DOI:10.31557/APJEC.2021.4.1.9

REVIEW

The Impact of Oil and Gas Development on the Landscape and Surface in Nigeria

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Abstract

This writing will focus on the impact on the impact of oil and gas development on the landscape, surface water and groundwater of the Niger Delta – while also assessing the various means of remediation in use. Geologically, the Niger Delta petroleum systems consist of Lower Cretaceous , Upper Cretaceous–lower Paleocene and Tertiary. When Nigeria became an independent nation on 1 October 1960, Shell–BP began to relinquish its acreage and its exploration licenses were converted into prospecting licenses that allowed development and production. The Federal Government of Nigeria started its Department of Petroleum Resources Inspectorate in 1970 and Nigeria joined the Organization of the Petroleum Exporting Countries in 1971. – and in order to take control of the country's petroleum industry, Nigeria nationalized BP's holding completely in 1979, and Shell–BP became Shell Petroleum Development Company of Nigeria. Oil spillages routinely occur in the Niger Delta. The official figures of SPDC show that between 1976 and 2001, 6,187 incidents in which 3 million barrels were spilled. The Niger Delta Environmental Survey An impact assessment of the 1983 Oshika oil spill. Spills of crude oil in Niger Delta farmlands have been reported since 1971. In general, toxicity depends on nature and type of crude oil , level of oil contamination, type of environment and degree of selective of individual organisms. Controlled burning effectively reduce the amount of oil in water, if done properly but it must be done in low wind and can cause air pollution. A principal target for emissions reduction is flaring and venting which causes most of the air pollution. Saltwater tanks can be often susceptible to lightning strikes due to build up in static electricity, with the spilled oil spreading to surrounding lands, waterways. This requires a secondary containment of the tanks that makes it easier to clean up the inevitable spill. In cases of expected major storms or flooding events, crude oil can be removed from tank batteries while refilling the tanks with saltwater to prevent them tipping over during the flooding event.

Keywords: Industrial-Environment Analysis- Impact Factor Research- Niger Delta Research- Impact Research

Asian Pac Environ Cancer, **4 (1)**, 9-17

Submission Date: 09/15/2021 Acceptance Date: 10/25/2021

Introduction

The Dutch disease, as they call it – Oil, a blessing and curse. As far as back as the 20th century when commercial oil and gas production started. Oil wealth has often been equated to a curse. A curse which affects the economy, the people and the environment.

This was first noticed in the 1950s when the Dutch currency appreciated due to a gas export boom. Experts then, noticed a corresponding reduction in the manufacturing and services sector [1]. Thus, when gas prices fell in the 1960s, the neglected sectors could not sustain the Dutch economy.

Time and time again, this same pattern has repeated itself in most oil and gas producing nations around the work. In Nigeria, the self-proclaimed 'Giant of Africa', the same scenario has been playing for the past fifty years to devastating effects especially in the Niger Delta, where oil is extracted in Nigeria.

Nigeria, the largest oil and gas producer in Africa, produces around 2 million barrels per day. It also holds the largest gas reserves on the continent and was the fifth-largest exporter of liquefied natural gas in 2018 [2]. The oil in Nigeria known as 'sweet oil' is quite unique because of its low sulfur content.

Petroleum exploration started in Araromi, Ondo state

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in 1908 by the Nigeria Bitumen Co. & British Colonial Petroleum [3] but it would take half-a-century later before production started when SPDC then known as Shell D'arcy (licensed in 1937) started oil production and export from the Oloibiri field in Bayelsa State at a rate of 5,100 barrels per day [3]. Subsequently, licenses were granted to Mobil in 1955, Tenneco in 1960, Chevron in 1961, Agip and Elf in 1962 to widen the scope of exploration and production. Today licenses have also been granted to indigenous companies in the country.

The entry of oil companies into the Niger Delta has no doubt brought great financial wealth. Indeed, there has been substantial improvements in the nation's economy over the past five decades. Currently oil revenue accounts for 70% of Nigeria's total revenue, as well as generating more than 14% of the GDP.

However, activities associated with petroleum exploration, development and production operations have local detrimental and significant impacts on the atmosphere, soils and sediments, surface and groundwater, marine environment, biologically diversity and sustainability of terrestrial ecosystems in the Niger Delta [4].

Petroleum is a naturally occurring complex mixture of predominantly hydrocarbon compounds and significant amounts of nitrogen, sulphur, and oxygen together with smaller amounts of nickel, vanadium, and various elements. Petroleum compounds occur in solid form as asphalt, liquid form as crude oil and/or gaseous form as natural gas. It is classified into; saturates (pentane, hexadecane, octacosane, cyclohexane), aromatics (naphthalene, phenanthrene, benzene, pyrene), asphaltenes (phenols, fatty acids, ketones, esters, and porphyrins), and resins (pyridines, quinolines, carbazoles, sulfoxides and amides) [5].

Soils and sediments are the ultimate sink for most petroleum contaminants, such as benzene, toluene, ethyl benzene, and xylenes (BTEX), aliphatic and polycyclic aromatic hydrocarbons (PAHs). Petroleum hydrocarbon contamination of soils and sediment is a global concern because of the toxicity [5]. The inadvertent discharges of petroleum hydrocarbons into the environment often pose threats to human health, safety and the environment, and have significant socio–economic consequences [4].

