using hand-held refractometer (APHA, 1998).

The questionnaire schedule was administered to respondents in the three communities where the sediment and water samples were collected. The questionnaires were administered to respondents (households) using the Cluster Survey method (Nachmaias and Nachmaias, 1996 and Riley, 1963), based on simple random sampling. The study population is the Niger Delta States (Bayelsa, Delta and Rivers), which account for over 75% of the crude oil production in Nigeria. The crude oil-exploration host communities in Niger Delta served as the sampling units, from which three were randomly selected for the study. The sample size is two hundred prorated based on 2007 population census (NPC, 2007) of the local government areas in which the communities are located. This sample size was considered adequate since they are rural communities. The sampled communities were; Nembe in Nembe local Government Area of Bayelsa State, Okpare in Ughelli North Local Government Area of Delta and Okrika in Okrika Local Government Area of Rivers State. Based on their population figures, the sample size for each community was as follows; Nembe 39, Okpare 95 and Okrika 66. The data obtained from water samples were subjected to an Analysis of Variance (ANOVA), while results from the sample survey were presented in simple statistics (pie charts).

III. Results

Table 1 : Mean values of the physicochemical parameters, and heavy metals concentrations in the water samples from the different locations observed.

Parameters	Nembe	Okrika	Okpare	Grand Mean
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	5.03±0.13	5.23±0.10	5.60±0.14	5.29±0.29
Sal. (mg/l)	12.98±0.43	13.05±0.44	7.90±0.14	11.31±2.95
Temp (^{0}C)	29.63±1.52	29.88±1.36	29.93±0.10	29.81±0.16
Transparency (%)	85.75±0.96	81.50±0.58	84.00±0.82	83.85±2.14
THC(mg/l)	1741.5±22.78	1883.75±24.13	1844.50±10.66	1823.25±73.47
DO mg/l	5.38±0.22	5.75±0.39	6.07±0.15	5.73±0.35
BOD (mg/l)	6.83±0.05	7.20±0.08	7.63±0.19	7.22±0.40
PO_3^- (mg/l)	1.41±0.03	1.25±0.06	0.83±0.10	1.16±0.30
NO^- (mg/l)	0.35±0.01	0.45±0.01	0.38±0.10	0.39±0.05
Heavy metals (mg/l)				
Pb	1.77±0.16	1.84±0.07	1.83±0.10	1.81±0.04
Zn	2.88±0.13	1.78±0.16	2.49±0.09	2.38±0.56
Cr	1.87±0.07	1.74±0.03	1.62±0.09	1.74±0.13
Cd	1.77±0.04	1.86±0.13	1.70±0.04	1.78±0.08
Cu	1.91±0.07	2.65±0.13	1.61±0.09	2.05±0.54

The pH of water samples from the study was acidic with mean pH ranging from 5.07±0.05-5.43±0.04 in wet season and 5.00±0.00-5.20±0.14 in the dry season (Table 1). It was observed that there was no significant difference $p \leq 0.05$ between the values for wet and dry seasons. The presence of several metals; lead, zinc, chromium, cadmium and copper in high concentration was also, observed in the water samples. Their mean concentration was 1.77±0.11 mg/l, 2.59±0.19mg/l, 1.74±0.17mg/l, 1.76±0.18mg/l and 1.76±0.18mg/l respectively (wet season) and 1.86±0.1mg/l, 2.75±0.19mg/l, 1.78±0.14mg/l, 1.82±0.16mg/l and 1.82±0.16mg/l respectively (dry season). There was no significant difference ($p \leq 0.05$) in the concentrations of the heavy metals across the three study sites.

IV. Survey Results

Results obtained from the structure questionnaire administered to respondents in the various study communities shows that about 77% of the respondents were of the view that mangrove wood has become scarce, while 7% said there was no scarcity of mangrove wood (Fig.1).

