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28.1 INTRODUCTION

The prospecting, exploration, development and production of oil and gas resources follow a sequence of steps that each affect vegetation in different ways. Firstly, geological and geophysical studies are conducted over large areas to identify favourable exploration targets. This is followed by more intensive study, testing and drilling in selected areas to locate and evaluate the oil and gas resource. Production facilities include wells and pumps, gathering and transportation lines, storage tanks and some primary processing facilities.

Construction of roads, airfields, drill sites and production facilities involves the removal of vegetation and usually some modification of topography. Clearing seismic lines may be required in areas of dense vegetation. Some modification in vegetation may result through planting of introduced species for erosion control. Reduction or modification of vegetation can reduce livestock forage, wildlife habitat and timber yield. Sensitive ecological areas, critical wildlife habitat, and endangered plant species can be inadvertently damaged or destroyed. Wetlands may be modified by access roads and drill pads, drained or filled. Habitat reduction or loss and on-going human activities will lead to some loss in wildlife populations, and sensitive species may be eliminated from the operational areas.

Onshore petroleum production activities also affect vegetation. The World Bank (1991) has observed that installations of pipelines can lead to soil erosion and that alteration of drainage patterns can lead to the killing and reduction of vegetation. Creation of rights of way along pipelines can lead to the invasion of exotic plants which may out-compete native vegetation. Furthermore, pipeline installation can result in habitat fragmentation of natural areas, a situation that could lead to loss of species and lowering of biodiversity. Ruptures and leaks from pipelines can contaminate soils which will in turn affect vegetation, and in some cases leaks from gas pipelines can cause fires that burn vegetation.

The marine aquatic communities are almost exclusively algal in West Africa (Lawson 1986) so the effects of off-shore oil activities on vegetation will not be as important as on land. However, trash and spilled oil floating ashore, clearance of pipeline landings and support facility sites and secondary effects of increased population will in some ways, affect vegetation on land.
The approach in this report is to briefly describe the vegetation of the oil producing areas and of other parts of Nigeria where there are major oil activities. Specific effects of oil exploration, production and processing in Nigeria will then be discussed. Some recommendations will made on how to avoid adverse effects resulting from the petroleum industry on vegetation.

Oil Industry Locations

The oil producing areas of Nigeria are concentrated in the Niger Delta and Nigeria's coastline. The soils of the Delta are developed on recent alluvial and beach deposits and Anderson (1966) reports that the freshwater alluvial zone occupies an area of 6989 km^2, the mangrove zone 6298 km^2 and the beach-ridge zone 1280 km^2. Anderson states that starting form the apex of the Niger Delta at Asimabiri, the freshwater alluvial zone extends about 100 km seawards and is followed by the saline mangrove zone which is about 16 km wide. Separating the mangrove zone from the Atlantic which the River Niger water reaches through 12 estuaries is a sand belt consisting of a succession of storm beaches. This beach-ridge belt varies in width from a few metres to 10 km but 1.6 km is perhaps an average. Nigeria's oil fields extend beyond the Niger Delta to the Cross River Basin in the east and to the mouths of the Benin River and beyond up to the shores of Ondo State in the West. Furthermore, there are several off-shore fields. In addition to the oil fields three operational refineries in Nigeria are located in Port Harcourt, Warri and Kaduna. There are also several refined petroleum storage depots in all parts of the country and these and the refinery in Kaduna are fed by long range, extensive pipeline systems (see Figure 28.1). Oil industry impacts on vegetation are logically expected to be mostly around the oil fields but since refining has implications for the environment, our discussion will in addition to the oil fields areas touch briefly on the vegetation zones through which the pipelines pass and in which the depots and refineries are located.