Despite these concerns, multinational oil companies operating in the Niger Delta region have failed to adopt best practice strategies for risks mitigation and comply with environmental regulations. This coupled with the failure of the Nigerian government to enforce the aforementioned environmental regulations contribute towards the unabated environmental contamination, with direct consequences on the surrounding populations' socio–economic wellbeing, human health and the environment.

This essay will focus on the impact on the impact of oil and gas development on the landscape, surface water and groundwater of the Niger Delta – while also assessing the various means of remediation in use.

The Niger Delta

The Niger Delta region is situated at the apex of the Gulf of Guinea on the west coast of Africa [6] in South–South Nigeria. It is home to some 31 million people [7] and makes up 7.5% of Nigeria's land mass [4]. A total of about 1,182 exploration wells have been drilled to date in the delta basin, and about 400 oil and gas fields of varying sizes have been documented [8]. This region cuts across over 800 oil–producing communities with an extensive network of over 900 producing oil wells and several petroleum productions– related facilities [9].

Geologically, the Niger Delta petroleum systems consist of Lower Cretaceous (lacustrine), Upper Cretaceous–lower Paleocene (marine) and Tertiary (deltaic) [10]. According to [11], a large portion of the world's oil and gas reserves are in tertiary terrigenous passive continental margins – accounting for the significant hydrocarbon deposits Nigeria's Niger Delta.

The ecological zones can be broadly grouped into tropical rainforest in the northern part of the Delta and mangrove forest in the warm coastlines of the south. Mangrove forests and swamps, characterized by regular salt–water inundation, lie at the center of a complex and sensitive ecosystem which is vital to the local economy and accommodates important flora and fauna [12]. According to World B classification, freshwater swamp forests lie in the hinterland away from the mangrove forest, where floodwater collect in countless swamps and ponds, saturating the soil for at least the rainy season. There are two other ecological zones; the lowland rainforests areas and barrier island forests – these two are starting to die out.

The Niger Delta, is the largest mangrove forest in Africa and the third largest in the world with a rich biodiversity of fauna and flora that include; mona monkey, speckle-throated otter, marsh mongoose, black squirrels, barracuda, shiny nose, antelopes, catfish, elephants, clawless otters, etc and the more common oil palm, mangrove species, salt ferns, etc. It's worth mentioning that a great number of Nigeria's endemic species are found in the Niger Delta, holding 60-80% of plant and animals species [13] which makes it all the more damning that the Niger Delta still doesn't a coastal/marine protected area!

Development of Oil & Gas in the Niger Delta

In February 1958, Shell-BP started exporting crude oil produced from Oloibiri and Afam oil field at Port Harcourt [14]. The giant Bomu oil field, which has estimated ultimate recovery of 0.311 billion of barrels of oil and a total of 0.608 billion of barrels of oil equivalent including gas, was discovered southeast of Port Harcourt-Rivers State in 1958 [15]. At this time; the petroleum sector began to play a vital role in shaping the Nigerian economy and political destiny of the country.

When Nigeria became an independent nation on 1 October 1960, Shell–BP began to relinquish its acreage and its exploration licenses were converted into prospecting licenses that allowed development and production [15]. Following the increasing dominance of the Nigerian economy by petroleum sector, the sole concession policy was abandoned and exclusive exploration right

was introduced to encourage other multinational oil companies aimed at accelerating petroleum exploration and production. Most of these multinational oil companies recorded considerable successes in oil and gas exploration and production in both onshore and offshore fields in the Niger Delta

The Federal Government of Nigeria started its Department of Petroleum Resources (DPR) Inspectorate in 1970 and Nigeria joined the Organization of the Petroleum Exporting Countries (OPEC)in 1971. The first national oil company, the Nigerian National Oil Corporation (NNOC), was created in 1971 and it later became the Nigerian National Petroleum Corporation (NNPC) in 1977 – and in order to take control of the country's petroleum industry, Nigeria nationalized BP's holding completely in 1979, and Shell–BP became Shell Petroleum Development Company of Nigeria (SPDC) [16]. Although several other oil companies have joined in exploration and production over the past decades, SPDC has the largest acreage in the country from which it produces some 39 per cent of the nation's oil and remains the major producer in the Nigeria's petroleum industry.

Over the past years, the Nigerian Federal Government has promulgated laws and regulations so that oil and gas exploration and production operations, on both onshore and offshore oilfields, could be controlled by systems of limits which aim at minimizing the associated environmental impacts. Some of the related environmental laws and regulations in the oil and gas sector include Oil Pipelines Act 1956 (amended in 1965); Mineral Oils (Safety) Regulations (1963); Oil in Navigable Waters acts (1968); Petroleum Acts (1969); Associated Gas Re–injection Act (1979); the Federal Environmental Protection Agency (FEPA) Act (1988); the National Policy on the Environment, 1989 (revised in 1999); National Environmental Protection (Effluent Limitations) Regulations (1991); Environmental Protection (Pollution Abatement in Industries Generating Wastes) Regulations (1991); Environmental Impact Assessment (EIA) Act (1992), and Department of Petroleum Resources (DPR) Environmental Guidelines and Standard for the Petroleum Industry in Nigeria (EGASPIN) (2002). According to [17], most of these statutory laws and regulations provide the framework for petroleum resources exploration and exploitation in Nigeria and only some of these environmental regulations give guidelines on issues of petroleum pollution.

