Australian Journal of Basic and Applied Sciences, 7(6): 178-183, 2013
ISSN 1991-8178

The effect of crude oil spill at Izombe, Imo State, Nigeria on plankton diversity and abundance

[1]Emmanuel M. Ikpeme, [2]Chinasa Uttah and [1]Emmanuel C. Uttah

[1]Department of Biological Sciences, Cross River University of Technology, Calabar, Nigeria.
[2]Department of Geography and Environmental Science, University of Calabar, Nigeria.

Abstract: This work was aimed at assessing the effect of crude oil spill on the diversity and abundance of plankton communities of the Njaba River area of the spill. Sampling was carried out in 1999 in nine clusters of stations, three each from upstream, spill-point and downstream transects. Each cluster was made up of three perpendicular sampling points across the river. Standard methods were used in collecting, preserving, identifying and counting the plankton. A total of 60 species of phytoplankton in 55 genera were collected. Phytoplankton constituted 62.9% of abundance and 71.4% of plankton species collected. The MDI for the upstream was comparable to that of the downstream, and both are significantly higher than the MDI for the spill-point ($\times^2$-test; $p < 0.05$). In all, 122 zooplankton specimens in 24 species and 23 genera were collected. Zooplankton from the upstream clusters accounted for 81.1% of overall abundance and 95.8% of all the species collected. The more pollution-sensitive species such as the meroplankton were only found upstream and were totally absent in both downstream and spill-point clusters. Index of similarity between upstream and downstream shows 76% similarity for phytoplankton and 81% for zooplankton; but the index of similarity between the spill-point and either the upstream or downstream was quite low. This indicates there are focalized dislocations in plankton abundance and diversity in the spill-point transects, and evidence of recovery downstream. In conclusion, there was a significant effect of the oil-spill on plankton abundance and diversity causing remediable perturbation beyond the carrying capacity of the spill-point transect.

Key words: Phytoplankton, zooplankton, oil-spill, biodiversity, abundance, Njaba River, Nigeria

INTRODUCTION

Phytoplankton and zooplankton are part of hydrobionts that act as indicators of the state of river ecosystem and water quality (Mitrofanova, 2008). The plankton is essentially non-motile relative to the water mass, but drifts with it, and is therefore susceptible to pollutants in the water. The plankton community in rivers is usually dominated by a small number of taxa (Admiraal *et al*, 1994; Kijhler 1994). Phytoplankton are the most important primary producers in the aquatic ecosystem. At the same time, these organisms are very sensitive to changes in their environment (Rzanicanin *et al*., 2005). They are food to the zooplankton and some herbivorous fishes. Phytoplankton species composition and relative abundance can be employed to explain prevailing environment status in an area (Quintana and Moreno-Amich, 2002).

Zooplankton are critical components of great rivers, linking primary production, microbial and detrital resources to higher trophic levels (Chick *et al*., 2006). They are composed of the permanent members whose entire life-cycles are spent as plankton (holoplankton); and the temporary members which comprise mostly of the egg and larval stages of benthic organisms (meroplankton). Zooplankton are small animals and float freely in the water column of rivers lakes and oceans and whose distribution is primarily determined by water currents among other factors. The zooplankton community of most rivers ranges in size from a few tens of microns (Protozoa) to > 2mm (macro-zooplankton). They play a pivotal role in aquatic food webs because they are important food for fish and invertebrate predators and they graze heavily on algae, bacteria, protozoa, and other invertebrates. Zooplankton communities are typically diverse (>20 species) and occur in almost all rivers, lakes and ponds.

In the Nigeria, oil spillages are regular phenomenon that occur through pipeline leakage and rupturing, accidental discharges (tank accident), discharges from refineries, among other causes (Zabbey, 2004). For example, between 1976 and 1997, there were 5334 reported cases of crude oil spillages that released about 2.8 million barrels of oil into land, swamp, estuaries and coastal waters of Nigeria (Dublin-Green *et al*. 1998). It must be noted that majority of oil spills occurring in Nigeria are unreported (Zabbey, 2004).