28.2 VEGETATION OF THE OIL FIELD AREAS

Strand vegetation on sandy shores

Lawson (1986) has recognized three types of coastal vegetation in sandy shores of West Africa, a situation that applies to Nigeria. Close to the sea is the pioneer zone made up of plants adapted to the highly saline environment brought about by near-constant inundation by sea water. The plants are usually rhizomatous or stoloniferous, a habit that keeps them attached to the sandy shores. Ipomea pres-caprae, a stoloniferous plant with trailing stem of considerable length is very common in the sea shore zone. The rhizamatous species, Sporobolus virginicus (grass), Remeiria maritima and Cyperus maritimus (both sedges) are also common. Further, inland upward-growing perennials are found. Those include Euphorbia glaucophylla, Portulaca foliosa, Phyllanthus amarus and Sansevieria sp. Most of those plants are to some extent, salt-tolerant.

Beyond the terraces of the exposed beaches and inner lagoon shores the sand slope decreases to provide a stretch of fairly level ground of varying width, the main strand vegetation communities of Boughey (1957). These have been extensively disturbed, as the entire coastline is occupied by coconut groves. Species found in the pioneer zone could still be found in undisturbed places but at reduced densities. The main species present are perennial suffrutescent herbs with some annuals and a few geophytes. Many are neither creepers nor rhizomatous and are not confined to coastal habits but rather widely distributed in sandy soils. This is the typical coastal savanna described by Adejuwon (1970) - and species such as Andropogan gayanus, Cenchrus biflorus, Indigofera hirsuta and several weed species are common. Wind action is still strong so the main strand zone has a flattened appearance, agricultural activity is evident.

The evergreen shrub zone of the strand vegetation occurs on the landward slopes of exposed beaches where the vegetation grades into the inland plant communities. The zone is utilized for the cultivation of cassava and groundnuts. The principal species of this evergreen scrub is Chrysobalanus orbicularis, Sophora occidentalis, Eugenia coronata and Phoenix reclinata (Boughey 1957). When the evergreen scrub has been destroyed, it rarely appears to regenerate. Instead, there is a landward invasion of species from the main strand zone.

Mangrove Vegetation

Mangrove is used collectively to describe woody plants occupying tidal land in the tropics (Lawson 1986). Walsh (1974) describes mangrove as woodland formation below high tide mark, sometimes forest-like, nearest in form to dry evergreen forest, a subformation of the littoral swamp forest. Mangrove habitats are usually flooded with water either permanently or at high tide with the water more or less brackish, on estuarine mud. There are 8,580 km^2 of mangrove in Nigeria (Moses 1990). In Nigeria, as in other parts of West Africa, there are five species of woody plants found in mangroves namely Rhizophora mangle, R. harrisonii, R. racemosa, Avicennia africana and Languncularia racemosa (White, 1983). Languncularia and another species, Conocarpus erectus are present only on high ground not frequently reached by salt water.

