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The marine and coastal environment of the West and Central African region and its state of pollution

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WACAF

I. CHARACTERISTICS OF THE REGION

1. GEOLOGY, MORPHOLOGY AND SEDIMENTOLOGY

1.1 Geology

The Pleistocene history of the WACAF region is closely connected with alternation of glacial and interglacial periods on the continents. Large and rather frequent fluctuations of oceanic level at that time had a marked influence on the mechanism of terrigenous sedimentation and the forming of the continental margin (Atlantic Ocean, 1977). This is noticed in the structure of the seaward borders between Guinea-Bissau and Sierra Leone which has been formed by the submergence of river valleys and lowland (ria or drowned coast).

The countries north of Cameroon are part of West Africa's Basement complex covered by sedimentary formations, sandstone deposits with rich oil reserves, e.g. around Nigeria. Volcanic highlands separate the northern parts from the southern parts of this Region, which form the western end of the East African Rift Valley. Three major types of soil are found in the Region, with the acid and nutrient-poor latosolic soils of equatorial and savannah regions predominant. Lateritic soils, also poor, occur, and relatively fertile red loams are present in the southern tropical areas. There are extensive river systems almost throughout the Region, with considerable run-off and transport of suspended matter, influencing coastal water conditions.

The geology of this coastline is infuenced by types and deposition of rocks, earth movements, relief, drainage and climate.

The structure of the continental margin off the Gulf of Guinea is related to the equatorial fracture system. It consists of an eastern flank of the mid-Atlantic ridge (Akpati, 1983).

The average width of the continental margin is 30-50 km with a depth of 100-120 m. The northern part of the Senegal shelf is relatively narrow, widening towards the south to about 40 km at the Senegal river estuary. The shelf-break is located at 200 m. In the southern parts the shelf-break is located at depths varying between 80 and 150 m. Submerged valleys occur frequently. In the Gulf of Guinea the shelf width is about 30 km, widening to about 70 km at the mouths, or deltas, of the Niger and Zaire (Congo) rivers. The submerged canyon of the latter cuts through the continental margin and slope, reaching the bottom of the Angola Basin at 4,000 m. From the Zaire (Congo) river to the South Angola borders the shelf is very narrow, about 4 km wide, with a maximum depth not exceeding 100 m. Near Walvis Bay there is again a change with an increase to a very wide shelf.

From 30°S to 15°N, on the oceanic side, the continental shelf borders a series of basins separated by rises or ridges, from south to north: Cape Basin, separated by the Walvis Ridge from the Angola Basin, bounded in the north by the Guinea Ridge; the relatively small Guinea and Sierra Leone Basins, extending along the equator, are bounded by the Liberia Rise and the Sierra Leone Rise. The Region is bounded in the north by the Cape Verde Plateau. These topographical divisions constitute important effects or constraints on the oceanographic conditions in the Region.

Knowledge of the continental shelf of the Region is relatively limited. Precise bathymetric charts are often lacking. It is evident that in relation to many modern uses of the sea bed, e.g. laying of pipelines, installation of drilling platforms, exploitation of sand, gravel and mineral deposits, such charts showing details of the sea bed of the continental margin and the exclusive economic zone are a prerequisite.

1.2 Morphology

The morphology of the coastline is influenced by current transports alongshore, tides, winds and waves. The coasts are mainly low, sandy and lacking natural harbours, with some exceptions associated with river mouths and areas of strong tides, e.g. in Guinea-Bissau (Porto Gole), the Niger Delta, at Mocamedes, Angola and Walvis Bay, Namibia. Four types of coastline are discerned: drowned coasts in the northern area: sandbar or lagoon coasts along the north of the Gulf of Guinea, mainly formed from deposits through wave motion; deltas associated with most of the rivers, usually with mangrove swamps and marshes; coast with sandpits, formed by accumulation of sand in bays, transported by strong alongshore currents, found in the southern parts of Angola.

The shores in the north-western part of the Region are relatively young, subject to both erosion and accumulation of terrigenous material, and in a smoothing stage of development. The coastline of the Gulf of Guinea is characterized by a system of offshore bars and lagoons. The bar system, caused by swells coming from the south, makes the coast rather inaccessible. Considerable erosion can occur in parts of the Gulf of Guinea. The Niger is a major source of sedimentary material. From the Congo to Namibia, areas of both erosion and accumulation shores can be found.

1.3 Sedimentology

Structure: Seismic research and coring have shown that the thickness of the bottom sediments varies from 2-3 km off Mauritania to 1-1.5 km or less off Sierra Leone and Liberia. In the Gulf of Guinea several depressions have been located with sedimentary deposits of 5-6 km thickness, reaching 8 km in a large depression near the Niger Delta. The Niger Delta receives sediments from an extended hinterland, and is sandy with marginal estuaries and barrier islands. The Gabon basin contains 16 to 18 km of sediments (Brink, 1974). In the southern part of the Region the sedimentary layers are 3-4 km thick (Litvin, 1980).

The rate of sedimentation varies in the range 30-100 mm per 1,000 years north of the Congo, being in the range 10-30 mm per 1,000 years further south.

Composition: Terrigenous sediments predominate over the greater part of the Region. In the north 50 to 80 per cent of all sediments are terrigenous. In the Gulf of Guinea and near the Angolan coast the terrigenous component in sediments reaches 90 per cent. This is a result of large quantities of suspended materials from the Niger (67 million tonnes/year) and the Congo (68 million tonnes/year). Near the coast of Namibia the terrigenous component in sediments equals approximately 50-70 per cent but it is gradually replaced by biogenic (carbonate) sediments. Sand and silt are the basic grain-size fractions in sediments of the region, covering 65--90 per cent. Only in the areas of main streams of aeolian dust (Sahara and Namibia deserts) does the percentage of sands predominate (50-60 per cent of sediments) (Emeljanov et al., 1976).

Concentrations of CaCO3 (less than 30 per cent) are inherent to sediments of the WACAF Region, especially in the coastal zones, where the diluting influence of components is very strong. Only in the southern part of the Region, near the Namibian coast, are there higher oncentrations of $CaCO_3$ (50-60 per cent) (Lisitzin, 1974).

Repeated concentrations of amorphous SiO_2 (less than 5 per cent) are inherent in sediments of the Region. Only in the northern part of the Namibian desert, near Walvis Bay is an area of high SiO_2 concentrations (up to 50 per cent) located (Lisitzin, 1974).

Organic carbon concentrations are mostly in a narrow range of 0.5-1.0 per cent, being larger (2 per cent) near the coasts of Zaire and Congo, probably due to the input of biogenic-rich material from the Congo river.

Average concentrations of Fe in sediments of the northern parts reach 1-3 per cent. In the Gulf of Guinea, especially near the mouths of the Niger and Congo rivers, there are rather high concentrations of Fe (up to 10-12 per cent). Presence of such concentrations can be explained by the transport of large quantities of iron-rich suspended matter from lateritic areas of the African continent. Sediments in the coastal zones of Angola and Namibia contain low concentrations of Fe (1.5-2.0 per cent or less) (Emeljanov et al., 1976).

Small concentrations of Mn (0.1-0.2 per cent) are common to most of the region. Only near the mouth of the Niger is there a zone of rather high concentrations, up to 1.0-1.5 per cent. Such a distribution of Mn in the coastal zone is explained by its close connection with the clay fraction of sediments. The clay fraction is largely transported further offshore. That is why its maximal concentrations are located in sediments and Fe-Mn nodules of deep oceanic basins (Atlantic Ocean, 1977; Lisitzin, 1974).

Stability: From the geological point of view the WACAF Region is fairly stable. Heat flow measurements conducted within the WACAF continental margin showed that it did not exceed 1.14 microcalories/cm^2/sec. The only relatively active volcano is located on the coast of Cameroon near Douala. Its origin is closely connected with a large fracture zone which extends from the continent to the south-west. Several submarine mountains and volcanic islands, like Fernando Po, Sao Tome and Principe, are present along this zone.

According to scientific estimates there is only one focal point of earthquakes at 60 km depth which is located near Accra (Ghana). Theoretically it can produce shocks of a magnitude equal to 6-7 on the Richter scale, but in practice earthquakes are very rare in the Region. The coastal population of the region does not have to be prepared for dangerous tsunami waves and catastrophic volcanic eruptions (Klenova and Lavrov, 1975). All the information testifies to the very high tectonic stability of this part of the African continent.

2. NATURAL ZONES OF THE REGION

It is already clear from the above that the Region covers some rather diverse zones, and this is further borne out when meteorological, climatic and physical oceanographical characteristics are considered. These conditions define a number of natural zones into which the Region can be divided. This helps to focus attention on the dominant features of each zone which to a large extent determine the natural conditions of the marine environment of that particular zone.

According to Schott (1944) there are three main natural zones covering the Region, namely: The Subtropical South-west African zone, to about 15° S, defined essentially by the Benguela Current; the Tropical Ascension zone to about the equator, influenced by the Benguela Current which in the northern part of the zone becomes the South Equatorial Current; the Gulf of Guinea zone, extending to Cape Verde, north of the equator but still influenced by water from the South Equatorial Current, as well as from the north in the Equatorial Counter Current and in the coastal wind-driven current. Each of these natural zones is characterized by its meteorological, climatic and oceanographical conditions, which all interact, and also influence conditions in the hinterland. The features of the hinterland also have an influence on the conditions in the sea.

The three main natural zones may be further divided when giving more detailed consideration to the ocean currents, but here the characteristics of the WACAF Region will be discussed more or less according to these basic divisions (see figure 1).

3. METEOROLOGY

3.1 Surface winds

The large-scale, seasonal wind patterns are basically determined by the two high pressure centres of the Atlantic, located between the Azores and the Canary Islands and between the Tristan da Cunha and St. Helena Islands, respectively (figure 2). The prevailing wind directions are from the north-east and south to south-east, in the northern and southern parts of the Region, respectively, with seasonal variations mainly in strength, except in the Gulf of Guinea where directions can vary considerably. The average force of the winds is 3-6 m/s, the weakest in the central parts and the strongest in the northern and southern parts.

The sea-land breeze system is very well developed along the whole coastline, with an onshore breeze in the afternoons and an offshore at night. The onshore breeze is usually stronger than the offshore. The sea-land breeze can influence the prevailing seasonal winds considerably: in Guinea and Guinea-Bissau the north-easterly trade wind in January is frequently reversed by a westerly wind in the afternoon; along the coast of Guinea strong south-westerly winds often replace the seasonal winds in the afternoon.

In the southern part of the Region the oceanographic influence on wind conditions is marked. Although the zone is in the general area of the south-east trades, the winds at the coast are predominantly from the south-west or south, whereas at sea the main direction is from the south-east. This implies transfer of dry and relatively low-temperature air towards the central parts of the Region. Also the Ascension zone falls in the area of the south-east trade winds, which, however, can be quite weak in this zone.

In the northern part of the Gulf of Guinea zone, from Cape Verde southwards, the north-east trades dominate, specially during winter, reaching their southern limit in March (Sierra Leone). In the Gulf of Guinea the south-west monsoon dominates, being strongest and reaching furthest north during summer. In between these wind systems the doldrums occur, with weak or varying winds. The SW Monsoon can be regarded as a slightly deflected continuation of the SE trades, hence no doldrum-like transition in between.

3.2 Air temperature (T°) at sea surface

In winter the air temperature for the whole region is +20°-26°C. Maximum temperature about +32°-36°C is observed near the coast of Liberia and along the northern part of the Gulf of Guinea including Nigeria. Minimum T°, about +12°-16°C, is found near Mauritania and near Zaire.

In summer, average T° is +20°-26°C for most part of the region. Maximum T° and its location are the same as for winter and minimal T°, about +8°-12°C is found near the coast of Namibia (Griffiths, 1972; Atlas of the World Ocean, 1976).

Annual fluctations of air temperature at sea surface are 0°-2°C for the Gulf of Guinea and the Ascension zones, but they achieve 6° and even more in the south-west African zone.

3.3 Humidity, precipitation and cloud conditions

The average value of relative humidity of the atmosphere in the region is 70-75 per cent annualy. The area of higher humidity (up to 80 per cent and more) coincides with the Gulf of Guinea.

There are two areas of minimal precipitation (less than 50 mm/year) in the region. One of them is located near Cape Verde Islands and the other near the coastal Namibian desert. The south-west African coast is dry because of the dry SE trade wind and the low temperatures of the water.

In the equatorial zone of the Gulf of Guinea the average precipitation is very high, 2,000 mm/yr. Near the coast of Liberia the volume of rain water collected during a year equals 5,500 mm/yr, and the wettest place in the world is located in Nigeria, where the annual precipitation reaches almost 1m (Atlantic Ocean, 1977; Atlas of the World Ocean, 1976).

It should be added that thunderstorms occur frequently in the Gulf of Guinea.

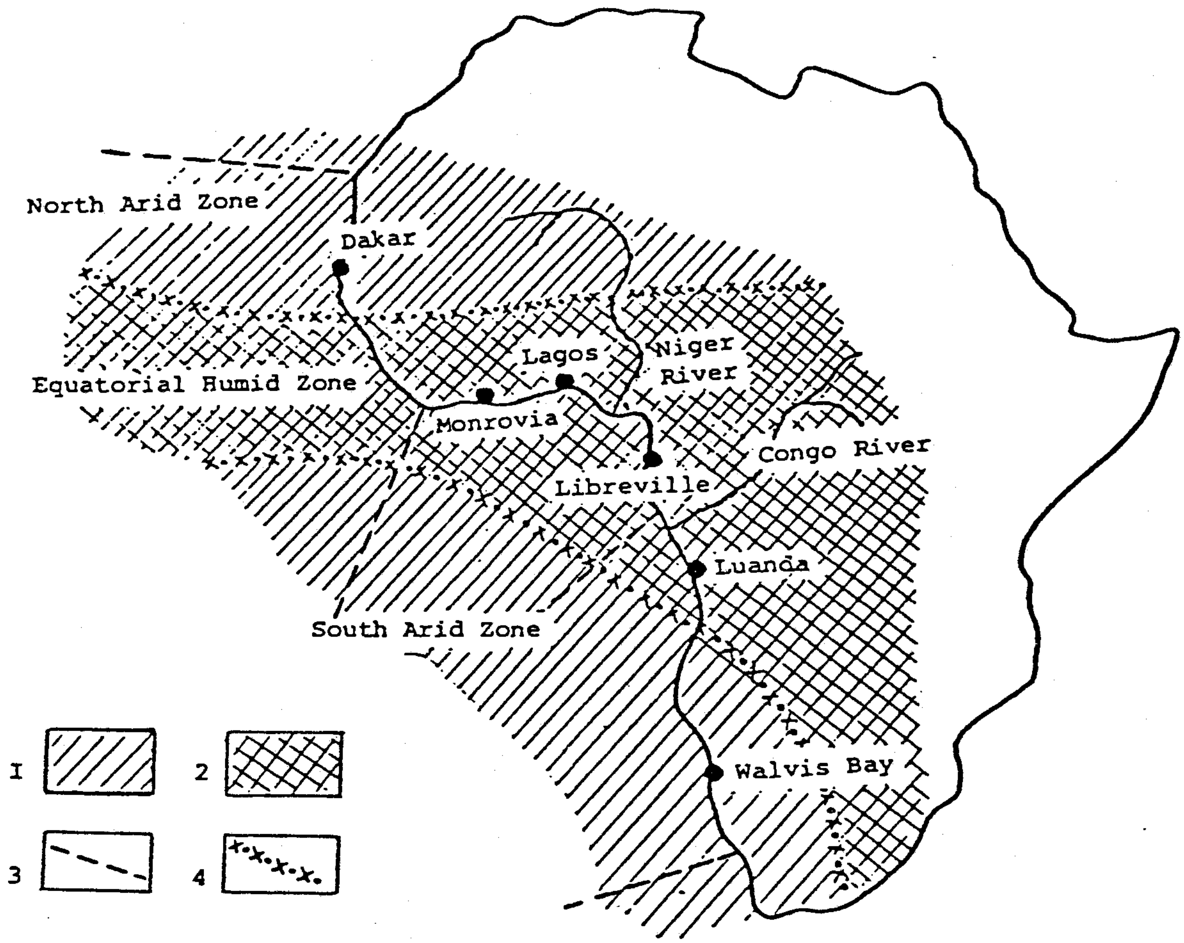
The cloud conditions in the south-west African zone are influenced by the low water temperatures, generating relatively high cloud coverage of stratocumulus. Fog is also frequent in this area. Also in the Ascension and Guinea zones the cloud coverage is usually abundant throughout the year. In the northern part of the Region, apart from Freetown and Cape Verde, there is little cloud coverage and the skies are often clear.

4. CLIMATOLOGY

According to a generally accepted scheme, based on the correlation between heat and moisture, the West and Central African Region is situated within three main climatic zones (see figure 3): namely the North and South Arid zones with the Equatorial Humid zone in between, which essentially coincides with the Ascension and Guinea zones.

(i) North arid zone

This zone includes Mauritania and most part of Senegal. It is characterized by a desert and semi-desert climate, considerable differences in seasonal temperatures of



(1) Arid zones
(2) Humid zones
(3) Borders between zones adopted in this report
(4) Borders between climatic zones (Lisitzin, 1974)

Figure 3: Approximate scheme of climatic zones in the region

surface air masses (in winter 25°-30°C, in summer 15°-20°C) and very limited precipitations (100-200 mm/year). Poor vegetation and scantiness of wildlife are the consequences of these natural conditions. Mauritania, for example, is almost completely covered by sandy and stony deserts and semi-desert areas.

