CHAPTER 17

COASTAL AND MARINE POLLUTION WITH REFERENCE TO THE RIO DEL REY BENIN IN THE CAMEROON

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Introduction

Coastal and marine pollution is of growing concern to environmentalists, governments, inter-governmental organisations (IGO) and non-governmental organisations (NGO). Most *coastal areas* of the world are contaminated especially with untreated or inadequately treated sewage and sediment from land clearing and erosion. *Seas and oceans* are polluted with hydrocarbonated effluents and the dumping of industrial wastes. Due to high levels of pollution indicators, oceans and seas take longer time in the dilution, dispersal and degradation of sewage, sludge, oil, and industrial wastes.

This chapter *discusses the geochemical and environmental implications resulting from environmental terrorism, spillage, seepage, acid rain, secondary porosity, heavy ions migration, false geochemical anomaly and contamination of subsurface waters in the light of coastal and marine pollution*. The geochemical implications of discharging untreated hydrocarbonated industrial effluents is considered with special reference to the Cameroon coastal and marine waters.

Short-term and long-term measures to reduce and prevent the pollution of coastal and marine areas are recommended. Useful pollution prevention methods are suggested in the paper. Some ways of cleaning up hydrocarbonated spills in coastal and marine areas are highlighted. The roles to be played by government and inter-governmental agencies as well as non-governmental organisations in monitoring and controlling coastal and marine environments as well as implementing policies and regulations that aim to make the seas and coasts to be pollution-free areas are emphasised.

General

The oceans cover 70% of the surface of the earth and play a very vital role in the survival of life on earth. The ocean waters form an integral part of the global hydrologic cycle, influence the earth's climate and participate in many biogeochemical activities.

The ocean peripheries form the coastal zones which are characterised by warm, nutrient rich, shallow water that slopes gently into the continental shelf. Coastal zones occupy 10% of oceanic area and probably water, and contains 90% of all ocean dwelling organisms. The open seas contain 90% of ocean area and about 10% of ocean species. The coastal areas are more susceptible to pollution than the open seas.

Until recently, pollution was not a concern in developing countries. The degree of pollution of coastal and marine waters is reaching an alarming stage which calls for action. There is every probability that if unchecked, may pose serious danger to our public health and socio-economic development. The effects of coastal and marine pollution have far reaching consequences and cannot be overemphasised.

Seepage and Heavy Ions Migration

Heavy metals in their ionic state migrate. It is possible to have "natural pollution" of streams, rivers and soils due to anomalously high concentrations of the metals. Migration of anomalous ionic concentrations of heavy metals into the seas and oceans eventually leads to regional coastal and marine pollution. Heavy metal such as mercury poses dangerous problems for human health and marine ecosystems: the Minamata disease that started in Japan (Fergusson, 1990), and Iraqi who died of mercury poisoning (Kazantis, 1980) are documented reminders of the kind of tragedy that can befall the humankind. *The discharge of heavy metals into seas and oceans causes an increase of concentration of the metals in living organisms. When threshold values are exceeded, toxic consequences occur, and humanity is not left out.*

Oil Pollution

In 1989 three billion tons of oil was consumed worldwide (Alloway and Ayres, 1993), and the consumption has been on the increase. Crude and refined oil are either accidentally or intentionally discharged into the seas and coasts. *Studies* (Miller, 1993) *show that more than 50% of the oil polluting the seas and coasts comes from waste oil. Oil is the main pollutant in most seas, oceans and coastal areas.*

The Mediterranean Sea is probably on the way of becoming a dead sea. An International Conference in 1971 on the island of Malta selected the Mediterranean Sea as a prototype of a polluted sea. Scientists and diplomats from 30 countries agreed on the need for multilateral pollution control legislation to help save the Mediterranean Sea. *The consensus was that oil is a serious pollutant and new legislation should be formulated to control oil tankers, refineries, terminal pipelines and the discharge of tank washings from all carriers* (Lansford, 1979).

Oil Spillage and Environmental Terrorism

Oil Spillage

Oil spillage is not technically waste disposal but is an important pollution event

(Alloway and Ayres, 1993). About 5% of oil discharged into the seas and oceans is due to tanker accidents – 23% from operational discharges, 40% associated with transportation and 45% for land and coastal refineries (Alloway and Ayres, 1993). Oil spills associated with tanker accidents must be seriously considered because of the strong potential for ecological and economic damages. The concentrated slick affects fisheries and tourism industries, and marine ecosystems.