Environmental Impact Assessment (EIA) was carried out on Izombe River to ascertain the impact of crude oil spill on the plankton communities. The aim of this work was to assess the impact of crude oil spill on the relative diversity, species composition and relative abundance of plankton communities in the upstream and downstream of the spill-point in the Izombe River.

Corresponding Author: Chinasa Uttah, Department of Geography and Environmental Science, University of Calabar, Nigeria Tel: +234-802-038-6100
E-mail: nasauttah@yahoo.com

MATERIALS AND METHODS

The Study Area:

Izombe is a town in Oguta Local Government Area of Imo State, Nigeria, located at 5° 38' 0" North, 6° 52' 0" East. It is a predominantly farming community, cultivating crops such as cassava, yam, three-leaf yams, and maize among others. Tree crops produced in the area include oil palm fruits, cocoanuts, breadfruits and pear. The town is traversed by a 10-kilometer stretch of the Njaba River, which is the largest water resource in the area.

Izombe hosts one of the largest onshore oil wells in Nigeria, and a flow station from where a network of oil pipelines emanates, traversing the town. Three major multinational oil companies operate in the community, producing over 70% of total oil from the Oguta area. There is gas flaring in the community which has been reported to negatively affect crop productivity, bringing down the yield (Okezie and Okeke, 1987).

Sampling Aesign:

Cross-sectional sampling was carried out in 1999 on nine clusters of stations, comprised of three clusters of sampling stations upstream of the spill-point, three clusters at spill-point, and three clusters downstream of the spill-point. Each cluster was made up of three perpendicular sampling points across the river. The results as presented in this study are from each of the three clusters of three perpendicular points.

Sampling Methods:

Standard sampling methods were used and these have been elaborated elsewhere (Uttah *et al*., 2008). Plankton net of 55 um mesh-size was used to collect sample of both the phytoplankton and zooplankton. The zooplankton samples were preserved with 5% formalin, while the phytoplankton samples were fixed with two drops of Lugol's iodine before transporting to the laboratory for counting and identification.

Laboratory Studies:

The plankton samples brought from the field were allowed to settle at least overnight. The laboratory method followed a modification of (de Vlaming *et al*, 2006). Each sample was first homogenized, then using a Hensen Stempel pipette; 1 mL aliquots were removed and placed onto a counting chamber. Using a dissecting microscope, the plankton were counted and placed into a vial containing 10% formalin solution for zooplankton, and Lugol's iodine for phytoplankton. This was repeated for 10 times and the mean was used to determine sample abundance, which was then used to determine the plankton density.

The second phase of sample processing was taxonomic identification. Each sample vial was emptied onto the Ward counting wheel, with each taxon being enumerated and recorded on a data sheet. As much as possible, the phytoplankton/ zooplankton were identified down to species level or genus level. To identify specimen to genus or species levels, individuals were removed and slide mounted for observation under a phase contrast compound microscope using standard keys.

Abbreviations:

MDI: Margalef's Diversity Index
SWDI: Shannon Weiner Diversity Index

RESULTS AND DISCUSSION

Phytoplankton Studies:

A total of sixty species of phytoplankton in fifty-five genera were collected. Phytoplankton constituted 62.9% of plankton abundance and 71.4% of plankton species collected. They were in six major taxa categories (see Table 1). These are Bacillariophyceae which made up 46.9% of relative abundance and 31 species or 51.7% of species richness. The predominance of Bacillariophyceae is congruent with results obtained from similar aquatic systems in Nigeria (Egborge, 1974). The dominance of the diatoms in abundance and diversity of phytoplankton in all the sampling stations as observed in this study had been reported elsewhere (Admiraal *et al*. 1994; Kijhler 1994; Tas and Okus, 2007). Hutchinson (1967) described them as the most important members of the freshwater phytoplankton, and are known to predominate in open lotic waters. The issue of species dominance has been a subject of scientific discuss among researchers. Both Edler (1979) and Smayda (1980) are of the opinion that same species dominate in the same waters at the same time year after year. However, different species could dominate in different seasons of the years in the same waters (Tas and Okus, 2007).