The influence of the African desert zone determines basic climatic properties for the coastal areas. Tropical air masses prevail there. Active evaporation from the sea surface is greater than the precipitation, leading to relatively high salinity of the surface waters. The weather is mainly of anticyclonic type with light clouds. Atmospheric visibility can be rather poor because of large amounts of aeolian dust originating from the African deserts, especially in summer (SCOPE-14, 1979; Lisitzin, 1974).

(ii) Equatorial humid zone

All the countries boardering the Gulf of Guinea are influenced by the climatic conditions of this zone: a humid tropical climate with practically stable atmospheric temperatures (20°-25°C) around the year and high atmospheric precipitation. These conditions are very favourable for intensive development of vegetation and all kinds of animals. Two main West African rivers, Niger and Congo, located there have an influence on the climate of the zone.

In the coastal areas, the equatorial air masses prevail, and they are characterized by high temperatures and humidity, with heavy clouds. Precipitation is much higher than evaporation and heavy tropical rains are very often accompanied by thunderstorms. Surface winds originating in these areas are of unstable character and rather weak.

This zone can be subdivided into several climatic areas affecting the countries in the zone: Cameroon and southern Nigeria are in an equatorial area with rainfall all the year, high temperatures and humidity; along the Ghana to Guinea coast there is heavy seasonal rainfall, alternating with a dry season; from eastern Ghana to Benin there is a coastal climate with low rainfall but humid air; in the north-western part of the zone dry and rainy seasons alternate.

(iii) South arid zone

Two countries of the Region (Angola and Namibia) are included in this zone. The climate of the South arid zone mainly depends upon the influence of desert and droughty areas of South Africa and in many details it is similar to the climate of North arid zone. Sparse atmospheric precipitations (less than 200 mm/year) and a considerable difference between winter and summer air temperatures are typical of this zone. Basic vegetation consists of drought-resistant bushes, thorns and grass. Several kinds of cactuses are distributed in semidesert areas of this zone. Considerable amounts of atmospheric dust are carried out to sea by winds from the Namibian desert, but the scale of aeolian transportation is much less than in the north zone (Lisitzin, 1974).

5. OCEANOGRAPHY

5.1 Sea-water circulation

Five distinct and relatively persistent oceanic currents are of importance for the transport of substances, water temperature, meteorology-climatology and biological conditions. They are the following, from the south (figure 4): the Benguela Current flowing along the coast of the south-west African zone, turning off the coast at about 6° S; the Guinea Current flowing eastwards and south-eastwards along the coast of the Gulf of Guinea, almost reaching the equator, and which to a large extent constitutes a continuation of the Equatorial countercurrent; the South Equatorial Current flowing westwards at some distance from the coast between about 10° S and the equator; and the Canary Current flowing south-westwards along the coast in the northern part of the Region, partly feeding the Guinea Current, partly the North Equatorial Current. Both the Canary and the Benguela Current transport cool water towards the equator. The average current velocities are about 20 cm/s. The Guinea Current carries warm water towards the coast, with velocities in the range of 1-3 knots, strongest in the summer months. All the currents are basically wind-driven, relatively shallow and varying seasonally with the change of wind conditions. This implies that current directions and velocities can vary considerably and that sometimes the currents are quite weak.

The cool water of the Benguela Current, which is most developed in the 15° S to 5° S region along the coast, partly enters the South Equatorial Current and partly mixes with the warm water of the Guinea Current. The transition zone between these three currents is front-like with turbulent mixing and a medium sized eddy motion.

The prevailing regional wind systems along the coasts of the Region generate an offshore flow component in the surface layer of the sea due to the combined action of the wind stress and the rotation of the earth. The offshore transport is compensated by onshore flow at intermediate, 50-300 m, depths and vertical flow towards the surface layer, so-called upwelling, in a band of some tens of kilometres adjacent to the coast. This is a very important feature of large parts of the coastline (Tomezak, 1979; Burkov, 1980; Offurum, 1981): along the north-west part of the coast from October to April; along parts of the northern coast of the Gulf of Guinea in limited areas during the summer months; along the southern coastline in the Benguela Current system, with a marked seasonal variation of strong upwelling in winter (August) and weak in summer (November-February) (figure 5). This upwelling system corresponds to the Peruvian upwelling system in the Pacific Ocean. Generally the strength of the upwelling fluctuates, depending upon the local and regional winds. Often the upwelling zone is separated from the open ocean waters by a frontal transition along which there can be a sinking tendency. Often the current velocities are strong in the upwelling areas.

Relatively marked poleward-flowing undercurrents are normally associated with the persistent upwelling systems. The undercurrents flow along the continental slope at depths between about 200 and 600 m, extending a few tens of kilometres seawards.

The deep and bottom water circulations of the Region are strongly influenced by the topographic barriers mentioned in section 1.1. Generally there is a slow movement towards the equator in the deep water. South-Atlantic bottom water is effectively prevented from entering from the south by the topographic barriers and can only enter from the north by the Romanche Deep Channel through the Mid-Atlantic Ridge.

5.2 Temperature and salinity

The average value of solar radiation in the Region is relatively high, 160-180 Kcal/cm^2/year compared to other parts of the Atlantic, being 140-150 Kcal/cm^2/year in the southern parts and reaching 200 Kcal/cm^2/year on the coasts of Senegal and Mauritania (Atlas of the World Ocean, 1976). The distribution of sea surface temperature (SST) is closely related to the solar radiation input absorbed by the

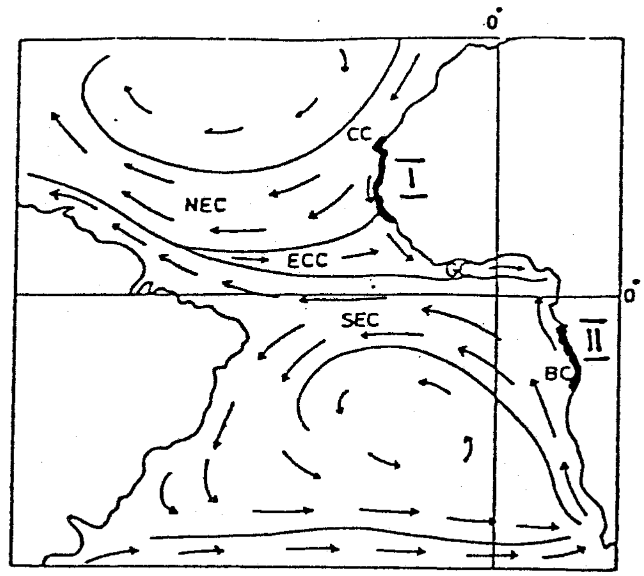


Figure 4: The basic elements of sea-water circulation in the Central Atlantic (Longhurst, 1962)

CC - Canary Current
NEC - North Equatorial Current
ECC - Equatorial Countercurrent
SEC - South Equatorial Current
GC - Guinea Current
BC - Benguela Current
I - North African Upwelling
II - South African Upwelling

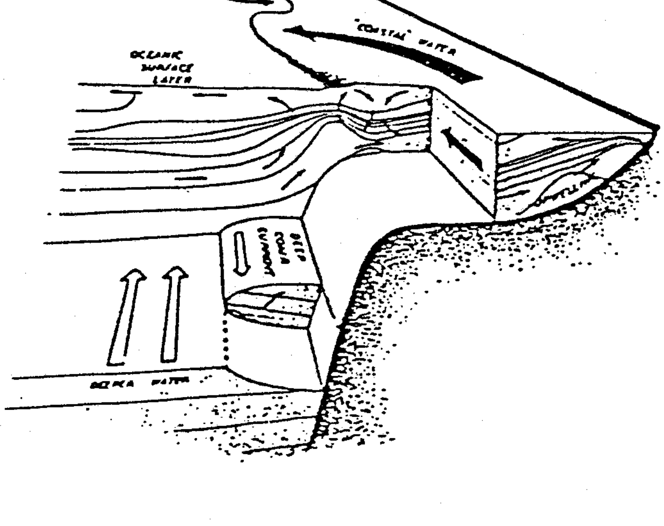


Figure 5: Schematic diagram of the structure of the Benguela Current and South African Upwelling (Hart, Currie 1962)

water. The highest temperatures of the surface waters are found in the Gulf of Guinea, with 28°-29°C in winter and 24°-26°C in summer (northern), being always 1°-2°C higher than the air temperature there. In the Gulf of Guinea, with a shallow thermocline, the largest seasonal SST variations in the equatorial Atlantic are found. In the other two zones the SST is markedly lower, especially during the periods of maximum upwelling in the respective winter seasons. This implies considerable negative (i.e. too low SST) temperature anomalies at some of the coastal cities in these zones, reaching values of 9°C in the southernmost part of the Region and 5°C in the northernmost. Along the equator the negative anomaly of the SST is 1°C. The range of variation of the SST in the Region is generally in the interval 3° to 7°C. The average SST distributions are shown in figure 6 and temperature ranges for summer and winter at different depths are given in table 1 (GATE, 1980). Outside the upwelling areas there is generally no or only weak temperature stratification in the top 50-100 m. In the upwelling areas however a thermocline is often found at depths less than 50 m (20-40 m).

At 400 m depth the temperature varies from about 10°C in the northernmost part of the Region to less than 8°C in the equatorial zone and about 8°C in the rest of the Region; at 100 m depth the temperature is in the range 3.5° (in the south) to 5°C (in the north) (Schott, 1944).

In the coastal region of the Gulf of Guinea zone the surface layer salinity is less than 34.5 parts per thousand (pmls), being very low in the apex of the Gulf, or about 20 (Schott, 1944). Further offshore in this region the salinity is less than 35.0. The low values are due both to the influence of the large rivers Congo and Niger, with an annual run-off of about 1,300 km^3/yr and 270 km^3/yr, respectively, and to the heavy rainfall in the area. Other relatively large rivers also enter the Region: Senegal, 78 km^3/yr; Orange, 107 km^3/yr, but they do not have such a pronounced influence.

The layer of mixed fresh/marine water has a strong influence on the structure and distribution of temperature and salinity fields in the region. A large vertical gradient of sea-water density, connected with salinity, is a very difficult barrier for the vertical movement of various substances. This process is extremely important for the exchange of biogenic components, and this natural barrier does not let various nourishing substances pass from depth to the surface layer and in consequence it reduces the biological productivity in warm, low-saline coastal waters.

Further out into the ocean the salinity increases above 35, reaching a maximum of about 36 in a tongue at 15°S (figure 7; Schott, 1944).

An indication of the salinity range in the top 100 m is given in table 2 (GATE, 1980). At the 400 m and 1,000 m depths the salinity is generally 34.5-34.8 (Schott, 1944).

5.3 Sea-water chemistry

5.3.1 General composition

Sea-water salt is composed of 11 major elements with concentrations above 1 mg/litre (table 3) and about 61 trace elements and various radioactive isotopes.

Annually about 25 billion tonnes of material are added to the ocean, over 90 per cent from rivers. The atmosphere is also an important source, in particular for the open ocean waters. Much of the material is removed by sedimentation, and considerable amounts of material introduced via rivers is retained in the coastal zone in this way.

Besides the dissolved salt, much material in sea-water occurs in particulate form and there is a continuous exchange between particulate and dissolved forms. When river water enters the estuarine zone flocculation processes generally occur due to the salinity of the sea-water, causing some material dissolved in the river water to be transformed into particulate forms which can settle on the bottom. The particulate matter in the sea plays a major role in transferring material, especially vertically but also quasi-horizontally since small particles (less than about 10 microns) can be carried far by the ocean currents. Major river plumes can be traced over long distances through their content of suspended particulate matter: examples are the Amazon and Congo river plumes in the Atlantic.

In the surface layer off West Africa, Emery and Honjo (1979) found large amounts of suspended matter, reflecting the influence of the high biological productivity in the upwelling areas and the transfer from land via wind erosion and via the Congo river. Total mean concentrations were in the range 0.5 to 2 mg/l in these areas and 0.1 mg/l away from the upwelling areas in the open ocean. The composition of the suspended matter very much reflected the plankton species distribution, organic matter and skeletal debris making up about 99 per cent of the total amount. Areas of high concentrations of mineral grains were related to supply from eroding cliffs and offshore winds (at relatively high latitudes) and the discharges from the Niger and the Congo together annually contribute about 150.10^6 tonnes of suspended sediment to the ocean (Heezen et al., 1964). The mineral grain concentrations were, however, very low at distances of 500 to 2,000 km from the shore, indicating that much of the material inshore is retained in the coastal zone. In the open ocean the amount of terrigenous (mineral) suspended matters can often be related to atmospheric deposition.

In the subsurface waters also, the high biological activity in the upwelling areas gives rise to large amounts of suspended matter, and in particular a bottom boundary layer with very considerable amounts can develop on the shelf and slope. In arid lagoon areas the concentration of particulate matter can also be very high. Part of this material can also enter the coastal zone through subsurface outflows due to the high density of the water (Kullenberg, 1978).

Some elements in the sea-water are particularly important biologically: O, C, H, Si, N, P, Fe, Mn. It should be noted that sea-water contains large amounts of the major nutrient elements N, P, Si, in different forms. Several of the trace elements are also biologically important, playing a role at the naturally low concentrations in primary production, but in addition to that being removed from the water and concentrated by organisms by several orders of magnitude. This removal process can occur through several mechanisms and at several different trophic levels; it is commonly referred to as bioaccumulation or biomagnification.

The biological activity in the sea of course plays a major role in the distribution of the biogenic elements, in particular in the top 500 metres. Primary production occurs in the euphotic zone, defined by the depth where the light level is 1 per cent of the incoming solar radiation just beneath the surface. The primary biological activity transforms dissolved elements into organic particulate matter, consuming carbon dioxide and releasing oxygen, which is further transformed by activities at higher levels, including the generation of detritus and faecal pellets. These can settle to the bottom, thereby transferring organic material to the sediments and the bottom-living organisms. In shallow waters the euphotic zone reaches the bottom, giving rise to plant life there and not only in the water column.

Further division of elements into groups may be carried out. For example, elements such as N, O, CO, Ar and other gases including hydrogen sulphide, may be combined into one group. It would lead too far to discuss all groups or elements separately, and only those of important in relation to biological conditions and potential pollution development will be considered specifically.

5.3.2 Carbon and the marine carbonate system

Dissolved organic carbon is a basic component of total organic carbon (up to 90-95 per cent) in sea-water. It is composed of 75 per cent of unstable and quickly decaying matter and of 25 per cent of relatively firm. Maximal concentrations of organic C are located in the upper (0-10 metres) layer and for most of the Region its average values achieve 1.5-2.5 mg C/l. But in coastal areas, especially in the highly productive zones, extreme concentrations can be more than 5-10 mg C/l (Atlantic Ocean, 1977).

The carbonate system is most important because it regulates many of the basic chemical and biochemical processes which are closely connected with the birth and existence of marine life. All the components of this system are closely correlated to each other, but the system itself aspires to stable chemical equilibrum. Even a small change of one component leads, without fail, to dislocation of the equilibrum in the whole system.

Such characteristics of seawater carbonate system as pH and the alkalinity (Alk) to chlorinity (Cl) ratio are very important for the living conditions of marine organisms.

The distribution of pH in the Region is shown in table 4 (Atlantic Ocean, 1977).

Table 4: The distribution of sea-water pH

	0m	300m	500m
Northern zone	8.25 - 8.30	7.80 - 7.95	7.73 - 7.88
Middle zone	8.20 - 8.25	7.85 - 7.95	7.76 - 7.81
Southern zone	8.25 - 8.30	7.70 - 8.10	7.68 - 7.98

These data show that maximal pH values are connected with the sea-surface layer, but at the 300 and 500m depths the value of pH is decreased to 7.7-7.8. This phenomenon could be explained as follows. It is well known that the value of seawater pH is inversely proportional to the concentration of CO_2 (dissolved). In the areas with maximal development of photosynthetic processes (the euphotic zone) there are very active processes of CO_2 consumption by phytoplankton which lead to increasing of seawater pH up to 8.4-8.6 in the surface layer. But beneath, at the 300 and 500m depths, vital processes of marine organisms and dissolution of terrigenous and biogenic carbonates produce large quantities of CO_2 (dissolved) that accordingly lead to decreasing seawater pH (Atlantic Ocean, 1977; UNESCO, 1976).

A noticeable lowering of pH in the surface water, to 8.0-8.1, is only observed in the upwelling zones where the supply of subsurface layer water carries CO_2 to the surface layer.

Values of Alk/Cl ratio fluctuate within the Region from 0.120 to 0.127. There are two main trends in the distribution: increase from sea surface to bottom layers and increase from the north to the south (see table 5).

Table 5: Distribution of Alk/Cl ratio in the Region (Atlantic Ocean, 1977; Atlas of the World Ocean, 1976).

	0m	300m	500m
Northern zone	0.121 - 0.122	0.120 - 0.122	0.121 - 0.122
Middle zone	0.120 - 0.121	0.121 - 0.122	0.122 - 0.124
Southern zone	0.121 - 0.124	0.122 - 0.123	0.122 - 0.124

Minimal Alk/Cl ratio is characteristic of sea surface layers in tropical and subtropical areas of the Region. It is connected with the active consumption of carbonates by phytoplankton. The above-mentioned process of dissolution of carbonaceous detritus and minerals in deep layers of seawater in this case leads to an increase in alkalinity and the Alk/Cl ratio. Intensive evaporation of marine water in the tropics and consequent increaseed salinity caused higher alkalinity in some parts of the Gulf of Guinea. At the same time atmospheric precipitation there leads to a general lowering of the Alk/Cl ratio in the upper layers.

