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TAR BALLS MONITORING - A CLASSICAL TOOL FOR THE ASSESSMENT AND EVALUATION OF MARINE POLLUTION BY PETROLEUM.

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ABSTRACT:

The Nigerian coastal waters and beaches have been subjected to the impact of organic and inorganic pollutants for some years now. Principally is the ubiquity of petroleum residues (tar balls) on the beaches. Concentrations of stranded tar balls have been employed here to assess the extent of beach pollution, temporal and spatial changes and the dynamics of tar distribution over a 4-year period (1985 to 1989, 1987 exclusive) along Ibeno – Okposo beach, Nigeria. Littoral observations showed that only wind and precipitation influenced the amount of tar on the beach. Based on these findings, an empirical formula (oil spill formula) has been proposed to estimate the total amount of oil in water after the occurrence of an accidental spill along the Nigerian coastline.

KEY WORDS: Tar balls, marine pollution assessment, oil spill formula, Nigeria.

INTRODUCTION:

Environmental pollution arising from the presence of oil and petroleum residues in the marine environment poses a serious threat to marine fauna and flora as well as the surrounding coast line. The ecological consequences of these pollutants include damage to animal life, direct or indirect losses in fisheries and impairment of the recreational values of beaches among others. Though the developed countries are providing some answers to most of these problems, activities in the developing countries have been very minimal.

Crude oil and its derivatives on entering the marine environment is immediately dispersed into different regions: the sea surface micro-layer, evaporation into the atmosphere, dissolution of soluble fraction into the upper water column and adsorption by sediments (Wheeler, 1978). The Nigerian coastline covering about 800km of the Atlantic coast has adjoining offshore and onshore oilfields. Despite the economic gains derived from the export of crude oil, sporadic oil spills and oil production/and refinery activities have contributed immensely to the continuous presence and increasing levels of petroleum hydrocarbons in the marine environment.

Oil spills have been recorded worldwide such as Torrey Canyon spill in 1967 discharging 700,000 billion barrels (bbls) into the environment, Amoco Cadiz in 1978 with an estimated discharge of 1.5 million bbls and Exxon Valdez in 1989 (260,000 bbls). In Nigeria, oil spill incidents include Funiwa –5 well blow out in 1980 during which about 400,000 bbls of crude oil was spilled, Oyakama oil spill in 1980 where 30,000 bbls of oil was discharged, the Oshika oil spill in 1993 releasing about 10,000 bbls into the environment and recently the discharge of 40,000 bbls of oil resulting from pipeline rupture belonging to Mobil Producing in January, 1998.

Oil films on the water surface is generally nauseating and invokes public reaction in the coastal communities where-ever it occurs. Scientifically, it reduces primary production, impairs vision, produces water coloration, causes fish tainting and cloggs the gills of fish and fishing gears. Additionally, floating particulates (tarry residues) contribute to increased turbidity of aquatic system. Such turbidity caused by floating tars (particulate hydrocarbon) can be highly dangerous since juvenile fish can ingest them directly as food. Their presence can lead to high total suspended load of the aquatic system. Settling of particulates by gravity to the bottom can also smoother benthic organisms.

This report assesses the extent of contamination of the beach by petroleum residues for a four-year period (1985-1989, 1987 exclusive). Such studies are indeed useful in predicting the dynamics of tar distribution, temporal and spatial trends and the vulnerability of littoral zone to the impact of tar. The information obtained can also be useful to the oil producing companies so that all efforts at achieving economic utilisation of the oil resources shall simultaneously contribute to the optimum protection of the environment.

THE STUDY AREA:

The Ibeno-Okposo beach is located in the South-eastern region of Nigeria about a 35 km long. It is found between a latitude $4^0\ 32^1$ and $4^0\ 36^1$ N and longitude $8^0\ 00^1$ and $8^0\ 16^1$E and flanked on the east by Cross river estuary and on the west by Qua Iboe river estuary (Asuquo ,1991). The beach is flat (low gradient) and composed of fine grain sand (Asuquo, 1994). A detailed study of the Ibeno beach showed that beach morphology changed within short distances of about 50-100 metres along shore with changes in breaker wave types resulting in changes in the amount of oil particulates deposited on the beach face (Nyong and Antia, 1985). The low profile of the sandy beach enhances predominantly spilling breaker waves with the most prevailing wind being offshore (Asuquo, 1991).

The intertidal (littoral) zone is the most visible portion of the marine environment during low tide. Stranded tar balls can be seen clearly where they have been deposited by the swash action of waves. They are usually found alongside with oceanic debris accumulating parallel to the water line. Tar on the beach reduces the recreational values of the beach and hinders its use for tourism. It is locally referred to as "Mbabak Inyang" (sea gum) because of its sticky tendency to any object it contacts with. Tar gums the soles of shoes and stains the clothes of tourist. The toxicological effects of tar on humans and organisms have not yet been fully understood. But the aromatic component is highly toxic, thus posing a potential health risk if ingested (Ehrhardt ,1972).

METHOD:

The methods of tar monitoring have been described previously (Asuquo, 1991). It involved marking a 1-m transect and fixing the position with the aid of two 5-m calibrated staff. The length of the transect from the water line to the backshore was noted. All visible tar on the surface and 2 cm below the sandy surface was handpicked into light cellophane bags marked TB-1, indicating tar balls from transect 1. The tars collected were washed with clean water in the laboratory and air-dried over-night at room temperature. The amount of tar deposited was quantified by gravimetry, calculations and documentation of data followed the method described in IOC Manual and Guides No. 12 (UNESCO ,1984).

RESULTS AND DISCUSSION:

Tar balls are ubiquitous in the marine environment . They originate mainly from fossil hydrocarbon sources (principally oil spills) which may be from point or non-point sources (Table 1).

Table 1. Point and non-point sources of fossil hydrocarbons in the Nigerian environment.

POINT SOURCES	% Comp.*	NON-POINT SOURCES	% Comp*
Sabotage	27.80	Offshore production/accidents	4.2
Engineering error/human	12.0	Third party	2.5
Oil Pipe line leakages	47.2	Losses during fueling of motorised boats/sand cuts	2.0
Domestic heating and forest fires	0.02	Accidents involving ships carrying oil	0.001
-	-	Runoff from fluvial discharge	4.1
(Unknown)	-	Incomplete combustion of oil	
-		Atmosphere input (gas flaring)	0.18
-		Deep sea oil seepages	

* Percentage composition (%) estimates are modified from Asuquo (1994).

The relative magnitudes of these sources indicate that oil pipeline leakages/equipment failure contributed the highest percentage (47.2%) followed by production error(12.0%). On the whole, point sources contributed 67.9% of total hydrocarbon input while only 32.1% originated from non-point sources (Table 1). Physical, photo-chemical (auto-oxidation) and microbiological processes transform spilled petroleum into tarry residues.

The results on tar concentrations obtained during the period were 1985, 0.40 - 2.84 gm/m^2/transect (ts) and 0.06 - 3.75 gm/m^2/month (mth) ; 1986, 0.02 - 3.16 gm/m^2/ts and 0.03 - 1.86 gm/m^2/mth; 1988, 0.03 - 0.77 gm/m^2/ts and 0.04 - 1.39 gm/m^2/mth and in 1989, 0.04 - 3.10 gm/m^2/ts and 0.02-5.46 gm/m^2/mth. Comparatively, the highest concentration of tar was observed in 1989 (5.46 gm/m^2) and the yearly distribution of tar followed the sequence:

1988 < 1986 < 1985 < 1989

During the period, the mean concentrations of tar and the ranges of oceanographic factors monitored are presented in Table 2.

Table 2: The levels of oceangraphic factors measured during the study period (1985 - 1989).

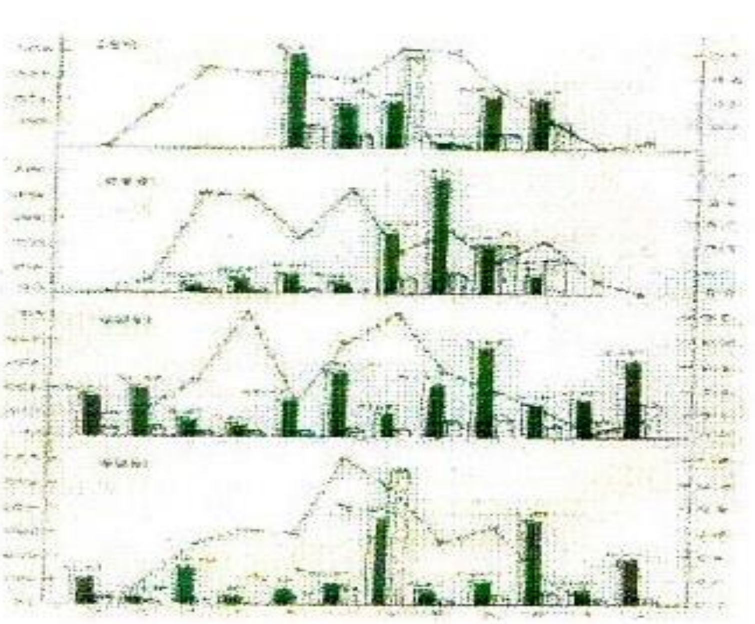
PARAMETER	1985	1986	1988	1989
Windspeed (m/Sec)	0.34-1.73	1.68-5.20	1.76-4.68	1.81-4.31
Longshore current velocity (m/Sec)	0.26-0.54	0.16-0.32	0.12-0.34	0.14-0.29
Prevailing wind	Offshore	Onshore	Offshore	Offshore
Dominant Breaker wave	Spilling	Spilling	Spilling	Spilling
Water Temperature (^{0}C)	ND	ND	28.3-32.0	26.3-31.4
*Total rainfall (mm)	0-407.5	0-434.3	18-517.6	0.1-602.4

* Data obtained from the Department of Geography, University of Calabar.

ND - Not determined.

The spatial distribution and amount of tar balls per unit beach area per month (g/m^2/mo) and per unit beach area per transect (g/m^2/transect (TR)) along Ibeno-Okposo beach are shown in Fig. 1. The symbol TR above open columns represent transects with the highest level of tar per month. The firm continuos lines indicate the variation of total monthly rainfall (precipitation) with tar during the period. The columns for March 1985 and 1986 represent accumulated concentration of tar balls for 3 months as no sampling was carried out during the preceding months.

Fig. 1

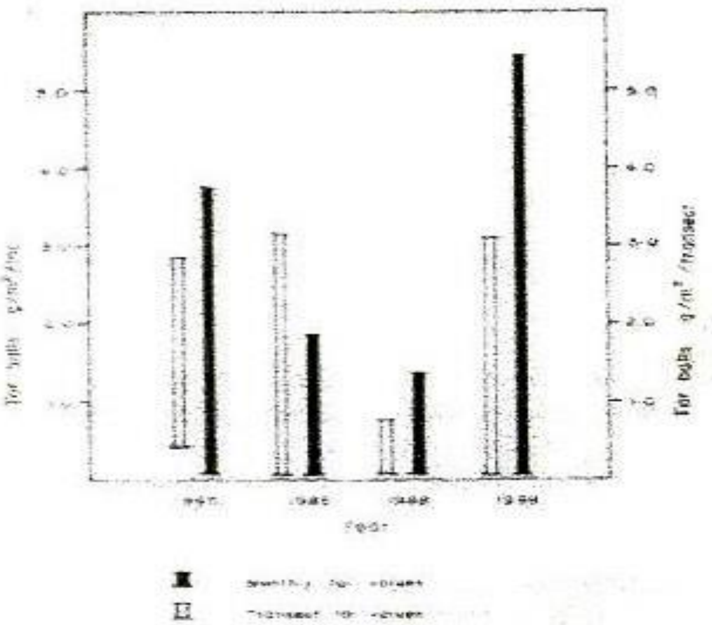


From this study, the highest concentrations of tar balls (3.75 and 5.46 g/m^2) were obtained in June 1985 and June 1989(wet season). Though relatively high when compared to tar concentrations in 1986 and 1988, the observed tar levels are low considering the amount of tar reported from Badagry (Lagos) beach (Okonya and Ibe, 1985) along the same coastline. The observed difference is due to a change in the morphology of the beaches. For instance, Ibeno/Okposo beach is characterised by fine sand and hard-packed foreshore with a flat profile. Consequently, considerable amount of energy is dissipated during wave breaking processes leaving little energy for the transportation of the tar particulates to the shore, resulting in the low level of tar. On the other hand, Badagry beach is composed of coarse sand with steep profiles (Nyong and Ntia, 1985). This topography enhances the retentive capacity of the beach to accumulate stranded tar particulates thereby contributing to the high level of tar.

The highest tar concentrations recorded in June 1985 and June 1989 correspond to the highest total rainfall of 407.5 mm and 470.2 mm respectively. The results show that tar concentration increased with precipitation contrary to previous observation that rainfall only aids the disappearance of tar (Odu, 1981). The increased tar levels could have originated from tars added from the washing and erosion of beach surfaces which exposes already buried tar in sediments. Most of the tars obtained during the period were collected between surface and 2cm beneath subsurface. Comparatively, low level of tar (< 1.0 gm/m^2) was observed in the dry season (October – March) than in the wet season (> 1.5 gm/m^2, April – Sept).

It was observed that high sunshine accelerated the melting of tar balls during the dry season and most of the tars were found in the molten state. Tarry residues collected in the wet season were highly weathered, turgid and of stable physical structure. Wind speed and precipitation varied directly with the level of tar balls ($r = 0.78$ and $r = 0.55$ at $P < 0.05$). Temperature showed no significant relationship ($P > 0.05$) with tar and there was no definite trend established between longshore current velocity and tar concentration (Asuquo , in preparation).

Figure 2:



A plot of the range of maximum yearly tar values (Fig. 2) illustrates the patterns of variability of tar balls during the 4-year period. The unshaded bars represent the transect mean tar concentrations. Tar levels decreased from 1985 to 1988 and increased sharply in 1989. The apparent cause for the decrease is contributed by the drop in the world oil market prices that reduced the quantity of crude oil export and the volume of oil tanker traffic which has been identified as the greatest contributor (34.9%) of spilled oil in the marine environment (Wheeler, 1978). The very low value obtained in 1988 is attributed to spills from minor sources as there were no reports of major spills within the region (Asuquo, 1991).

An estimate of the amount or quantity of spilled oil after several hours of incident can be obtained if the concentration of oil per litre of water is calculated and the effect of prevailing wind and precipitation is assumed to be at a minimum. At a steady state, the percentage of hydrocarbons (%THC) extracted from one litre of surface water is proportional to quantity of oil spilled (Qsp) assuming that at least 1ml out of every 100mls is lost through evaporation (Vep). Then,

$$\%THC \ \alpha \ Qsp \quad \text{(at steady state)}$$

Mathematically,

$$\%THC = \frac{Qsp + Vep}{T \ . \ 10^6}$$

Where T = time elapsed after spill incident
10^6 = millions of barrel of oil

Then,

$$Qsp + Vep = \%THC \ . \ T \ . \ 10^6$$

Therefore,

$$\mathbf{Qsp = (\%THC \ . \ T \ . \ 10^6) - Vep}$$

Where $\%THC = \frac{Vex \ . \ 100}{\text{Volume of water}}$

Vep = 0.01 (constant)

Vex = amount of extracted hydrocarbon (gm) from 1 liter of surface water

Thus the quantity of spilled oil (Qsp) after hours of incident is the product of the percentage concentration of extract with the time elapsed (T) minus volatile hydrocarbons lost through evaporation (Vep) expressed as millions of barrel (bbls) of oil. Thus the degree of impact can be projected based on the above expression.

For instance, considering a particular incident where the mean concentration of extracted total hydrocarbon (Vex) was obtained to be 278 mg after 4hours of oil spill , the Qsp shall be 111.2 mbls (actual value is 111.16 after subtracting amount lost by evaporation).

CONCLUSION:

Tar balls are directly generated from spilled petroleum in water. The trend in tar concentration during the 4 years presented here is an example of the extent to which our coastal environment has been impacted by petroleum. Thus, monitoring of tar residues by the rate of accumulation and dispersion can provide sufficient data and information that are used in establishing the extent of pollution, spatial and temporal variability (seasonal changes) and in predicting the period of highest contamination of beaches by tar. Such an assessment facilitates the understanding of the basic environmental factors responsible for the transportation and distribution of tar since these factors are usually measured simultaneously with tar concentration. Thus, tar pollution of different beaches or regions can be compared. Tar balls collected during quantitative assessment can be used to determine the origin of the pollutant since they may emanate from similar or different sources (Asuquo et al 1996).

Time-series monitoring of tar provides the information and data on the trends in the abundance and distribution of tar. Any enhanced level could be easily detected. Such valuable information could be utilised in the planning and management of our coastal resources. Secondly, an estimate of the amount of spilled oil that could be transformed into tarry residues can be obtained if the relative knowledge of prevalent environmental factors and the amount of extracted oil in water is known.

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