JASEM ISSN 1119-8362
All rights reserved

Available Online at
http:// www.bioline.org.br/ja

J. Appl. Sci. Environ. Mgt. 2004
Vol. 8 (2) 71 - 75

Short Communication

Aquatic Oil Pollution Impact Indicators

[1]ENUJIUGHA, V N; [2] *NWANNA, L C

1. Dept. of Crop Production
2. Dept. of Fisheries and Wildlife
Federal University of Technology, P. M. B. 704, Akure, Nigeria.

ABSRTACT: Aquatic oil pollution impact indicators such as oil-grease, low dissolved oxygen concentration, increased biochemical oxygen demand, increased water temperature and acidity of the water are associated with aquatic habitat degradation, reduced productivity and or loss of biodiversity. These impact indicators are interrelated and connected in a chain reaction that a severe shift in any of the parameters will induce negative changes in others. For instance, introduction of significant quantities of crude oil into the aquatic ecosystem will cause increase in biochemical oxygen demand, reduction in dissolved oxygen concentration, increased temperature and pH of the water body. The resultant effect of these abnormal shifts in the impact indicators is disorders in the physiological status and reduction in the immune status of aquatic organisms, which may lead to mortality. Therefore to ensure sustainable management and optimum exploitation of the aquatic resources, it is necessary to set safe limits for the pollution impact indicators. This paper reviews the deleterious impacts of these indicators on the aquatic habitat and productivity, and establishes the safe limits for each impact indicator in relation to the freshwater, brackish water and marine ecosystems. @JASEM

The study of the environment and the impacts of human activities on natural ecosystems has recently assumed a worldwide focus. Obviously, man's constant quest to fully utilize the product of the environment has led to the production of wastes in such proportions as to threaten the very existence of certain strategic ecological habitats and directly or indirectly affects human population. According to Sheehan *et al*. (1984), releases into the environment of persistent chemicals lead to an exposure level which ultimately depends on the time the chemical remains in circulation, and how many times it is circulated in some sense, before ultimate removal.

Spills are uncontrolled releases of any product including crude oil, chemicals or waste caused by equipment failure, operation mishaps, human error or intentional damage to facilities. The extent of damage depends on what, where and how much has been spilled and how long it remains in the immediate and impacted environment (SPDC, 1997). High inertia and elasticity are properties expected of a physically and chemically varying ecosystem with an extensive history of pollutant stress. In the case of crude oil releases, especially where the recipient environment is aquatic, the impacts are in the range of unquantifiable damages to fishes and other economically important aquatic organisms, as well as the direct and indirect negative effects on the socio-economic lives of human settlers whose survival has much to do with the products of aquatic environment.

The problems of point oil spills remain a serious concern. By point oil spills reference is made to occasions when a significant amount of a chemical (in this case, hydrocarbons) has entered in ecosystem at a point (in both space and time) and effects of contamination are expected in a well-defined more or less local area (Sheehan *et al.*, 1984). The assumption is that the oil does not rapidly diffuse away, but remains in the immediate vicinity at a noticeably high concentration, or perhaps moves, but in such a way that levels remain high as it moves.

Apart from uncontrolled oil spills, production operations inevitably release effluent in the form of produced waters, storm waters and flushing wastes into the aquatic environment and these are found to contain significant quantities of hydrocarbons and associated pollutants. For instance, a major crude oil terminal in the Niger Delta was found to empty its effluent directly into the brackish waters of Warri River with hydrocarbon content of the effluent being well over the permissible limit for such environment (SEEMS, 1997).

The question that immediately probes one's mind is: How do we predict both the volume of oil pollution and the obvious environmental impacts by some measurable parameters, and how do we set limits for these parameters with respect to the different aquatic environments? Then also one is faced with the question of how the environmental performance of oil industry operators can be assessed and adequately improved upon. This paper seeks to address these questions, especially as it concerns the oil industry in Nigeria. Commendably the Federal Environmental Protection Agency (FEPA) and the Department of Petroleum Resources (DPR) have

*Corresponding author

recently come up with guidelines for evaluation of environmental performance.