A large increase in the ratio is found near the estuaries of West and Central African rivers, especially the Congo, Niger and Orange, because of the influence of fresh water. Coastal zones in the south are exposed to the effect of the waters from the Southern Atlantic, which have a rather high Alk/Cl ratio, up to 0.124 (Atlantic Ocean, 1977).

Besides dissolved organic carbon, sea-water also contains particulate organic carbon (POC), usually defined by the lower limit of 0.8 mcm size. Pocklington and Mac Kinnon (1982) recently summarized data on POC for areas of the world ocean and, in particular, considered the area off Senegal and the Gambia, from 11° to 18° N. They found that the range of POC levels for the ocean are 17-215 mcg/l, with open ocean areas having low means, upwelling areas higher (60-195 mcg/l) and areas with terrigenous and anthropogenic inputs highest (215-234 mcg/l). Off Senegal and the Gambia the mean value of POC was 68 mcg/l, considerably lower than in the northern and southern upwelling areas, with mean values of 133 mcg/l and 152 mcg/l, respectively. A likely implication is that the upwelling off Senegal is less productive, which could be due to a more limited duration of favourable upwelling conditions there (Pocklington and Mac Kinnon, 1982).

5.3.3 Dissolved gases

All the gases of the atmosphere are dissolved in oceanic waters, but among them oxygen is the most important for marine life because it participates in all biochemical and chemical processes. Two basic processes, apart from the transfer across the air-sea interface, in the upper 200 metres layer are responsible for the distribution of dissolved oxygen in sea-water: oxygen production by phytoplankton and oxygen consumption by marine organisms. Different combinations of them within the marine waters of the Region lead to some decrease in oxygen concentration in tropical waters and to some increase in oxygen concentrations in subtropical and temperate areas (see figure 8).

In the surface waters of the Gulf of Guinea there is a large area of relatively low oxygen concentration (less than 5 ml/l). The other areas of the Region are characterized by higher concentrations of oxygen (up to 5.5-6.0 ml/l). Seasonal changes of oxygen concentrations in the tropics and subtropics are very small. There are two maxima of oxygen in the water column of the Region. The upper maximum is located at a depth of 0-10 m to 20-40 m and associated with the vital activity of light-loving species of phytoplankton. The lower maximum at a depth of 50 to 90 metres depends upon dark-loving species of phytoplankton which produce oxygen using biogenic elements concentrated near the pycnocline (Atlantic Ocean, 1977; UNESCO, 1976).

In subsurface waters the oxygen consumption by the decay of sinking organic matter is noticeable in the occurrence of oxygen minima in bands extending out from the coast at about 200 m depth in the major upwelling zones of the northern and southern parts of the Region. There the oxygen content is less than 2 ml/l (figure 8). Generally the oxygen content decreases from the surface layer downwards. Already at 50 m depth it is less than 3 ml/l in large parts of the coastal zones of the Region. This is a natural phenomenon but it is clearly very important to bear in mind in relation to additional loads of oxygen consuming material brought to these zones by human activities. In subsurface waters of upwelling areas there are generally layers of low oxygen concentrations, and often they are so low that additional oxygen consumption could have very deleterious effects.

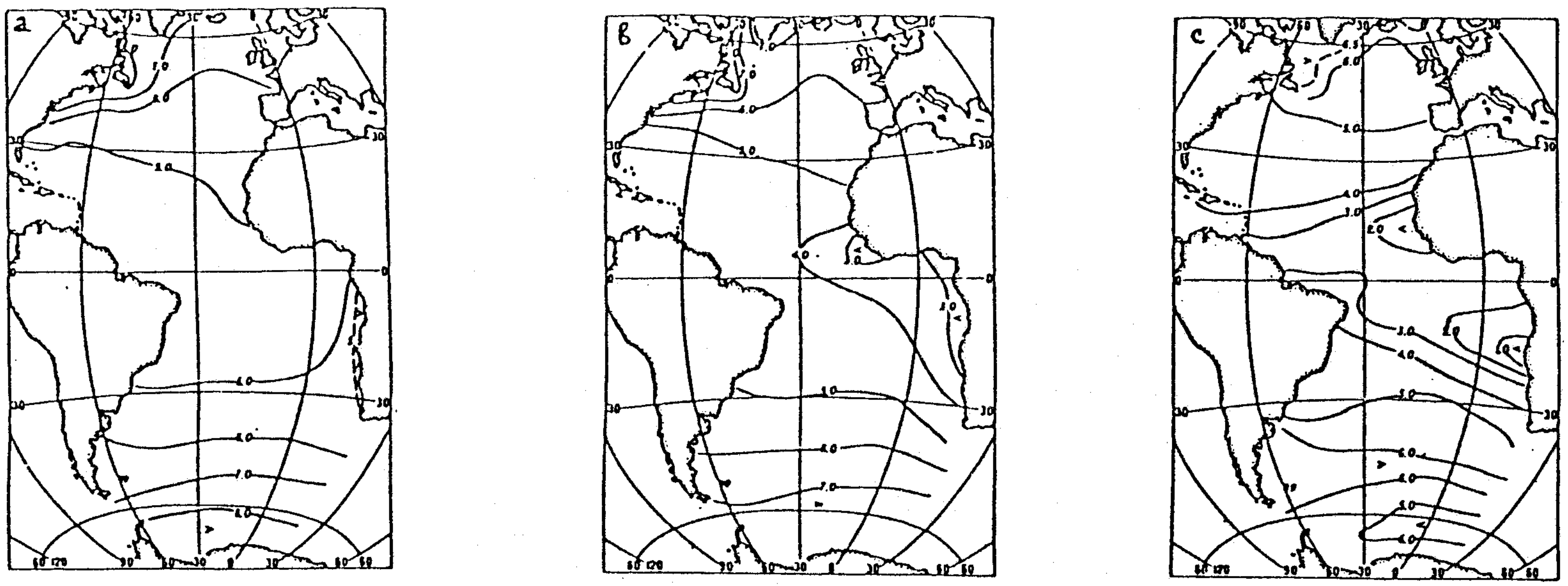
5.3.4 Major nutrient elements

The major nutrient elements are nitrogen, phosphorus and silicon. Generally these elements are depleted in the euphotic zone due to biological activity, and regenerated at intermediate depths, mostly in the top 500 m. The great importance of coastal upwelling lies in the transfer of these nutrients from the 200-400 m depth interval to the euphotic zone.

It should be noted that other elements are also required as nutrients for the biological production: several major constituents as well as minor constituents or trace elements, including organic growth factors and vitamins.

Nitrogen can be found in sea-water of the Region in four basic forms: organic nitrogen; ammonia - the first product of organic matter decay; nitrates - the most resistant form of inorganic nitrogen; and nitrites (Atlantic Ocean, 1977).

Dissolved organic nitrogen forms 90-95 per cent of total organic nitrogen. Maximal concentrations are associated with the layer of photosynthesis where they achieve up to 10-20 micrograme-atom N/litre and even more. From surface to sea bottom organic nitrogen concentrations decrease to 3-5 mcg-atom N/l.



(a) at sea surface

(b) 50 metres

(c) 200 metres

Figure 8: Distribution of dissolved oxygen (in ml/l) at different depths (Atlantic Ocean, 1977)

Ammonia also has maximal concentrations (1-5 mcg-atom N/l) in the zone of photosynthesis, where the processes of organic matter decay are also very active.

The nitrates are consumed by phytoplankton during the process of photosynthesis and so their concentrations in the surface layer of sea-water are minimal (0.5-1.0 mcg-atom N/l) practically everywhere in the Region. Only in the upwelling zones, near Senegal and Mauritania and also near Angola and Namibia, can concentrations of nitrates achieve fairly high level because of deep water upwelling (10-15 and even 25-30 mcg-atom N/l).

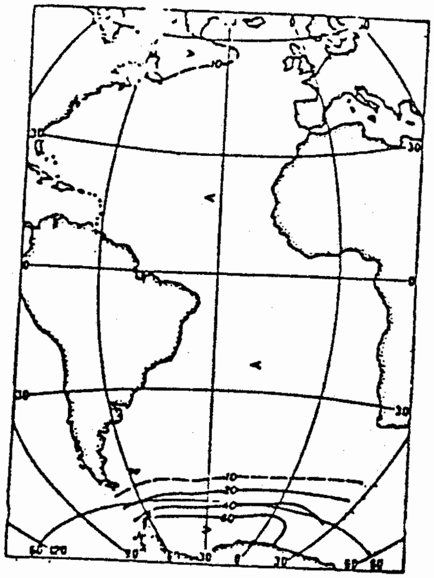
The nitrites are usually found in the primary nitrite maximum near the surface layer, and in rather small concentrations (0.01-0.1 mcg-atom N/l). Maximal concentrations of nitrites are associated with the pycnocline layer at depths of 50-100 metres and in some cases can achieve 0.5 mcg-atom N/l (UNESCO, 1976). The secondary nitrite maximum is a feature of highly productive upwelling areas and can be situated deeper, e.g. at 200-300 m depth in the Peru upwelling area.

Organic phosphorus in sea-water is mainly found in dissolved form. Its maximal concentrations in the layer of photosynthesis can achieve 0.5-1.0 mcg-atom P/l in some parts of the Region. In sea-water, deeper than 100 metres, organic phosphorus is practically absent. 90-95 per cent of inorganic phosphorus also exists in dissolved form. Its minimal concentrations (up to 0.1-0.2 mcg-atom P/l) are associated with the layer of photosynthesis because of its active consumption by phytoplankton. Maximal values can achieve 2.0-2.2 mcg-atom P/l at depths of 500 metres and more. High concentrations of inorganic phosphorus in the Region are closely connected with the above-mentioned upwelling zones (see table 6) (UNESCO, 1976; Atlantic Ocean, 1977).

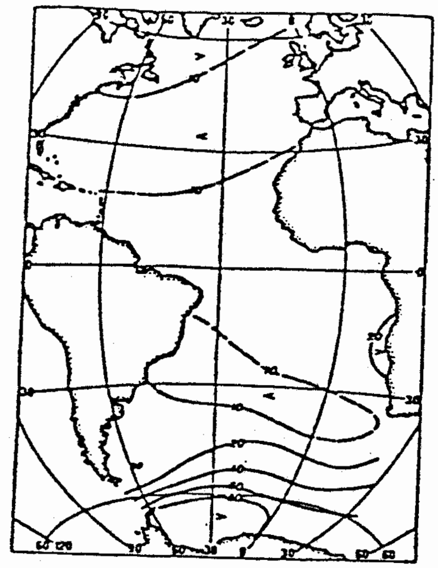
Table 6: Distribution of inorganic phosphorus in sea-water (in mcg-atom P/l)

	0m		50m		100m	200m
	W	S	W	S		
Northern zone	< 0.25	< 0.25	0.25-0.5	1-1.5	1-1.5	1 - 2
Middle zone	< 0.25	< 0.25	0.5-1.0	1-1.5	> 1.0	> 1.5
Southern zone	0.25-1.0	0.25-0.5	> 1.0	> 1.5	1.5-2.0	> 2.0

Dissolved non-organic silicon is the main form (more then 95 per cent) of silicic substances in sea-water. Suspended non-organic silicon accounts for only 1 per cent and organic amorphous silicon in suspended matter - no more than 2-3 per cent. Minimal concentrations of silicon are associated with sea surface layers and 10 mcg-atom Si/l is a usual annual average concentration for the whole Region. Bottom waters have rather high silicon concentrations (up to 15-20 mcg-atom Si/l) and its local increase in coastal areas of Angola and Namibia is connected with the upwelling of deep water (see figure 9) (UNESCO, 1976; Geochemistry of Silicon, 1966).



(a) sea surface



(b) 200 metres

Figure 9: Distribution of dissolved silicon (in mcg-atom Si/1) (Atlantic Ocean, 1977)

5.3.5 Minor nutrient elements, trace elements and metals

The minor, or trace, elements have concentrations less than 1 mg/kg, and the concentration for an individual element can vary very considerably. Average concentrations can be given in some cases (table 3). These elements are of great importance for bio-geochemical cycles in the sea. Often the concept of residence time is used to demonstrate the chemical and biological activity of the element. The residence time T (tau) is defined as A/(dA/dt), where A is the total amount of the element dissolved in the sea and dA/dt is the amount introduced to or removed from the sea each year, assuming a steady state. The residence time is relatively short, in the order of a hundred years, for elements like Al, Ti, Cr, Fl, and very long, often in the order of 10^6-10^8 years, for the alkali and alkaline earth metals. These elements can be removed from sea-water by inorganic processes through adsorption and precipitation. Adsorption, or scavenging, by suspended matter and sinking detritus is the main process. Trace elements can also be removed by organic processes such as plankton uptake through assimilation. Often the elements become more concentrated in plankton than in the water, with concentration factors in the range 103 to 105. It has not been clarified that the phytoplankton trace element levels reflect the background level in the water.

Trace elements have a significant influence on photosynthetic production. The distinction between "good" and "bad" waters with regard to phytoplankton growth has often been related to the effects of trace metal species and the presence or absence of organic chelators.

Heavy metals have received special interest. Higher marine organisms absorb, ingest, excrete, store and regulate their body burden of metals. A major way of uptake is absorption from solution through the gills or over the body surface, and removal appears to be mainly through urine and rectal fluids. The degree of toxicity of the metals will vary with the metal and the organisms. As a crude generalization the order of toxicity may be given as Hg>Ag>Cu>Cd>Zn>Pb>Cr>Ni>Co. Temperature and salinity may have a significant influence on the toxicity. Sublethal effects of exposure to heavy metals may be significant.

There is a very limited amount of data available on the concentration levels of trace elements, and due to analytical and sampling complexities different data sets cannot generally be used for intercomparisons of levels in different areas.

Mercury concentrations show variability in the range 5-1,090 ng/l, the majority of mean values being less than 50 ng/l (Jones, 1975; Fitzgerald, 1976). Cadmium values off north-west Africa have been observed in the range 80-620 ng/l, mean 120 ng/l, whereas values in the surface layers of the North Atlantic were 40-300 ng/l (Jones 1975). For the South Atlantic and for open ocean waters overall Chester and Stones (1974) reported values of Cd in the range 40-170 ng/l, with a mean of 70 ng/l.

Off north-west Africa Riley and Taylor (1972) found copper content in filtered sea water from depths between 10 and 2,500 m in the range 0.5-12.3 mcg/l, with a mean of 1.1 mcg/l. Chester and Stones (1974) reported values between 0.4 and 3.8 mcg Cu/l, mean 1.2, for waters in the eastern Atlantic, and values between 0.7 and 3.4 mcg Cu/l for waters in the South Atlantic. Zinc concentration off north-west Africa were in the range 2.1-22.0 mcg Zn/l, with a mean of 8.2 (Riley and Taylor 1972). Chester and Stones (1974) found values in the range 0.9-5.2 mcg Zn/l in the north-eastern Atlantic and 0.06-2.2 mcg Zn/l for the South Atlantic. The slightly higher levels found in the upwelling area off Africa may reflect zinc enrichment by high biological activity in the upwelling area.

A number of radioactive nuclides occur naturally in the sea. In regard to pollution the interest is focused on the artificially produced nuclides. The input from the nuclear fuel cycle is increasing in importance relative to the weapon testing source. Nuclides injected with waste water from plants in Europe can now be found over most of the northern North Atlantic, at least up to the Arctic Basin (Riley and Skirrow, 1975).

Practically all the metals are found in the marine environment, some of them in moderate concentrations, for example Ca and Mg, and others in very low trace concentrations, e.g. Au and Ag. Almost all metals are bioaccumulated in one or more components of the marine food-chain. They are the most persistent of substances in the environment. They can be neither transformed nor destroyed, although they can be combined in various compounds and complexes. A point to note here is that certain metals can form, with organic substances, highly toxic metallorganic complexes, like methyl mercuric chloride and that some of these combinations can be carried by bacteria into the natural environment. Some metals such as Hg, Cu and Ag are toxic at high concentrations to marine organisms, whereas others like Ca, Mg and Na are comparatively innocuous. Moreover many metals such as K, Ca, Fe, Mg and even Zn are vital for the nutrition of marine organisms, as discussed above.

It is now well known that certain marine organisms have a high affinity for particular chemical elements. For example Zn, Cd, Hg and some other metals are actively concentrated in them at rather high levels and there is some evidence of serious direct harm to organisms containing high concentrations of these elements.

Wood and Goldberg (1977) divided metals of biological concern into three basic groups:

(1) Light metals, normally transported as mobile cations in aqueous solutions (e.g. Na^+ and K^+);

(2) Transition metals (e.g. Fe, Cu, Co and Mn) which may be essential for biological activity at trace levels and may be toxic at high concentrations;

(3) Heavy metals or metalloids that may be required for metabolic activity at trace concentrations, but which at slightly higher levels are toxic to the cell, e.g. Hg, Se, Pb, Sn, As.

Metals could also be classified in terms of their relative toxicity and availability. Toxic metals forming organo-metallic compounds, like metalkyls, are of special concern. These include Hg, Sn, As, Se, Cd, and Pb.