Under the 1988 FEPA Act, penalties and enforcement mechanisms were imposed, multinational oil companies could be held liable for costs of clean–up, restoration and multinational oil companies could pay compensation to parties injured by their illegal practices. However, the existing statutory laws and regulations for environmental protection applicable to the Nigerian petroleum industry appear to be grossly inadequate and ineffective [18]. The government's environmental regulations are often affected by the limitations of technology, the need to support industry and the influence of public opinion [19]. In the Nigeria's Niger Delta, the participation of communities in the environmental decision–making process is a relatively new process and often ineffective with little or no sustainable development goals [20]. Over the past fifty years, the multinational oil companies operating in the Niger Delta region have failed to adopt sustainable exploration and production practices due to increased costs of complying with environmental regulations. Although comprehensive system of environmental regulations is now in place, environmental pollution associated with oil and gas exploration and production operations has continued to persist under these laws for several reasons.

The Consequences So Far...

In 2006, UNDP submitted a report suggesting the dire straits in the Niger Delta which stated that the degree and rate of degradation in the Niger Delta was pushing it towards an ecological disaster" [21].

It is a fact that all aspects of oil and gas exploration and exploitation have deleterious effects on the local ecosystem and biodiversity. Oil exploration by seismic companies involves surveying, clearing of seismic lines, and massive dynamiting for geological excavations. The explosion of dynamite in aquatic environments leads to narcotic effects and mortality of fish and other faunal organisms [22]. Destabilization of sedimentary materials associated with dynamite shooting causes increases in turbidity, blockage of filter feeding apparatuses in benthic fauna, and reduction of plant photosynthetic activity due to reduced light penetration. The burying of oil and gas pipelines in the Delta fragments rich ecosystems such as rainforests and mangroves. Apart from the reduction in habitat area, clearing of pipeline track segregates natural populations, which may in turn distort breeding behaviour. Oil spillages routinely occur in the Niger Delta. Sources of oil entering the environment are variable, including pipeline leakage and rupturing, accidental discharges (e.g. tank accidents), discharges from refineries and urban centres, etc. [12].

A World Bank survey [23] estimated that about 2.3million cubic metres of crude oil is spilt in about 300 separate incidents in the region each year; observing that oil companies deliberately understate the incidents of oil spillage, and that the total volume of oil spilt might be as much as ten times the official figures. The official figures of SPDC [24] show that between 1976 and 2001, 6,187 incidents in which 3 million barrels were spilled. Greater than 70 per cent of this volume went unrecovered [21]. Following from the World Bank [23] assertion, it may be concluded that more than 30 million barrels have been spilled into the delta environment in the same period.

The Niger Delta Environmental Survey [25] attributes some of the reasons for the high incidence of spills as the very old age of the pipelines and the lack of regular inspection and maintenance. Corrosion of equipment which account for high percentage of all spills could be related to the small size of the oil fields in the Niger Delta which has an extensive network of pipelines, between the fields as well as numerous small networks of flow lines –that carry oil from wellheads to flow stations, allowing many opportunities for leaks. These pipelines which were

laid about 50years ago according to the then prevailing standards and estimated to have a life span of about fifteen years are old and susceptible to corrosion. Poor management practices are common features around oil installations leading to oil leaks and spills in the region. Leaks and spills also affect ground water quality.

Most of these oil-spill incidents reported in Nigeria occurred in the mangrove swamp forest of the Niger Delta region. The mangrove forest as discussed earlier, is one of the most productive ecosystems in the world with a rich community of fauna and flora — the negative effects of the oil spills are obvious. It is pertinent to note that the majority of oil spills occurring in the Niger Delta are considered 'minor' and so are not reported. Some of the prominent oil spillages recorded in the Niger Delta petroleum industry include: the Bomu II blowout, 1970; the Forcados terminal spillage, 1980; the Funiwa 5oil well blowout, 1980; the Oyakana pipeline spillage, 1980; the Okoma pipeline spillage, 1985; the Oshika pipeline spillage, 1993; and the Goi Trans Niger pipeline oil spill, 2004.

Also, the Funiwa 5 oil well blowout in 1980 and Jones Creek oil spillage of 1998 – these two spills together resulted in greatest mangrove devastation ever recorded worldwide. In addition to deforestation, spills deplete aquatic fauna. The spilled oil and indeed untreated oil industry related effluent are considered priority pollutants as they interfere with biological life in surface waters creating unsightly floating matter and film. This situation is of high ecological concern as a result of simultaneous transformation of oily compounds by biochemical, chemical, microbiological and photochemical processes. The consumption of dissolved oxygen by bacteria feeding on the spilled hydrocarbons also contributes to the death of fishes

This feeling has been buttressed by results of research;

a) An impact assessment of the 1983 Oshika oil spill by [26] confirmed the death of floating and submerged aquatic vegetations especially water lettuce, crabs, fish and birds.

b) NDES, 1997 shows that the pollution levels of aquatic ecosystems observed in the region are a result of unregulated effluent discharges and unsustainable methods of petroleum extraction [25]

c) Ndiokwere, 1990 also report high levels of heavy metals in soils and plants near the Warri Refinery [27].

d) Emoyan et al., 2006 have also confirmed high levels of heavy metal contamination of River Ijana - an effluent receiving stream that flows by the same refinery [28].

e) Braide et al., 2004 observed high concentrations of heavy metals in the Miniweja stream in the eastern Niger Delta [29].

f) Furthermore, Spiff and Horsfall, 2002 reported trace metal contamination of the intertidal flats of the Upper New Calabar River in the Niger Delta [30].

g) Meanwhile, Rowell, 1977, Atuanya, 1987, Anoliefo, 1991, have independent studies, that documented the adverse effects of crude oil, engine oil and spent lubricating oil on soils and the suppression of germination of seeds, regeneration as well as stomata abnormalities in diverse food crops [31-33].