Oil slicks can spread either very rapidly or very slowly depending on a number of factors: oil quality, oil quantity, ocean and sea conditions, rate of evaporation of volatile components and rate of dissolution of certain classes of aromatic hydrocarbons. Floating oil mousse is transported very fast to beaches as tar balls.

Examples of Spillage

A number of documented cases of oil spills with huge ecological and economic losses were from:

*The **Atlantic Express*** released 276,000 tons of oil affected Tobago in 1979. The Castello Belver released 256,000 tons of oil and affected South Africa in 1983. The Amoco Cadiz released 2,239,000 tons of oil and affected France in 1978.

*The **Exxon Valdez*** released 45,000 of oil and affected Alaska in 1989. The Brear released 85,000 tons and affected Scotland. The North Cape Oil Spill released 828,000 gallons of oil and affected the USA in 1997. The Exxon Valdez and North Cape Oil spills are further discussed.

The Exxon Valdez Oil Spill

On 24 March, 1989, the Prince William Sound was so far the biggest oil spill in the United States Waters. The full consequence of the disaster may never be known for decades. Research so far carried out reports of the fate, transport, effect of oil on biotal and archeological sites resulting from the incident. A comprehensive analysis of the water has been carried out to verify the containment of hydrocarbons. Results reported on the Internet showed that the extent of oiling declined substantially between 1989 and 1992 and the oil was located in the biologically least productive upper tidal and supratidal zones. Pockets of subsurface oil could probably still be found in the intertidal or supratidal zones. Clay flocculation created solids-stabilised oil-in-water emulsions on shoreline sediments and these emulsions of complex and varied floc aggregates reacted with hydrodynamic forces beneficiating and accelerating the removal of oil from shoreline sediments.

Investigation proved that immediate cause of the accident could be the result of a drunken captain. The oil company (Exxon) pleaded guilty to federal felony and misdemeanour charges. Exxon has spent about $500 million dollars and still faces lawsuits to the tune of $59 billion dollars.

The North Cape Oil Spill

On 19 January, 1997, the North Cape barge was grounded after the tug boat pushing it caught fire in a very severe winter storm. Oil spill has treated the main ecosystem affecting lives of fish, birds and recreational beaches. Although the EPA regulations stipulate loppin of hydrocarbon in marine and coastal waters to be considered harmful to marine life, yet there is damage to the fragile ponds and marshes which serve as breeding places for shellfish. Clean-up exercises were prompt. That notwithstanding, there is evidence of damage and until the next few decades a thorough damage evaluation will not be realised.

Environmental Terrorism

It is reported widely that during the Gulf war, the Iraqi's deliberately discharged oil into the Persian Gulf. Fires which were difficult to put out in war time, were set on many oil wells. Marine life was destroyed and smoke rich in polycyclic aromatic hydrocarbons (TAH) was discharged into the atmosphere affecting regional weather patterns.

These acts of environmental terrorism caused very serious damage to the ecosystem and may affect posterity if not abated.

Oil Spill Management

Because of the economic and ecological implications of oil spills, there is need to have spill response operations on board oil tankers. Effective customised courses tailored to meet this need have been implemented at the Centre for Marine Training and Safety in the United States of America.

Training programmes incorporate aspects like movement, containment and clean up of oil; use and operation of boom and skinullers; shoreline protection, clean-up and restoration; oil recovery from soil and oily debris disposal; containing and recovering of oil from surface waters; and prevention of oil spills. A number of companies are engaged in the manufacturing of propylene absorbents for oil and chemical spills, and a range of oil skimmers and oil water separation systems.

Environmental Implications

Lansford (1979) reported that new and complex chemical processes used in industry have increased the possibility of releasing pollutants that are hard to detect and control. Wastewater from municipalities, schools and colleges and industries, feed lots and swarms, may be sources of bacteria and other micro-organisms capable to producing diseases in human beings and animals including livestock. These pathogens cause infection of the intestinal tract namely typhoid and paratyphoid fever, bacillary and amoebic dysentery, cholera and viral hepatitis.

Mercury, a waste product of a variety of industries, moves along the food chain from water and plants to fish, birds and humans. Marine life, especially fish in mercury polluted waters become contaminated with methyl mercury (CH_3Hg) as a result of mercurial waste discharge. Contaminated fish is eaten. Methyl mercury as a result of mercurial waste drain through the blood, resulting in severe neurological diseases such as blindness, deafness and intellectual deterioration. Obidiwe (1990) pointed out that it is not common to find polychlorinated biphenyls (PCBs) in industry effluents discharged into seas and oceans. PCB is highly resistant to both heat and biological degradation, soluble in water, carcinogenic, mutagenic and teratogenic. Polyvinyl chloride (PVC) and polythene are not biodegradable and they cause serious aesthetic and carcinogenic problems.

Most coastal areas serve as *drainage deltaic and estuarine river basins.* Coastal areas are generally shallow and serve as *pollution acceptors.* High levels of phosphate and nitrate plant nutrients have risen sharply in polluted coastal areas causing *algal blooms and oxygen depletion.* Industrial toxic wastes that find themselves in marine and coastal environments have posed as *vectors of health hazards.*

The Chesapeake Bay in the USA is the largest source of blue crabs in the world and of oysters in the United States (Miller, 1992). It is also an important recreational sporting area for shipping, boating, sailing and sport fishing. The bay has experienced a population growth of 500% within the last 50 years. Nine large rivers and 141 streams and creeks serve as pollution channels to the bay. With less than 1% of waste entering the bay flushed into the Atlantic ocean, it is evident that agents of pollution from domestic, recreational and industrial activities are at play. Million (1992) reports that point source discharge of numerous toxic wastes is a major problem, and this has affected the commercial harvesting of sea food in the area. The Federal and State Government of the United States are engaged in a clean-up exercise of the area which will eventually cost several billion dollars!

Geochemical Implications

Not until recently, the geochemistry of migration of hydrocarbon fluids has been discussed from a more or less theoretical standpoint by many investigators such as Banker (1967), McAuliffe (1966), Cordel (1973) and Price (1976). Although advanced technology and improved methods of instrumentation have facilitated the study of geochemical aspects of oils occurring in the natural environment, the circumstances under which meaningful information relating to oil exploration and pollution can be gathered are rather restrictive.

Secondary porosity is significant to dominant in many reservoirs. Zuhair (1981) reported that secondary porosity is as a result of dissolution of carbonate minerals, feldspars, rock fragments, aggregates and pellets. Carbonic acid is considered to be the primary agent responsible for dissolution of these materials. Continued reaction of constituents with carbonic acid results, in the long run, in changes in water composition and corresponding partial dissolution of silica. The availability of carbon dioxide in the hydrodynamic system accompanies changes in fluid pressure. Generation and migration of hydrocarbons and carbon dioxide creates abnormal pore pressure which results in the formation of open fractures.

The baseline distribution of hydrocarbons over a wide area is an important factor to be considered when prospecting techniques to locate any anomalous occurrences of hydrocarbons. Anomalous hydrocarbon compositions of surface and subsurface sediments could confirm seepage which may aid in locating previously unidentified petroleum sources for future exploration.

Alternatively, such measurements could also indicate pollution resulting from fossil fuel development or other anthropogenic activity (Venkatesan, 1983).

The dissolution of feldspar is enhanced by increasing concentration of carbon dioxide in the reservoir fluid, and dissolved silica are the main constituents released into solution. The solubility of silica may be accompanied by the following mechanisms:

- ❑ An increase in pH of the solution as a result of consumption of feldspar

- ❑ Shift in the reaction of silica and water to favour dissolution of quartz
  $SiO_2 + 2H_2O \rightarrow Si(O)_4$

- ❑ Dissolution of quartz occurring as a result of reaction between silicic acid and bicarbonate ion
  $H_4SiO_4 + HCO_3 \rightarrow H_3SiO_4 + CO_2 + H_2O$

- ❑ Increase in solubility of quartz with increasing temperature.

Major alteration products such as kaolinite, illite and chlorite depend mainly on the concentration of carbon dioxide, the resident time of reaction the primary minerals and initial composition of formation of water. Detailed core description data on the visual redox boundaries, mineralogy, and hydrostratigraphy constitute the foundation for geochemical investigations of contaminant migration from waste dumps (Bimal, 1989). Unstable geochemical parameters such as pH, redox couples, alkalinity, specific conductance, temperature, major and minor elements are useful parameters in monitoring and controlling of contaminant migration in subsurface waters along coastlines.

Point Source Study: The National Refinery Corporation, Limbe, The Cameroon

The National Refinery Corporation in Cameroon is located within the outskirts of Linibe Municipality which is part of the Rio Del Rey Basin, at the shores of the Atlantic Ocean.

The Geology

The sedimentary basins of Cameroon are mentioned. Further discussion of the structure and stratigraphy is focused on the Rio del Rey Basin due to on-going oil exploration activities.

Sedimentary Basins

There are five major basins in Cameroon: Three coastal basins (The Rio Del Rey, Kribi and Douala basins) and two in-land basins (The Garoua and Logone-Ribni basins). The coastal basins form a string of basins which extends from the north along the Gulf of Guinea in Nigeria to the south of upper limits of the Cameroon-Equatorial Guinea. These basins form a composite Cameroon Basin which is triangular in shape with its widest part being about 60 km in the vicinity of the Cameroon Mountain. It narrows to the north of Kribi covering an area of 700 km^2 and further extends within the sea on a continental platform with an average of 25 km (Ngoune, 1984). The Logone-Binii and Garoua basins are located in similar geologic environments as the Benue basin in Nigeria and the Chad basin in Chad.

Structure

The Rio Del Rey basin is an eastward extension of the Niger Delta and is located geographically between 80°20'-80°55' longitude east and 4'05'4940 latitude north. Regionally, it is flanked in the west by the Cameroon St. Helene Volcanic and in the east by the 27' Fracture Zone.

Stratigraphy

There are four main formations (The Isongo, Akata, Agbada and Benin formations) covering a depth of 2.5 km. The sediments span from Lower Tertiary to recent. The Isongo formation is encountered mostly in the south east of the Rio Del Rey basin. It represents a mixed facies of marine shale and fan sands and could be a prospective target in future exploration programmes. The Akata formation succeeds the Isongo formation. It consists of marine shales and clays that have been overpressured (Lamoro, 1981). The Agbada Formation overlies the Akata Formation and consists of alternations of sands and shale. The coarse clastic beds are the oil reservoirs of the up-to-date discovered oil fields. The Tertiary sequence of the Niger Delta continues eastward in the Rio Del Rey basin as the Benin formation occurring in a fringe zone of shale diapirs, sandy clays, dark green sandstone, lignite and fragments of volcanic rocks.

Effluent Treatment and Disposal

Effluent Type

There are two categories of wastewater's generated at the refinery area. They are:

- ❑ Used water containing hydrocarbon from different units in the refinery and from oil tankers.

- ❑ Industrial and domestic sewage which contains waste resulting from human activities such as washing, cooking, and allied industrial processes taking place at the refinery.

Standard of Pre-treated Hydrocarbonated Wastewater

The treatment line for hydrocarbonated water handles 250 m^3/hr of wastewater which should have the following properties:

A.	pH	5.9-9.0
B.	Temperature	30°C Max.
C.	Hydrocarbon	300 ppm
D.	Suspended matter	200 ppm
E.	Phenol	0.5 ppm
F.	BOD	40 ppm
G.	COD	150 ppm

The effluent leaving the treatment line should contain less or equal to 5 ppm of Hydrocarbon, using the hexane extracting method.

Treatment and Disposal

The collected wastewater and industrial effluent is treated with *anti-foaming chemicals*. The foam is a product of decomposition of oils, sewage and humic matter and it is an indication of high alkalinity.

Dissolved air flotation machine is used for the treatment of the wastewater collected. Dissolved pressurised air released causes bubbles which promote migration of solid particles to the top. The solid floats as a scum at the surface of the tank which is removed by a skimming mechanism. Hydrocarbons float at the surface, are harvested and recycled by fractional distillation in the plant. The treated wastewater is vomited into the ocean.

Before discharge, the treated hydrocarbonated wastewater should have a pH of 5.5 - 7.5 and should contain at most 30 ppm of suspended matter.

Geochemical Implications

The treatment of hydrocarbonated effluent from the refinery *reduces pollution*. However, there may be non point-source contamination that may cause ecological imbalance and reduce the aesthetics of the beach which is used as a recreational facility. Further discussion is centred on arising geochemical implications due to pollution resulting from hydrocarbonated effluent along the coastal line.

The Isongo formation is believed to be the main oil reservoir. Due to its position in the stratigraphic sequence, hydrocarbonated effluent may cause a false geochemical anomaly that may be interpreted as higher oil reserve in the formation. Sub-surface groundwater contamination in its aquifers have called for special treatment requiring the removal and extraction of obnoxious odour and hydrocarbons.

The Akata formation consists of impermeable overpressured marine shale and clays. The absence of sandstones and carbonates in this formation makes it difficult for seepage and secondary porosity to occur.

Hydrocarbonated effluent can penetrate the Agbada formation at different points of exposure of sandstone layers. The trapped pollutant gradually dissolves the layers of sandstone, causing secondary porosity, false geochemical signatures and contamination of aquifers.

The Benin formation is the most vulnerable to pollution. High seepage rates would occur because of unconsolidated sands and consolidated sandstone. With the release of carbon dioxide as one of the final products of fractionation of hydrocarbons, condensation takes place with the formation of carbonic acid which maintains an ionic equilibrium:

$$H_2CO_3 \longrightarrow 2H^+ + CO_3^{2-}$$

The H^+ reacts with SiO_2 to form H_4SiO_4 represented in the following equations:

$$SiO_2 + 2H_2 \longrightarrow H_4SiO_4$$

$$H_4SiO_4 \longrightarrow H_3SiO_{4-} + H^+$$

$$H_4SiO_4 \rightarrow HCO_3\text{-}\ H_3SiO_4 + CO_4 + H_4O$$

Since the Benin formation is the youngest formation occurring in the stratigraphic sequence of the Rio Del Rey basin, inhabitants may find it difficult to harvest subsurface water for human consumption due to possible high values of HC ppm in the water.

Recommendations

A number of recommendations that *address ways of protecting marine and coastal waters* have been advanced by concerned parties. Miller (1992) forwards the following suggestions for protecting marine and coastal waters from being polluted, and in cleaning up pollutants:

- ❑ *Municipal sewage treatment plant,* and *industrial facilities should stop discharging their toxic pollutants into the sea.* MDCs may overcome this problem but not the LDCs. Budgetary constraints make it difficult for LDCs to carry out effective treatment and disposal of their waste.

- ❑ *Water should be managed properly by industries and homes.* This type of measure reduces the amount of water consumed and hence the amount of wastewater flowing into treatment plants which eventually is discharged into seas and oceans. The use of disposable plastics should also be reduced.

- ❑ *The seas and oceans should not be used as the ultimate dumping site of pollutants.* The dumping of sludge and hazardous material into coastal and marine environments should be prohibited and enacted by national and international laws. Also, sludges from empty oil tankers should not be dumped in the sea as well as garbage and plastic items from sailing vessels.

- *Thorough and verifiable Environmental Impact Assessment* (EIA) should be carried out to ascertain the extent of environmental damage before development projects can be carried out.

- *Vulnerable marine areas should be declared marine sanctuaries* and human activities drastically minimised.

- *Governments should increase taxes on coastal development projects* in a bid to discourage entrepreneurs from executing the project.

- *Financial institutions are encouraged to promote unfavourable financial conditions which will tend to regulate the types and density of development projects in coastal and marine environments.*

- *National and international energy policies should be institutionalised* which encourage the use of alternative and renewable energy resources instead of oil.

- *Used oils should be recycled and reused.*

- Most oil spills in seas and oceans are as a result of damage on the hulls of ships. *All oil tankers should be required to have double hulls. The navigation routes of oil tankers should be far from sensitive coastal areas that may be suspected to have submerged rocks.*

- *Oil companies should bear heavy financial responsibilities for oil spills.* Companies may be closed either temporarily or permanently if the accident rate is on the increase. Oil spill clean-up capabilities should be greatly improved in terms of technology and time response of emergency clean up crews.

Conclusion

Although coastal and marine pollution is an issue of serious concern in more developed countries, it is an apparently growing environmental problem in the less developed countries that have primary and secondary industries. Regulations need to be enforced protecting coastal and marine environments in these countries before the situation gets out of hand.

- The Cameroon government and its National Refinery should continue to monitor the hydrocarbonated effluent, and continuously carry out EIA within the coastal waters and environs.

- Similar monitoring exercises should be conducted in other oil producing coastal areas in neighbouring countries.

- Most seas and oceans are polluted with industrial effluent and oil slicks with the potential of upsetting ecosystems including some endangered species, causing huge economic and environmental damages, coupled with a wide variety of health hazards. Coastal and marine pollution should be reduced as much as possible. We owe an obligation to hand an unpolluted earth to posterity.

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