Marine contamination by these metals has been primarily observed in coastal waters as a consequence of river, industrial and municipal sewage discharges and also direct waste dumping. It should, however, be emphasized that the atmospheric transfer to the open ocean of many metals of concern is large, sometimes reaching 50 per cent or more of the input via rivers, e.g. for zinc, cadmium, lead, mercury and selenium (GESAMP, 1982). Some of the metals to be found in the oceans that have been extensively studied in the past few years are briefly described below: lead, cadmium and mercury.

The basic amounts of lead appear to be transported to the marine environment via the atmosphere. The fact is that concentrations of lead have been altered in vast areas of coastal waters as a result of the use of lead alkyls as antiknock additives in the fuels of internal combustion engines. The residence time of lead in marine water has been estimated at 400 years (Goldberg, 1976). In highly productive coastal areas lead actively participates in biochemical interaction with other components of water and is consumed by marine organisms with food. As a result, the residence time of lead in the coastal waters of the Region is evaluated at only one or two months. Lead contaminations in sea-water of the Region are not dangerous at present to marine organisms or the coastal population of human beings.

Cadmium enters the marine environment as a result of human activities both through the atmosphere and the hydrosphere. Most of the cadmium is introduced into sea-water as a result of volatilization of the metal which takes place during the smelting of sulphide ores used in the manufacture of metallic alloys, or reprocessed from cadmium-plated materials or alloys containing cadmium (Goldberg, 1976).

This type of industry is not developed in the Region and for this reason Cd-contamination is not dangerous at present in the coastal waters of Western Africa.

Mercury in sea-water exists as chloro-complexes with a residence time calculated to be 80,000 years. Mercury can enter the food chain at the level of micro-organisms, where the conversion to methyl mercury takes place as a detoxification reaction. Much of it introduced into the coastal areas is probably retained there and becomes associated with the marine biosphere. Some estimates show that in estuaries phytoplankton might remove as much as 20 per cent of mercury annually. In coastal and open-ocean areas about 1 per cent of mercury in the upper 100 metres of sea-water can be removed by phytoplankton each year (Topping and Windom, 1981). These facts might explain the relatively low concentrations of mercury in the coastal waters of the Region. Average levels are 40-41 ng/l there, but fluctuations of concentrations are very high, from 0.5 up to 113 ng/l (Chester et al., 1973; Gardner, 1975). In general, waters of the world ocean exhibit mercury levels of about 5 mcg/l, or about two orders of magnitude below the levels that produce sublethal effects. Concentrations of mercury in the Region are considerably less than the average oceanic level, which testifies to the absence of Hg-danger there at present.

An analysis of industrial and municipal development levels and the existing industries in the Region suggest that coastal water contamination by these metals is at present small.

5.3.6 Specific substances

There are a number of other substances introduced into the marine environment through human activities which are of concern, both natural ones such as hydrocarbons and artificial ones like the persistent synthetic organic chemicals DDT and its main metabolites (DDD and DDE) and polychlorinated biphenyls. The distribution and fate of these substances are also influenced by the sea-water chemistry and the biological activity. Observations have been made of concentration levels of such substances in some components of the marine environment of the Region, which will be recalled here, whereas the pollution aspects and sources of the contamination will be discussed in section 8.

Hydrocarbons in the sea can originate from petroleum, via seepage or by human activities, or from a biogenic source. The hydrocarbons in the sea are complex mixtures of saturated and aromatic compounds having from 14 to 32 carbon atoms per molecule (Brown et al., 1973). Some observations suggest that aromatics are present in relatively smaller concentrations than would be expected if the source of the hydrocarbons was only crude oil or refinery products (Brown and Huffman, 1976). The marine biogenic sources do not appear to yield aromatic hydrocarbon mixtures. Loss of hydrocarbons from sea-water occurs through evaporation and through dissolution, both processes operating for the light compounds containing less than 14 carbon molecules (NAS, 1975). Bacterial degradation is a major removal process. Brown and Huffman (1976) found concentration levels of hydrocarbons of 1.3-13 ppb in the surface layers of open coastal waters of the Atlantic, including extensive sampling within the Region, except in the Gulf of Guinea. The aromatics were found to have relatively little persistence, compared to other compounds. Polynuclear aromatic hydrocarbons are of natural origin or are combustion products built on units of benzene nuclei: the active 3.4 benzopyrene has been found in plankton, both in polluted areas and in areas not subject to pollution (Johnson, 1976). These substances degrade slowly and their potential hazard suggests that they merit attention (Izrael and Tsyban, 1981: GESAMP, 1982).

As regards halogenated hydrocarbons, or synthetical chemicals (and pesticides), studies have focused on the behaviour and occurrence of DDT with metabolites and PCBs. Overviews have been presented by Goldberg (1975) and GESAMP (1982). Harvey et al., (1974) found an average value of 30 ng/l of PCBs in the eastern and western Atlantic for the years 1971 and 1972. For comparison it may be mentioned that in 1973 and 1974 the levels in the Sargasso Sea were 1 ng/l and 0.8 ng/l, respectively. The ratio of DDT to PCB was less than 0.05 in the surface waters. Harvey et al., (1972) reported values of DDT in the Sargasso and zooplankton from western sub-tropical Atlantic areas in the range $<$0.01-9.5 mcg per kg fresh (or wet) weight. Extended analyses of these compounds in fish have been carried out within the International Council for the Exploration of the Sea (ICES) framework in the North Atlantic (ICES 1977-a). For open ocean areas pesticide levels in cod muscle varied from less than 1 to 10 mcg/kg wet weight. Liver concentrations were considerably larger, also showing variations between regions. Total DDT levels were in the range 1.8-0.18 ng/kg. PCB levels in cod liver were in the range 0.44 to 4.1 ng/kg, wet weight.

6. THE BIOLOGICAL SYSTEM

6.1 General conditions and characteristics

The biological system of the Region is strongly influenced by the physical water circulation, upwelling and transfer of material from land by the great rivers Niger and Congo. The primary productivity in the upwelling areas in the north, centred around 20° N (Cape Blanco), and in the Benguela Current regime is among the richest in the world; values up to about 3,500 g Cm^{-2} yr^{-1} have been reported from the southern area. The fish stocks in each area are different. In particular in the Gulf of Guinea localized upwelling zones occur, but these have been less well studied. A large number of primary production studies have been carried out, demonstrating a large variability over the Region and a large variability in time at given locations. The depth of the most pronounced production also varies. This variability is to a large extent related to the physical conditions influencing the supply of nutrients and other material, the stratification in the water column, the incoming radiation, the level of mixing and regional water circulation. Hulburt (1976) did not find that the primary production was nutrient-limited, neither in the high - nor in the low - production parts of the Region. Examples of values of primary production observed in the Region are (in units of $g.Cm^{-2}.yr^{-1}$): Canary Current: 35-350; Gulf of Guinea, northern part: 3-15; southern part 30-70; Congo estuary: 250; Niger estuary: 580; Benguela Current upwelling: 390-2 500; (all from Kondratjeva, 1979); Cape Sierra Leone, Conakry, Tema: 250; Gulf of Guinea: 105 (Nellen, 1967); Cape Blanco upwelling area: 365-1 100 (Huntsman and Barber 1977). Schulz (1982) presents data indicating slightly higher primary production in the southern upwelling system than in the northern one. On the basis of an analysis of all influencing factors he concludes that the conditions for primary production are better in the southern area.

Zooplankton is the next step in the food-chain, grazing on the phytoplankton, generating larger particles which to a large extent settle thereby transferring organic material to the bottom. The zooplankton also regenerates the nitrogen used by the phytoplankton; this yields an average supply of about 25 per cent of the total nitrogen demand of the phytoplankton in the north-west African upwelling area (Smith and Whitledge, 1977). These authors also found that small zooplankton species, in the range 100-500 mcm, dominated the biomass nearshore, while zooplankton larger than 1,000 mcm were the major component offshore. The total biomass of zooplankton in the offshore area was 13 g dry weight m^{-2}, decreasing to 1.7-3.8 units in the nearshore area. In the nearshore zone immature crustacean forms (eggs, nauplii, and copepo) were in a larger proportion than offshore. The offshore samples, about 35 n.m. from the coast, were dominated by Acartia sp. and unidentified nauplii. In the southern upwelling area (the Benguela Current regime) zooplankton maxima, in numbers and biomass, have likewise been observed offshore of the main upwelling area, around 20° S (Kondratjeva 1979).

Phytoplankton and zooplankton distributions are very much influenced by physical conditions and processes. These include: stratification in the water column; light conditions; currents and in particular current variations; turbulent mixing, often generated by wind influence; wave motions. In eastern coastal boundary layers wind-generated continental shelf waves may have a strong influence on the zooplankton distribution (Walsh, 1977; Pastel, 1982).

Studies of suspended particulate matter have yielded information on the distribution and composition of the plankton community in different parts of the Region. Riley et al., (1964) found high amounts of aggregate particles of organic matter in the Guinea Current regime from about 15° to 11°N, with diatoms being the major constituent of the flora. The composition varied widely from station to station, with Thalassiosira or Chaetoceros spp. often being dominant at stations with the highest standing crops. In the area south of this regime, about 10°-6°N, the same authors found low amounts of aggregates and few diatoms. This was a biological regime similar to that found in the North Equatorial Current, while the Guinea Current regime was similar to the upwelling regime to the north. Riley et al., (1964) found a direct relationship between organic aggregates and the volume of phytoplankton. The mean carbon values in the Guinea region were 0.6 mg C/litre and 0.36 mg C/litre in the adjacent southern area, along the coast.

Emery and Honjo (1979) likewise found that siliceous remains of diatoms were the most abundant of the skeletal debris from surface waters off western Africa: discoid diatoms Chaetoceros spp., Rhyzosolenia spp. and Coscinodiscus spp.. The distribution pattern suggested abundance in areas of coastal upwelling and in the eastern region of the Gulf of Guinea associated with the Niger and Congo rivers. The pattern established from the debris was very similar to the plankton productivity presented in the charts by Koblenz-Mishke et al., (1970) and others. The most abundant after diatoms were dinoflagellates: Gonyaulax spp., Ceratium spp., Peridinium spp. and others. Silicoflagellate skeletonne were present but very scarce, the concentrations clearly related to the physical circulation regimes. Radiolarian skeletonne were relatively rare and showed no aerial preference. Emery and Honjo (1979) also observed a member of organic surface films of 0.3-8 mcm thickness concentrated in the north and south upwelling areas, and clearly of natural biogenic origin. In conclusion it can be stated that the distributions of diatoms, dinoflagellates, silicoflagellates and other marine plankton reflects the areas of upwelling and river discharge; the importance of the latter was shown both by the abundance of total diatoms and the presence of freshwater species (Emery and Honjo, 1979).

6.2 Living resources

The areas of high primary productivity coupled with the upwelling areas in the northern and southern parts of the Region are particularly rich in fish production. There are differences in fish populations between the areas, especially as regards the demersal communities (Bas, 1983).

In the northern area the pelagic fish population is dominated by Sardina pilchardus, whereas in the Benguela Current regime it is Sardinops ocellata. Two groups of pelagic species are found throughout the Region, namely: Sardinella aurita, preferring intertropical waters, and different species of the genus Trachurus (Bas, 1983).

The demersal population covers a wide variety of species. In the equatorial zone the fisheries exploitation of these species (belonging to the genus Otholitus) is not particularly important. Crustaceans: shrimps, prawns and lobsters occupy a wide range of areas from lobsters in coastal zones in the northen and southern areas to prawn grounds in the Gulf of Guinea and deep water shrimps from Senegal to Angola. As far as potential developments concerned the euphasiids and different groups of vertically migrating species, e.g. the myctophids, are of particular interest (Bas, 1983).

The detailed distribution and abundance of pelagic fish have been studied in some areas in connection with research programmes concerned in particular with the upwelling areas. Thorne et al., (1977) observed the congregations of fish associated with the upper continental slope and midshelf, respectively, at about 21° N during the Coastal Upwelling Ecosystem Analysis (CUEA) investigations. This abundance of fish could be connected with the distribution of zooplankton in the northern upwelling area. The slope congregation primarily of horse mackerel (Trachurus sp.) was associated with the high abundance of large (over 500 mcm) zooplankton, while the midshelf congregation was primarily sardine associated with the small zooplankton and phytoplankton maxima of the midshelf. The authors estimated the average abundance of fish at 60 gm^{-2} wet weight over an area of 4,000 m^2. This clearly indicates how the different fish distributions are related to primary biological and physical conditions. This is further elucidated below.

Living resources in the marine and coastal areas of the Region are extremely abundant, but their geographical distribution between different West African countries and zones is irregular. Except for tuna, the important fishery resources (pelagic and demersal) of West Africa are concentrated on the continental shelf. Rich population of shrimps and marine molluscs are also located there (figure 10).

The most considerable fishing grounds are found in areas of upwelling, where deep nutrient-laden waters brought towards the surface are responsible for extremely large primary production of organic matter. This is consumed by zooplankton and successively higher trophic levels. For example, zooplankton biomass in these areas achieves 400 mg/m2 and more (see figure 11) and primary production of Phytoplankton, 500 mg C/m2/day and more (see figure 12; Krey, 1975). High productivity and hence rich fishery resources are linked with the following enrichment areas:

(1) along the coast from Senegal to Liberia particularly during February-March and July-August. This is associated with the upwelling in the north-west frontal zone;

(2) from Gabon to Congo, for July-August and February-March, linked with the upwelling zone in the Benguela Current regime;

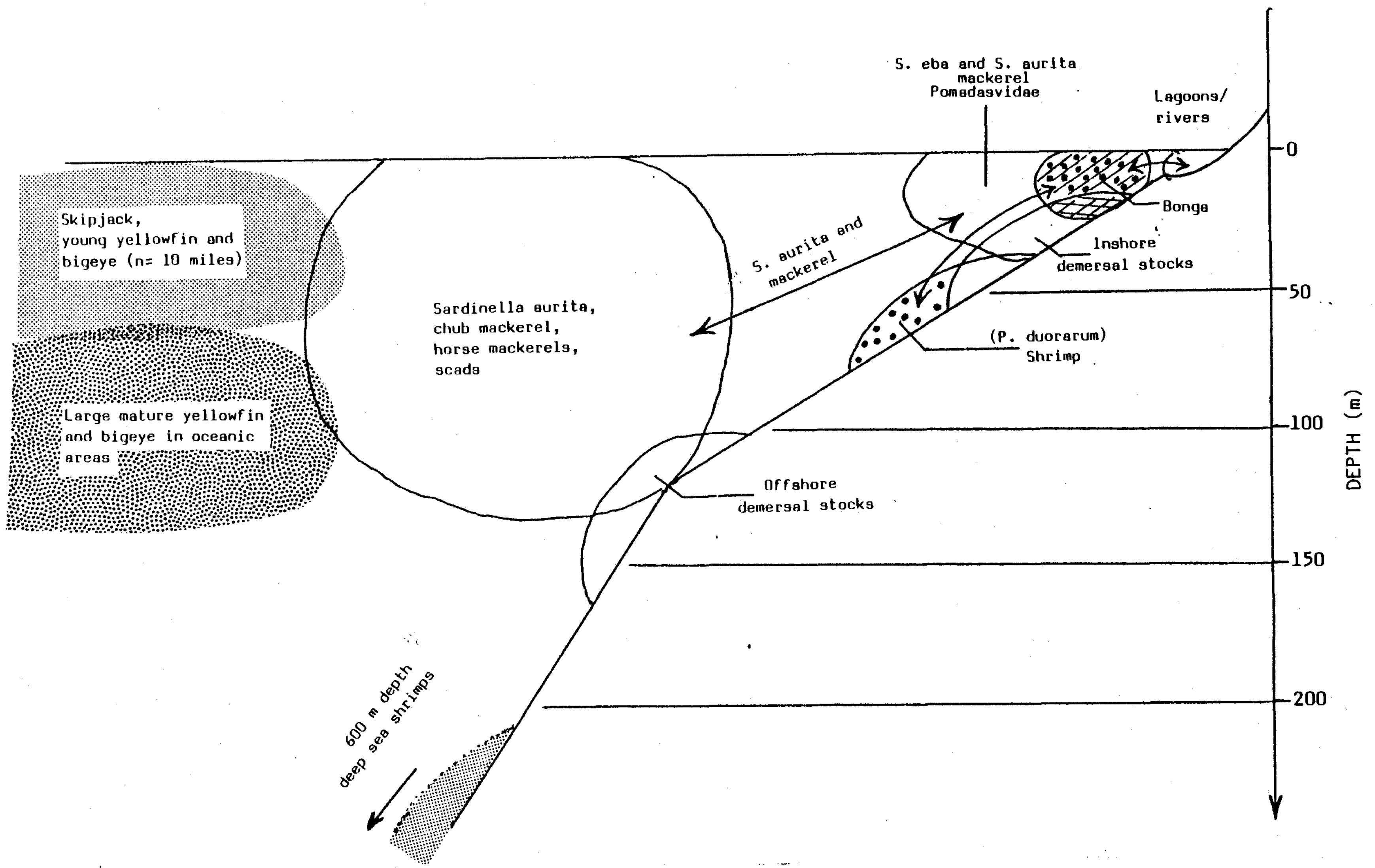


Figure 10: The distribution by depth of fish species and species groups off the coast of West Africa between 20°N and 15°S (Saentongo, 1979)