Impacts of Oil and Gas on Landscape

The overall effects of oil spill on biota and ecosystem health are manifold. Oil interferes with the functioning of various organ systems of plants and animals. It creates environmental conditions unfavourable for life; for example, oil on a water surface forms a layer which prevents oxygen penetration into water bodies, and this in turn leads to suffocation of certain aquatic organisms. Crude oil contains toxic components, which cause outright mortality of plants and animals as well as other sub-lethal damage. Generally, toxicity is dependent on the nature and type of crude oil, the level of oil contamination, the type of environment, and the selective degree of sensitivity of individual organisms [4].

Gas flaring associated with oil production in the Niger Delta is very unfriendly to natural ecosystems and biodiversity. Gas flares typically contain more than 250 toxins. Perhaps more important is the finding, in a study of the impact of gas flaring on the environment, which revealed that there was almost 100% loss in yield of all crops cultivated about 200 metres away from the Izombe station, 45% loss of those about 600 metres away, and around 10% loss in yield for crops one kilometre away from the flare [34]. Further, assessment of the PAH compound ratios, phenanthrene/ anthracene and fluoranthene/ pyrene, suggested that predominant presence of PAHs of pyrogenic sources in surface soils is an indication that oil leakage and/or gas flaring contributes to soil contamination [35]. According to [36], it has been found that the residents perceive gas flaring as hazardous to health, environment, and general well-being of the oil–producing host communities.

A large portion of the terrestrial ecosystems and shorelines in the oil producing communities in the Niger Delta region are important agricultural lands which are under continuous cultivation and support peasant farming. Spillage of crude oil into agricultural lands in the Niger Delta has been reported since 1971 [37]. It is known that various types of crude oil can exert acute or chronic toxicity or both on soil properties and microflora [37]. The presence of high concentrations of petroleum hydrocarbon in soil may cause oxygen deprivation and subsequent death of soil fauna due to asphyxiation [38]. Studies have investigated the effect of crude oil contamination of soil on the germination and growth performance of some agricultural crops [39]. The effect of crude oil–contaminated soil on the germination and growth performance of Abelmoschus esculentus, a widely cultivated vegetable crop in Nigeria, have been reported

[39]. According to [39], petroleum hydrocarbon contamination of agricultural soil hindered germination, affects the crop agronomic growth performance of Abelmoschus esculentus L. and subsequently result in poor crop yield.

Leakages and fire incidents are also associated with gas production and transportation. In 2004, the Nigerian Liquefied Natural Gas (NLNG) pipeline traversing the Kala-Akama and Okrika mangrove swamps (in the Niger Delta) leaked and caught fire. The fire burned uncontrollably for three days [22]; local plants and animals inhabiting the affected area were killed. It must be stressed that incidents such as this one can result in the elimination of whole populations of endangered species which have restricted distribution. During construction of the NLNG gas plant in Bonny, footprints of hippopotami were seen [22]. These giant animals, known to have flourished in the Finima area which the NLNG plant complex now occupies, have vanished completely since then. Whether the rare Finima hippo population all died out or embarked on forced migration to some relatively 'safe' and undisturbed area remains unclear. In any case, it is well-known that wildlife caused to migrate by anthropogenic disturbances are prone to suffering ecological catastrophes.

Defoliation and mortality of the mangroves have been observed in swamps affected by oil spills [40]. The effects of oil pollution on the diversity and functioning of fish and turtle communities in the Niger Delta have been reported [41].

In the aquatic environment, the oil slick sometimes floats on the water surface where it is dispersed to shorelines by wind and wave actions and invariably affecting the soil. When oil spillage occurs onshore or near shore, the soil and other components of the terrestrial ecosystem are inevitably affected [42].

The improper disposal of produced water on the ground is associated with salt scars and potentially contaminated land that is difficult to remediate. According to [43] adverse impacts to mangrove vegetation are the most obvious signs of environmental effects resulting from produced water spills or discharges. The toxicity of produced water is directly related to high salinity (3000 to > 350,000 mg/L total dissolved solids [TDS]) [44] and other parameters such as toxic metals, soluble organics and radionuclides contents [45].

Impact on Surface/Groundwater

Preliminary results of ground water quality evaluation around the WRPC show elevated levels of BTEX in shallow boreholes and dug well water [46]. This is interesting because Warri, an oil town of more than forty years, and arguably the most important industrial centre in southwestern Nigeria does not have a reliable public water supply system, and consumers must rely on private sources, usually shallow boreholes and hand dug wells. Indeed, this is the situation in most parts of the delta. Because water table conditions are prevalent, depth to water is on average less than a meter in the wet season and the topography is virtually flat, spills as well as effluent impact directly on ground water [4]. The situation is compounded by the fact that there is neither water quality surveillance nor monitoring systems anywhere in the region. As it is well known, unrecovered spilled hydrocarbon could under these conditions be retained for years in the vadose zone as well as on the phreatic surface from where it would serve as a continuous water supply contaminant point source [4].