In the freshly deposited mud along creeks and estuaries Rhizophora racemosa could attain a height of 45 m and a girth of 2.5 m above the 5 m long stilt roots. The stilt roots do not penetrate the soils in the manner of normal roots because immediately it gets below the surface of the mud, it divides into inumerable rootlets which completely cover the soil as a mat. The tree therefore stands upon a system of arches supported by a thick felt raft of its own making to which it is securely anchored (White 1983). According to Rosevear (1947) this raft of rootlets which is often a metre or more thick together with the detritus it collects tends to form a peat that raises the general surface gradually until it is only just flooded at high waters (see Lawson 1986). Thus, where the soil level is raised sufficiently to allow less frequent immersion in sea water and mud, the soil is no longer suitable for the attainment of the great heights seen at the creek and estuary edges. On the death of a tree the fibres of the roots remain in the soil without significant decomposition and after two or three generations of Rhizophora the accumulation of organic fibres converts the soil into a peaty clay called 'Chikoko'. This peaty clay no longer supports vigorous growth of Rhizophora racemosa and subsequent generations are stunted (Anderson 1966). Anderson (1966) observes that 'Chikoko' occupies about 90% of the area of the Niger Delta under mangroves. The mangroves growing on them rarely exceed 3-4 m. The stunting of Rhizophora species growing on 'Chikoko' may account for the confusion in the taxonomy of the genus in West Africa. It is generally held that R. racemosa grows by the water's edge while R. harrisonii follows with R. mangle being found in the dry inner limit of the Rhizophora zone (Keay 1953). According to Lewis and Jackson (undated), R. racemosa has multiple(racemose) blunt-tipped flower buds per stem while R. harrisonii also has multiple but pointed buds. R. mangle has 2 to 4 flower buds with pointed tips. Lawson (1986) has observed that Avicennia grows well on very sandy beaches whereas Rhizophora always appears to be restricted to muddy areas. He further observes that this feature correlates well with the ability of Avicennia to withstand drier conditions since sand does not retain water. However, Anderson (1966) had observed that Avicennia germinans occurs in places, scattered rather sparsely amongst the Rhizophora in the Niger Delta. He further states that Avicennia is not an indicator of a sandy soil in the Delta. Another observation on the occurrence of Avicennia is that it is found sequentially behind the Rhizophora zone (White 1983). Our observation in the Niger Delta and along Nigeria's west coast is that Avicennia is not as abundant as Rhizophora in the Delta but assumes dominance in the transgressive mud coast in western Nigeria. Enyenihi et al. (1987) also observed pure stands of wide expanse towards the sea in areas of high salinities in the Qua Iboe and Cross River Estuaries in eastern Nigeria. Jackson (1964) observed that Avicennia becomes dominant and often excludes other species along the inner edges of the closed lagoons, up to the high water mark. According to White (1983) Avicennia establishes as a pure stand when sand from the sea rather than mud from the river is deposited. In conclusion, it can be stated that Rhizophora is dominant in sheltered coastal situations where sea water and fresh mud must get to at least on occasions while muddy or sandy coasts that dip gently out to sea usually have Avicennia.

Two other wood mangrove species are Languncularia racemosa and Conocarpus erectus. These two relatively small plants are sometimes present in the vicinity of higher ground indicating low tolerance of salt water. Conocarpus is the more common of the two. Pandanus candelabrum is associated with Rhizophora close to water channels. Also present are scrambling shrubs typified by Machaerium lunota, Dalbergia ecastaphyllum and Hibiscus tiliaceous. The fern Acrosticheum aureum often grows amongst the short Rhizophora on 'Chikoko'. Also found sparsely distributed are several Cyperaceae and the salt grass Paspalum vaginatum. In coastal marshes Paspalum forms extensive aquatic grasslands which could reach up to 1 ha in size as was observed near Obenla (06° O1N, 04° 54'E) on Nigeria's western coast (Isichei, 1992).

Nypa fruticans ('Nipa' palm), introduced into the country early last century for a botanical garden in Calabar has spread to almost all parts of the Niger Delta and is displacing mangroves at the Creek edges.

In the creeks and channels and lagoons accessible to freshwater, water hyacinth, (Eichhornia crassipes) and Pistia stratiotes are frequently found as floating vegetation.

Freshwater Swamp Forest

Nigeria's freshwater swamp forests occur in a zone on the landward side of the coastal mangrove forests and cover an estimated land area of about 18000 km^2 (Skoup and Co. 1980). In the mangrove zone where lagoons, creeks, estuaries and other water channels receive sea water at certain times of the year and fresh water at other times, the preponderant vegetation is mangrove. In the freshwater zone the water is fresh all the time or nearly so. In fact, as soon as mangrove vegetation is deprived of sea water such as happens when there is a blockage or artificial change in topography, freshwater swamp forest results. There are two types of vegetation in freshwater swamps, namely, aquatic vegetation that grows in freshwater, and freshwater swamp forests. These two system are not mutually exclusive and the aquatic vegetation is in fact regarded as an early successional stage of the freshwater swamp forest.

It is believed that sucession begins with submerged and free-floating aquatic plant communities. The former includes Ceratophyllum demersun and Utricularia sp and the latter consists of a well developed sudd of grasses and others including Pistia striatiotes. John (1986) has discussed the

Benin, Mosinmi, Ibadan, Ilorin, Suleja, Minna, Kaduna, Jos, Gombe, Kano, Gusau, Enugu, Makurdi and Yola. All these depots are linked to the refineries by pipelines. It could thus be stated that all vegetation zones in Nigeria are affected by the oil industry but the intensity of effects varies. High intensity effects are noticeable in the oil producing areas while minor vegetation disturbances occur in the northern areas where only storage depots and pipelines supplying them are the major oil activities.

The northern areas of Nigeria are covered by Savanna vegetation, starting from a forest/savanna transition zone characterized by such trees as Daniella oliveri, Parkia biglobosa, Lophira lanceolata and several Combretum and Terminalia species. In wetter places true rainforest trees may be present. Tall grasses such as Andropogon tectorum, Panicum maximum and Pennisetum purpureum are common in the zone which has its northern limits around Oyo, Kogi, and Enugu states. The Guinea zone extends to Niger and Kebbi states in the West and to Bauchi and Gongola States in the east. The Guinea Zone is characterized by shorter trees such as Isoberlinia sp, Vitellaria paradoxa and Adansonia digitata. Grasses are also shorter, usually less than 1.2 m tall. Sokoto, Kano, Yobe and Borno States are in the Sudan zone which is severely disturbed by human activities.

28.3 IMPACTS OF THE OIL INDUSTRY ON VEGETATION

Exploratory and Related Activities

Seismic activities and construction of oil and gas facilities such as refineries, pipelines, flowstations, gas compression plants and oil depots involve removal of vegetation. Usually, a narrow strip of vegetation is involved in the case of Seismic lines and pipelines but tankage depots and refineries could occupy several hectares. Refineries take up large spaces and the Eleme Petrochemical Complex in Port Harcourt, for example, occupies 9 km^2 (Awobajo 1987).

When the narrow strip cleared for Seismic surveys and pipeline construction is, however, summed up for the whole pipeline length, it is found that the quantity of vegetation removed is considerable. For example, EcoDevelopment Consultancy Group (1995) estimated that 115ha of mangrove and freshwater swamps will be lost during the construction of approximately 37km of spurlines as part of the Trans-Ramos Trunkline project in the Delta. Isichei (1993) estimated that the construction of the Enugu - Markurdi - Yola section, a 650 km stretch of the NNPC refined products pipeline would involve the removal of 230000 trees going by the density of trees and the 15 m width cleared for the pipeline. The pipeline runs from Port Harcourt - Enugu - Markurdi - Yola. A similar pipeline in the west runs from Warri - Auchi - Suleja - Kaduna - Jos - Gombe. Not only will the vegetation at these sites be lost but the potential for regeneration is more or less permanently removed because the topsoil that habours seeds is also removed by scraping. If the cleared vegetation is disposed of by burying, their decay will result in the emission of methane, or, if the wood is burned there will be emission of carbon dioxide, oxides of nitrogen, and trace gases, all implicated in global warming. Isichei further observes that there is a likelihood of the loss of biodiversity as the pipeline passed through species - rich riparian forests. Wildlife was affected as one of the riparian forests through which the pipeline passed was a habitat to guenon, an endangered species. It was also noted that the pipeline, designed to carry flammable petroleum products could exacerbate the annual savanna burning problem in Nigeria. Migratory herdsman could use the pipeline route in their north-south movement and trampling by cattle has the potential of increasing soil erosion in the Benue Basin.

Direct Effects

i. **Oil Spills**

Ifeadi and Nwankwo (1987) report that within the years 1976-1986 that about 1.8 million barrels of crude oil was spilled into land, swamp and offshore environments in Nigeria (Table 28.1). This figure represents the net volume spilled, that is, total spillage less recoveries. Most of the spillage incidents occur on land but a large proportion of the spilled volume come from offshore sources. Ageing pipelines and corrosion have resulted in an increase in oil spill incidents, in the last few years. Oil companies have also alleged sabotage as cause of spills as oil producing communities protest their neglect by various tiers of government. Vegetation forms the most visible aspect of the Nigerian terrestrial environment so most of the spilled oil definitely impact on vegetation either directly or indirectly through soil, and to a lesser extent through water which also forms a growth medium for plants. Most of the offshore spills eventually find their way to land, depending on their duration and quantity, and wind and ocean current activities.

Tablo 28. 1: Quantities of Crude Oil Spilled into Land, Swamp and Offshore Environments Nigeria, 1976-1986 (After Ifeadi and Nwankwo 1987)

(a): Net volume of oil spilled to environment 1976-1986: 1806398.9		
Type of Environment	**Quantity of oil spilled 1976-1986**	**Percentage of spill incidents**
Land	101 764	81.1
Swamp	513, 231	12.6
Offshore	1449 898	6.3
(b): Major Causes of Crude Oil Spill In Nigerian Oil Industry Operations, 1976-1986 (After Ifeadi & Nwankwo 1987)		
Cause of spill	**%of spill incidents**	**% quantity of spilled oil**
Sabotage	20.3	3.2
Corrosion	18.4	?
Equipment Malfunction	37.0	37.2

How offshore oil spills affect vegetation and other aspects of the environment depend on the nature of the shoreline. Murday et al. (1988) identify eleven different shoreline types between Molume (05°58'N, O4° 56'E) in Ondo State, and Escravos, Benin and Escravos River/Creek Complex on the Nigerian Western coast. The classification of the shoreline is based on the interactions between spilled oil and shorelines in different geomorphological settings. These shoreline types vary from exposed vertical seawall and eroding mudscarp on cut banks which may not be sensitive to spilled crude oil offshore (because no higher plants will be impacted) to freshwater swamp forest on land, and mangrove which are very sensitive to an oil spill. Vegetation on beach ridge sands and sandy coasts will be severely affected because spilled oil will be transported to them by wave action and by tides. Spaulding et al. 1987 show by modelling that the principal slick transport pattern for deep water spills on the Nigerian western shelf and nearby deep waters is toward the southeast due to the combination of the predominant winds from the west and the southerly directed main ocean currents. Nearshroe spills are transported to the northwest by the nearshroe currents and shoreward by the wind. On land topography is very important with the quantity of oil spilled determining the extent of flow. In pipeline bursts pressure is an important factor because it influences the height of initial oil spray and therefore determines whether trees and shrubs in addition to herbs are affected. On land winds play a minimal role in the spread of spilled oil. Baker (1981) has reviewed the impact of the petroleum industry on mangroves, both the vegetation and the fauna it supports. She also reviewed some case histories where death resulted form the oiling of leaves, pneumatophores and prop roots of mangrove plants. Ekekwe (1981) reports on the effects of the Funiwa - 5 Offshroe Oil Well blow-out in 1980 on the coastal mangroves along the Fishtown and Sangana Creeks in the foreshore of the Niger Delta.

Mangroves and other kinds of wetlands are particularly sensitive to oil spills as they usually involve anaerobic environments and the plants must ventilate their root systems through pores or openings that are prone to coating and clogging (Lugo et al. 1981). Moreover, the plants depend on soil microbial populations to make nutrients available and must obtain their nutrients and freshwater through their roots. Lugo et al. concludes that any stressor that alters these processes has been found to have profound effects on wetland ecosystems. From their study of a mangrove ecosystem affected by an oil spill in Bahia Sucia, Puerto Rico, Lugo et al. observed that 8-25% of the mangrove ecosystem gas exchange occurs through soil sediments, trunks and specialized roots. As gaseous exchange is reduced in mangroves during a spill, roots and aerobic microbes soon lose their capacity to function at normal rates. According to them, the normal response of mangroves that are exposed to oil coating appears to be the rapid drop of leaves with subsequent susceptibility of new leaves to deformation, reduction in size and insect attacks (see also Lewis 1983). Chan (1976) found that an oil coating of more than 50% of the surface area of red mangrove (Rhizophora mangle) seedlings or prop roots in the field resulted in mortality within two months. Baker (1976) had observed that oil may enter plants through the stomata or through the roots and affect photosynthesis and respiration rates, translocation process, seed germination and flowering. In a laboratory experiment with Pistia striatiotes, a floating plant in many Nigerian freshwaters, Ezeala (1987) observed a 63% reduction in chlorophylls, a 65% decrease in leaf area and an 80% reduction in productivity after seven weeks at a crude oil pollution level of 0.5 ml per m^2 of water surface.

ii. **Emissions Related to the Oil Industry**

Worldwide, several pollutants in the atmosphere are attributed to the petroleum industry. Such pollutants include sulphur dioxide, nitrogen dioxide and lead emitted from automobile exhausts. There are also several other gases that are released during production, refining and end-use of petroleum (Table 28.2). These gases in addition to being pollutants themselves also participate in reactions that produce other important pollutants like ozone and peroxyacyl nitrates, PAN. In addition to chemical effects there are also direct physical effects of heat, light and vibrations associated with flaring of gases in the petroleum industry that affect vegetation. Most pollutants are produced during the burning of natural gas, during refining and, as mentioned above during use of refined petroleum products.

Egbuna (1987) reported that 77% of the natural gas associated with crude oil in Nigerian oil fields in 1985 were flared. Gas production for that year, amounted to 2118 million standard cubic feet. 77% of this was flared and produced heat equivalent to 60 X 10^9 Kwh. Table 28.3 shows the numbers of operational oil wells and fields in Nigeria with estimates of the numbers of flaring points for each of the years 1980 - 1988. Several oil wells constitute an oil field and it is assumed that each field is served by at least one flare point. Conservatively it could be stated that each year there are 100 flare points in Nigeria, some of the flares having been in operation for two decades. The magnitude of the effects of flaring could thus be tremendous.

Isichei and Sanford (1976) observed that air, surface soil and leaf temperatures increased and air relatively humidity decreased within about 110 m of gas flares near Port Harcourt. They also observed that leaf chlorophyll content and internode lengths of Chromolaena odorata (Syn: Eupatoruim odoratum) plants decreased close to the flares and that flowering in the plant was suppressed close to the flares. They further observed that there was a bare area of 30-40 m radius around the flares and that plants that follow the C_4 photosynthetic pathway and creeping plants increased near the flares. In another report Ukegbu and Okeke (1987) observed 100% loss in yield in all crops cultivated about 200 m away from the Izombe flare in Imo State. They report a 45% loss in yield in all crops 600 m, and about 10% loss for crops 1000 m away from the flare. They however, observed that soil physical and chemical characteristics were not affected by the flare but that microbial abundance decreased near the flares. It is to be noted that there have been changes in flare stack design since these two studies were carried out. Newer stacks are now horizontal and low resulting in flames whose extent of luminosity is reduced. The low stature of the stacks may, however, mean that their heating effect may be more localized and intense. SEEMS (1992) reports the temperature of the Kokori (Delta State) flare to be between 900 and 1300°C. The chemical composition of natural gas from two fields is shown in Table 28.2 and the number of oil wells and estimated flaring points are shown in Table 28.3.

Table 28. 2: Percent Molar Composition of Nigerian Natural Gas

Chemical compound	AGIP (1)	Flopetrol fluid Analysis Lab 1987 (2)	SEEMS (3)
Methane	81.46	72.42	68.42
Ethane	5.31	9.82	7.65
Propane	5.56	9.85	11.27
N-butane	2.07	2.71	4.00
I-butane	1.40	2.40	4.42
N-pentane	0.57	0.49	0.94
I-pentane	0.71	0.68	1.55
Hexanes	0.46	0.33	0.18
Heptanes	0.34	0.20	
Nitrogen	0.77	0.54	0.16
Carbon dioxide	1.35	0.56	1.02

(1) Izombe Flowstation; (2) Kokori Field July 1987; (3) Kokori Field March 1993.

Table 28. 3: Numbers of Operational Oil Wells, Oil Fields and Estimated Gas Flaring Points in Nigeria, 1980-1988*

Years	No of wells operating	No of fields	Estimate one flare point per field No of flare points
1980	1453	131	131
1981	1137	122	122
1982	1126	137	137
1983	1005	154	6154
1984	1201	144	144
1985	1140	128	128
1986	1255	139	139
1987	1175	143	143
1988	1350	150	150

Source: NNPC Statistical Bulletin,{for the Respective Years}

Table 28. 4: The Adverse Effects of Pollutants on Vegetation

Pollutant	Dose	Effect
O_3	Mild Severe	Effects on upper surface, premature aging, suppressed growth Collapse of leaf, necrosis and bleaching
PAN	Mild	Bronzing of lower leaf surface (upper surface normal), suppressed growth, Young leaves more susceptible
SO_2	Mild Severe	Interveinal chronic bleaching of leaves Necrosis in interveinal areas and skeletonized leaves
Ethylene	Mild	Epinasty, leaf abscission
NO_2	Mild	Suppressed growth, leaf bleaching
Fluorides	Cumulative effect of 1 ppb can be significant	Necrosis at leaf tip
Mixtures	O_3-SO_2 0.028 - 0.28 ppm, 2 - 4 hours O_3-SO_2 0.03-0.1 ppm, 4 hours NO_2-SO_2 0.01-0.1 ppm, 4 hours	Leaf damage on tobacco plants. Tomato leaf damage in Bel W3 variety Moderate leaf injury to Bel W3 tobacco

The gases emitted during combustion of the natural gas in the flares include well known pollutants that negatively affect vegetation. Such gases include SO_x and NO_x and hydrocarbons some of which when deposited could cause increased acidity in the environment. The effects of some of the gases and their secondary compounds on vegetation are outlined in Table 28.4. The role of sulphur dioxide, nitrogen dioxide in pollution episodes are well known but ozone, PAN, ethylene and fluorides are not commonly discussed in our environment.

Ozone formation takes place during combustion of fossil fuel in internal combustion engines as follows: NO_2 produced by combustion is split by sunlight into nitric oxide (NO) and atomic oxygen, which combines with molecular oxygen of the atmosphere to form ozone. It may be stated here that Nigeria's natural gas has some nitrogen and sulphur so is a source of NO_x and SO_X. Isichei and Akeredolu (1988) estimate that use of gasoline, natural gas burning for energy generation, flaring and in industries emits about 64.4×10^6 kg nitrogen per year in Nigeria.

PAN, peroxyacyl nitrates, is one of the series of compounds formed when ozone reacts with olefins. Ethylene is produced during combustion of fossil fuels. Fluoride is widespread as a component of soil, rocks and minerals. When these materials are heated fluoride is emitted in toxic quantities. Fluoride is also emitted from a wide variety of industrial processes (Treshow 1970). Sulphur is present in gasoline, sulphur compounds being components of crude oil (Obuasi 1987).

Sulphur dioxide and nitrogen dioxide end up as acids in the environment. Effects of acidity on vegetation can be direct when acids impinge directly on vegetation or indirect through the effects of acid deposition on soils or biota. Generally, effects of acidity show as decline in vegetation productivity, direct plant mortality and increased susceptibility to ancillary causes of mortality such as fungus and insect infestation (McDowell 1988, Houlden et al 1991, Tiedemann et al 1991). There are few documented effects of acidity in the tropics including Nigeria.

Effects of Wastes

Wastes generated during oil and gas extraction include produced water and drilling muds. Uhuegbulem and Dala (1981) have described the handling of production effluents in a freshwater swamp forest oil field in eastern Nigerian. They observed that some trees in the vicinity of the flare pit that received produce water dried up and they attributed the drying to the abnormal salinity of the water rather than the flare heat. Oladimeji and Onwumere (1987) tested the toxicity of treated petroleum refinery effluent from the Kaduna refinery and reported that fish accumulated trace metals hundred fold what was in the effluent. They concluded that reliance on only chemical analysis of industrial waste may be misleading and recommended integrated strategies that involve regular ecological monitoring of receiving waters to determine the effect on biota. No tests were carried out on plants.

In addition to waters, solid wastes can be a significant portion of the pollutant load generated by the oil industry (Telliard et al. 1981). These include oil skimming, tank bottom cleanings, filter clays and treatment sludges. Current disposal practices include incineration, landfarming, landfilling, ponding, disposal wells and ocean disposal. Waste disposal, be it water or solid wastes, if not carried out with care will ultimately create derelict land. Bradshaw (1989) defines derelict land as land which has been so damaged by industrial and other development that it is incapable of beneficial use without treatment. Vegetation is usually one of the early victims of derelict land creation due to severe alteration of growth conditions for plants. The oil industry might be creating a situation whereby wastelands dot the landscape near oil facilities.

To solid and liquid wastes must be added soil dumps. Dredging of sites for well heads in swamps, construction of flowstations and preparation of land for tankage depots, refineries and terminals involve removal of soil from one place and dumping in another. Dumped earth such as mangrove peat alters the topography in such a way that the dump may deny mangroves access to sea water and the plants may suffocate due to coverage of the surface root mats by sediments. The mangroves die and are replaced by freshwater swamp forest (see Eco Development Consultancy Group 1991). On drier land and mangroves entirely different vegetation grows on such dump sites.

28.4 SUMMARY AND RECOMMENDATIONS

Summary

(i) Vegetation forms the most visible aspect of the terrestrial landscape and its decline or unusual rapid change is the culmination of an environmental crisis. Several aspects of the prospecting and exploration of petroleum deposits, the mining, processing and use of petroleum products affect vegetation. The ways these processes affect vegetation are outlined.

(ii) Most of Nigeria's oil fields are located in the Niger Delta and the coastal areas. The vegetation formations in these areas are described so that the impacts of the petroleum industry on them can be put in proper perspective. The vegetation types include strand vegetation characterized by creeping plants on beach ridges, mangrove vegetation on the shorelines and on the banks of the estuaries that form the distributaries of the River Niger. Freshwater swamp forests and lowland rainforest proper are found further inland. Brief descriptions are also given of the vegetation of the various other parts of Nigeria where there are oil installations such as refineries and storage depots and the pipelines that serve them.

(iii) Direct impacts of the petroleum industry on vegetation include crude oil spills and emissions from natural gas burning, oil refining and end-use. Indirect effects include vegetation loss during exploration and construction of facilities. The issue of waste disposal which creates derelict land is also discussed.

Recommendations

(i) it is recommended that oil spills be minimized. It is surprising that equipment malfunction contributes a high proportion of spill incidents and quantity of oil spilled (Table 1a) Ageing pipelines should be replaced as is now being done by SPDC. Flaring of associated natural gas should be stopped since such waste and environmental damage are no longer justifiable. It is also suggested that produced water be more intensively treated and that efforts should be made to avoid creation of wastelands due to dumping.

(ii) Environmental impact studies are now being carried out before projects are commenced in oil companies but the practice needs to be more widespread in the petroleum industry in accordance with the law. There is also the need to intensify the restoration of oil-impacted environments.

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