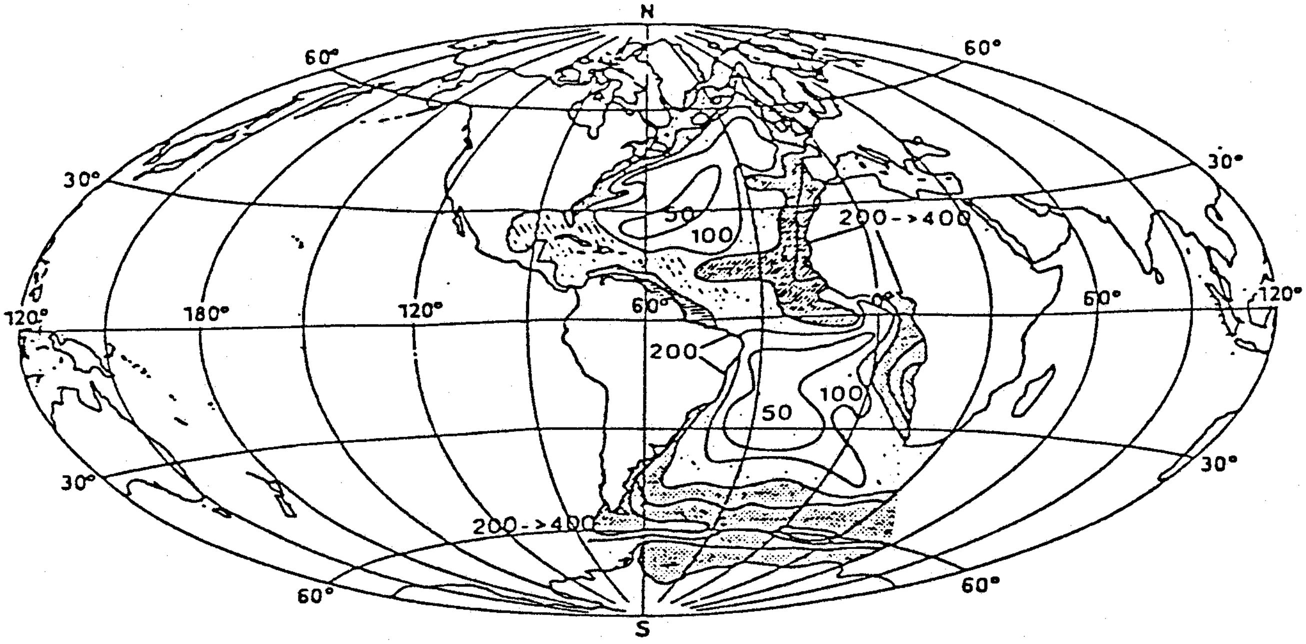


Figure 11: Biomass of zooplankton (in mg/m^3) (Hela, Laevastu, 1962)

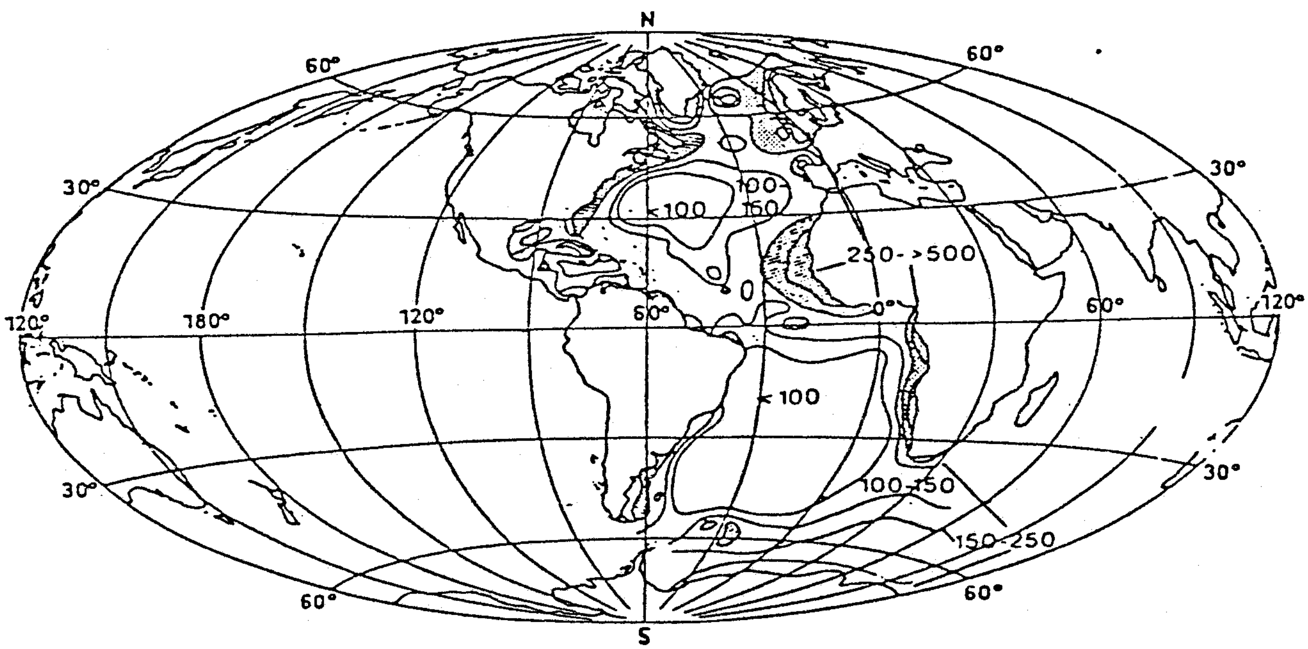


Figure 12: Primary production of phytoplankton (in mg c/m^2/day) (Koblenz-Mishke et al., 1971)

(3) a third region of high productivity is located along the coast of Ghana-Ivory Coast and associated with seasonal upwelling during July- August;

(4) high productivity is also known in the outflow region of the Zaire/Congo river to a distance of about 300 miles.

All the basic fishery areas in the Region and migration patterns of important pelagic fish are shown in figure 13. Thus the richest fishing grounds in the Region are associated with desert coasts and relatively low populations, while the most populated states such as Ghana, Nigeria and Ivory Coast have relatively smaller fisheries resources (Williams, 1975; FAO, 1979).

The importance of fishing varies considerably from country to country. In Mauritania fish exports rank second, but well below iron ore. Senegal achieved a remarkable increase in fishing in the last decade and ocean products featured significantly among its exports. About 70 per cent of the catch is exported, including shrimp, of which it is Africa's leading producer. Domestic consumption is also high and the country ranks fifth in the world per capita use of fish. Gambia's catch is also increasing steadily and a new company is processing crabs, oysters and lobsters (Ssentongo, 1979).

Several of the countries tend to be net importers, though many export tuna and shrimp. Liberia, Ghana, Togo and Benin have many communities engaged in fishing. Nigeria consumes the continent's largest quantities of fish, but imports about three quarters of its needs.

Among the West and Central African countries, the largest catches are those of Namibia, followed by Nigeria, Senegal, Ghana and Angola (see table 7).

The data given in table 7 show that during the last decade fish catches have been subject to big changes. In some countries such as Mauritania, Angola, Senegal, Gabon and Congo, the amount of the catch fluctuated during this period. The general tendency for most of the countries is to increase their catch. However, on the other hand, Angola and Namibia have had considerably smaller catches of fish and other marine resources in the last five years.

Foreign vessels also play a very large role in sea fisheries, particularly in more distant waters for tuna. The USSR, Spain, Japan and Norway use large freezer-trawlers and factory fishmeal ships that are capable of catching and processing great quantities of fish without being dependent on nearby ports (Ferreira, 1979).

The lagoons along the coast are also areas of high productivity. In general, this is associated with the dry season when nutrients are being concentrated. Productivity during floods or the rainy seasons is generally poor in the lagoons.

Fish and shrimp are the major resources of the Region, and at the same time in some countries like Senegal, Sierra Leone, Nigeria and others, edible molluscs from near-shore are harvested in considerable quantities (Offurum, 1981). The present total annual catch estimated by FAO's Fishery Committee for Eastern Central Atlantic Fisheries (CECAF) is 3.5 million tonnes.

The development of fisheries in the CINECA region (Co-operative Investigation of the Northern Part of the Eastern Central Atlantic) extending from Gibraltar to 10°N, has been studied in the cooperative FAO/UNDP project. Ansa-Emmin (1982) distinguished between artisanal, local semi-industrial or industrial, and long-distance fisheries mainly conducted by non-African countries. In Senegal the artisanal landings carried out from canoes increased from 83,000 t in 1965 to 278,400 t in 1975. In Gambia the artisanal catches increased from 3,000 t in 1965 to 14,000 t in 1976, and artisanal landings in Guinea were estimated at 7,000 t at that time. In 1976 the landings of the ten most important species in the industrialized local fisheries in Senegal was about 64,000 t, including trawlers, shrimpers and purse seiners. The long-distance fishing in the CINECA region include fisheries by European countries, the USSR, Japan and Korea. As examples of the catches by these fleets it can be mentioned that vessels from France and Spain fishing off Morocco and the Sahara in 1970 caught up to 42,000 t of sardine, and that one factory ship (Interpêche) yielded between 80,000 t and 216,000 t in 1973-1977 for the CINECA region. Ansa-Emmin (1982) summarized the knowledge of the state of exploitation of various stocks in the CINECA region, and concluded that most of the major resources in the area are fully exploited. He also concluded, however, that catch information was far from satisfactory and that fisheries assessment and management partly for this reason were developing only slowly. Information on activities of international organizations concerned with fisheries and on regional fishery bodies can be obtained from FAO (1981).

6.3 Special ecosystems and resources

There are a large number of nearshore and coastal zone ecosystems in the Region which require special consideration in relation to their support for the offshore systems and for their sensitivity to pollution. A review of these has been given in IMCO/UNEP (1982). Among them are:

(i) Rocky beach communities, subject to much physical influence, and making use of sheltered rocky coasts and geological structures for protection from surf, tidal currents and waves;

(ii) Flat, fine-grained sandy beaches and sloping, medium-to-coarse grained-sandy beaches;

(iii) Gravel beaches with extensive biological activity;

(iv) Estuaries, which are often important as spawning and nursery areas for many commercially important species, e.g., oysters, crabs, shrimps;

(v) Mangroves which harbour a large animal community, and supply fish, molluscs, crustaceans with food and shelter;

(vi) Salt marshes, often being nursery grounds for important species, and often both importing and exporting biologically important components;

(vii) Bays and lagoons, found throughout the Region, are of great importance as nursery grounds for shellfish, sport and commercial fisheries, as well as generators of primary and secondary production which can be used for other parts of the system. These beaches and nearshore parts of the overall ecosystem are often particularly sensitive to exploitation and pollution.

7. NON-LIVING RESOURCES OF THE REGION

Countries of the Region have rich and diverse mineral resources. Many of the land-based mineral deposits have already been explored or are at the stage of active exploitation. All the important basic minerals of the Region can be combined into several groups: the iron and ferro-alloys group (mainly manganese), non-ferrous industrial metals such as tin and bauxite, mineral fuels (uranium), and non-metals such as phosphate rock and sulphur. Some countries of the Region have land based mineral deposits which are of great importance on a world scale. For example Guinea has very rich resources of bauxite, Gabon has large deposits of manganese and iron ores, Zaire is the main producer of cobalt, tin and copper, Togo and Senegal have rich deposits of phosphate rocks (Offurum, 1981). Angola, Namibia and Zaire play an important role in the world market as producers of diamonds, gold and uranium (Countries of the World, 1979; Courier, 1978).

The exploration of marine mineral resources has recently been started in the coastal areas of the Region. Now we can speak about rich deposits of oil and gas in the submeridional belt of coastal basins which extend throughout the whole Region (see figure 14), the diamond fields of Zaire, Angola and Namibia, and the phosphorus enriched bottom sediments in offshore areas of the Gulf of Guinea (Ferreira, 1979; Chukumerije, 1981; Ocean Industry 1980).

The industrialized countries of the world, now affected by energy crises, pay their attention primarily to the oil resources of the Region. Six countries of West Africa have already actively started to exploit their oil resources and from 50 to 95 per cent of the crude oil extracted is being exported to Western Europe and Northern America (Ocean Industry, 1980; Hunn et al., 1981).

The oil resources of the Region already explored are estimated at about 2,400 million tonne and more than 80 per cent of them belong to Nigeria. Based on the present rate (1980-1982) of oil production (about 130 million t/y), countries of the Region will be able to exploit their deposits for at least 18 years.

These figures are obviously estimates and will probably be subject to changes as new reserves are found. The rapid development is illustrated by the increase in refining capacity in countries such as Angola, Ghana, Ivory Coast, Nigeria and Senegal from 2,000 barrels per day in 1960 to 276,000 barrels/day, or 13.9 million tonne per year, in 1979. The average offshore production (in 1,000 b/d) was in 1979 in Nigeria about 380 b/d, in Cameroon about 10 b/d, in Angola about 95 b/d and in Gabon about 120 b/d (IMCO/UNEP, 1982, see figures 3-6). In all, eight refineries are situated along the coast from Senegal to Angola.

Data combined in table 8 show that for five countries out of six, the main oil production is connected with deposits in the coastal areas and only Nigeria has extracted more than 75 per cent of total oil from land-based bore- holes.

At present, the average ratio between continental and marine oil production in the Region is approximately 3 to 1. The degree of importance that each country of the Region assigns to its mineral resource development varies as much as the proven stock of mineral resources of the types mentioned above and the availability of the necessary economic and social infrastructure. In this situation there is a group of countries in the Region including all oil-producers, Liberia and Sierra Leone whose economies depend considerably upon national mineral deposits and the activity of mining and processing industries. In other countries such as Cape Verde, Guinea Bissau, Sao Tome and Principe, Benin and Equatorial Guinea there is practically no mining, although some mineral deposits are available there (Africa South of the Sahara, 1980).

Most of the Region is situated in a latitudinal belt where ocean thermal energy extraction is feasible, and for some of the countries in the Region this energy source has a very high potential (UNDIESA/UNEP, 1983). Another potential energy source is oceanic bioconversion for which the entire Region contains suitable sites. Both these energy sources will require some research as to environmental impact and

II. STATE OF THE MARINE ENVIRONMENT

8. SOURCES AND INPUTS OF POLLUTANTS

8.1 Introduction

Various types of substances (often referred to as pollutants) are introduced into the marine environment through human activities. The resulting contamination may give rise to a deleterious effect which then constitutes pollution. It should be recalled that marine pollution is defined as the "introduction by man directly or indirectly of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishery, impairing the quality for use of sea-water and reduction of amenities" (GESAMP, 1977).

Several potential sources of marine contamination are present in the Region or will appear there in the near future. The main ones are:

- Industrial pollution (including the refining of oil)

- Municipal sewage

- Agricultural waste

- Oil pollution (including pollution from mining and transportation).

Surveys of river inputs of water, sediment and quantities of chemical compounds, and of inputs from industrial sources to the Region have recently been completed (UNIDO/UNEP, 1982; UNESCO/UNEP, 1982), as well as a survey of the status of oil pollution (IMCO/UNEP, 1982). Here information relevant to the problem of assessing the state of the marine environment of the Region will be summarized, considering the northern, middle and southern zones separately (see figure 1 for definition of the zones).

Before doing this, however, it is illustrative to summarize the situation in Nigeria, the most important country in the UNEP West and Central African Regional Seas Activity Programme, as it was presented recently by Osibanjo (1983). Nigeria is the leading oil producer of Africa. The population is over 80 million, or about 20 per cent of the continent's total, with about 12 million living at the coast. Lagos, with about 5 million inhabitants, is the capital and main port. The Niger Delta and the Lagos Lagoon support major coastal ecosystems of great importance for the coastal population. Major high-grade crude petroleum production occurs in the Niger Delta basin.

All the major sources of pollution to the coastal zone referred to above are present in Nigeria and produce a very significant load on the nearshore and coastal zones. Diverse industries are developing rapidly and large concentrations of population are evolving with newly built cities and ports. Development and construction of proper waste treatment plants and waste disposal facilities are lagging behind. This has increased the pollution load. The rapid physical development has also brought about increased physical pressure on the coastal zone, including increased erosion.

About 60 per cent of the industry is located in coastal cities. Facilities for water or air pollution control are usually very limited. In Lagos raw industrial effluents are discharged directly into the lagoon and streams. The implications are increases, by factors of 5 to 50, of suspended solids, BOD_5 and COD (in mgO_2 per litre) in the receiving streams compared to a typical unpolluted stream (Ajayi and Osibanjo, 1981).

Domestic, liquid wastes are generally discharged directly into open drains, streams or lagoons. In Lagos large amounts of untreated domestic liquid waste are dumped in the lagoon, which receives more than 60.10^6 litres annually in this way (Ekundayo 1977; Phillips 1982). Domestic solid wastes are likewise often dumped in streams, although open incineration and dumping at landfill sites also commonly occur.

A strong increase in food production has been accompanied by an enhenced use of fertilizers (nitrogen, phosphorus) as well as organochlorine pesticides such as DDT, lindane, dieldrin and herbicides. Due to heavy precipitation in some areas, considerable run-off of fertilizers and pesticides occurs from farmlands into rivers and coastal zones. Concentration levels in freshwater fish of total DDT fall in the range 0.05-2.1 mg/kg wet weight (Osibanjo and Jensen, 1980). This may be compared with levels in the range 1-200 mg/kg wet weight found in Baltic cod (GESAMP, 1982).