According to [47], the assessment of the petroleum contamination threat on groundwater showed that PAHs concentrations ranged from 1.92-40.47 μgl^{-1} and undetectable levels of high molecular weight PAHs have been attributed to their low water solubility [13]. According to [48], groundwater contamination resulting from the leakage of crude oil and refined petroleum products during extraction and processing operations is a serious environmental problem in the Niger Delta region. Groundwater evaluation is increasingly tilting toward a watershed approach due to large-scale contamination, resulting from urban development, rapid population growth, and land use changes [49]. Contamination of controlled water sources in the Niger Delta have made the people to resort to drilling borehole for drinking water, therefore, the protection of groundwater supply is importance to help mitigate potential risks associated with petroleum contamination. Considering the fact that ground water is one of most precious natural resource across Africa [50], there is a need for widespread adoption of sustainable development strategies for risks mitigation, effective understanding of the hydrogeology and adoption of microbial strategies in the management of petroleum contamination of environment.

The discharges of petroleum hydrocarbon and petroleum–contaminated production wastes in freshwater environments and overflowing of oily wastes in burrow pits during heavy rains has had deleterious effects on soil and several sources of controlled waters [51] studying the Sombriero River found that the appearance of water at Bille was darkish brown with hydrocarbons odour while at Degema/Abonnema was cloudy, with a comparison to existing baseline data showing an increase in alkalinity, turbidity, TSS and TDS. A comparative study undertaken by [52] showed most of the trace metals to be above the US EPA Maximum Contaminant Level indicative of water pollution [53] in studying the Nun River discovered a significant deterioration of the river quality due oil production activities as seen in the comparative high values of trace metals, conductivity, DO, etc in comparison to the baseline data [54] analyzing samples of oil residue from the Esi River for heavy metals and total petroleum hydrocarbon concentration found the nickel-vanadium ratio of 1.71 and high concentration of Pb to indicative of severe pollution.

Prior to the institution of statutory laws and regulations in the 1970s, the major petroleum– derived wastes such as produced water, spent drilling muds, drilling cuttings and wastes that require handling during site abandonment were commonly discharged into coastal waters, swamps, and unlined evaporation ponds. In particular, produced water is the largest volume waste stream associated with oil and

gas exploration and production processes. The chemical composition of the oil field produced water is complex, including large amounts of dissolved salts, hydrocarbons, heavy metals, organic and inorganic components, naturally occurring radioactive materials (NORMs) and chemicals added in the oil extraction and separation steps (43, 80). Produced water is either discharged into above ground storage facilities or re-injected into a subsurface formation as a permanent disposal/secondary recovery process during onshore operations, whilst it is either discharged through shore side outfalls or coastal rim releases (within 4 miles from shore) during offshore or coastal operations [55]. In many cases, the past and current disposal practices such as these have caused severe environmental contamination of coastal waters, groundwater water, soils and sediments, and marine ecosystems in the Niger Delta.

In the marine environment, contaminants with petroleum–contaminated produced water are toxic to a wide variety of aquatic organisms or estuarine organisms, therefore, there is no justification for the continuous disposal of produced water into ecologically sensitive areas in the Niger Delta. According to [56], the chemical complexity of petroleum hydrocarbon and organic contaminants poses many important challenges for exposure in marine ecosystems that support productive fisheries throughout the world. Important toxic effects associated with petroleum contamination in the shoreline could be difficult to identify which specific chemicals in complex oil mixtures are causing early life stage toxicity in fish [56].

Assessing The Reversibility Of The Identified Impacts

Reversing the half-a-century generated negative impact on the Niger Delta requires a three-pronged approach that focuses on not just:

a) remediating polluted areas, but also;

b) reducing pollution;

c) and protecting unpolluted/pristine areas in the Niger Delta.

Remediating polluted areas

Cleaning up and recovering an area subjected to oil spill is difficult and often depends upon many factors, including the type of oil spilled, the temperature of the water (affecting evaporation and biodegradation), and the types of shorelines and beaches involved [57]. This is compounded by the expensive nature of physical cleanups of oil spills.

Microorganisms such as Fusobacteria species present a cheap means oil spill cleanup because of their ability to colonize and degrade oil slicks on the sea surface [58].

Similar to the use of bacteria is the bioremediation accelerator which makes use of a binder molecule that moves hydrocarbons out of water and into gels. The accelerator acts as a herding agent in water and on the surface, floating molecules such as phenol and BTEX to the surface of the water, forming gel-like agglomerations. Whether applied on land or on water, the nutrient-rich emulsion creates a bloom of local, indigenous, pre-existing, hydrocarbon-consuming bacteria. These specific bacteria break down the hydrocarbons into water and carbon dioxide, with EPA tests showing 98% of alkanes biodegraded in 28 days; and aromatics being biodegraded 200 times faster than in nature [59].

Dispersants can be used to dissipate oil slicks [60]. A dispersant is usually a colloid added to a suspension, to improve the separation of particles and to prevent settling or clumping. The oil is then effectively spread throughout a larger volume of water than the surface from where the oil was dispersed. However, laboratory experiments show that dispersants increase toxic hydrocarbon levels in fish by a factor of up to 100 and may kill fish eggs [61]. Dispersed oil droplets also infiltrate into deeper water and can lethally contaminate coral [62].

Solidifiers composed of tiny, floating, dry ice pellets, [63] and hydrophobic polymers have the potential to adsorb and absorb. Solidifiers are insoluble in water; therefore, the removal of the solidified oil is easy and the oil will not leach out. Solidifiers have been proven to be relatively non-toxic to aquatic and wildlife and have been proven to suppress harmful vapors commonly associated with hydrocarbons such as benzene, xylene and naphthalene

A vacuum or centrifuge can be used to separate the oil from the water – allowing a tanker to be filled with near pure oil. Usually, the water is returned to the sea, making the process more efficient, but allowing small amounts of oil to go back as well [64].

Controlled burning effectively reduce the amount of oil in water, if done properly but it must be done in low wind and can cause air pollution [65].

In some cases, natural attenuation of oil may be most appropriate, due to the invasive nature of facilitated methods of remediation, particularly in ecologically sensitive areas such as wetlands.

Reducing Pollution

Reducing pollution entails use of improved technologies and techniques and ensuring best practices in the industry that mitigate and reduce the risk of pollution.

A principal target for emissions reduction is flaring and venting which causes most of the air pollution. Technological advances in valve design have the potential to reduce fugitive emissions, whilst improved flare design has increased combustion efficiency.

Reinjection of produced water either into the reservoir or into another formation seems like a practical solution is common practice in the industry, however the truth is such suitable geological formations are getting harder to come by in the Niger Delta, often in cases where the reinjection operation is carried out, seepage/discharge into the groundwater is an aftermath.

Reuse, recycling and recovery of waste materials include the use of drill cuttings for brick manufacture and road bed material, use of flared gas for fuel, and used of produced water as wash water – this is actually a good option as it ensures the continuous circulation or/and

beneficial use for materials that would otherwise be toxic to the environment.

Drilling techniques like horizontal drilling, slim-hole drilling and heliportable drilling provide considerable environmental advantages, such as minimizing land take and footprint, reduction in waste material. The use of vibroseis on land and air guns seems to reduce dependence on explosives as well which are comparatively more detrimental.

Protecting pristine/unpolluted areas

Protecting pristine/unpolluted areas from the impact of oil and gas pollution often involves taking preventive measures against inevitable circumstances due to delicate nature of the environment and the infrastructure in use by the industry.

The Niger Delta has an extensive network of pipelines, flow-lines, gathering systems, tank batteries, salt-water tanks that also happen to pass through areas where E & P activities is not being conducted. Some of these are areas not even polluted but are at risk because of this network system.

While there is indeed an existing program set in place to check and replace aging parts of the pipeline network in the Niger Delta – the corrosivity of the soil in the Niger Delta itself seems to be destroying pipes faster than the expected time of replacement. This preventive mechanism requires periodic monitoring.

Saltwater tanks can be often susceptible to lightning strikes due to build up in static electricity, with the spilled oil spreading to surrounding lands, waterways. This requires a secondary containment of the tanks that makes it easier to clean up the inevitable spill.

In cases of expected major storms or flooding events, crude oil can be removed from tank batteries while refilling the tanks with saltwater to prevent them tipping over during the flooding event. After the storm, it's important inspect the sites for damage.

Protecting pristine areas also involves setting up protected lands and coastal reserves where oil and gas development hasn't started to ensure continuous biodiversity and survival of endemic species.

In conclusion, the damage is already done, the Niger Delta is a wasteland, continuously deteriorating due to the negligence of primary stakeholders. The landscape visually is unsightly and unproductive. The consequences, far reaching, as seen in impact assessments conducted on the marine and terrestrial ecosystems.

That said, short-term measures in the form of remediation techniques as discussed in Section 1.4 which will yield benefits. Further recommendations include;

a) Establishing and maintaining a baseline data system on the current state of the Niger Delta ranging through the physicochemical properties of immediate recipients of pollution impact like land, water, air and wildlife. Indeed, there are literature and research available currently scattered that need just be collated together into a database;

b) Similar to these is placing the environmental data of the multinational involved in oil and gas E & P in the public domain. This can be enforced legally to promote transparency.

In the long term, a more productive relationship between the Government, Multinationals and the Niger Delta needs to be initiated. A commitment towards achieving remediation and reclamation of the Niger Delta over time-scales of 20yrs – 50yrs should be at the fore-front;

a) The Niger Delta people need to take more responsibility into protecting their own communities; short term gain/greed should be laid aside for a sustainable future.

b) Aside from incorporating best practices in their mode of operations, the Multinationals need to be deliberate about financially empowering their host communities; by providing gainful job opportunities that will bring much of these people out of poverty and discourage them from being instruments of sabotage.

c) The Government has the responsibility of being the sole arbiter between the two parties while also fulfilling its own obligations in lawful enforcement of stated regulations in place to protect the environment.

d) The obvious corruption that has been the bane of efforts can be combated by strengthening the voice of the people in general through NGOs who can serve as whistle blowers and hold all parties accountable to their actions.

Acknowledgments

All acclamation and praises are for "Almighty ALLAH". I would like to acknowledge two people. One is late Khan Abul Hossain, a Bangladeshi freedom fighter, my friend, a batchmate of mine from LLB course of Dhaka International University & with whom I spent a lot of time during my research periods. And another person is Md Kabirul Hasan sir, the best teacher of my life until today and his lectures during my preparation for Junior School Certificate (JSC) Exam was a great foundation to start my research work(s). It might be quite impossible for me to do these research(es) for human kind without their inspiration, mental support & support by giving knowledge.

References

1. Ross M. Nigeria: Drivers of Change Program. Nigeria's Oil Sector and the Poor. UK Department for International Development. 2003.
2. BP. (2019, June). BP 2019 Statistical Review of World Energy.
3. Udosen C, Etok A, George I. Fifty years of oil exploration in Nigeria: the paradox of plenty. Global Journal of Social Sciences. 2010 02 22;8(2). https://doi.org/10.4314/gjss.v8i2.51579
4. Aniefiok EU. Petroleum Exploration and Production: Past and Present Environmental Issues in the Nigeria's Niger Delta. American Journal of Environmental Protection. 2013.
5. Ite and Semple, I. A. Biodegradation of Petroleum Hydrocarbons in Contaminated Soils. In Microbial Biotechnology: Energy and Environment. 2012.
6. Doust H. Petroleum Geology of the Niger-Delta. Geological Society , London Special Publications. 1990.
7. Young E. Food and Development. 2012.
8. Obaje N. Geology and Mineral Resources of Nigeria. Springer.

2009.
9. Osuji et al, L. O . Trace Heavy Metals Associated with Crude Oil: A Case Study of Eboha-8 Oil-Spill-Polluted Site in Niger Delta, Nigeria,". Chemistry and Biodiversity. 2004.
10. Hanck et al, R. S. "Chapter 16: Niger Delta Petroleum Systems, Nigeria," Petroleum Systems of South Atlantic Margins. AAPG Memoir. 2000.
11. Curtis DM. Comparative Tertiary petroleum geology of the Gulf Coast, Niger, and Beaufort-Mackenzie delta areas. Geological Journal. 1986 07;21(3):225-255. https://doi.org/10.1002/gj.3350210303
12. Ugochukwu and Ertel, U. C. Negative Impacts of Oil Exploration on Biodiversity Management in the Niger De area of Nigeria, Impact Assessment and Project Appraisal. 2012.
13. Ebeku K. Oil and the Niger Delta People In International Law. Resource Rights. Environmental and Equity Issues. 2005.
14. Pearson S. Petroleum and the Nigerian Economy. 1970.
15. Vassilou S. A to Z of the Petroleum Industry. 2009.
16. Genova A. Oil and Nationalism in Nigeria. 2007.
17. Salu A. Securing Environmental Protection in the Nigerian Oil Industry. Journal of Financial and Investment Law. 1999.
18. Ogri O. A Review of the Nigerian Petroleum Industry and the Associated Environmental Problems. 2001.
19. Doyle et al, D. A. Drilling and Production Discharges in the Marine Environment. In Environmental Technology in the Oil Industry. 2008;. https://doi.org/10.1007/978-1-4020-5472-3_6
20. Adomakai, Sheate AR. Community Participation and Environmental Decison Making in the Niger Detla. 2004.
21. UNDP. (2006). Niger Delta Human Development Report.
22. Zabbey N. Impacts of Extractive Industries on the Biodiversity of the Niger Delta Region. National Workshop on Coastal and Marine Biodiversity Management. 2004.
23. Grevy P. The Niger Delta in Nigeria: A Pollution Assessment Study. World Bank. 1995.
24. SPDC. (2004). Annual Report.
25. NDES. (1997). Environmental and Socio Economic Characteristics.
26. Powell et al, P. C. Oshika Oil Spill Environmental Impact; Effect on Aquatic Biology. . NNPC/FMHE International Seminar. 1985.
27. Ndiokwere CE. The Occurence of Heavy Metals in the Vicinity of Industrial Complexes in Nigeria. Environ Int. 1990.
28. Emoyan et al., E. O. Evaluation of Heavy Metals Loading of River Ijana in Ekpan-Warri, Nigeria. Journal Appl Sci Environ Mgt. 2006.
29. Braide et al., B. S. Water Quality of Miniweja Stream, A Swamp Forest Stream Receiving Non-Point Source Waste Discharges in Eastern Niger Delta, Nigeria. Scientia Africana. 2004.
30. Spiff and Horsfall, S. A. Trace Metal in Intertidal Flats Sediments of the Upper New Calabar River in Niger Delta Area of Nigeria. Scientia Africana. 2002.
31. Rowell M. The Effects of Crude Oil Spills on Soils. A Review of Literature In The Reclamation of Agricultural Soils after Oil Spills. 1997.
32. Atuanya, E E. Effect of Waste Engine Oil Pollution on Physical and Chemical Properties of Soil. A Case Study of Waste Oil Contaminated Delta Soil in Bendel State. Nig, J. Applied Sci. 1987.
33. Anoliefo G. Forcados Blend Crude Oil Effect in Respiration, Metabolism, Elemental Composition and Growth of Citrullus Vulgans. 1991.
34. Okezie, Okeke, O. D. Flaring of Associated Gas in Oil Industry: Impact on Growth, Productivity and Yield of Selected Farm Crops - Izombe Flow Station Experience. Nigerian National Petroleum Corporation (NNPC) Workshop. 1987.
35. Sojinu OS, Wang J, Sonibare O, Zeng EY. Polycyclic aromatic hydrocarbons in sediments and soils from oil exploration areas of the Niger Delta, Nigeria. Journal of Hazardous Materials. 2010 02;174(1-3):641-647. https://doi.org/10.1016/j.jhazmat.2009.09.099
36. Edino MO, Nsofor GN, Bombom LS. Perceptions and attitudes towards gas flaring in the Niger Delta, Nigeria. The Environmentalist. 2009 08 18;30(1):67-75. https://doi.org/10.1007/s10669-009-9244-2
37. Odu C. Microbiology of Soils Contaminated with Petroleum Hydrocarbons: Extent of Contamination and Some Soil and Microbial Properties after Contamination. Journal of Institute of Petroleum. 1972.
38. Osuji LC, Onojake CM. Field reconnaissance and estimation of petroleum hydrocarbon and heavy metal contents of soils affected by the Ebocha-8 oil spillage in Niger Delta, Nigeria. Journal of Environmental Management. 2006 04;79(2):133-139. https://doi.org/10.1016/j.jenvman.2005.06.004
39. Oyedeji AA, Adebiyi AO, Omotoyinbo MA, Ogunkunle CO. Effect of Crude Oil-Contaminated Soil on Germination and Growth Performance of <i>Abelmoschus esculentus</i> L. Moench—A Widely Cultivated Vegetable Crop in Nigeria. American Journal of Plant Sciences. 2012;03(10):1451-1454. https://doi.org/10.4236/ajps.2012.310174
40. Linden and Jerelov, L. O. The Mangrove Swamps: An Ecosystem in Danger. Ambio. 1980.
41. Luiselli, Akani, L. L. An Indirect Assessment of the Effects of Oil Pollution on the Diversity and Functioning of Turtle Communities in the Niger Delta. Animal Biodiversity and Conservation. 2002.
42. Osuji, Opiah OL. Hydrocarbon Contaminaation of a Terrestial Ecosystem: The Case of Oshire-2 Oil Spill in Niger Delta, Nigeria. The Environmentalist. 2007.
43. Roach et al, R. R. Assessment of Produced Water Impacts in Galveston Bay System. US Fish and Wildlife Report. 1992.
44. Osuji L. Some Environmental Hazards of Oil Pollution in Niger Delta, Nigeria . African J. Interdsci. Stud. 2002.
45. Allen R, Robinson K. Environmental Aspects of Produced Water Disposal. Middle East Oil Show. Middle East Oil Show. 1993. https://doi.org/10.2118/25549-ms
46. Akpoborie et al, I. E. The Quality of Groundwater from Dug Wells in Parts of the Western Niger Delta. Knowledge Review. 2008.
47. Anyakora C, Coker H. Assessment of the PAHs contamination threat on groundwater: a case study of the Niger Delta region of Nigeria. International Journal of Risk Assessment and Management. 2009;13(2):150. https://doi.org/10.1504/ijram.2009.030327
48. Ayotamuno M, Kogbara R, Ogaji S, Probert S. Petroleum contaminated ground-water: Remediation using activated carbon. Applied Energy. 2006 Nov;83(11):1258-1264. https://doi.org/10.1016/j.apenergy.2006.01.004
49. Ophori D. A Preliminary Analysis of Regional Groundwater Movement in the Niger Delta, Nigeria. Journal of Environmental Systems. 2006.
50. Adelana, MacDonald, A. S. Applied Groundwater Studies in Africa. IAH Selected Papers on Hydrogeology. 2008.
51. Otevia, Ndokiari OF. The Effect of Crude Oil Spill on the Surface Water of the Lower Niger Delta (Sombriero River). Allied Academics. 2018.

52. Nduka JK, Orisakwe OE. Water-quality issues in the Niger Delta of Nigeria: a look at heavy metal levels and some physicochemical properties. Environmental Science and Pollution Research. 2010 07 08;18(2):237-246. https://doi.org/10.1007/s11356-010-0366-3
53. Ifelebuegu AO, Ukpebor JE, Ahukannah AU, Nnadi EO, Theophilus SC. Environmental effects of crude oil spill on the physicochemical and hydrobiological characteristics of the Nun River, Niger Delta. Environmental Monitoring and Assessment. 2017 03 20;189(4). https://doi.org/10.1007/s10661-017-5882-x
54. Akporido SO, Onianwa PC. Heavy Metals and Total Petroleum Hydrocarbon Concentrations in Surface Water of Esi River, Western Niger Delta. Research Journal of Environmental Sciences. 2015 02 01;9(2):88-100. https://doi.org/10.3923/rjes.2015.88.100
55. Tellez GT, Nirmalakhandan N, Gardea-Torresdey JL. Performance evaluation of an activated sludge system for removing petroleum hydrocarbons from oilfield produced water. Advances in Environmental Research. 2002 Oct;6(4):455-470. https://doi.org/10.1016/s1093-0191(01)00073-9
56. Incardona JP, Collier TK, Scholz NL. Oil spills and fish health: exposing the heart of the matter. Journal of Exposure Science & Environmental Epidemiology. 2010 Nov 10;21(1):3-4. https://doi.org/10.1038/jes.2010.51
57. Holleman M. Lingering Lessons of the Exxon Valdez Oil Spill. Retrieved from Commondreams.org. 2010.
58. Gutierrez T, Berry D, Teske A, Aitken M. Enrichment of Fusobacteria in Sea Surface Oil Slicks from the Deepwater Horizon Oil Spill. Microorganisms. 2016 07 27;4(3):24. https://doi.org/10.3390/microorganisms4030024
59. EPA. (2010). NCP Product Schedule | Emergency Management | US EPA.
60. ITPOF. (2010). Spill Response - Dispersants.
61. Sohn E. Spill Response - Dispersants Kill Fish Eggs. Environmental Toxicology and Chemistry. 2010.
62. Barry C. Slick-Death: Oil Spill Treatments Kill Coral. Science News. 2007.
63. Gordon D. Zapping Oil Spills With Dry Ice and Ingenuity. Los Angeles Times. 1994.
64. Fountain H. Advances in Oil Spill Cleanup Lag Since Valdez. 2010.
65. Mullin JC. Introduction/Overview to in Situ Burning of Oil Spills. Spill Science & Technology Bulletin. 2003.