Collections from the upstream clusters constituted 59.9% of total phytoplankton abundance, and 78.3% of phytoplankton species richness collected in the study (see Table 2). For the downstream, it was 31.4% and 58.3% respectively; while for the spill-point, it was 8.7% and 18.3% respectively. The same was true for the evenness as measured by the SWDI. The MDI for the upstream was comparable to that of the downstream, and both are significantly higher than the MDI for the spill-point (t-test; $p < 0.05$).

Table 1: Abundance and relative abundance of all Phytoplankton collected from the various clusters pooled together.

Taxa	Abundance	Relative abundance (%)	Species Richness (%)
Bacillariophyceae	97	46.9	31 (51.7)
Chlorophyceae	35	16.9	10 (16.7)
Chrysophyceae	6	2.9	2 (3.3)
Cyanophyceae	46	22.2	12 (20.0)
Dinophyceae	17	8.2	3 (5.0)
Xanthophyceae	6	2.9	2 (3.3)
Total	207	100.0	60 (100.0)

Collections from the upstream clusters constituted 59.9% of total phytoplankton abundance, and 78.3% of phytoplankton species richness collected in the study (see Table 2). For the downstream, it was 31.4% and 58.3% respectively; while for the spill-point, it was 8.7% and 18.3% respectively. The same was true for the evenness as measured by the SWDI.

The MDI for the upstream was comparable to that of the downstream, and both are significantly higher than the MDI for the spill-point ($\times^2$-test; $p < 0.05$). The marked significant difference between the Diversity indices of the spill point and especially the Upstream cluster (Control) may be indicative of occurrence of stress beyond the carrying capacity of the spill-point clusters. Oil is extremely toxic to phytoplankton, especially where concentrations of both oil and plankton tend to accumulate. This observation has been corroborated by some earlier findings in the marine environment that phytoplankton was reduced depending on the oil pollution level in sea water (Tas and Okus, 2007). According to Strickland (1983), crude oils from different locations vary in composition and toxicity, but most of the petroleum products refined for people's use (gasoline, lubricating oil, diesel and home heating fuel) are rich in light fraction, and so are more toxic than plain crude oil. When spilled onto seawater, much of the lighter fraction evaporates, sinks to the bottom, or is decomposed by bacteria, but depending on the conditions (such as wind, waves, and so on,) some of it also dissolves. The invisible dissolved compounds pose the principal threat to plankton. Petroleum hydrocarbons reduce phytoplankton photosynthesis by 36-40% (Tomajka, 1985; Guven *et al*., 2005). Dugdale (1975) described the growth of an algal population as being proportional to the effect of light on photosynthesis (Ryther, 1956; Yentsch, 1974), the concentration of nutrients, and the maximum specific growth rate. Pollutants can affect the relation between growth rate and each of these variables (Walsh, 1978). MacIsaac and Dugdale (1976) demonstrated that reduction of light caused reduction in rate of uptake of ammonia and nitrate by marine phytoplankton. Phytoplankton that are contaminated with oil will affect higher levels of the food chain including the zooplankton.

Table 2: Numerical Abundance and diversity of major taxa of Phytoplankton at the various study stations.

Taxa	Upstream Abund (SR)	Spill-point Abund (SR)	Downstream Abund (SR)
Bacillariophyceae	50 (22)	7 (3)	34 (20)
Chlorophyceae	19 (8)	4 (2)	12 (7)
Chrysophyceae	3(2)	2 (2)	1 (1)
Cyanophyceae	34(11)	4 (3)	14 (5)
Dinophyceae	15(3)	0 (0)	2 (1)
Xanthophyceae	3(1)	1 (1)	2 (1)
Total abundance	124	18	65
Species richness	47	11	35
MGI	9.45	3.46	8.14
SWDI	3.536	2.293	3.443

Zooplankton Studies:

A total of 122 zooplankton specimens in 24 species and 23 genera were collected from the study (see Table 3). In terms of abundance, copepods were predominant representing more than half of the total abundance, and more than a third of the species richness. The copepods dominated in all the sampling points. Copepods are generally known to be dominant members of holoplanktonic crustacea; and are known to be tolerant of wide range salinities and including even conditions that may be described as adverse (Uttah, *et al*., 2008). The zooplankton species composition observed in this study is identical to that of other proximal water bodies of similar size and ecology (Uttah and Uttah, 2009). Copepods are dominant members of the holoplanktonic Crustacea. Studies have shown that crustaceans play important roles in stream and lake food webs (Covich *et al*., 1999).

Table 3: Abundance and relative abundance of all zooplankton collected from the various clusters pooled together.

Taxa	Abundance	Relative abundance (%)	Species Richness (%)
Protozoa	19	15.57	6 (25.0)
Copepoda	63	51.64	9 (37.5)
Rotifera	18	14.75	3 (12.5)
Cladocera	10	8.19	3 (12.5)
Polychaeta larvae	8	6.55	1 (4.2)
Pisces larvae	1	0.81	1 (4.2)
Arthropoda larvae	3	2.46	1 (4.2)
Total	122	100.00	24 (100.0)

Zooplankton abundance from the upstream clusters accounted for 81.1% of overall abundance from the study while 95.8% of the species collected in the study were found in the upstream clusters (see Table 4). The more pollution-sensitive species such as the meroplankton were only found upstream and were totally absent in both downstream and spill-point clusters. Rotifers, the microscopic faunal component living mostly in high quality fresh water, were found only in the upstream and to a less extent in the downstream clusters. Rotifers are good indicators of saprobity, and are now being used as an important aquatic faunal component for bio-monitoring (Prasenjit and Chakraborty, 2006). These scenarios are indications existence of perturbation in the spill-point that is beyond its carrying capacity. Additionally, the MDI and SWDI of the Upstream clusters were comparable to that of the downstream, and both were significantly higher than those of the spill-point clusters ($\times^2$-test; $p < 0.05$). Plankton in an environment that is contaminated with oil will concentrate the oil or its derivations to toxic levels which will affect higher levels of the food chain. Smothering, tainting and concentration of toxic components would affect aquatic organisms especially mollusks in shallow water systems. Molluscs, crustaceans and fishes are all highly susceptible to oil pollution during their juvenile stages. This may explain their marked absence in both spill sampling point and the downstream sampling point. Zooplankton are greatly reduced by oil spills (Miller *et al*., 1978). Toxicity of petroleum components to zooplankton and larvae of animals, especially those of fish have been demonstrated (Walsh, 1978).

Table 4: Numerical Abundance and diversity of major taxa of zooplankton at the various study stations.

Taxa	Upstream	Spill-point	Downstream
Protozoa	18 (5)	0 (0)	1 (1)
Copepoda	47 (9)	5 (3)	11 (6)
Rotifera	15 (3)	0 (0)	3 (2)
Cladocera	7 (3)	0 (0)	3 (2)
Polychaeta larvae	8 (1)	0 (0)	0 (0)
Pisces larvae	1 (1)	0 (0)	0 (0)
Arthropoda larvae	3 (1)	0 (0)	0 (0)
Total abundance	99	5	18
Species richness	23	3	11
MGI	4.80	1.670	3.46
SWDI	2.874	1.330	2.323

Result of analysis of the similarity of species composition between upstream and downstream, using the Index of similarity shows 76% similarity for phytoplankton and 81% for zooplankton (Table 5). This shows that high percentage of species observed in the study were present in both clusters. The result shows that the index of similarity between the spill-point and either the upstream or downstream was quite low, indicating evidence of focalized dislocations in plankton abundance and diversity especially in the spill-point transect (Uttah and Uttah, 2009). This means that a lot of plankton species found in the upstream cluster (control) was missing in the spill-point clusters. This poor Index of similarity was more marked with the upstream clusters than with the downstream clusters.