The oil revenues are extremely important for Nigeria. At the same time petroleum pollution is the major threat to marine ecosystems there. The major source is spillage during production, with other sources in decreasing order of importance being transportation by tankers, refinery discharges, normal ship traffic discharges and river inputs. A review of oil spill incidents during 1976-1980 suggested that spills occur mainly in swamp zones of the Niger Delta and offshore (Awobajo 1981).

The worst incident as yet has been the offshore blow-out on 17 January 1980 when 421,000 barrels were released. Farming areas and mangroves were afflicted and marine animals were killed. Fisheries were temporarily disrupted. In addition contamination of drinking water and tainting of fish can often be related to oil pollution.

Studies have indicated that most of the rivers and streams in the Niger Delta are contaminated by oil (Imevbore and Adeyemi, 1983), with oil levels in surface waters in the range 10-65 ppm, generally increasing towards the seacoast. This could be compared with the levels of 1.3-13 ppb in the surface layers of the open ocean of the Region found by Brown and Huffman (1976).

Further discussion of the marine pollution load is given by Tutuwan (1981).

Existing data do not permit an evaluation of the environmental consequences of the development described above. However, it should be fairly obvious that proper consideration must be given to prevention of environmental deterioration and protection of human health, marine resources and amenities.

8.2 Industrial contamination

Industrial contamination in the Region is connected with coastal industrial centres, sea ports and traffic. At the same time this type of contamination could be brought into the coastal zone by rivers and temporary streams from more remote land-based sources. The composition and concentration of industrial waste depend on the type of industry and the efficiency of available waste water treatment facilities. Pollution from port activities can be due to losses during loading, releases from ships and accidental losses.

Mining of minerals in the coastal zone can generate wastes harmful to marine ecosystems: coral reefs, mangroves and fisheries resources (UNEP, 1977). The mining process itself may also lead to ecosystem damage.

Additional damage concerns the aesthetic quality of the beaches and reduction of their use for tourism and recreation.

Beach-sand mining for the construction industry does not usually introduce any pollutants to the marine environment, but it can produce severe and irreparable beach erosion and can lead to the death of mangroves, which are abundant in the region (GESAMP, 1980).

It is necessary to emphasize that the experts who evaluated the state of industrial marine pollution in the Region (IMCO/UNEP, 1982; UNIDO/UNEP, 1982) could not use direct measurments of pollutants in coastal waters. They had at their disposal only information concerning types and quantity of industrial and semi-manufactured goods produced by enterprises in the Region. On this basis the experts could only estimate the possible output of pollutants from different industries.

8.2.1 Northern zone

Countries included in this zone could be conditionally divided into two groups. One of them combines Cape Verde, the Gambia and Guinea-Bissau, which are at present not industrially developed. They are mainly agricultural countries and owing to favourable natural conditions they have an opportunity to use marine fisheries resources. These countries also have various and fairly rich mineral deposits but their research and mining are only at the initial stage. Accordingly they have no large sea ports and industrial centres. This situation explains the relatively small quantity of industrial contamination in their coastal areas at present. Possibly these countries will face such problems in the future, when they start mining and mineral processing activities, especially in the shelf zone.

The other group of countries in the zone like Mauritania, Senegal, Ghana, Liberia and Sierra Leone are relatively developed. Some of them have well-explored and actively exploited deposits of Fe and Cu ores, oil and gas. In the coastal areas they have large sea ports and industrial centres like Dakar, Conakry, Freetown and Monrovia. All of them have sources of industrial contamination because of wastes from the mineral processing, metallurgical, textile and food production and other industries. Transportation and loading of raw materials and semi-manufactured goods are also sources of contamination, as is the process of oil refining, which is carried out in at least three of these countries.

Data, summarized in table 9 (UNIDO/UNEP, 1982), show that the most of the contaminants discharged into this zone result from the activities of two industries: edible oils and leather. They together cause about 70 per cent of all industrial contamination, including 71 per cent of total BOD_5, 65 per cent SS, 71 per cent COD and 82 per cent of oil and grease. The main centres of edible oils and leather production are located in Dakar (Senegal), Ile de Kassia (Guinea) and Freetown (Sierra Leone).

Considerable amounts of solid suspended pollutants (up to 30 per cent), BOD_5 (22 per cent) and COD (about 15 per cent) are present in wastes of enterprises producing various drinks and food products (beer, soft drinks, sugar, dairy products, meat). The textile industry is one of the sources of COD (up to 8-9 per cent) and phenols (more than 50 per cent) in this zone.

Petroleum refining and handling enterprises also produce different contaminants including 5 per cent BOD_5, 2.5 per cent solid waste, 5 per cent oil and grease, and 5.5 per cent COD. Besides this industry is responsible for 100 per cent of ammonia nitrogen and 45 per cent of phenols in the total sum of pollutants in this coastal area. All the petroleum refining centres are associated with sea ports. The total

Table 9: Estimated mass of pollutants discharged to the Northern zone of the Region by Industrial sectors (in tonne/year)

Type of industry	Type of pollutants										
	BOD_5*	SS*	Oil+* Grease	COD*	Ammonia Nitrogen	Phenols	Total Chrome	Fluoride	Cyanide	Total Phosphorus	Total
Petroleum refining and handling	714.4	454.1	272.0	1,993.1	148.5	3.4	9.1	-	-	-	3,594.6
Edible oils	5500.0	4807.4	3452.9	13761.9	-	-	-	-	-	-	27 522.2
Beer	2,122.7	896.2	-	2,335.2	-	-	-	-	-	-	5,444.1
Soft drinks	346.6	476.5	-	867.7	-	-	-	-	-	-	1,690.8
Soap and detergents	147.8	252.0	17.8	370.4	-	-	-	-	-	-	788.0
Fish and shrimps	-	2,829.2	682.3	-	-	-	-	-	-	-	3,511.5
Sugar	848.6	976.6	-	2,117.2	-	-	-	-	-	-	3,942.4
Textile	240.2	613.9	-	2,984.7	-	4.1	4.1	-	-	-	3,847.0
Paint	0.8	1.3	-	2.1	-	-	-	-	-	-	4.2
Rice	2.8	1.6	-	7.0	-	-	-	-	-	-	11.4
Dairy products	20.0	30.0	-	51.2	-	-	-	-	-	-	101.2
Fruits and vegetables	34.9	43.0	-	87.0	-	-	-	-	-	-	164.9
Meat	0.6	1.0	0.3	1.5	-	-	-	-	-	-	3.4
Leather	5334.0	6660.0	1000.0	13000.0	-	-	134.0	-	-	-	26,128.0
Fertilizer	-	381.6	-	-	-	-	-	38.2	-	114.6	534.4
Asphalt	0.7	0.6	0.2	4.1	0.4	0.1	0.1	-	-	-	6.2
Metal working and coating	0.3	1.7	0.1	0.8	0.1	0.1	-	0.7	-	-	3.8
Alcohol and blending of spirits	0.4	-	-	1.0	-	-	-	-	-	-	1.4
Explosives	1.0	20.5	-	2.7	-	0.2	0.2	-	-	-	24.6
Flour	3.7	3.3	-	9.3	-	-	-	-	-	-	16.3
Total	15319.5	18540.5	5425.5	37596.9	149.0	7.7	147.4	38.9	-	114.6	77 340.0

* The explanation of specific parameters used in the text and tables (BOD_5, SS, Oil and Grease, COD) are given in the appendix.

discharge by industrial sectors into this zone is evaluated at approximately 20 per cent of the total industrial input to the Region (table 10).

8.2.2 Middle zone

The industrial development of countries in this zone is much higher than in the other regions. The main reason for this is associated with the presence of rich oil and gas deposits in the Gulf of Guinea. At least five countries (Ghana, Togo, Cameroon, Nigeria and Gabon) out of the eight are oil-producing and each of them has a highly developed oil-processing industry. Wastes from petroleum refining enterprises and oil leakages from storage and pipelines produce considerable inputs to the coastal areas, especially near sea ports.

The total contribution of this industry to industrial discharge in this zone reaches 25 per cent and it accounts about 97 per cent of the total oil and grease and 87 per cent of ammonia nitrogen (table 11).

Many countries here also have rich mineral deposits, including manganese, phosphates, bauxites and cement raw materials. Mineral mining processes and the preliminary processing and transportation of products give rise to different types of contaminants.

Large quantities of suspended solids (up to 38 per cent) are carried out to the coastal areas with wastes released from phosphate mining and processing enterprises.

Sewage from this industry also contains fluoride (about 60 per cent of the total fluoride amount in the industrial discharge of this zone) and total phosphorous (practically 100 per cent).

The cement industry in Gabon and Togo produces a considerable amount of particle rich waste water and atmospheric pollutants. The process of smelting aluminium from bauxite in Ghana and Cameroon is accompanied by industrial wastes with high concentrations of solid particles and fluoride.

An important source of pollutants in this zone (about 40 per cent) is made up of waste from the textile industry, whose basic enterprises are located in Ghana (Tema), Benin (Cotonou) and some of the towns and villages on the Nigerian coast. This industry produces about 65 per cent of COD in this zone, about 30 per cent of SS, considerable amounts of BOD_5, Phenols and Chrome.

Significant volumes of industrial waste waters are produced in the zone by the processing of agricultural and food products (up to 10 per cent), and primarily by industries producing edible oils and brewage.

The wood processing industry, developed in practically all countries of the Region, also produces wastes including substances such as small pieces of wood, shavings, glues and varnishes , which can be harmful to the coastal environment. These liquid and solid wastes decay in offshore lagoons and can have deleterious effects on marine organisms, especially fish and shrimps.

There is little doubt that all the main sources of industrial discharges in the zone are concentrated in the big cities and sea ports, such as Abidjan, Accra, Lagos and Libreville. Some enterprises are located near coastal lagoons and they usually discharge waste into them. In these cases a considerable number of living marine organisms may be killed and these lagoons may become a source of coastal pollution and infection.

Table 10: Estimated mass of pollutants discharged to the Region by industrial sectors (in tonne/year) (UNIDO/UNEP, 1982)

Zones	Type of pollutants											
	BOD_5	SS	Oil+ Grease	COD	Ammonia Nitrogen	Phenols	Total Chrome	Fluoride	Cyanide	Total Phosphorus	Total	%
Northern	15,319.5	18,540.5	5,425.5	37,596.9	149.0	7.7	147.4	38.9	-	114.6	77,340.0	19.6
Middle	29,960.9	61,242.4	61,690.1	138,217.5	456.8	339.8	244.4	3,915.7	9.0	7,065.3	303,141.9	76.8
Southern	2,006.7	1,400.1	5,072.7	5,470.9	63.5	6.5	7.4	-	0.5	-	14,048.4	3.6
Total	47,267.0	81,142.8	72,168.2	178,993.8	669.3	354.0	399.2	3,954.6	9.5	7,179.9	394,550.3	100%

The total amount of pollutants discharged to the coastal area of the zone is much greater than in the other two zones. The total weight of suspended solids in industrial wastes released into the Gulf of Guinea is three times more than in the Northern zone, and similar ratios hold for other contaminations.

The total mass of industrial discharges produced in all the countries of the zone is estimated at more than 75 per cent of industrial discharge of the Region (see table 10).

8.2.3 Southern zone

The countries of this zone are not at a high economic level at present, but they possess rich deposits of important minerals. The main perspectives are associated with large oil deposits in the coastal area. Although the exploitation and processing of oil and gas resources are only at the preliminary stage in the zone, there are already three quite large centres for petroleum refining in Luanda and Cabinda (Angola) and Pointe Noire (Congo). These industries produce the largest quantity of discharges in the zone (about 50 per cent) including 98 per cent of the total oil and grease and 21 per cent COD for the whole zone (table 12).

Some countries of the zone, and first of all Congo and Angola, are fairly important exporters of printed textiles for the internal African market. Large textile enterprises in Brazzaville (Congo) and Huambo (Angola) produce different types of contaminants, including textile dyes.

Textile enterprises are considerable contributors to pollution in the zone (16,6 per cent) including 33 per cent COD and 27.2 per cent SS. At the same time this industry, together with petroleum refining, discharges more than 65 per cent of phenols and 100 per cent of total chrome.

The processing of agricultural raw materials and the manufacture of food products, both for domestic consumption and for export, are also quite important sources of contaminants in the region.

Fishery and fish processing are well developed in the countries of the zone. The shelf area usually associated with productive fisheries is very narrow near Angola and Namibia, but the nutrient-rich waters of the Benguela current can support an annual catch of approximately $1,500.10^3$ tonnes (FAO, 1980). Large fish processing and freezing enterprises are located in Moçamedes and Benguela (Angola) and Walvis Bay (Namibia).

Some quantities of pollutants (about 5-6 per cent) are associated with the edible oils industry. It is estimated that the waste from edible oil enterprises contains considerable amounts of BOD_5 (more than 8 per cent), SS (10.6 per cent) and COD (7.5 per cent). Large amounts of BOD_5 (45.3 per cent) and SS (about 31 per cent) are contained in the sewage of breweries.

Wastes discharged after manufacturing plywood, veneers, lumber, paper, etc. contain high concentrations of different chemicals and suspended wood remains. One of the basic wood processing centres is located in Pointe Noire (Congo).

A considerable amount of contamination may possibly appear in the zone due to mining and processing of solid minerals. For example, rich ore deposits of Pb, Zn, Sn and Cu have recently been discovered in the Congo. Zaire at present produces the world's largest quantity of cobalt (about 43 per cent) and it is also one of the biggest producers of copper and tin.

Table 12: Estimated mass of pollutants discharged to the Southern zone of the Region by Ihdustrial sectors (in tonne/year) (UNIDO/UNEP, 1982)

Type of industry	Type of pollutants										
	BOD_5	SS	Oil+ Grease	COD	Ammonia Nitrogen	Phenols	Total Chrome	Fluoride	Cyanide	Total Phosphorus	Total
Petroleum refining and handling	342.1	238.0	4948.6	1165.3	61.1	1.8	4.8	-	-	-	6761.7
Edible oils	164.1	143.5	103.0	410.6	-	-	-	-	-	-	821.2
Beer	900.7	417.7	-	989.0	-	-	-	-	-	-	2307.4
Soft drinks	56.7	77.9	-	141.8	-	-	-	-	-	-	276.4
Soap and detergents	5.9	10.1	0.7	14.7	-	-	-	-	-	-	31.4
Fish and shrimps			no data								
Sugar	77.4	16.2	-	193.4	-	-	-	-	-	-	287.0
Textiles	144.7	369.8	-	1797.8	-	2.6	2.6	-	-	-	2317.5
Explosives			no data								
Paint	20.1	20.1	-	20.1	-	-	-	-	-	-	60.3
Flour	96.6	85.7	-	242.1	-	-	-	-	-	-	424.4
Dairy products			no data								

Table 12 (continued)

Type of industry	BOD_5	SS	Oil+ Grease	COD	Ammonia Nitrogen	Phenols	Total Chrome	Fluoride	Cyanide	Total Phosphorus	Total
Wood products, plywood, veneers, lumber	198.4	-	-	496.1	-	2.1	-	-	-	-	696.6
Pulp and paper			no data								
Cement			no data								
Tubes and tyres	-	20.1	20.1	-	-	-	-	-	-	-	40.2
Steel	-	1.0	0.3	-	2.4	20.1	-	-	0.5	-	24.3
Total	2006.7	1400.1	5072.7	5470.9	63.5	26.6	7.4	-	0.5	-	14048.4

The estimated discharge of industrial pollutants in the coastal waters of the zone is the lowest for the Region. For example, the total mass of BOD_5 in this zone is 1,990 tonnes/year, or 15 times less than the same for the Middle zone and eight times less than for the Northern zone.

The total discharge by all the industrial centres of the zone has been estimated at about 4 per cent of total industrial discharge in the Region (see table 10).

8.2.4 Discussion

The main producer of industrial pollutants (by weight) in the region is the textile industry whose sewage contains more than 30 per cent of all polluting substances, including 16 per cent BOD_5, 24 per cent SS and 52 per cent COD. It is also responsible for discharges of such pollutants as phenols (37 per cent) and total chrome (33 per cent). Contamination of the coastal areas by oily water discharges is inevitable and in the areas where they flow directly into the lagoons, the problem is particularly serious. Petroleum refining and handling industries produce about 20 per cent of all the pollution in the Region. Among them are 90 per cent of total oil and grease and 90 per cent of ammonia nitrogen. Considerable amounts of pollutants (about 25 per cent) are connected with the output of food products, including beer, soft drinks and spirits. Enterprises in these industries annually release into the coastal area 51 per cent BOD_5, 26 per cent SS, 27 per cent COD and 8.5 per cent oil and grease.

Mineral exploitation in the region and, first of all, mining and processing of phosphate minerals into fertilizers, produce considerable discharges, the amount of which is estimated as 8,5 per cent. The main hazard of this process is the discharge into coastal waters of huge quantities of suspended solids (about 30 per cent of the total amount), which have physical and chemical influences on the coastal environment. Large amounts of fluoride (about 60 per cent) and total phosphorus (almost 100 per cent) are also connected with the production of fertilizers.

These pollutants form about 95 per cent of the total release to the Region. Other types are discharged into coastal areas in relatively small concentrations and, in general, they cannot exert a decisive influence on the state of the environment in the Region, although in some cases such pollutants, e.g. cyanides, are also very dangerous.

The main industries responsible for selected types of pollutants in the Region are shown in table 13 (UNIDO/UNEP, 1982).