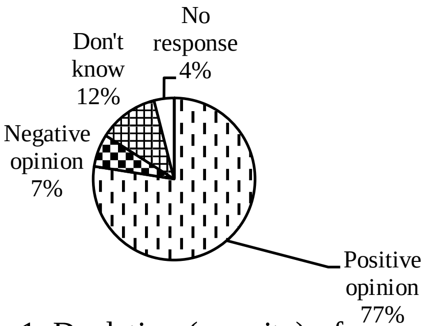

Figure 1: Depletion (scarcity) of mangrove wood

Figure 1

Also, respondents' response to impact of crude oil on fish catch in the shows that about 75% of the respondents held the view that there was decrease in fish catch, while 8% claimed fish catch had actually increased in the region (Fig. 2).

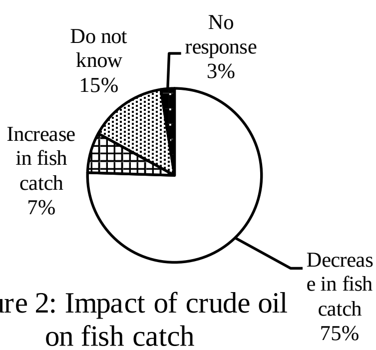

Figure 2: Impact of crude oil on fish catch

Figure 2

V. Discussion

The water quality in an aquatic environment is very important for the survival of its flora and fauna. This is usually assessed by the pH and the heavy metal concentration in the water, which are key parameters in many ecological studies. A strong relationship exists between pH and the physiology of most aquatic organisms (Kinne, 1970). Thus, the range of pH in an environment is used to detect the impacts of pollution (RPI, 1985). The pH of the water samples in this study was acidic ranging from 5.03 in Nembe to 5.6 at Okpare with a mean of 5.29 ± 0.29 (Table 1). The low pH observed in the water samples would seem to indicate the unhealthy nature of water in the Niger Delta region. The pH of the study, when compared to a base study report RPI (1985): 7.50-7.80; and Dublin-Green (1990): 6.90-7.60, seems to show that water quality deteriorated over the years in the Niger Delta. Water quality, as several studies have shown, has impacts on species composition, assemblages and distribution of plankton (Boney, 1983), benthos (Dance and Hynes, 1980; Jones, 1987; Hart and Zabbey, 2005) and fish (Boney, 1983; Kutty, 1987). The pH values obtained in this study are outside the 6.00 to 9.00 range, which were suggested for optimal fish production (Boyd and Lichtkoppler, 1979; Cup, 1986; Onuoha and Nwadukwe, 1987).

Several heavy metals; chromium, zinc, copper, cadmium and lead detected in the water samples (Table 1) had levels higher than the prescribed limits by WHO/ FAO (1976). The high concentration of heavy metals coupled with the low pH observed, are indicative of high levels of pollution of the Niger Delta environment. Several studies have associated the high pollution levels to oil spills from oil-related activities in the region (Kinigoma, 2001; Amusan and Adeniyi, 2005; Wogu, and Okaka 2011). Pollution from crude oil especially light crude, besides giving rise to poor water quality is a major threat to mangroves (Hanley, 1992; Kadam, 1992; Tarn and Wong, 1995). Nigeria produces mainly light crude and this has been shown to impacts more adversely on mangroves (Proffitt *et al.,* 1997; Duke *et al.,* 2000) than heavy crude. This is because mangroves sediment retains oil as it behaves like a sink; leading to persistence of oil on or inside the sediments (Maia-Santos *et al.,* 2012). Thus, mangrove sediment retains high proportion of heavy metals (Tarn and Wong, 1995). This acutely impacts mangroves (Garrity *et al.,* 1994) and disrupts the structure of mangroves habitat (Nadeau and Berquist, 1977; Jackson *et al.,* 1989; Duke *et al.,* 1997). The effects of oil pollution are long lasting (Corredor *et al.,* 1990; Teal *et al.,* 1985; Burns *et al.,* 1993, 1994) up to 50 years (Ekekwe, 1981; Duke and Burns, 1999; Brito *et al.,* 2009). Several studies have reported negative impacts of oil pollution on Mangroves. Duke *et al.* (1993) reported that oil pollution impairs the growth of mangrove seedlings, while Emuedo and Anoliefo, (2008) reported that oil impairs root growth in mangroves, leading to eventual death. Crude oil impact has both acute and chronic effects on mangroves (Jackson *et al.,* 1989; Grant *et al.,* 1993; Böer, 1993; Burns *et al.,* 1993; Dodge *et al.,* 1995; Wardrop *et al.,* 1996). Even when oil exposure does not out-rightly kill mangrove, it severely weakens mangroves to a point where they succumb to natural stresses that they would ordinarily have survived (Snedaker *et al.,* 1997). In addition, when trees are impacted upon by oil, there is the loss of benefits previously derived from the trees; such as nursery for fish species and prawns (Cappo, 1995a, b) or in the prevention of shoreline erosion (Furukawa and Wolanski, 1996; Duke *et al.,* 1997).

All these have had grave implications on sustainability of the mangrove ecosystem in the Niger Delta. The mangroves ecosystem provides the major sources of economic activities and food for oil-host communities in the Niger Delta. Crabs, Oysters, Cockles and Periwinkles are easily gathered around the roots of mangroves (Ejituwu, 2003). However, oil pollution coupled with the poor water quality has led to the heavy loss of mangroves in the region. This has also been further exacerbated by negative effects of other oil-related activities such as dredging of channels and canals that have led to physical felling and or death of trees (Ohimain *et al.,* 2008). Okonta and Douglas (2001) also reported that by 1999 Shell had cut over 24,000 miles of seismic lines through mangrove forests. These have resulted in huge reduction of mangroves in the Niger Delta. Indeed, a study FAO, (2005) reported that mangroves in the Niger Delta have the most rapid rate of depletion in the world. During the focus group discussions, most participants complained about mangrove wood scarcity. This view was also expressed by about 77% of the respondents of the sampled survey (Fig.1). The loss of mangroves has implication for sustainability in the region. Studies show that mangrove loss in the Niger Delta has reduced the uses to which the wood is put and the cost prohibitive (Wilcox and Powell, 1985; Bassey, 1999; Raji *et al,* 2000).

Also, the mangrove ecosystem is the basic nursery for aquatic species, especially fish (Rutzler and Feller, 1987). The Niger Delta mangroves provide breeding grounds for numerous species of fin fish, prawns, and as habitat for crabs and molluscs (IPIECA, 1993). It would seem that huge loss of mangroves coupled with the poor water quality has led to reduction in fish stocks. This has correspondingly reduced fish catches significantly in the region. This is shown in the result of the sample survey (Fig.2) where about 75% of the respondents opined that fish catches have reduced in the Niger Delta. In addition, this has resulted in the virtual extinction of some fauna in the region. Omoweh (1998) reported the virtual extinction of cat fish, manatee or sea cow, electric fish, hippopotamus and shark in the Niger Delta. Emuedo (2010) reported that iguana (Ogborigbo), edible frog (Okhere), and small red cray fish (Iku-ewhewhe) have also become virtual extinct in the region. Furthermore, poor water quality has also led to the bio-accumulation of heavy metals by common fish species found in the region; Tympanotonus fuscatus var radula (periwinkle) (Davies *et al.,* 2006), Bonga Shad (Ethmalosa fimbriata) (Etesin and Nsikak, 2007), Synodontis clarias (catfish) Agbozu, *et al.,* 2007), Shrimp (Macrobrachium felicinum) (Opuene, and Agbozu, 2008), Tilapia (Tilapia nicolitica) (Godwin *et al.,* 2011).

VI. Conclusion

The quality of water in an aquatic environment is very important for the survival of its flora and fauna. Water quality also has a role to play in the overall health of an environment. This study showed very low pH levels as well as levels of heavy metal much higher than the WHO prescribed limits; indicating the unhealthy state of the Niger Delta environment. The incessant oil spills in the region have led to chronic pollution of the environment with much negative impacts on the mangrove ecosystem. As shown by the study, this has resulted in mangrove forests depletion, with severe consequences; scarcity of mangrove wood, reduction in fish stocks. As Sullivan *et al.* (2008) has asserted "for 75% of rural poor (as in the Niger Delta), across the world, access to good water makes the difference between life and death". The study has thus shown that oil activities have adversely affected water quality in the mangrove ecosystem with overall negative effects on the sustainability in the Niger Delta environment. The government and the multinational oil corporations are therefore advised to carry out proper cleanup of all subsequent oil spills and embark on a remediation of the water bodies in the region.

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