Table 5: Matrix of Indices of Similarity between the sampling station clusters

	Spill-point	Downstream
Phytoplankton		
Upstream	0.28	0.76
Downstream	0.43	-
Zooplankton		
Upstream	0.30	0.81
Downstream	0.53	-

This may be explained by the fact that impact of an oil spill is expected to be more marked downstream than upstream. Changes in species composition induced by crude oil exposure were the most predictable features of the natural and experimental spills over a very wide range in dose (Miller *et al*., 2004). However, this was not pronounced in this study. The impact of the oil spill was striking in the downstream sampling point, but the effect waned with increasing distance downstream due perhaps to dilution factor. The downstream clusters showed evidence of some form of recovery from the effects of the spill (Bonacina, 2001). This is explained by the relatively high Index of similarity between the Upstream and the downstream clusters.

It must be made clear that the effects of oil on plankton is dependent on myriads of factors such as the type of oil, environmental conditions, and the planktonic communities involved (Varela *et al*., 2006).

Conclusion:

Evidence from phytoplankton and zooplankton do indicate significant but remediable perturbation beyond the carrying capacities of the spill-point transect at the time of study. Being a lotic system with inherent and efficient self-recovery and self-purification mechanisms that maintain her ecological integrity, the Izombe River has shown signs of self-recovery in the downstream area.

REFERENCES

Admiraal, W., L. Breebart, G.M.J. Tubbing, B. Vanzanten, E.D. Deruijter, V. Stevennck, R. Bijkerk, 1994. Seasonal variation in composition and production of planktonic communities in the Lower River Rhine. *Freshwater Biology*, 32: 519-531.

Bonacina, C., 2001. Has Lake Orta completely recovered from its heavy polluted condition? A seventy years long history. Journal of Limnology, 60(2): 285-287.

Chick, J.H., J. Havel, J. Jack, K. Medley, A. Levchuk, 2006. Analysis of EMAP Great Rivers zooplankton data: update and preliminary results. *Abstracts of the Great River Ecosystems Reference Condition Workshop*, January 10-11, Cincinnati, OH.

Covich, A.P., M.A. Palmer, T.A. Crowl, 1999. The Role of Benthic Invertebrate Species in Freshwater Ecosystems Zoobenthic species influence energy flows and nutrient cycling. *Bio-Science*, 49(2): 119-127.

de Vlaming, V., K. Goding, D. Markiewicz, R. Wallace, R. Holmes, 2006. Survey of Zooplankton Community Structure and Abundance in Agriculture-dominated Waterways in the Lower Sacramento River Watershed. California. 69pp. www.zooplankton.1pdf Accessed.

Dublin-Green, C.O., J.N. Nwankwo, D.O. Irechukwu, 1998. *Effective Regulation and Management of HSE issues in the Petroleum Industry in Nigeria*. In proceedings of International conference on Health, Safety and Environment in Oil and Gas exploration and production, Paper No. SPE 40/26. June 7-10, Caracas, Venezula.

Egborge, A.B.M., 1994. *Water Pollution in Nigeria Vol. 1: Biodiversity and Chemistry of Warri River*, (Ben Miller Books Nig. Ltd.) Lagos, Nigeria, pp: 313.

Elder, L., 1979. Phytoplankton succession in the Baltic Sea. *Acta Botanica Fenn.*, 110: 75-78.

Guven, K.C., H.I. Sur, E. Okus, A. Yuksek, S. Unlu, H. Altiok, S. Tas, A.E. Muftuoglu, N. Yilmaz, A. Aslan-Yilmaz, U. Karhan, 2005. Oil pollution of Volgoneft 248 accident. Final Report, Istanbul, Turkey.

Hutchinson, G.E., 1967. *A Treatise on Limnology*. Vol. II. Introduction to lake biology and the limnoplankton. John Wiley & Sons, Inc., New York.

Kohler, J., 1994. Origin and succession of phytoplankton in a river-lake system (Spree, Germany). *Hydrobiol.*, 289: 73-83.

Miller, M.C., V. Alexander, R.J. Barsdate, 1978. The effects of oil spills on phytoplankton in an arctic lake and ponds. *Arctic*, 31(3): 192-218.

Mitrofanova, E., 2008. Indicative significance of phytoplankton for estimation of large river state near cities and settlements (Ob and Tom Rivers as a case study, Russia) *Geophysical Research Abstract* 10: A-00166.

Prasenjit, P., S.K. Chakraborty, 2006. Diversity of zooplanktonic rotifers of rivers Shilabati, West Midnapore district, west Bengal, India. *Aquaculture* 7(1): 1-19.

Quintana, X.D., R. Moreno-Amich, 2002. Phytoplankton composition of Emporda salt marshes, Spain and its response to Freshwater flux regulation. Journal of Coastal Research, 36: 581-590.

Rzanicanin, A., M. Cvijan, J. Krizamic, 2005. Phytoplankton of the Tisa River *Archives of Biological Science*, Belgrade, 57(3): 223-235.

Smayda, T.J. 1980. Phytoplankton species succession. In: Morris, I. (ed) The physiological ecology of phytoplankton. Studies in Ecology, 7: 493-570.

Strickland, R.M., 1983. The Fertile Fjord-Plankton in Puget Sound. http://www.wsg.washington.edu/communications/online/fjord/index.html. Accessed 30th July, 2012.

Tomajka, J., 1985. The influence of petroleum hydrocarbons on the primary production of the Danube River plankton. *Acta Hydrochim Hydrobiologi*, 13: 615-618.

Tas, S., E. Okus, 2007. Effects of oil pollution on the phytoplankton community in the kucukcekmece bay, north-eastern Sea of Marmara, Turkey. *Rapp. Comm. int. Mer Medit.*, 38: 320.

Uttah, E.C., C. Uttah, 2009. Biotic assessors of environmental integrity in an area hosting oil exploratory activities in the Niger Delta, Nigeria. *Environmental Analar*, 13: 1555-1558.

Uttah, E.C., C. Uttah, P.N. Akpan, E.M. Ikpeme, J. Asor, 2008. Bio-survey of Plankton as indicators of water quality for recreational activities in Calabar River, Nigeria, Journal of Applied Science & Environmental Management, 12(2): 35-42.

Varela, M., A. Bode, J. Lorenzo, T.A. lvarez-Ossorio, A. Miranda, T. Patrocinio, R. Anado´n, L. Viesca, N. Rodrı´guez, L. Valde´s, J. Cabal, A. Urrutia, C. Garcı´a-Soto, M. Rodrı´guez, A.N. Anto´n, F. lvarez-Salgado, S. Groom, 2006. The effect of the ''Prestige'' oil spill on the plankton of the N–NW Spanish coast. Marine Pollution Bulletin, 53: 272-286.

Walsh, G.E., 1978. Toxic Effects of Pollutants on Plankton. In: Butler, G.C. ed. Principles of Ecotoxicology. John Wiley & Sons, New York. pp: 335.

Zabbey, N., 2004. Impacts of extractive industries on the biodiversity of the Niger delta region, Nigeria. Paper presented at a 3-Day National Workshop on Coastal and Marine Biodiversity Management, Held at Pyramid Hotel, September 7-9, Calabar, Nigeria.