The Choice of Major Pollution Impact Indicators: The first thing that comes to mind in the selection of major aquatic oil pollution impact indicators is an understanding of those environmental attributes which influence the survival of aquatic life, such that a shift in the ecosystem balance and biodiversity usually results from an alteration in their measurable proportions. Obviously, the boundaries of natural ecosystem are determined by the environment, that is, by what forms of life can be sustained by prevailing environmental conditions. In this light the choice of parameters has to do with maximum productivity of fish and other aquatic life as well as the well-being of human dwellers and their farmlands in cases where flooding are witnessed or recorded.

According to Damaskos and Papadopoulos (1983), the generally accepted indicators of water quality are dissolved oxygen (DO) and the biochemical oxygen demand (BOD). High oxygen depletion can be so severe as to affect fish life. If the DO value falls below the minimum oxygen requirement for the particular species of fish, they are subjected to stress, which can result in mortality. The oxygen content of natural waters varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure. Chapman and Kimstach (1992) noted that DO concentrations below 5mg/1 adversely affect the functioning and survival of biological communities, and below 2 mg/1 may lead to the death of most fish. The optimum concentration of DO for fish and other aquatic life is given in Table 1.

Table 1: Optimum environmental conditions for fish and aquatic life.

Environmental Parameter	Optimum value/range
Dissolved oxygen (DO)	5 – 7 mg/1
Biochemical oxygen demand (BOD)	10 – 20 mg/1
PH	6.0 – 9.0
Temperature	9 – 34^{O} C
Total dissolved solids (TDS)	1,600mg/l
Copper	0.1mg/1

Sources: Chapman and Kimstach (1992); Chatopadhyay et al. (1988)

The BOD is estimated by the amount of oxygen required for the aerobic microorganisms (in the case of oil pollution, hydrocarbon degraders) present in the water body to oxidize the organic matter to a stable inorganic form. Thus, when we say that a water body has a BOD value of đ mg/1 we mean that the concentration of biodegradable organic matter in one litre of it is such that the micro-organisms need đ mg of oxygen in order to be able to oxidize it. The result of a study carried out by Chattopadhyay *et al*. (1988) indicated 10 – 20 mg/1 as the optimum BOD range for fish culture in effluent or polluted waters. The addition of significant quantities of crude oil to any water body causes an immediate rise in the BOD due to the activities of hydrocarbon degraders and the blockade of oxygen dissolution.

Changes in pH (or the hydrogen ion activity) can indicate the presence of certain pollutants, particularly when continuously measured and recorded, together with the conductivity of a water body. The pH of 1 unit could result in an increase of lead by a factor of 2.1 in the blood of an exposed organism (Sheehan *et al.*, 1984). What is known, of course, is that pH changes can drastically affect the structure and function of the ecosystem, both directly and indirectly by, for example, increasing the concentration of heavy metals in the water through increased leaching from sediments. Helz *et al.* (1975) found out that cadmium, which is toxic to many organisms, could be readily remobilized from sediments.

It is important to note that the pH of any water body is dependent on its temperature. And temperature affects physical, chemical and biological processes in water bodies and, therefore, the concentration of many variables. According to Chapman and Kimstach (1992), increased temperature increases the rate of chemical reactions and decreases the solubility of gases (especially oxygen) in water. Respiration rates of aquatic organisms increase leading to increased oxygen consumption and increased decomposition of organic matter.

Crude oil is associated with some toxic heavy metals most of which contaminate the oil through underground deposits, especially lead and chromium. Iron is in great abundance in tropical and subtropical aquifers and is also associated with crude oil deposits. High iron concentrations in groundwater are widely reported from developing countries, where iron is often an important water quality issue. Some metals also get into oil due to pipeline ageing and corrosion. Metal-induced depression of productivity most certainly occurs and may persist in polluted aquatic systems. Certain organisms have been shown to have some ability to regulate levels of copper and zinc in muscle (Sheehan *et al.*, 1984). However, bioaccumulation of metals such as lead and chromium by fish is expected, and this spells danger to the human populations consuming such fish. Results obtained by Rai and Chandra (1992) show marked accumulation of copper, manganese, lead, and iron by the alga *Hydrodictyon reticulatum* under both field and laboratory conditions. Fish usually preys upon algae and other planktonic and benthic organisms; and when there is bioaccumulation of heavy metals in fish, there is likelihood of morbidity and mortality in man along the food chain. Usually bioaccumulation of toxic metals can occur to certain extent before chronic-effects thresholds are reached.

An important indicator of significance in aquatic oil pollution monitoring and control is the actual volume of oil released, which is approximated by the milligrams of oil in a litre of the water. Oil pollution, apart from causing depletion of oxygen and suffocation of aquatic species, affects plants and cultivated crops in lowland areas characterized by seasonal flooding. Ilangovan and Vivekanandan (1992) working with blackgram *(Vigna mungo)* concluded that oil pollution in soil might deplete oxygen at the rhizosphere because of possible depletion of soil oxygen by hydrocarbon-degrading micro-organisms and, therefore, oil polluted soil directly affects the overall physiology of the plant as evidenced by lower levels of macro and micro-biomolecules of the plant as well as polarity, thereby reducing plant growth. According to these workers, as a result of continuous aqueous oil effluent irrigation in about 25 acres of crop field, oil compounds infiltrated up to 50cm depth of the soil. Also total phenolic content of the leaves in the plant increased significantly.

Limits of Major Indicators for the Freshwater Environment:

The activities of major oil field operators, especially in Nigeria, are such that unavoidable hydrocarbon releases into the immediate environment are expected. This is particularly the case in flowstations, gas plants and compressor stations where effluent are generated during normal production operations. Facilities located in inland areas, especially environments characterized by seasonal flooding, contribute immensely to environmental degradation thereby endangering both aquatic life and human settlers within the vicinity. Oil spillage obviously decreases aquatic productivity and impacts negatively on the economic and social lives of local fishermen. DPR (1991) has outlined a set of standards/limits of some major oil pollution impact indicators in oilfield effluent released into freshwater environments. The limits for physico-chemical parameters and mineral concentrations are presented in Tables 2 and 3.

Table 2: The DPR Limits of major physico-chemical parameters in effluent inputs into freshwater and marine environment.

Parameter	**Freshwater**	**Marine**
PH	6.5 – 8.5	
Temperature (^{O} C)	35	35
Salinity (mg/1)	600	2,000
Oil and Grease (mg/1)	10	20
Turbidity (NTU)	10	15
BOD (mg/1)	2,000	
TSS (mg/1)	30	50

Source: DPR (1991)

Table 3: DPR Limits for Heavy metal concentrations in fresh water environments.

Parameter	**Concentration (mg/1)**
Lead	0.05
Iron	1.5
Copper	1.0
Zinc	1.0
Chromium	0.03

Source: DPR (1991)

And relative to the volume of oil pollution in the immediate and nearby environments, these parameters usually reveal impact magnitude by the degree of deviations in their measured values from set limits.

Examining the oil-grease input into the environment and comparing with DPR limit of 10 mg/1 can easily assess the environmental performance of oilfield operators in the inland areas. Figure 1 shows the oil-grease content of a flowstation effluent in the Niger Delta determined over a one-year period (December 1995 – November 1996). The presentation which is adapted from SEEMS (1997) show that produced waters as point sources have their compositions affected by factors other than separator efficiency. For instance, the percentage of lift-gas applied for oil-water separation may largely depend on the subjective assessment by production personnel.

It is expected that substantial dilution of the effluent will occur to such as extent that the recipient freshwaters when examined will conform to World Health Organization (WHO) standard. For example the WHO turbidity limit for freshwaters is 5 NTU (Chapman and Kimstach, 1992). Heavy metal content is also greatly reduced by algal growth. Of course, algae are know to concentrate many trace metals in their tissues, and as the algae die and sink, their metal content may be carried down to the sediments. However, the danger is in the consumption of the algae by fish which accumulate them to levels toxic to man.

Limits Of Impact Indicators In Estuarine And Marine Environments

The brackish water and marine environments are generally characterized by high salinities, total solids and temperatures compared to freshwaters. Whenever there is a spill or oil influx into such environments, the main concern must be the volume of oil spilled as well as turbidity and suspended solids content. Heavy metal composition is of lesser interest, as sea waters are known to contain trace metals in significant concentrations (Helz *et al.*, 1975).

DPR (1991) gave limits of some important physico-chemical parameters for anthropogenic inputs into estuarine and marine environments in Table 2. The maximum allowable oil-grease concentration is 20 mg/1 for effluent released into offshore environment. This is only for produced waters, especially for facilities in swamp locations. These are of course controlled releases, and do not include well flushing and equipment repair/maintenance waste waters.

Seawater salinities above 2,000 mg/1 show clearly the presence of pollutants which may impact estuarine fish species. Biodiversity sustainability is of utmost importance as a shift in ecosystem balance may result in stress and depression of certain susceptible species. It is important to note that for every salinity value of 35,000 mg/1, the sodium content is 10,770 mg/1 with sodium/salinity ratio put at 1:3.26 (SEEMS, 1997). This means that high salinity might not be favourable for aquatic life.

Conclusion: We have examined the important indices for evaluating the severity or otherwise of aquatic oil pollution impact. The choice of these variables is found to be governed by the consideration of aquatic productivity and socio-economic life of human settlers. The limits for anthropogenic or controlled effluent inputs have been assessed both for freshwater and estuarine/marine environments. From the foregoing, a conclusion can be drawn that regular environmental performance evaluation of oilfield activities must be the hallmark of any meaningful environmental policy. Continuous effluent monitoring and environmental evaluation are needful, as even the controlled inputs into the environment are not consistent in their composition of important parameters. Regulatory agencies such as the Federal Environment Protection Agency (FEPA) and the Department of Petroleum Resources (DPR) have a task of seeing to the implementation of environment–friendly progrmames by the oilfield operators.

REFRENCES

Chapman, D; Kimstach, V.(1992), The Selection of Water Quality Variable In: Water Quality Assessments(Chapman, D. Ed.) Chapman and Hall Ltd., London pp. 51-119

Chattopadhyay, G N; Saha, PK; Gosh, A; Karmakar H C (1988), A Study on Optimun BOD Levels for Fish Culture in Wastewater Ponds. Biological Wastes, 25(2), 79-85.

Damaskos, S. D. and Papadopoulos, A. S. (1983); A General Stochastic Model for Predicting BOD and DO in Streams. International Journal of Environmental Studies, 21(2), 229 – 237.

DPR (1991); Guidelines and Standards for Petroleum Industry in Nigeria. The Department of Petroleum Resources, The Federal Ministry of Petroleum and Mineral Resources.

Helz, G. R., Hugget, R. J. and Hill, J. M. (1975); Behaviour of Mn, Fe, Cu, Zn, Cd, and Pb Discharged from a Wastewater Treatment Plant into an Estuarine Environment. Water Research, 9, 631 – 636

Ilangovan, K and Vivekanandan, M. (1992); Effects of oil Pollution on Soil Respiration and Growth of

Vigna mungo (L.) Hepper. The science of the Total Environment, 116 (1/2), 182 – 194

Rai, U. N. and Chandra, P. (1992), Accumulation of Copper, Lead, Managanese and Iron by Field Populations of Hydrodictyon reticulatum (Linn..) Lagerheim. The Science of the Total Environment; 116 (3), 203 – 211

SEEMS (1997); Report on Aqueous Effluent Monitoring. Submitted to shell Petroleum Development Company (West), 60p.

Sheehan, P.J., Miller, D.R., Butler, G.C., Bourdeau P. and Ridgeway, J.M. (1984); Effects of Pollutants at Ecosystem Level. Scientific Committee on Problems of the Environment (SCOPE) No. 22. John Wiley and Sons, Chichester, 443 pp

SPDC (1997); Annual Report for 1996. The shell Petroleum Development Company.