The total amount of contaminants discharged to the coastal areas of the Region from industrial sources has been estimated. Lack of data on concentration levels in the marine environment there makes it impossible to relate the input to levels in the environment. From the present information on total inputs as compared with inputs in areas in Europe, the United States and Japan it might be judged that the industrial contamination of the marine environment of the Region at present does not give reason for concern (Goldberg, 1976; Bunich, 1977). However, a baseline study of the coastal zones of the Region would give a much firmer basis for an evaluation. The continued development of industry in the Region emphasizes the need for this (see figure 15).

8.3 Municipal sewage input

8.3.1 General considerations

The municipal or domestic sewage input is the most common source of contaminants in the coastal zone. Municipal, sewage as understood here contains domestic wastes: organic matter, nutrients, micro-organisms (bacteria, viruses) and parasitic worms. Oil and metals may also be present. It should be noted that often municipal drainage systems may be mixed with industrial wastes, adding chemicals to the sewage. Wastes from municipal services are usually included, e.g. from hospitals.

The amount of liquid sewage usually depends upon the water usage per capita which is 400 to 800 litres per day per person in developed countries. The solid waste is estimated at 1.5-2.5 kg. It is not known how large the usage per capita is in the Region: about 50 per cent of the consumption in highly developed countries might be used for an estimate.

Marine pollution caused by municipal sewage mainly from urban areas is generally known to be a problem in the whole Region and is associated with all major cities within the coastal area. The absence of proper sewage systems and the lack of any other treatment facilities lead to acute problems in a few countries of the Region.

Practically everywhere waste treatment plants are only in the planning stage and with a few exceptions all wastes are directly dumped into the sea or on to the beaches.

Almost all the non-water content, apart from the inert solids related to the washing of clothes and food, are degradable and have a rapid and high oxygen demand. Thus, if discharged into relatively stagnant water with poor water exchange, the process of deoxygenation of the receiving water may occur, especially in coastal lagoons. If the sewage solids settle in quantity on the sea or lagoon bottom they may accumulate there faster than the degradation process can decompose them. The sediments in this case become anaerobic and this leads to a foul smell as the gases given off come to the surface. And this is only one important problem among many environmental problems connected with municipal sewage.

Countries of the Region are relatively heavily populated. The total population is about 175 million, and 8-10 per cent, or about 17 million people live in the towns and villages of the coastal zone generating a direct input of domestic sewage to the coastal zone.

The port capitals are located in the areas where major industrial and other socio-economic activities are concentrated. The tourist industry is growing rapidly and may at times significantly increase the effective population of certain coastal areas. It is thus expected that the coastal areas around these population centres and areas of human activity will be the foci of concern as regards coastal pollution.

Basic available information concerning sewage produced by the population of the Region is combined in table 14. All the data for this table were collected and processed by the same UNIDO experts who had prepared the materials on industrial pollution described in the previous chapter (UNIDO/UNEP, 1982).

Table 14 shows a comparison of the amount of BOD_5 and SS potentially discharged to the ocean by the population of the major coastal cities and industrial sectors. The BOD_5 estimate was based upon a per capita discharge of 64 grammes per day and 91

Table 14: Estimated amounts of municipal sewage in comparison with industrial pollution in the Region

ZONES	Estimated population*** 1000*	Municipal sewage BOD_5 tonne/year	%*	SS tonne/year	%*	Industrial pollution BOD_5 tonne/year	%**	SS tonne/year	%**
Northern	17,350	62,535	21.6	88,930	21.6	15,320	24.5	18,542	20.8
Middle	117,960	205,612	71.1	292,401	71.1	29,962	14.6	61,243	20.9
Southern	36,800	20,814	7.3	29,598	7.3	1,986	9.5	1,360	4.6
Total	172,110	288,961	100.0	410,929	100.0	47,269	16.3 (average)	81,145	19.7 (average)

* Percentage of the total amc.nt of municipal sewage in the Region

** Percentage of industrial pollution of the amount of municipal sewage in certain zones

*** Estimated population of the Region, but without Mauritania, Cape Verde and Namibia (Africa South of the Sahara, grammes per capita per day was used to estimate the SS discharged by the population of the Region.

It should be stressed that practically everywhere in the Region the amount of municipal sewage is much larger than the industrial waste discharge.

8.3.2 Northern zone

The total population in this zone is evaluated at about 17.5 million or about 10 per cent of the population in the Region. The estimated mass of municipal pollutants (for BOD_5 and SS together) is 21.6 per cent of the total. The main producers of this sewage are the large metropolian cities and sea ports such as Dakar, Conakry, Freetown and Monrovia. They are responsible for about 72 per cent BOD_5 and 72.5 per cent SS discharged to the coastal area of the zone.

The distribution of municipal sewage between the countries is also irregular. For example Senegal, being one of the most developed countries in the the zone, has the biggest coastal population (about 8 per cent of the total population of this zone), which produces 45 per cent BOD_5 and SS of the whole municipal sewage of the zone. For comparison, Sierra Leone has about 2 per cent of the population in the coastal area which produces about 12 per cent BOD_5 and SS.

8.3.3 Middle zone

The middle zone is the most industrialized. About 70 per cent of the population of the Region lives there, a considerable amount of it (about 14.0 million or 12 per cent) in the coastal area. For this reason the total amount of domestic sewage there achieves 71 per cent of the total amount for the Region.

Although industry in the zone produces considerable amounts of waste, the domestic sewage production is usually larger, except in a few countries, like Togo. There the industrial waste contains about 24.10^3 tonne of suspended solids, about a factor of three more than the municipal waste.

8.3.4 Southern zone

The total population of this zone is about 37 million, or 20 per cent of the population in the Region. However, the population on the coast is very limited, the major cities not exceeding 100-200 thousand inhabitants. The largest industrial centre at Luanda has 600 thousand inhabitants (Africa South of the Sahara, 1980). This means that the municipal sewage released to the coastal area in this zone is relatively small, about 7 per cent of the total domestic sewage of the Region. The industrial discharge is also small in this zone (see table 12).

However, the countries of this zone have rather good prospects for industrial development of their coastal areas. This will undoubtedly lead to a considerable influx of manpower into growing cities and also increase the amount of municipal and industrial discharges.

8.4 Agricultural waste

This type of marine contamination in the Region is mainly composed of fertilizers and pesticides. Most of the African countries are already self-sufficient in terms of agricultural production and in many cases they depend heavily on the export of such products as coffee, cocoa, palm oil, sugar and cotton. Worldwide demand for these goods is growing annually and the use of fertilizers is one of the efficient means to increase the harvest and improve the quality of agricultural goods.

The inorganic fertilizers used in the Region are mainly nitrogen and phosphorus-based compounds. It is probably safe to say that agricultural development is being pursued in all the countries and in order to increase yields fertilizers are being used on a very wide scale. For this reason some countries of the Region have already built or are going to build in the near future fertilizer-producing enterprises with production based on local raw materials.

Such enterprises have been built in Senegal with a production rate of more than 110,000 tonnes/year and Ivory Coast (more than 85,000 tonnes/year). Semi-manufactured goods for agricultural fertilizers are being produced in Togo (about 7 million tonnes/year) (Middlebrooks et al., 1980a). The operation of a large fertilizer plant is planned in Cameroon. The Congo, one of the basic African suppliers of potash, produces about 300,000 tonnes/year of potassium fertilizers. Practically all the fertilizers produced in these countries are being used within the West and Central African Region and almost every country in the Region imports various chemical fertilizers from the industrialized states of Europe and North America (World in figures, 1978). Nevertheless the total volume of agricultural fertilizers annually used in the Region does not yet give rise to great concern from the environmental point of view. Except in estuaries and areas with limited water exchange, it is unlikely that the use of fertilizers on land and their subsequent run-off into the sea are going to cause harmful eutrophication. It is certainly unlikely that it will be sufficient to start the process of eutrophication in the coastal area on a large scale.

The rate of use of pesticides in the world has grown since World War II. During this period they have played an important role in the control of different agricultural pests, including insects, nematodes, vertebrates, weeds, fungi and others. Various artificial and natural poisonous substances are widely used against agricultural vermin and help to protect the harvest. This is extremely important for African countries because of the leading role of agriculture in their economy.

One of the most important applications of pesticides is connected with the control of different arthropods of great medical importance, as they are the indirect cause of such diseases as malaria, filariasis, yellow fever and bilharziasis. The people of the Region often suffer from various infectious diseases and from this point of view the use of pesticides is extremely important (Atayi, 1978; Meith-Avcin and Helmer, 1978).

It is known that pesticides are being utilized in almost all the countries of the Region. In 1972 only, nearly 10,000 tonnes of pesticides were used in agriculture in six countries of the Gulf of Guinea and in 1974 only two of these countries used over 8,000 tonnes (Cvjetanovic, 1977). The production of pesticides is mainly developed in such countries as Senegal (1,690 tonnes/year in powder and 800,000 spray cans/year) and Ivory Coast (2,300 tonnes/year) (Middlebrooks et al., 1980b). Considerable amounts of pesticides are imported by African countries from Europe and the United States. According to statistics all the developing countries of the world including those of the Region consume annually 8-10 per cent of all pesticides produced in the world (Odhiambo, 1979).

Pesticides, together with fertilizers being used for agricultural needs in the internal continental areas of the Region, can partly enter rivers or temporary streams and by these means be carried out to the coastal areas.

Practically all the fish, crabs and shrimp in the coastal areas are exposed to pesticides which penetrate into organisms along with water and food and are accumulated there. The danger for human beings posed by the consumption of persistent chemical poisons with food is now well known (Goldberg, 1976).

Together with other suspended and dissolved chemical substances pesticides can participate in the processes of coastal sedimentation, and in the case of a large influx of pesticides into sea-water this might create zones of high concentration levels for long periods.

8.5 Petroleum hydrocarbons

8.5.1 General aspects

Petroleum is a complex mixture of compounds with different physical and chemical properties. No single method exists for the analysis of total oil which would be acceptable in all situations, and great care must be taken in sampling. Hydrocarbons are synthesized by living organisms and the biotic production components are very different from those of petroleum that cause concern: light or polycyclic aromatic hydrocarbons, light alicyclics, heterocyclic nuclei and their alkyl derivatives which are not known to be produced through recent biosynthesis (GESAMP, 1982). Biotic production of alkanes greatly exceeds the petroleum discharge into the sea.

Contamination by crude and refined oil arises from tanker accidents, deballasting operations and tank washing, refinery discharges, municipal and industrial wastes, losses from pipelines and offshore production. Oil also enters the sea from natural seepages. The best recent estimate of the total input of petroleum to the marine environment is about six million tonnes.

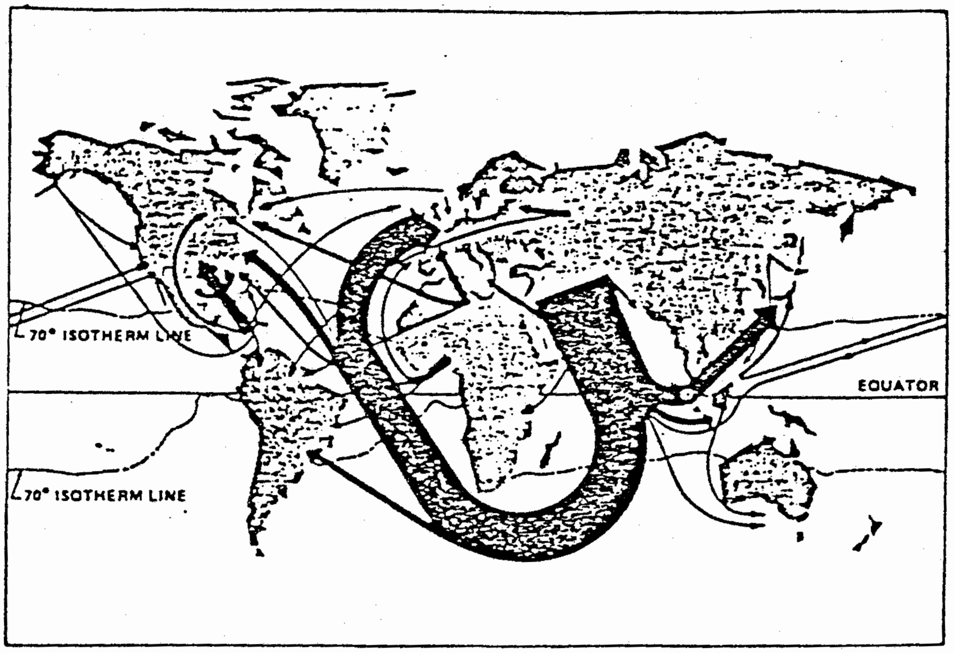
Oil entering the sea through spills will be subject to many physical, chemical and biological processes. The first few days after a spill, spreading and evaporation together with photochemical and other oxidative processes are important. After this, degradation by micro-organisms becomes significant, in particular for the paraffinic and olefinic fractions. Oil components like PNAHs become oxidized to a form which cannot be further broken down by bacteria. Bacteria can destroy up to 50 per cent of such stable components as benzo (a) pyrene (Izrael and Tsyban, 1981). Degradation by micro-organisms requires an adequate oxygen and nutrient supply.

Particulate oil residues are distributed throughout the oceans; a recent estimate yields 15,000 to 20,000 tonnes on the surface of the North Atlantic (GESAMP, 1982). These residues are formed following an oil discharge from tanker washings, or are formed over longer periods in the sea from weathering of spilled crude or heavy oil products. The level of contamination is closely connected with tanker and other shipping lines, which is also quite marked outside Africa, both East and West (figure 16). Considerable fouling of sandy beaches in the Region by pelagic tar has also been reported. Okera (1974) observed large quantities of soft, brownish-black lumps up to 7-8 cm in diameter washed ashore on Sierra Leone beaches. The maximum occurred from June to August, probably as a result of the south-west monsoon and the strengthening of the Guinea Current.

It had earlier been concluded by IOC/FAO/WHO/UNEP (1978) that "pollution by petroleum hydrocarbons is increasing in the coastal waters and on the beaches along the whole coast of the Gulf of Guinea and adjacent areas. The origin of this pollution is primarily the heavy maritime transport of crude oil, and to a lesser extent the local exploration, exploitation and refinement of petroleum." However, there is certainly likelihood of an increase in local discharges through offshore exploitation and refinement.

Contamination of the coastal environment in the Region by petroleum hydrocarbons seems to be one of the most important pollution problems currently. Oil stranded on

(a) Main oil movements by sea (British Petroleum, 1978)



(b) Location at which visible oil slicks were presented at the time of observation (IOC, 1982)

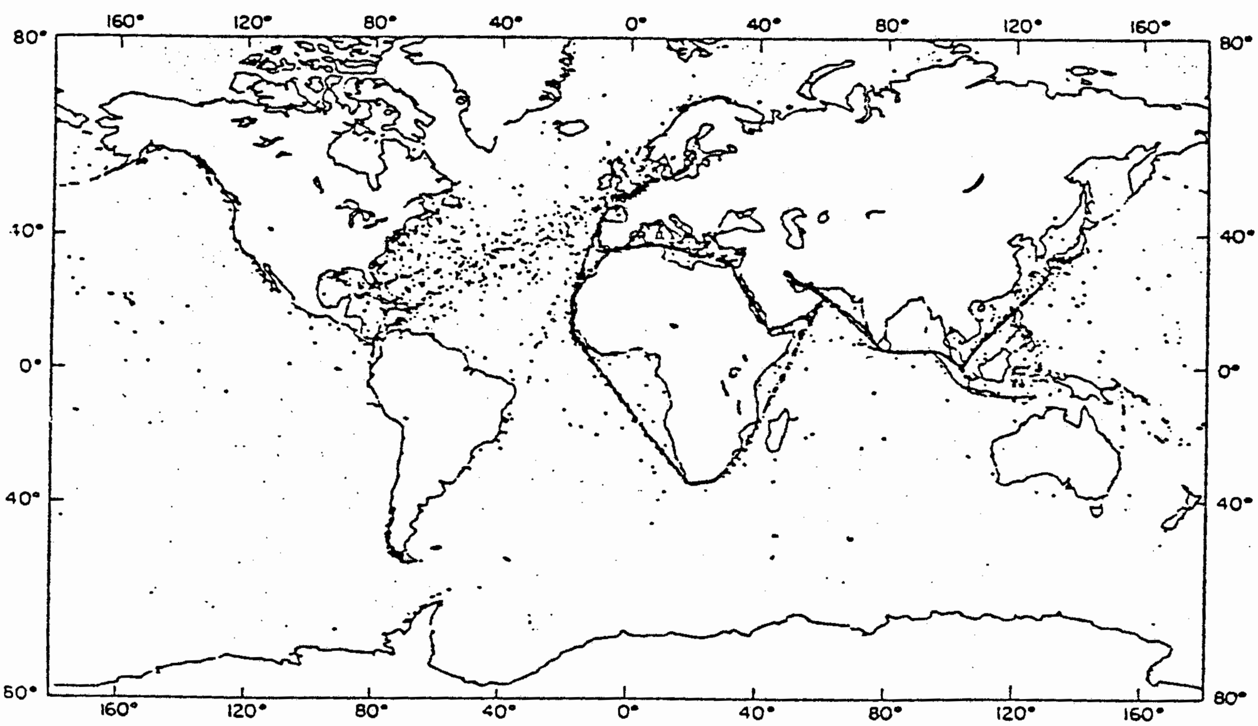


Figure 16: Oil contaminations connected with tankers and other shipping lines

the beaches is unsightly and gets on people's skin and clothes if they walk, sit or swim in the areas contaminated by oil. Sea birds, especially divers, are liable to become covered by oil and in their attempts to cleanse themselves might ingest the oil. In the most serious cases their feathers are so matted with oil that they become hardly recognizable and perish.

Only one tonne of crude oil covers about 12.10^3 hectares of sea surface with a thin layer impenetrable to any gas. During this process all the light fractions of oil are evaporated, but heavy fractions containing sulphur, metals and paraffin are gradually accumulated.

There is no doubt that petroleum contains many compounds harmful to marine organisms, especially at the most sensitive stages of life such as eggs and larvae. In the case of a large spillage in a fish spawning or nursery (larval) area it is certainly conceivable that a proportion of eggs or larvae might be affected, even in relation to the scale of natural mortality. However, it is unlikely that detectable effects would be caused on a year class and hence the overall stock of particular species.

There are several major potential sources of oil contamination in the coastal area of the Region.

8.5.2 Oil pollution from production and refining

The total world flux of oil to the coastal waters from underwater drilling and production operations is estimated to be 0.08 million tonnes per year. About three-quarters, or 0.06 million tonnes per year is lost from major accidents and spills (i.e. spills above eight tonnes each), usually of an unpredictable nature. Normal operations have been assumed to account for 0.02 megatonne per year through individual discharges of eight tonnes or less (Goldberg, 1976).

A number of sources can give rise to oil pollution from production: dramatic but short-lived spillages (platform fires, blow-outs, pipeline accidents); chronic causes in the form of drilling muds, deck drainage from platforms, and oil in produced formation water discharged into the sea. In 1979 ten oil spills occurred that were due to production - and refining - related causes, indicating the potential of this pollution source (IMCO/UNEP, 1982).

Drilling activity in the Region is now of wide coverage, using high technology and modern equipment. Up to 1981 three oil rig blow-outs had occurred in the Region (Times Atlas, 1983).

The potential for further development and further oil and gas discoveries in the Region is large. Most of these areas are located in the offshore zone. Areas of relatively high risk associated with pollution related to exploitation of such resources are shown in figure 14.

8.5.3 Oil pollution from shipping

There is very heavy tanker traffic through the Region transporting crude oil to Europe, the United States and South America; about 420 million tonnes of crude oil went to Western Europe by this route in 1976. Oil is also imported into the Region for refining, and the refined products produced domestically are exported. About 111 million tonnes left the area in 1976 (IMCO/UNEP, 1982). It is clear that this very considerable activity yields a potential for oil pollution. Portmann (1978) found that nearly three quarters of the nations have "common" to "serious" levels of oil pollution on their beaches. Much of this is undoubtedly due to the offshore tanker traffic, since prevailing currents and winds in large areas of the Region will transfer oil residues on the surface towards the beaches. The worst problems occur, according to Portmann (1978), in and around ports, especially those handling oil exports and imports.

It is very difficult to predict shipping-related spills, but empirical relations have been worked out relating the number of spills to the total production volume per year. Using such a format for the Region would indicate a total oil input of about 34 million tonnes per year in the form of larger spills of over 1,000 barrels. One major spill occurred in 1979 (IMCO/UNEP, 1982). A larger number of smaller spills would also be expected, about 500 per year based on extrapolation of experience from the United States (IMCO/UNEP, 1982); this may, however, be misleading as tanker accidents in the Region have occurred only about 10 times in the period 1975-80. Up to 1981 three major tanker accidents (50,000-236,000 tonnes) had occurred in the Region (Times Atlas, 1983).

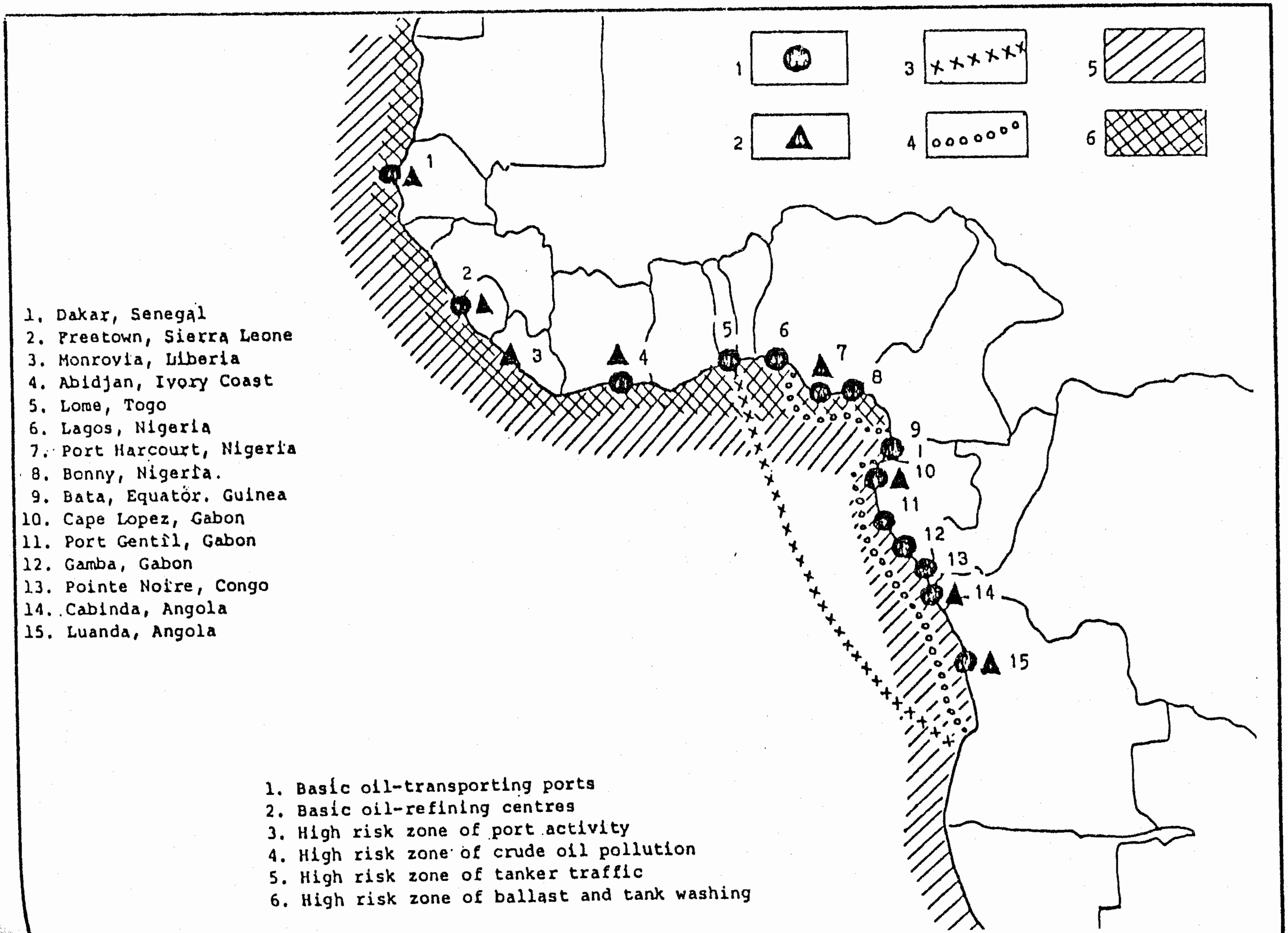
More than 70 per cent of all the oil discharged or spilled from tankers is due to routine operations, particularly bilge washings. An increasing number of tankers have separate ballast systems, thanks to the wide adoption of international codes and conventions, but many tankers still load the empty oil tanks with sea-water for the return leg of a trip. Oily ballast water is then discharged on arrival. It has been estimated that the discharge of such untreated ballast might be as high as 0.5 per cent of the total oil shipment (Goldberg, 1976). Statistics of the discharges of oily water after washing the bilges and tanks show that a zone of high risk from this type of oil pollution is located near the northern part of the Gulf of Guinea and continues north to Mauritania (see figure 17). Zones of possible dangerous impact of this pollution on coastal areas are located from Nigeria to Liberia.

To reduce pollution from this source a number of different systems have been worked out recently. Most of the tankers turning round the Cape of Good Hope are VLCC (very large crude carriers), more than half of which are now equipped with specialized washing facilities (LOT) which eliminate the need for water washing (Portmann, 1978).

8.5.4 Other sources of oil pollution

One of the possible sources of oil pollution in the Region is connected with various pipelines often used for direct transportation of oil. Usually they are made of steel, although materials like aluminium are also being used. To prepare steel pipelines for underwater exploitation they are treated with substances highly resistant to corrosion (for example by coating them with epoxy resin and cold applied enamel). However, abrasion takes place that leads to steel corrosion and sometimes the destruction of tubes and, due to this, dangerous accidents occur. Considerable amount of oil pollution is also associated with various kinds of port activities. Spillage rates at terminal operations in well controlled ports are in the order of $(1.1\text{-}2.2).10^{-6}$ times the amount pumped from tanker to oil store-houses and back. The range of losses at terminals is between 0.0015 to 0.005 million tonne per year. The rate of loss due to bilges and bunkering is estimated to be 0,5 million tonnes per year, which is equivalent to about 10 tonnes per ship per year (Goldberg, 1976).

All the main ports of the Region participating in the handling of crude oil and oil products are shown in figure 17 and so are the basic "high risk zones" connected with these operations.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1. Dakar, Senegal
2. Freetown, Sierra Leone
3. Monrovia, Liberia
4. Abidjan, Ivory Coast
5. Lome, Togo
6. Lagos, Nigeria
7. Port Harcourt, Nigeria
8. Bonny, Nigeria.
9. Bata, Equator. Guinea
10. Cape Lopez, Gabon
11. Port Gentil, Gabon
12. Gamba, Gabon
13. Pointe Noire, Congo
14. Cabinda, Angola
15. Luanda, Angola
1. Basic oil-transporting ports
2. Basic oil-refining centres
3. High risk zone of port activity
4. High risk zone of crude oil pollution
5. High risk zone of tanker traffic
6. High risk zone of ballast and tank washing

The world atmospheric flux of petroleum is estimated to be about 70 million tonnes per year and a certain proportion of this amount enters the ocean surface with rain, fall-outs or air-sea interaction. According to some estimates the average value of atmospheric oil-pollution is about 0.6 million tonnes per year for the world ocean. (Goldberg, 1976).

The total discharge from all these sources has been estimated at more than 6 million tonnes of crude oil and oil products to the ocean environment in a year (Goldberg, 1976). Some other evaluations even exceed 10-12 million tonnes (Bunich, 1977). In this review we have no opportunity to estimate the amount of oil pollution in the coastal area of the whole Region because of the lack of necessary information. In some oil-producing countries such as Nigeria, Gabon and Angola a rather serious level of oil pollution is indicated at present. Taking into consideration the active development of oil production in most of the countries, especially in their shelf areas, the Region is potentially facing very serious oil pollution problems if efficient preventive measures are not instigated.

8.6 Overall evaluation

The estimates of waste inputs given above are mainly based on projections of waste water amounts utilizing production, employee or water consumption data (UNIDO/UNEP, 1982). This is an accepted method, but it is very desirable that direct information is gathered in future on quantities of waste water discharges and their content of contaminants and other characteristics. This would probably yield a safer basis for an environmental assessment.

The UNIDO/UNEP study (UNIDO/UNEP, 1982) concludes that immediate planning and implementation of pollution control programmes are needed in the zone of greatest industrialization, including Nigeria, Cameroon, Equatorial Guinea, Sao Tome and Principe and Gabon, and that the largest potential for a serious problem to develop on a large scale is at hand in that zone. The same study concluded that, in general, the industrial development was relatively limited and that the discharges from industries were currently creating little impact on the environment except in isolated cases. However, that situation is likely to change because of the concerted efforts being made towards expanding industry in the Region.

Substantial quantities of oil, brewery, tannery, non-carbonated beverages, textile and food processing wastes are discharged in some areas of the Region. Receiving waters have been polluted, and it is conceivable that harmful effects may result. The oil pollution is noticeable through the accumulation of oil residues on the beaches, and coating of boats with oil.

The status of oil pollution problems is presented in fair detail on a country by country basis in the IMCO/UNEP report (IMCO/UNEP, 1982).

Sewage disposal is a major problem in the Region. Proper waste outfalls will have to be constructed, and the characteristics of the receiving coastal waters must be considered. In areas of strong tides, currents and wave action, dilution and removal of released material can be achieved.

Waste treatment facilities will also have to be installed and made to function. However, technological developments may well be required for this in some areas, due to the special climatic conditions. These must in any case be properly considered in the construction of treatment plants. Co-ordination between industrial and municipal systems should always be established. But the desirability or appropriateness of combining industrial and domestic waste treatments should be carefully considered in different cases.

9. EFFECTS OF CONTAMINANTS ON THE MARINE ENVIRONMENT OF THE REGION

9.1 General comments

Lack of data from the Region makes it very difficult to assess the marine pollution effects. In some cases inferences can be made from observations and experiences in other regions.

Let us first note some generalities.

The environment does have a capacity to receive waste of all kinds and it must be recognized that the disposal of a small quantity of even highly toxic material does not necessarily cause pollution. The capacity of the environment to receive waste varies considerably and it depends particularly on the nature of the waste and that of the receiving waters. The coastal environment is a highly variable one, being dependent on local marine characteristics and strongly influenced by land processes. It is a very sensitive and fragile system subject to irreversible alterations. The coastal area is a "natural filter" for all kinds of pollutants poured out from the land and living organisms play a rather important role in the filtration process.

It is estimated that coastal waters to the edge of the continental shelf constitute only about 10 per cent of the whole world ocean area. But it should be taken into consideration that about 99 per cent of the world fish catch originates from these coastal waters and from relatively small (0.1 per cent) upwelling zones (Ssentongo, 1979). The coastal zone of the Region is a very important resource for the population and of great economic value.

Conditions in the nearshore and coastal marine environment can also influence the health of the local population and of tourists.

Typhoid fever, paratyphoid fever and infectious hepatitis are examples of diseases that have been caused by the consumption of raw or partially cooked oysters, clams and mussels that have been harvested from coastal waters into which raw or inadequately treated sewage had been discharged (Meith-Avcin and Helmer, 1978). One of the most known forms of poisoning by sea food is so called "Minamata disease", caused by consumption of methyl mercury contaminated fish and shell-fish.

There is a risk of enteric infection from swimming in water containing untreated or inadequately treated sewage. A health hazard also exists if the beaches become fouled with certain pollutants, especially intact faecal materials. Some studies have traced human diseases to contact with faecal remains in the beach environment.

Aesthetic values are also important, and pollution can drastically degrade these. Water pollution in the coastal areas produces such visual manifestations as foam caused by detergents and pulpmill effluents, and floatables arising from sewage and other waste waters. Turbidity introduced by mine tailings and brownish waste waters from sugar refineries and distilleries all tend to discolour and give an unpleasant appearance to the oceanic water into which they are discharged. In the same way, plastics and other discards of our modern society are repugnant to the eye.

It is clear that pollution can have a great impact on major industries of the region. Acute as well as chronic oil spills can give rise to tainting of marine products, making them useless as human food (GESAMP 1977a; 1982). Thus the fishing industry cannot market their products. The tourism industry will be affected both by the deteriorating condition of beaches and swimming water, and by low-quality or unreliable food products.

9.2 Effects on marine ecosystems

It is clear that the most significant effects of marine pollution occur in the coastal zone (GESAMP, 1982) where vulnerable ecosystems can be wiped out. Again, hard basic data from the Region are lacking. In general, it is very difficult to assess ecosystem effects and relate them to given sources of contaminants. Some general comments can be made here, which are especially pertinent to the conditions and activities in the Region.

Habitats of marine organisms might be adversely affected by solids settling on the bottom and by materials leached from them. Sedimentation from coastal mining operations may alter tropical waters unfavourably. Coral reefs and mangrove areas can be seriously affected (United Nations/GESAMP, 1977, 1980). Erosion from improper land management may affect coastal spawning grounds as well as those of the rivers. Organic substances in both dissolved and solid forms decompose and remove oxygen from the water. This can be a serious problem in partially confined areas, such as embayments and lagoons, where the water is not frequently replaced. It may even occur in basins on the exposed continental shelf where there is little or no flushing action by bottom currents. In areas where the volume of waste is very large compared to the amount of water available to dilute it, even the salt composition of sea-water might be changed significantly. The inflow of fresh water over coastal sea-water causes a stratification to take place in the absence of tidal and wind mixing. This, in effect, reduces vertical mixing, and such processes as aeration of deeper water tend to be minimized. Moreover, the comparatively fresh surface layer may have a low buffering capacity and can be affected by a pollutant in much the same way as a river or a lake.

Particularly important for the countries of the Region in connection with the effect of pollutants on coastal ecosystems is the impact of pollution and high silt load on mangrove areas (UNEP/UNESCO, 1981; Portmann, 1978).

Mangroves provide an area of shelter for the juvenile forms of many fish species and a source of food, shelter and settlement substrate for a wide variety of shellfish. The mangrove roots can also greatly reduce the impact of the sea waves on the land.

The influence of chemical and especially oil pollution on the mangroves simultaneously with the impact of a high silt load, is very destructive. In some cases mangroves can die within a few weeks. The loss of the natural mangrove buffer between sea and land, apart from the obvious potential effect of loss of fish and shellfish shelter areas, can mean the onset of coastal erosion. This is already a serious problem in many areas of the Region. Another problem is connected with the probability of tropical reef ecosystems being affected by oil and other types of pollution. