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Aspects of Aquatic Pollution in Nigeria

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Abstract: Water pollution is a major problem in the global context. Yet aquatic resources consists of extremely wide range of floral and fauna resources which offer a broad array of goods with potential utilitarian application in agriculture, innovative industry and the pharmaceutical industry which renders valuable benefits and services. The slow poisoning of the waters is witnessed in Nigeria and the destruction of vegetation and agricultural land by oil spills which occur during petroleum operations. But since the inception of the oil industry in Nigeria, more than twenty-five years ago, there has been no concerned and effective effort on the part of the government, let alone the oil operators, to control environmental problems associated with the industry'. The article reviews the meaning of water pollution, water pollution categories, point source pollution, non-point source pollution, ground water pollution, causes of water pollution, pathogens, chemicals and other contaminants, thermal pollution, transport and chemical reactions of pollution, measurement of pollution, sampling, physical testing, chemical testing, biological testing, control of water pollution, domestic sewage, industrial waste water, agricultural waste water, construction site storm water urban runoff(storm water), radiation pollution, the Federal Environmental Protection Agency, The National Policy on Environment, The national environmental reference laboratory, Water resources management, Strategies under the National Policy on Environment, Industrial water pollution control programme, Industrial effluent standards to provide some information on the Nigeria situation.

Key words: Causes, control, effects, fate, Government policies, Nigeria, types, water pollution

INTRODUCTION

Human and industrial activities result in the discharge of various pollutants in to the aquatic environment threatening the health of the population and damaging the quality of the environment by rendering water bodies unsuitable (Abowei and Sikoki, 2005). Yet aquatic resources consists of extremely wide range of flora and fauna resources which offer a broad array of goods with potential utilitarian application in agriculture, innovative industry and the pharmaceutical industry which renders valuable benefits and services. Aquatic environment also provides food and shelter for fishes, crustacean s, mollusks, sea turtles, whales, crocodiles and nutrient supplies for economically important fish species (Zabadal *et al*., 2005). It must be apparent that without a rigorous programme of regulation and control of aquatic pollution and mismanagement of aquatic resources, all the criteria and standards will protect the quality of the aquatic environment. But it will also be clear that if a pollution control programme is to be effective, and if maximum benefit is o be realized with a given expenditure, well found and comprehensive criteria must be available (Young and Haveman, 1985).

Water pollution is a major problem in the global context (Yang and Yongguan, 2004). It has been suggested that it is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily (World Bank, 1990). An estimated 700 million Indians have no access to a proper toilet, and 1,000 Indian children die of diarrheal sickness every day. Some 90% of China's cities suffer from some degree of water pollution, and nearly 500 million people lack access to safe drinking water. In addition to the acute problems of water pollution in developing countries, industrialized countries continue to struggle with pollution problems as well (Sanchez-Choliz and Duarte, 2005). In the most recent national report on water quality in the United States, 45% of assessed stream miles, 47% of assessed lake acres, and 32% of assessed bay and estuarine square miles were classified as polluted (Roy *et al*., 2003).

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, like serving as drinking water, and/or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish. Natural phenomena such as volcanoes, algae blooms, storms, and

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earthquakes also cause major changes in water quality and the ecological status of water (Farid, 2002).

Nigeria is located approximately between latitude 4º and 14º North of the Equator, and between longitudes 2º2′ and 14º30′ East of the Greenwich meridian. It is bordered to the north by the Republics of Niger and Chad, to the south by the Atlantic Ocean, to the east by the Republic of Cameroon and to the west by the Republic of Benin. The population is more than 100 million, spread unevenly over a national territory of 923,770 km^2. Nigeria has the eighth largest national population in the world and about a quarter of the total population of all the countries in Sub-Sahara Africa. The climate, which affects the quality and quantity of the country's water resources, results from the influence of two main wind systems: the moist, relatively cool, monsoon wind which blows from the south-west across the Atlantic Ocean towards the country and brings rainfall, and the hot, dry, dust-laden Harmattan wind which blows from the north-east across the Sahara desert with its accompanying dry weather and dust-laden air. The mean temperature is generally between 25 and 30ºC (77 and 86ºF), althoughbecause of the moderating influence of the sea the mean daily and annual maximum temperatures increase from the coast towards the interior. In the dry season the temperatures are more extreme, ranging between 20 and 30ºC (68 and 86ºF) (FGN, 1993).

The Department of Petroleum Resources estimated 1.89 million barrels of petroleum were spilled into the Niger Delta between 1976 and 1996 out of a total of 2.4 million barrels[2] spilled in 4,835 incidents (approximately 220 thousand cubic metres). The Nigerian National Petroleum Corporation places the quantity of petroleum jettisoned into the environment yearly at 2,300 cubic metres with an average of 300 individual spills annually. However, because this amount does not take into account "minor" spills, the World Bank argues that the true quantity of petroleum spilled into the environment could be as much as ten times the officially claimed amount. The largest individual spills include the blowout of a Texaco offshore station which in 1980 dumped an estimated 400,000 barrels (64,000 m^3) of crude oil into the Gulf of Guinea and Royal Dutch Shell's Forcados Terminal tank failure which produced a spillage estimated at 580,000 barrels (92,000 m^3). In 2010 Baird reported that between 9 million and 13 million barrels have been spilled in the Niger Delta since 1958. One source even calculates that the total amount of petroleum in barrels spilled between 1960 and 1997 is upwards of 100 million barrels (16,000,000 m^3).

Nigeria has abundant water resources although they are unevenly distributed over the country. The highest annual precipitation of about 3,000 mm occurs in the Niger Delta and mangrove swamp areas of the south-east, where rain falls for more than eight months a year. There is a progressive reduction in precipitation northwards with the most arid north-eastern Sahelian region receiving as little as 500 mm a -1 precipitation from about 3-4 months of rainfall. Widespread flooding occurs in the southern parts of the country, while the northern parts experience chronic water shortages during the dry season when rain fed springs, streams and boreholes dry up (FGN, 1988a).

There are four major drainage systems in the country: The Niger River Basin Drainage System with its major tributaries of Benue, Sokoto-Rima, Kaduna, Gongola, Katsina-Ala, Donga, Tarabe, Hawal and Anambara Rivers. The Lake Chad Inland Drainage System comprising the Kano, Hadejia, Jama'are Misau, Komadougou-Yobe, Yedoseram and Ebeji Rivers. The Atlantic Drainage System (east of the Niger) comprising the Cross, Imo, Qua Iboe and Kwa Rivers. The Atlantic Drainage System (west of the Niger) made up of the Ogun, Oshun, Owena and Benin Rivers. Apart from the Lake Chad Inland Drainage System, the remaining three drainage systems terminate in the Atlantic Ocean with an extensive network of delta channels. Groundwater resources are limited by the geological structure of the country, more than half of which is underlain by the Pre-Cambrian Basement Complex, composed mainly of metamorphic and igneous rocks (FGN, 1988b). However, there are fairly extensive areas of fractured schists, quartzites and metamorphosed derivatives of ancient sediments from which water is often available at great depth. The sedimentary formations such as the Tertiary deposits of the Chad-Sokoto basins, the Cretaceous deposits of the Niger and Benue troughs, and the sedimentary formation of the Niger Delta, yield groundwater in varying quantities (FGN, 1993).

The delta covers 20,000km^2 within wetlands of 70,000km^2 formed primarily by sediment deposition. Home to 20 million people and 40 different ethnic groups, this floodplain makes up 7.5% of Nigeria's total land mass. It is the largest wetland and maintains the third-largest drainage basin in Africa. The Delta's environment can be broken down into four ecological zones: coastal barrier islands, mangrove swamp forests, freshwater swamps, and lowland rainforests. This incredibly well-endowed ecosystem contains one of the highest concentrations of biodiversity on the planet, in addition to supporting abundant flora and fauna, arable terrain that can sustain a wide variety of crops, lumber or agricultural trees, and more species of freshwater fish than any ecosystem in West Africa. The region could experience a loss of 40% of its inhabitable terrain in the next thirty years as a result of extensive dam construction in the region. The carelessness of the oil industry has also precipitated this situation, which can perhaps be best encapsulated by a 1983 report issued by the NNPC, long before popular unrest surfaced.

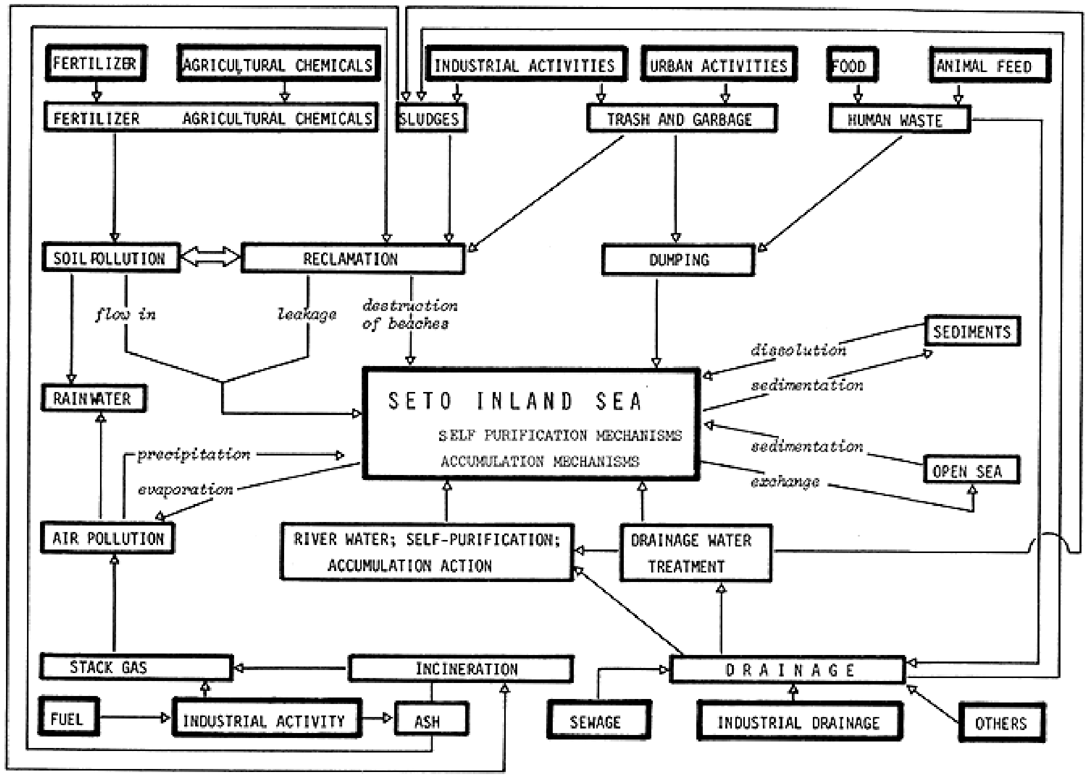

Fig. 1: Processes pollution in the aquatic environment (Guha *et al*.,1997)

The article reviews the meaning of water pollution, water pollution categories, point source pollution, non-point source pollution, ground water pollution, causes of water pollution, pathogens, chemicals and other contaminants, thermal pollution, transport and chemical reactions of pollution, measurement of pollution, sampling, physical testing, chemical testing, biological testing, control of water pollution, domestic sewage, industrial waste water, agricultural waste water, construction site storm water urban runoff(storm water), radiation pollution, the Federal Environmental Protection Agency, The National Policy on Environment, The national environmental reference laboratory, Water resources management, Strategies under the National Policy on Environment, Industrial water pollution control programme, Industrial effluent standards to provide some information on the Nigeria situation.

MEANING OF WATER POLLUTION

Water pollution is the contamination of water bodies (e.g., lakes, rivers, oceans and ground water). Water pollution affects plants and organisms living in these bodies of water; and, in almost all cases the effect is damaging not only to individual species and populations, but also to the natural biological communities (Fewtrell and Colford, 2004).

Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds (Fig. 1). State resulting when substances are released into a body of water, where they become dissolved or suspended in the water or deposited on the bottom, accumulating to the extent that they overwhelm its capacity to absorb, break down, or recycle them, and thus interfering with the functioning of aquatic ecosystems (Gleick, 1998).

Water pollution in Nigeria occurs in both rural and urban areas. In rural areas, drinking water from natural sources such as rivers and streams is usually polluted by organic substances from upstream users who use water for agricultural activities. The most common form of stream pollution associated with forestry activities is increased concentrations of soil particles washed into the stream by land disturbance. The large particles sink to the bottom and increase the bed load while, depending on the stream velocity, smaller particles remain in suspension. In the river Niger, for example, studies have shown that the suspended matter can obstruct the penetration of light and limit the photosynthetic zone to less than 1 m depth.

Suspended sediments in watercourses have become a serious concern for the water supply authorities because they lead to increased water treatment costs (FEPA, 1989).

Many factories in Nigeria are located on river banks and use the rivers as open sewers for their effluents. The major industries responsible for water pollution in Nigeria include petroleum, mining (for gold, tin and coal) wood and pulp, pharmaceuticals, textiles, plastics, iron and steel, brewing, distillery fermentation, paint and food. Of all these, the petroleum industry presents the greatest threat to water quality. From time to time accidental oil spillages occur which endanger local sources of water supply and freshwater living resources, especially in the rural areas (FEPA, 1991a).

The problems associated with the lack of adequate water resources in the country threaten to place the health of about 40 million people at risk Recent World Bank studies (World Bank, 1990) suggest that it would cost in excess of US$ 109 a year to correct such problems if ground and surface water contamination goes unchecked. The people most affected tend to be the urban and landless poor. In the long-term, the present level of environmental degradation could create health problems from waterborne diseases for most of this population. Many people are already affected by having to consume unsafe drinking water. Water contamination also places other resources at risk; fisheries and land resources, for example, have already been affected significantly. Most of the environmental pollution problems arise from anthropogenic sources, mainly from domestic and industrial activities FEPA, 1991b).

Contributions to water pollution include substances drawn from the air, silt from soil erosion, chemical fertilizers and pesticides, runoff from septic tanks, outflow from livestock feedlots, chemical wastes (some toxic) from industries, and sewage and other urban wastes from cities and towns. A community far upstream in a watershed may thus receive relatively clean water, whereas one farther downstream receives a partly diluted mixture of urban, industrial, and rural wastes. When organic matter exceeds the capacity of microorganisms in the water to break it down and recycle it, the excess of nutrients in such matter encourages algal water blooms (Guha *et al*., 1997).

When these algae die, their remains add further to the organic wastes already in the water, and eventually the water becomes deficient in oxygen. Organisms that do not require oxygen then attack the organic wastes, releasing gases such as methane and hydrogen sulfide, which are harmful to the oxygen-requiring forms of life. The result is a foul-smelling, waste-filled body of water. Aquatic pollution can be classified according to pollution source and type (Fig. 2). Figure 3 shows the state of disposal of industrial wastes by means of dumping vessels. Numerals are expressed in units of one thousand tons. Amounts of industrial wastes used for land reclamation are cited in certain cases. Figure 4 shows the concentration levels

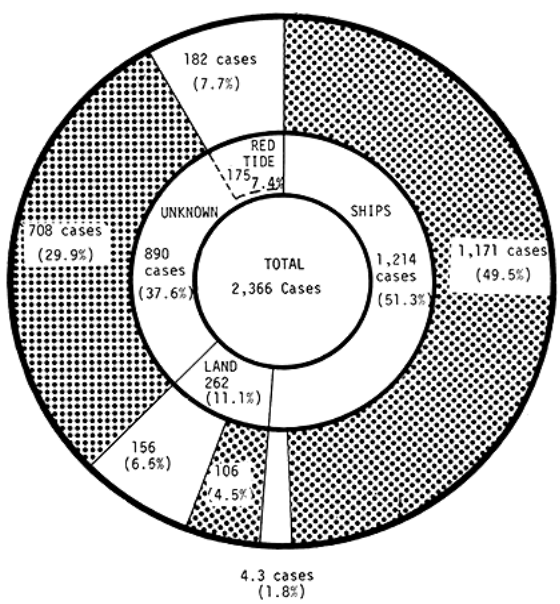

Fig. 2: Outbreaks of aquatic pollution classified according to pollution source and type (Guha *et al*., 2000), Stippled areas of outer ring indicate oil-related pollution; unstippled areas denote pollution unrelated to petroleum

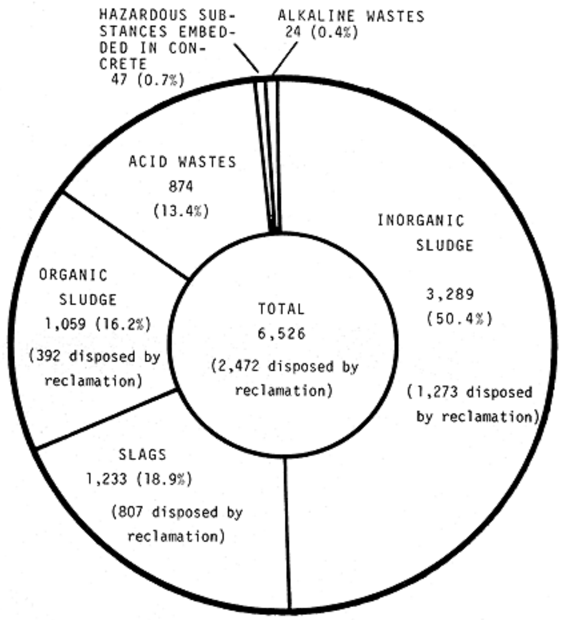

Fig. 3: The state of disposal of industrial wastes by means of dumping vessels. Numerals are expressed in units of one thousand tons. Amounts of industrial wastes used for land reclamation are cited in certain cases (Gunatilake *et al*., 2001)

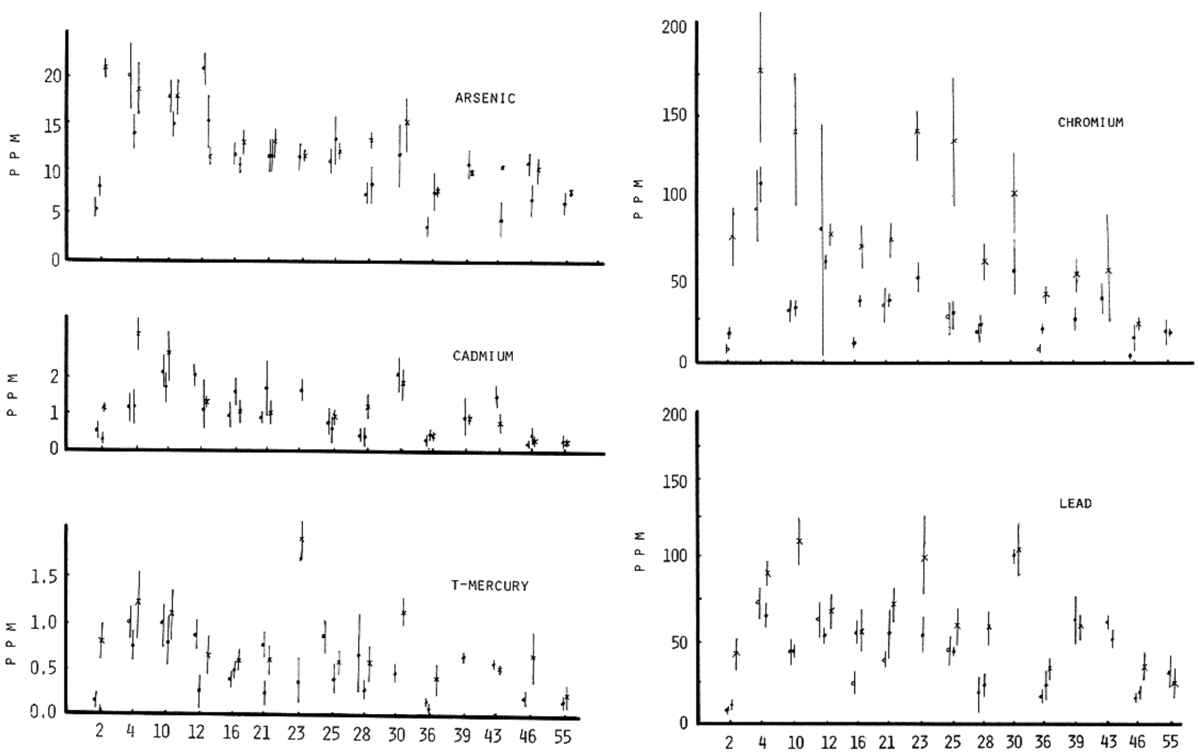

Fig. 4: Concentration levels of some heavy metal pollutants in water (Harrington *et al*., 1989)

Table 1: Concentrations of PCBs detected in fish exceeded the allowable limit of 3 ppm

Species of fish	Level of PCBs (ppm)
Mackerel	5
Conger eel	8
Kelp greenling	4
Gray mullet	6
Konoshiro	6
Common sea bass	3
Yellowtail	4
Eel	43
Young bass	3

Hertz-Picciotto *et al*. (2000)

Table 2. Average values of heavy metals in Oysters

Heavy metal	Concentration (ppm)
Arsenic	0.45-1.84
Copper	15.4-28.3
Lead	0.1-0.4
Zinc	213-641
Cadmium	0.3-1.7
Chromium	0.02-0.05
Mercury (total)	<0.02

Hsueh *et al*. (1998)

of some heavy metal pollutants in water. Table 1 shows the concentrations of PCBs detected in fish exceeded the allowable limit of 3 ppm. Table 2 shows the average Values of Heavy Metals in Oysters (Guha *et al*., 2000).

Water pollution categories: Surface water and groundwater have often been studied and managed as separate resources, although they are interrelated. Sources of surface water pollution are generally grouped into two categories based on their origin.

Point source pollution: Point source pollution refers to contaminants (Harrington *et al*., 1989; Hertz-Picciotto, *et al*., 2000; Hsueh *et al*., 1998) that enter a waterway through a discrete conveyance, such as a pipe or ditch (Fig. 5). Examples of sources of this category include discharges from a sewage treatment plant, a factory, or a city storm drain. The U.S. Clean Water Act (CWA) defines point source for regulatory enforcement purposes. The CWA definition of point source was amended in 1987 to include municipal storm sewer systems, as well as industrial storm water, such as from construction sites.

Non-point source pollution: Non-point source (NPS) pollution refers to diffuse contamination that does not originate from a single discrete source. NPS pollution is often the cumulative effect of small amounts of contaminants gathered from a large area. The leaching out of nitrogen compounds from agricultural land which has been fertilized is a typical example. Nutrient run off in storm water from "sheet flow" over an agricultural field or a forest are also cited as examples of NPS pollution (Hung and Shaw, 2004).

Fig. 5: Point source pollution, (http://en.wikipedia.org/wiki/file:jacueanga-angra-dos-reis-de-janeiro-brazil-brasfels.jpg)

Contaminated storm water washed off of parking lots, roads and highways, called urban runoff, is sometimes included under the category of NPS pollution. However, this runoff is typically channeled into storm drain systems and discharged through pipes to local surface waters, and is a point source. However where such water is not channeled and drains directly to ground it is a non-point source (khan, 1997).

Groundwater pollution: Interactions between groundwater and surface water are complex. Consequently, groundwater pollution, sometimes referred to as groundwater contamination, is not as easily classified as surface water pollution (Kurokawa *et al*., 2001). By its very nature, groundwater aquifers are susceptible to contamination from sources that may not directly affect surface water bodies, and the distinction of point vs. non-point source may be irrelevant. A spill or ongoing releases of chemical or radionuclide contaminants into soil (located away from a surface water body) may not create point source or non-point source pollution, but can contaminate the aquifer below, defined as a toxin plume (Lai *et al*., 1994). The movement of the plume, a plume front, can be part of a hydrological-transport model or ground water model. Analysis of groundwater contamination may focus on the soil characteristics and site geology, hydrogeology, hydrology, and the nature of the contaminants (Majumdar and Guha, 1996).

Causes of water pollution: Oil spills are a common event in Nigeria and occur due to a number of causes, including: corrosion of pipelines and tankers (accounting for 50% of all spills), sabotage (28%), and oil production operations

(21%), with 1% of the spills being accounted for by inadequate or non-functional production equipment. The largest contributor to the oil spill total, corrosion of pipes and tanks, is the rupturing or leaking of production infrastructures that are described as, "very old and lack regular inspection and maintenance". A reason that corrosion accounts for such a high percentage of all spills is that as a result of the small size of the oilfields in the Niger Delta, there is an extensive network of pipelines between the fields, as well as numerous small networks of flowlines-the narrow diameter pipes that carry oil from wellheads to flowstations-allowing many opportunities for leaks. In onshore areas most pipelines and flowlines are laid above ground. Pipelines, which have an estimate life span of about fifteen years, are old and susceptible to corrosion. Many of the pipelines are as old as twenty to twenty-five years. Even Shell admits that "most of the facilities were constructed between the 1960s and early 1980s to the then prevailing standards. SPDC [Shell Petroleum and Development Company] would not build them that way today." Sabotage is performed primarily through what is known as "bunkering", whereby the saboteur attempts to tap the pipeline. In the process of extraction sometimes the pipeline is damaged or destroyed. Oil extracted in this manner can often be sold.

Sabotage and theft through oil siphoning has become a major issue in the Niger River Delta states as well, contributing to further environmental degradation. Damaged lines may go unnoticed for days, and repair of the damaged pipes takes even longer. Oil siphoning has become a big business, with the stolen oil quickly making its way onto the black market. While the popularity of selling stolen oil increases, the number of deaths are increasing. In late December 2006 more than 200 people were killed in the Lagos region of Nigeria in an oil line explosion. Nigerian regulations of the oil industry are weak and rarely enforced allowing, in essence, the industry to self-regulate.

Effects: Oil spillage has a major impact on the ecosystem into which it is released. Immense tracts of the mangrove forests, which are especially susceptible to oil (mainly because it is stored in the soil and re-released annually during inundations), have been destroyed. An estimated 5 to 10% of Nigerian mangrove ecosystems have been wiped out either by settlement or oil. The rainforest which previously occupied some 7,400 km² of land has disappeared as well.

Spills in populated areas often spread out over a wide area, destroying crops and aquacultures through contamination of the groundwater and soils. The consumption of dissolved oxygen by bacteria feeding on the spilled hydrocarbons also contributes to the death of fish. In agricultural communities, often a year's supply of food can be destroyed instantaneously. Because of the careless nature of oil operations in the Delta, the environment is growing increasingly uninhabitable. People in the affected areas complain about health issues including breathing problems and skin lesions; many have lost basic human rights such as health, access to food, clean water, and an ability to work.

Vegetation in the Niger River Delta consists of extensive mangrove forests, brackish swamp forests, and rainforests. The large expanses of mangrove forests are estimated to cover approximately 5,000 to 8,580 km² of land. Mangroves remain very important to the indigenous people of Nigeria as well as to the various organisms that inhabit these ecosystems.

Human impact from poor land management upstream coupled with the constant pollution of petroleum has caused five to ten percent of these mangrove forests to disappear. The volatile, quickly penetrating, and viscous properties of petroleum have wiped out large areas of vegetation. When spills occur close to and within the drainage basin, the hydrologic force of both the river and tides force spilled petroleum to move up into areas of vegetation.

Mangrove forests are included in a highly complex trophic system. If oil directly affects any organism within an ecosystem, it can indirectly affect a host of other organisms. These floral communities rely on nutrient cycling, clean water, sunlight, and proper substrates. With ideal conditions they offer habitat structure, and input of energy via photosynthesis to the organisms they interact with. The effects of petroleum spills on mangroves are known to acidify the soils, halt cellular respiration, and starve roots of vital oxygen.

An area of mangroves that has been destroyed by petroleum may be susceptible to other problems. These areas may not be suitable for any native plant growth until bacteria and microorganisms can remediate the conditions. A particular species of mangrove, Rhizophora racemosa lives higher in the delta system. As the soils supporting R. racemosa become too toxic, a non-native invasive species of palm, Nypa fruticans, quickly colonizes the area. This invasive species has a shallower root system that destabilizes the banks along the waterways, further impacting sediment distribution lower in the delta system. N. fruticans also impedes navigation and decreases overall biodiversity. In places where N. fruticans has invaded, communities are investigating how the palm can be used by local people.

The loss of mangrove forests is not only degrading life for plants and animals, but for humans as well. These systems are highly valued by the indigenous people living in the affected areas. Mangrove forests have been a major source of wood for local people. They also are important to a variety of species vital to subsistence practices for local indigenous groups, who unfortunately see little to none of the economic benefits of petroleum. Mangroves also provide essential habitat for rare and endangered species like the manatee and pygmy hippopotamus. Poor policy decisions regarding the allocation of petroleum revenue has caused political unrest in Nigeria.

This clash among governing bodies, oil corporations, and the people of Nigeria has resulted in sabotage to petroleum pipelines, further exacerbating the threat to mangrove forests. The future for mangrove forests and other floral communities is not all negative. Local and outside groups have provided funds and labor to remediate and restore the destroyed mangrove swamps. The federal government of Nigeria established the Niger Delta Development Commission (NDDC) in 2000 which aims to suppress the environmental and ecological impacts petroleum has had in the region. Governmental and nongovernmental organizations have also utilized technology to identify the source and movement of petroleum spills.

The fishing industry is an essential part of Nigeria's sustainability because it provides much needed protein and nutrients for people, but with the higher demand on fishing, fish populations are declining as they are being depleted faster than they are able to restore their number. Fishing needs to be limited along the Niger River and aquacultures should be created to provide for the growing demand on the fishing industry. Aquaculture allows for fish to be farmed for production and provide more jobs for the local people of Nigeria.

Overfishing is not the only impact on marine communities. Climate change, habitat loss, and pollution are all added pressures to these important ecosystems. The banks of the Niger River are desirable and ideal locations for people to settle. The river provides water for drinking, bathing, cleaning, and fishing for both the dinner table and trading to make a profit. As the people have settled along the shores of the rivers and coasts, marine and terrestrial habitats are being lost and ecosystems are being drastically changed. The shoreline along the Niger River is important in maintaining the temperature of the water because the slightest change in water temperature can be fatal to certain marine species. Trees and shrubs provide shade and habitat for marine species, while reducing fluctuation in water temperature.

The Niger River is an important ecosystem that needs to be protected, for it is home to 36 families and nearly 250 species of fish, of which 20 are endemic, meaning they are found nowhere else on Earth. With the loss of habitat and the climate getting warmer, every prevention of temperature increase is necessary to maintain some of the marine environments. Other than restoring habitat, pollution can also be reduced. Problems such as pesticides from agricultural fields could be reduced if a natural pesticide was used, or the fields were moved farther away from the local waterways. Oil pollution can be lowered as well; if spills were reduced then habitat and environmental impacts could be minimized. By limiting the devastation caused by disturbances to the marine environment, such as pollution, overfishing, and habitat loss, the productivity and biodiversity of the marine ecosystems would increase.

The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical or sensory changes such as elevated temperature and discoloration (Maduka, 2006). While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration is often the key in determining what is a natural component of water, and what is a contaminant. Oxygen-depleting substances may be natural materials, such as plant matter (e.g., leaves and grass) as well as man-made chemicals. Other natural and anthropogenic substances may cause turbidity (cloudiness) which blocks light and disrupts plant growth, and clogs the gills of some fish species (Murty *et al*., 1999).

Many of the chemical substances are toxic. Pathogens can produce waterborne diseases in either human or animal hosts (O-Shea, 2002). Alteration of water's physical chemistry includes acidity (change in pH), electrical conductivity, temperature, and

Fig. 6: Population of aquatic birds affected by pollution

Fig. 7: A manhole cover unable to contain a sanitary sewer overflow, (htt://en.wikipedia.org/wiki/file:sewer-overflow-ri-epa.jpg)

Fig. 8: A polluted river draining an abandoned copper mine, (htt://en.wikipedia.org/wiki/file:angleseycopper stream.jpg

eutrophication. Eutrophication is an increase in the concentration of chemical nutrients in an ecosystem to an extent that increases in the primary productivity of the ecosystem (Paudel *et al*., 2005). Depending on the degree of eutrophication, subsequent negative environmental effects such as anoxia (oxygen depletion) and severe reductions in water quality may occur, affecting fish and other animal populations (Fig. 6).

Water Hyacinth is an invasive species that was introduced into Africa as an ornamental plant, and which thrives in polluted environments. Water Hyacinth has the capability to completely clog the waterways in which it grows, making it nearly impossible to navigate fishing boats. In recent years it has found its way into the Niger River, choking out both sunlight and oxygen to the marine organisms that live there. When a species such as Water Hyacinth makes its way into the ecosystem, it competes with native plants for sunlight, diminishing energy resources within the marine environment. With the loss of energy some populations will not be able to survive, or their numbers may drop beyond a point of no return, creating a threatened environment. Added to the loss of energy, water hyacinth also takes up and depletes the water of oxygen which is essential to the livelihood of all marine organisms.

Pathogens: Pathogen discharges may also be caused by poorly managed livestock operations (Fig. 7). Coliform bacteria are a commonly used bacterial indicator of water pollution, although not an actual cause of disease. Other microorganisms sometimes found in surface waters which have caused human health problems include: *Burkholderia pseudomallei*, *Cryptosporidium parvum*, *Giardia lamblia*, *Salmonella*, *Novovirus* and other viruses (Abdalla *et al*., 1992).

Parasitic worms (helminths): High levels of pathogens may result from inadequately treated sewage discharges (Ahmad and Bandaranayke, 1997). This can be caused by a sewage plant designed with less than secondary treatment (more typical in less-developed countries). In developed countries, older cities with aging infrastructure may have leaky sewage collection systems (pipes, pumps, valves), which can cause sanitary sewer overflows. Some cities also have combined sewers, which may discharge untreated sewage during rain storms (Ahmad *et al*., 2002a).

Chemical and other contaminants: Contaminants may include organic and inorganic substances.

Organic: Water pollutants include.

Detergents: Disinfection by-products found in chemically disinfected drinking water, such as chloroform. Food processing waste, which can include oxygen-demanding substances, fats and grease. Insecticides and herbicides, a huge range of organo-halides and other chemical compounds. Petroleum hydrocarbons, including fuels Gasoline, diesel fuel, jet fuels; and fuel oil and lubricants (motor oil), and fuel combustion bye products, from storm water runoff. Tree and bush debris from logging operations (Ahmad *et al*., 2002b).

Volatile organic compounds (VOCs), such as industrial solvents, from improper storage. Chlorinated solvents, which are Dense Non-Aqueous Phase Liquids (DNAPLs), may fall to the bottom of reservoirs, since they don't mix well with water and are denser. Various chemical compounds found in personal hygiene and cosmetic products (Alberini *et al*., 1996)

Inorganic water pollutants include: Acidity caused by industrial discharges (especially sulfur dioxide from power plants) and Ammonia from food processing waste, chemical waste as industrial byproducts, Fertilizers containing nutrients-nitrates and phosphates-which are found in storm water runoff from agriculture, as well as

Fig. 9: Muddy River polluted by sediment, (http://en.wikipedia.org/wiki/file:muddy-usgs.jpg)

Fig. 10: Potrero generating station discharges heated water (http://en.wikipedia.org/wiki/file:unit3-potrero-power-plant.jpg)

commercial and residential use (Ammann *et al*., 2003). Heavy metals from motor vehicles (via urban storm water runoff) and acid mine drainage (Fig. 8) (Astolfi *et al*., 1981). Silt (sediment) in runoff from construction sites (Fig. 9), logging, slash and burn practices or land clearing sites.

Macroscopic pollution: Large visible items polluting the water-may be termed "floatables" in an urban storm water context, or marine debris when found on the open seas, and can include such items as: Trash (e.g., paper, plastic, or food waste) discarded by people on the ground, and that are washed by rainfall into storm drains and eventually discharged into surface waters Nurdles small ubiquitous waterborne plastic pellets (Armstrong *et al*., 1984).

Radiation pollution: Radiation is the emission of particles, rays or waves produced from disintegration of radioactive isotopes is of two types: Thermal and ionizing radiation. Thermal (heat) radiation consists of ultraviolet rays causing some sensation of heating effect; and visible rays causing the highest heating effect. Thermal pollution is the rise or fall in the temperature of a natural body of water caused by human influence. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers. Elevated water temperatures decreases oxygen levels (which can kill fish) and affects ecosystem composition, such as invasion by new thermophlic species. Urban runoff may also elevate temperature in surface waters. Thermal pollution can also be caused by the release of very cold water from the base of reservoirs into warmer rivers (Abowei and Sikoki, 2005).

Ionizing radiation (radioactivity) consists of alpha rays (α-rays) which are positively charged particles with very low penetrating powers, Beta rays (β-rays) which are negatively charged but higher penetrating power and Gamma rays (γ-rays) which are electro-magnetive and are neutral (No-charge), but with the highest penetrating power. Any or all of the above mentioned forms of radiation directly or indirectly gets into the aquatic environment through various sources which could be regarded as pollution (Abowei and Sikoki, 2005).

The sun an ultimate source of energy is a source of thermal radiation. Other sources of thermal radiation include: Flames generated from the burning of coals and woods; gas flares from petrochemical industries, combustibles like engines and pump compressors in ships (Fig. 10) which compresses and exchanges air and explosives like dynamites by ignorant fishers (Barton, 2003).

Ionizing radiation is not only by nuclear and power plants; nuclear power fuel production, processing plants and c and uranium activities of all sorts, but also results from more common activities such as burning of coals which emits radioactive particles to the atmosphere which are finally washed in to the sea at a greater rate than any known nuclear plant (Beach, 2001).

Other sources of ionizing radiation are weapons testing, marine drainage, accidental spillages and a few isolated industries. Some highly dangerous radioactive wastes are disposed of by dumping in to the oceans. Radioactive chemicals (traces) used to trace biochemical pathways sometimes are washed into the aquatic habitat. Plowshare programme in which left over nuclear devices are used to create instant harbours or stimulate the release of natural gas from underground rocks formation is also a source (Borgono and Greiber, 1971).

Thermal radiation changes the temperature of the aquatic system. Temperature is very strong synergistic parameter, generally enhancing most pollutant effects. Increase in temperature reduces the Dissolved Oxygen (DO) concentration and increases the solubility of other pollutants. Radioactive substances introduced in to the aquatic environment could initially be partitioned among three phases: The living biosphere, sea water; and inorganic and organic particles. On different time scales and various sites, the ultimate fate of all such elements are removed to the sea floor or discharged into the atmosphere. Several factors determine the fate of radionuclide in the aquatic system. The most useful of which are residence time, the degree of under saturation or super saturation, sorption by marine sediments and biological activity (Buchet *et al*., 1984).

The effects of radionuclide in water are based on: the physical structure, the chemical component; and the biota. The bulk of the radionuclide in the aquatic environment is introduced through nuclear explosions and sea-based nuclear rectors. The weak sorption of ^{90}Sr and ^{45}Ca. On marine sediments suggests that these radionuclide are involved in ion exchange reactions with their stable isotopes, which are relatively abundant in sea water. ^{90}Sr is associated with carbonates precipitated in situ. The radionuclide ^{60}Cr is associated with Mn and Fe oxides and ^{137}Cs is taken up by incorporation in the lattice of certain clay minerals. Similar mineral related reactions, each one highly specific probability control radionuclide uptake by marine sediments. It is highly probable that the introduction of various radionuclides like ^{24}Na, ^{26}Al, ^{3}H, ^{14}C, ^{35}Cl, etc., may result in certain combination that may affect the pH, salinity, solvent ability, light penetration, and where there is temperature rise due to water based reactors and denudes. Oxygen retention and solubility are reduced and enhanced respectively (Abowei and Sikoki, 2005).

All types of ionizing radiation produce changes in living cells and some changes, at least are regarded as deleterious. It is assumed that any radiation exposure in excess of the natural level might produce deleterious changes. The biological consequences of low-level irradiation have grown into a subject of importance in all environments. Lethal amounts of acute radiation differ widely among organisms because biological variations are further complicated by the interaction of environmental factors such as temperature, dissolved oxygen, chemical composition and salinity (Abowei and Sikoki, 2005).

Nigeria flares more natural gas associated with oil extraction than any other country, with estimates suggesting that of the 3.5 billion cubic feet (100,000,000 m^3) of associated gas (AG) produced annually, 2.5 billion cubic feet (70,000,000 m^3), or about 70% is wasted via flaring.[citation needed] This equals about 25% of the UK's total natural gas consumption, and is the equivalent to 40% of the entire African continent's gas consumption in 2001. Statistical data associated with gas flaring are notoriously unreliable, but Nigeria may waste US $ 2 billion per year by flaring associated gas. Flaring is done as it is costly to separate commercially viable associated gas from the oil. Companies operating in Nigeria also harvest natural gas for commercial purposes, but prefer to extract it from deposits where it is found in isolation as non-associated gas. Thus associated gas is burned off to decrease costs.

Gas flaring is generally discouraged as it releases toxic components into the atmospshere and contributes to climate change. In Western Europe 99% of associated gas is used or re-injected into the ground. Gas flaring in Nigeria began simultaneously with oil extraction in the 1960s by Shell-BP. Alternatives to flaring are gas re-injection, or to store it for use as an energy source. If properly stored, the gas could also be utilized for community projects.

Gas flaring releases of large amounts of methane, which has a high global warming potential. The methane is accompanied by the other major greenhouse gas, carbon dioxide, of which Nigeria was estimated to have emitted more than 34.38 million metric tons of in 2002, accounting for about 50% of all industrial emissions in the country and 30% of the total CO2 emissions. While flaring in the west has been minimized, in Nigeria it has grown proportionally with oil production.

The international community, the Nigerian government, and the oil corporations seem in agreement that gas flaring needs to be curtailed. Efforts to do so, however, have been limited although flaring has been declared illegal since 1984 under section 3 of the "Associated Gas Reinjection Act" of Nigeria. While OPEC and Shell, the biggest flarer of natural gas in Nigeria, alike claim that only 50% of all associated gas is burnt off via flaring at present, these data are contested. The World Bank reported in 2004 that, "Nigeria currently flares 75% of the gas it produces.

Gas flares have potentially harmful effects on the health and livelihood of the communities in their vicinity, as they release a variety of poisonous chemicals including nitrogen dioxides, sulphur dioxide, volatile organic compounds like benzene, toluene, xylene and hydrogen sulfide, as well as carcinogens like benzapyrene and dioxin. Humans exposed to such substances can suffer from a variety of respiratory problems. These chemicals can aggravate asthma, cause breathing difficulties and pain, as well as chronic bronchitis. Benzene known to be emitted from gas flares in undocumented quantities, is well recognized as a cause for leukemia and other blood-related diseases. A study done by Climate Justice estimates that exposure to benzene would result in eight new cases of cancer yearly in Bayelsa State alone.

Gas flares are often located close to local communities, and regularly lack adequate fencing or protection for villagers who may risk working near heat of the flare. Many of these communities claim that nearby flares cause acid rain which corrodes their homes and other local structures, many of which have zinc-based roofing. Some people resort to the use of asbestos-based material, which is stronger in repelling acid rain deterioration. Unfortunately, this only contributes to their own declining health and the health of their environment. Asbestos exposure increases the risk of forming lung cancer, mesothelioma, and asbestosis.

Whether or not flares contribute to acid rain is debatable, as some independent studies conducted have found that the sulphur dioxide and nitrous oxide content of most flares was insufficient to establish a link between flaring and acid rain. Other studies from U.S. Energy Information Administration (EIA) report that gas flaring is "a major contributor to air pollution and acid rain". Older flares are rarely relocated away from villages, and are known to coat the land and communities in the area with soot and to damage adjacent vegetation. Almost no vegetation can grow in the area directly surrounding the flare due to the prevailing heat.

In November 2005 a judgement by the Federal High Court of Nigeria ordered that gas flaring must stop in a Niger Delta community as it violates guaranteed constitutional rights to life and dignity. In a case brought against the Shell Petroleum Development Company of Nigeria (Shell), Justice C. V. Nwokorie ruled in Benin City that "the damaging and wasteful practice of flaring cannot lawfully continue.

Transport and chemical reactions of water pollutants: Most water pollutants are eventually carried by rivers into the oceans. In some areas of the world the influence can be traced hundred miles from the mouth by studies using hydrology transport models. Advanced computer models such as SWMM or the DSSAM Model have been used in many locations worldwide to examine the fate of pollutants in aquatic systems. Indicator filter feeding species such as copepods have also been used to study pollutant fates in the New York Bight, for example. The highest toxin loads are not directly at the mouth of the Hudson River, but 100 km south, since several days are required for incorporation into plankton tissue.

The Hudson discharge flows south along the coast due to corriolis force. Further south then are areas of oxygen depletion, caused by chemicals using up oxygen and by algae blooms, caused by excess nutrients from algal cell death and decomposition. Fish and shellfish kills have been reported, because toxins climb the food chain after small fish consume copepods, then large fish eat smaller fish, etc. Each successive step up the food chain causes a stepwise concentration of pollutants such as heavy metals (e.g., mercury) and persistent organic pollutants such as DDT. This is known as biomagnifications, which is occasionally used interchangeably with bioaccumulation (Cao and Ikeda, 2005).

Large gyres (vortexes) in the oceans trap floating plastic debris. The North Pacific Gyre for example has collected the so-called "Great Pacific Garbage Patch" that is now estimated at 100 times the size of Texas. Many of these long-lasting pieces wind up in the stomachs of marine birds and animals. This results in obstruction of digestive pathways which leads to reduced appetite or even starvation (Cebrian *et al*., 1983).

Many chemicals undergo reactive decay or chemically change especially over long periods of time in groundwater reservoirs. A noteworthy class of such chemicals is the chlorinated hydrocarbons such as trichloroethylene (used in industrial metal degreasing and electronics manufacturing) and tetrachloroethylene used in the dry cleaning industry (note latest advances in liquid carbon dioxide in dry cleaning that avoids all use of chemicals). Both of these chemicals, which are carcinogens themselves, undergo partial decomposition reactions, leading to new hazardous chemicals (including dichloroethylene and vinyl chloride) (Chakraborty and Saha, 1987).

Groundwater pollution is much more difficult to abate than surface pollution because groundwater can move great distances through unseen aquifers. Non-porous aquifers such as clays partially purify water of bacteria by simple filtration (adsorption and absorption), dilution, and, in some cases, chemical reactions and biological activity: However, in some cases, the pollutants merely transform to soil contaminants. Groundwater that moves through cracks and caverns is not filtered and can be transported as easily as surface water. In fact, this can be aggravated by the human tendency to use natural sinkholes as dumps in areas of Karst topography (Chakraborty *et al*., 2004).

There are a variety of secondary effects stemming not from the original pollutant, but a derivative condition. An example is silt-bearing surface runoff, which can inhibit

Fig. 11: Environmental scientist preparing water auto samplers (htt://en.wikipedia.org/wiki/file:research-water-sampling-equipment.jpg)

the penetration of sunlight through the water column, hampering photosynthesis in aquatic plants (Chen *et al*., 1995).

Measurement of water pollution: Water pollution may be analyzed through several broad categories of methods: physical, chemical and biological. Most involve collection of samples, followed by specialized analytical tests. Some methods may be conducted *in situ,* without sampling, such as temperature. Government agencies and research organizations have published standardized, validated analytical test methods to facilitate the comparability of results from disparate testing events (Chiou *et al*., 1997).

Sampling: Sampling of water for physical or chemical testing can be done by several methods, depending on the accuracy needed and the characteristics of the contaminant. Many contamination events are sharply restricted in time, most commonly in association with rain events. For this reason "grab" samples are often inadequate for fully quantifying contaminant levels. Scientists gathering this type of data often employ auto-sampler devices (Fig. 11) that pump increments of water at either time or discharge intervals (Chowdhury, 1999).

Sampling for biological testing involves collection of plants and/or animals from the surface water body. Depending on the type of assessment, the organisms may be identified for bio-surveys (population counts) and returned to the water body, or they may be dissected for bioassays to determine toxicity (Dasgupta, 2004).

Physical testing: Common physical tests of water include temperature, solids concentration like Total Suspended Solids (TSS) and turbidity.

Chemical testing: Water samples may be examined using the principles of analytical chemistry. Many published test methods are available for both organic and inorganic compounds. Frequently used methods include pH, biochemical Oxygen Demand (BOD), chemical Oxygen Demand (COD), nutrients (nitrate and phosphorus compounds), metals (including copper, zinc, cadmium, lead and mercury), oil and grease, Total Petroleum Hydrocarbons (TPH), and pesticides (Diwakar and Nagaraj, 2002).

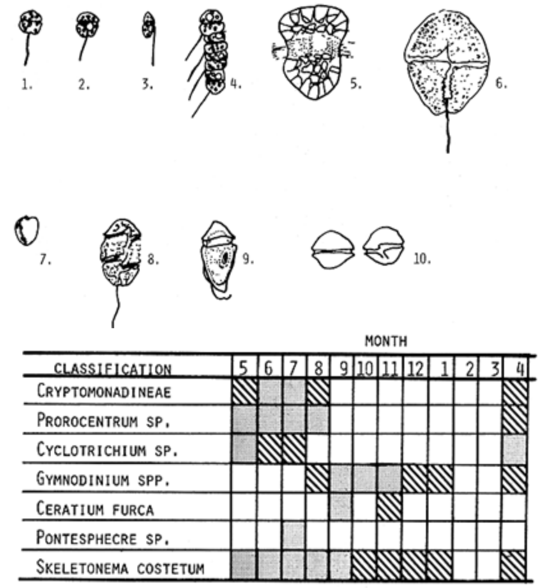

Fig. 12: Seasonal variation in the density of red tide organisms. A red tide condition is denoted by the darkened areas; the normal condition is given by diagonal lines

Biological testing: Biological testing involves the use of plant, animal, and/or microbial indicators to monitor the health of an aquatic ecosystem. For instance, Fig. 12 shows seasonal variation in the density of red tide organisms.

Control of water pollution: The use of biological remediation has also been implemented in areas of the delta to detoxify and restore ecosystems damaged by oil spills. Bioremediation involves biological components in the remediation or cleanup of a specific site. A study conducted in Ogbogu located in one of the largest oil producing regions of Nigeria has utilized two plant species to clean up spills. The first stage of cleanup involves Hibiscus cannabinus, a plant species indigenous to West Africa. H. cannabinus is an annual herbaceous plant originally used for pulp production. This species has high rates of absorbency and can be laid down on top of the water to absorb oil. The oil saturated plant material is

Fig. 13: Deer island waste water treatment plant, (http://en.wikipedia.org/wiki/file:Deer-island-ma.jpg)

Fig. 14: Dissolved air flotation system for treating industrial wastewater, (http://en.wikipedia.org/wiki/file:redox-daf-unit-225-m3-h1000-gdm)

then removed and sent to a safe location where the hydrocarbons can be broken down and detoxified by microorganisms. The second stage of bioremediation involves a plant known as Vetiveria zizanioides, a perennial grass species. V. zizanioides has a deep fibrous root network that can both tolerate chemicals in the soil and can also detoxify soils through time requiring little maintenance. The people of Ogbogu hope to use these methods of bioremediation to improve the quality of drinking water, soil conditions, and the health of their surrounding environment.

Within the Imo State of Nigeria, a study was conducted in the city of Egbema to determine the microfloral communities present at the site of an oil spill. These microorganisms have the ability to break down the oil, decreasing the toxic conditions. This is recognized as another method of bioremediation and scientists are trying to determine whether the properties these microorganisms possess can be utilized for the cleanup of future spills. However bleak this situation may seem for the Niger Delta region there are clearly alternatives that can be implemented to save it from future contamination. Satellite imagery combined with the use of Geographical Information Systems (GIS) can be put to work to quickly identify and track spilled oil. To hasten the cleanup of spills, regional cleanup sites along the problem areas could help contain spills more quickly. To make these tasks feasible more funding must be provided by the stakeholders of the oil industry. Nongovernmental organizations will keep fighting the damaging effects of oil, but will not win the battle alone.

Domestic sewage is 99.9% pure water; the other 0.1% is pollutants. While found in low concentrations, these pollutants pose risk on a large scale. In urban areas, domestic sewage is typically treated by centralized sewage treatment plants (Fig. 13). In the U.S., most of these plants are operated by local government agencies, frequently referred to as Publicly Owned Treatment Works (POTW). Municipal treatment plants are designed to control conventional pollutants: BOD and suspended solids. Well-designed and operated systems (i.e., secondary treatment or better) can remove 90 percent or more of these pollutants. Some plants have additional sub-systems to treat nutrients and pathogens. Most municipal plants are not designed to treat toxic pollutants found in industrial wastewater (Diwakar and Nagaraj, 2002).

Cities with sanitary sewer overflows or combined sewer overflows employ one or more engineering approaches to reduce discharges of untreated sewage, including: utilizing a green infrastructure approach to improve storm water management capacity throughout the system, and reduce the hydraulic overloading of the treatment plant repair and replacement of leaking and malfunctioning equipment increasing overall hydraulic capacity of the sewage collection system (often a very expensive option) (Esrey *et al*., 1985).

A household or business not served by a municipal treatment plant may have an individual septic tank, which treats the wastewater on site and discharges into the soil. Alternatively, domestic wastewater may be sent to a nearby privately owned treatment system (e.g., in a rural community).

Industrial waste water treatment: Some industrial facilities generate ordinary domestic sewage that can be treated by municipal facilities (Fig. 14). Industries that generate wastewater with high concentrations of conventional pollutants (e.g., oil and grease), toxic pollutants (e.g., heavy metals, volatile organic compounds) or other nonconventional pollutants such as ammonia, need specialized treatment systems. Some of these facilities can install a pre-treatment system to remove the toxic components, and then send the partially treated wastewater to the municipal system. Industries generating large volumes of wastewater typically operate their own complete on-site treatment systems (Esrey, *et al*., 1991).

Fig.15: Dissolved air flotation system for treating industrial wastewater (http://en.wikipedia.org/wiki/ file:redox-daf-unit-225-m3-h1000-gdm)

Fig. 16: Confined Animal Feeding Operation in the United States, (http://en.wikipedia.org/wiki/file:confined-animal- feeding- operation.jpg)

Some industries have been successful at redesigning their manufacturing processes to reduce or eliminate pollutants, through a process called pollution prevention. Heated water generated by power plants or manufacturing plants may be controlled with: cooling ponds, man-made bodies of water designed for cooling by evaporation, convection, and radiation cooling towers, which transfer waste heat to the atmosphere through evaporation and/or heat transfer cogeneration, a process where waste heat is recycled for domestic and/or industrial heating purposes.

Nonpoint source controls: Sediment (loose soil) washed off fields is the largest source of agricultural pollution in the United States. Farmers may utilize erosion controls to reduce runoff flows and retain soil on their fields. Common techniques include contour plowing, crop mulching, crop rotation, planting perennial crops and installing riparian buffers. Nutrients (nitrogen and phosphorus) are typically applied to farmland as commercial fertilizer; animal manure; or spraying of municipal or industrial wastewater (effluent) or sludge. Nutrients may also enter runoff from crop residues,

Fig. 17: Silt fence installed on a construction site, (http://en.wikipedia.org/wiki/file:silt_fence.jpg)

Fig. 18: Retention basin for controlling urban runoff, (http://en.wikipedia.org/wiki/file:Trounce_pond.jpg)

irrigation water, wildlife, and atmospheric deposition Farmers can develop and implement nutrient management plans to reduce excess application of nutrients.

To minimize pesticide impacts, farmers may use Integrated Pest Management (IPM) techniques (which can include biological pest control) to maintain control over pests, reduce reliance on chemical pesticides, and protect water quality.

Point source wastewater treatment: Farms with large livestock and poultry operations (Fig. 16), such as factory farms, are called concentrated animal feeding operations or confined animal feeding operations in the U.S. and are being subject to increasing government regulation. Animal slurries are usually treated by containment in lagoons before disposal by spray or trickle application to grassland. Constructed wetlands are sometimes used to facilitate treatment of animal wastes, as are anaerobic lagoons. Some animal slurry are treated by mixing with straw and composted at high temperature to produce bacteriological sterile and friable manure for soil improvement.

Sediment from construction sites is managed by installation of: erosion controls, such as mulching and hydro seeding, and sediment controls, such as sediment basins and silt fences (Fig. 17). Discharge of toxic

Fig. 19: The use of booms to prevent oil spread

chemicals such as motor fuels and concrete washout is prevented by use of: spill prevention and control plans, and specially designed containers (e.g., for concrete washout) and structures such as overflow controls and diversion beams.

Effective control of urban runoff (Fig. 18) involves reducing the velocity and flow of storm water, as well as reducing pollutant discharges. Local governments use a variety of storm water management techniques to reduce the effects of urban runoff. These techniques, called Best Management Practices (BMPs) in the U.S., may focus on water quantity control, while others focus on improving water quality, and some perform both functions.

Pollution prevention practices include low impact development techniques, installation of green roofs and improved chemical handling (e.g., management of motor fuels and oil, fertilizers and pesticides). Runoff mitigation systems include infiltration basins, bio-retention systems, constructed wetlands, retention basins and similar devices such as use of booms (Fig. 19).

Thermal pollution from runoff can be controlled by storm water management facilities that absorb the runoff or direct it into groundwater, such as bio retention systems and infiltration basins. Retention basins tend to be less effective at reducing temperature, as the water may be heated by the sun before being discharged to a receiving stream.

The federal environmental protection agency: The Federal Military Government has placed great importance on the environment and established the Federal Environmental Protection Agency (FEPA) by Decree 58 of 30 December 1988 (FGN, 1988a). The FEPA has statutory responsibility for overall protection of the environment and its initial functions and priorities included: Coordinating all environmental activities and programmes within the country; Serving as the national environmental focal point and the coordinating body for all bilateral and multilateral activities on the environment with other countries and international organizations; Setting and enforcing ambient and emission standards for air, water and noise pollution; Controlling substances which may affect the stratosphere, especially the ozone layer. Preventing and controlling discharges to air, water or soil of harmful and hazardous substances.

The national policy on environment: The National Policy on the Environment was launched by the President in Abuja on 27 November 1989 (FEPA, 1989). The goal of that policy was to achieve sustainable development in Nigeria and, in particular to: Secure for all Nigerians a quality environment adequate for their health and well-being; Conserve and use the environment and natural resources for the benefit of present and future generations; Restore, maintain and enhance ecosystems and ecological processes essential for the functioning of the biosphere and for the preservation of biological diversity and to adopt the principle of optimum sustainable yield in the use of living natural resources and ecosystems; Raise public awareness and promote understanding of essential linkages between environment and development and to encourage individual and community participation in environmental improvement efforts; Co-operate in good faith with other countries, international organizations and agencies to achieve optimal use of trans-boundary natural resources and effective prevention or abatement of trans-boundary environmental pollution; The introduction of guidelines and standards was part of the implementation of the policy and the environmental pollution abatement strategy contained therein.

The guidelines and standards relate to six areas of environmental pollution control: Effluent limitations; Water quality for industrial water uses at point of intake; Industrial emission limitations; Noise exposure limitations; Management of solid and hazardous wastes; Pollution abatement in industries; Environmental protection measures are only meaningful if the environment to be protected is adequately understood. Neither over-protection nor under-protection of the environment is desirable. Ideally, standards should be set based on nationally generated, environmental baseline data. Such data are scarce in Nigeria in the present circumstances. An alternative approach is to adapt standards and guidelines adopted by the World Health Organization (WHO) and the developed nations of Europe and America. The water quality component of the guidelines are based on the WHO guidelines. However, in transposing data between countries, socio-economic and climatic differences must be taken into account.

Establishment of environmental monitoring programmes: With the establishment of the guidelines and standards, the FEPA is initiating a monitoring programme to ensure that the set standards are met. The objectives of the programme include: Establishment of an environmental baseline; Detection and evaluation of environmental trends; Provision of advance warning of approaching critical conditions; Detection of accidental critical events which may exceed the rate of recovery of the Environment; Prevention of potential threats to the human environment; Provision of a means of data storage and retrieval. Efforts are being made to build zonal laboratories in various parts of the country to provide adequate monitoring coverage for domestic, recreational and industrial causes and effects of environmental degradation. Six zonal laboratories were proposed at the following cities: Lagos, Abuja, Benin, Kano, Jos and Port Harcourt. The Lagos laboratory has already been commissioned and is also serving as the national reference laboratory.

The national environmental reference laboratory: The FEPA's Lagos Office and Zonal Laboratory Complex were commissioned in October 1990. The Lagos Complex is acting as a national environmental reference laboratory and is serving the environmental monitoring activities of the States and the Federal Capital Territory. The Lagos Laboratory Complex is made up of six units: Water and wastewater laboratory; Analytical instrument laboratory; Toxic chemical laboratory; Microbiology laboratory; General purpose laboratory, including bioassay techniques.

Once adequately equipped, the laboratory complex will provide the FEPA with the capability to generate reliable data for determining compliance with the National Interim Guidelines and Standards which were set up by the government to monitor and control industrial domestic and industrial pollution.

Water resources management: The turning point for water resources development and management in Nigeria occurred after the severe drought of the 1960s. The Government's response to the catastrophe was the initiation of strategies for co-ordinated and effective water resources development, culminating in the mid-1970s in the creation of the Federal Ministry of Water Resources and the River Basin Development Authorities. The activities of these institutions were further strengthened in 1981 by the establishment of the National Committee on Water Resources, and by the Water Boards at the state level. These bodies were charged with taking an inventory, and ensuring rational and systematic planned management and conservation, of the country's water resources. In the 1970s and early 1980s, water resources management in Nigeria was faced with a lot of problems which slowed down the development of the resource.

Some of these problems included: The deficiency of the resource itself; Unnecessary duplication and overlap in organizations, structures and functions of the relevant bodies; The ill-defined and uncoordinated roles of the Federal, State and Local Government agencies responsible for water resources development; Failure to recognize the inter-relationship between surface and ground waters, and between water resources and land use; Lack of effective water and environmental protection laws, and the means to enforce the already existing laws.

In the late 1980s, Nigeria began to make serious efforts to address these problems: a national body was created to co-ordinate all environmental protection activities in the country; a comprehensive national environmental policy was formulated which, among other things, addressed the issue of water resources; and the Hazardous Waste Decree was promulgated with the intention of discouraging reckless and illegal dumping of hazardous and harmful wastes on land and into water courses (FGN, 1988b).

Strategies under the national policy on environment: Implementation of the Nigerian National Policy on Environment depends on specific actions directed towards major sectors and towards problem areas of the environment (FEPA, 1989). The management approach adopted in the policy is based on an integrated, holistic and systematic view of environmental issues. The programme activities of this policy are expected to establish and strengthen legal, institutional, regulatory, research, monitoring, evaluation, public information, and other relevant mechanisms for ensuring the attainment of the specific goals and targets of the policy. They will also encourage environmental assessment of proposed activities which may affect the environment or the use of natural resources prior to their commencement. The strategies put forward for effective water resources management in Nigeria include: Promulgation of a national water resources law to co-ordinate water resources development; Formulation of a water resources master plan; Improvement of water use efficiency for sustainable development; Implementation of water conservation measures including inter-basin water transfer; Establishment and enforcement of national water quality and emission standards to protect human health and aquatic ecosystems and species; Establishment of environmental monitoring stations or networks to locate and monitor sources of environmental pollutants and to determine their actual or potential danger to human health and the environment; Continuous data collection for resource monitoring and management; Introduction of economic incentives.

The on-going programmes to assess the available water resources of the country are being strengthened to provide, among other things, data on: Hydrological features affecting surface water resources; The location of groundwater resources and their characteristics in terms of depths; yields, permeability, storage and recharge; Per capita water use and requirements; Changes in hydrological regimes resulting from human activities, such as water use or extraction, pollution and the effects of mining and lumbering; The management of small and large dams; Irrigation problems with regard to crop water requirements, salinity, drainage andPollution from fertilizers, pesticides and cultivation activities; Existing freshwater living resources.

As part of the strategies for the implementation of the National Policy on Environment in the water sector, a comprehensive national water resources master plan has now been drawn up with support from the Government of Japan, through the Japan International Cooperation Agency (JICA). For the first time, a decree on water resources protection and management has been promulgated (FGN, 1993), with the purpose of: Promoting the optimum planning, development and use of the Nigeria's water resources; Ensuring the co-ordination of such activities as are likely to influence the quality, quantity, distribution, use and management of water; Ensuring the application of appropriate standards an techniques for the investigation, use, control, protection, management and administration of water resources; Facilitating technical assistance and rehabilitation for water supplies.

Industrial water pollution control programme: Industrialization is considered vital to the nation's socio-economic development as well as to its political standing in the international community. Industry provides employment opportunities for a large proportion of the population in medium to highly developed economies. The characteristics and complexity of wastes discharged by industries vary according to the process technology, the size of the industry and the nature of the products. Ideally, the sitting of industries should achieve a balance between socio-economic and environmental considerations. Relevant factors are availability and access to raw materials, the proximity of water sources, a market for the products, the cost of effective transportation, and the location of major settlements, labor and infrastructural amenities. In developing countries such as Nigeria, the sitting of industries is determined by various criteria, some of which are environmentally unacceptable and pose serious threats to public health.

The establishment of industrial estates beside residential areas in most state capitals and large urban centers in Nigeria is significant in this respect. Surface water and groundwater contamination, air pollution, solid waste dumps and general environmental degradation, including the loss of land and aquatic resources, are major environmental problems caused by industrialization in Nigeria. Improper disposal of untreated industrial wastes has resulted in colored, murky, odorous and unwholesome surface waters, fish kills and a loss of recreational amenities. A significant proportion of the population still relies on surface waters for drinking, washing, fishing and swimming. Industry also needs water of acceptable quality for processing.

Economic development can be compatible with environmental conservation and the present problems of environmental resource degradation need not arise within the framework of sustainable development. Failure to halt further deterioration of environmental quality might jeopardize the health of a large proportion of the population, resulting in serious political and socio-economic implications.

Industrial effluent standards: The latest issue of the Directory of Industries in Nigeria published by the Federal Ministry of Industry indicates that over 3,000 industrial establishments exist in the country. These industries vary in process technology, size, nature of products, characteristics of the wastes discharged and the receiving environment. Presently, there are 10 major industrial categories readily discernible in Nigeria: metals and mining; food, beverages and tobacco; breweries, distilleries and blending of spirits; textiles; tanneries; leather products; wood processing and manufacture, including furniture and fixtures; pulp, paper and paper products; chemical and allied industries; and others.

Ideally, each effluent should be detoxified with the installation of pollution abatement equipment based on the Best Practical Technology (BPT) or Best Available Technology (BAT) approach. The high cost of imported BPT and BAT, and the lack of locally available environmental pollution technology, normally requires that Uniform Effluent Standards (UES) are based on the pollution potential of the effluent or the effectiveness of current treatment technology. This approach is easy to administer, but it can result in over-protection in some areas and under-protection in others. To overcome this problem, uniform effluent limits based on the assimilative capacity of the receiving water have been drawn up for all categories of industrial effluents in Nigeria.

Additional effluent limits have been provided for individual industries with certain peculiarities (FEPA, 1991a). Specific regulations to protect groundwater from pollution have also been issued by the FEPA (FEPA, 1991b, c). Industrial sites have to meet concentration limits for their effluents. These are specified in facility permits issued to the industries and enforcement takes.

The Nigerian guidelines require industries to monitor their effluents in-house while the FEPA cross-checks the effluents characteristics to ascertain the degree of compliance with the set standards. Analytical methods commonly used for the determination of significant variables in waters and wastewaters are prescribed by the FEPA for all parties involved in the monitoring exercises. Well-tested, standard methods for water and wastewater analysis used by United States Environmental Protection Agency (EPA), the UK Department of Environment (DOE), the American Public Health Association (APHA) or the American Society for Testing and Materials (ASTM) were adopted for monitoring purposes. For reporting purposes, the analytical method(s) used have to be specified.

CONCLUSION

The meaning of water pollution, water pollution categories, point source pollution, non-point source pollution, ground water pollution, causes of water pollution, pathogens, chemicals and other contaminants, thermal pollution, transport and chemical reactions of pollution, measurement of pollution, sampling, physical testing, chemical testing, biological testing, control of water pollution, domestic sewage, industrial waste water, agricultural waste water, construction site storm water urban runoff(storm water), radiation pollution, the Federal Environmental Protection Agency, The National Policy on Environment, The national environmental reference laboratory, Water resources management, Strategies under the National Policy on Environment, Industrial water pollution control programme and Industrial effluent standards are some vital information on the Nigeria aquatic environment pollution situation.

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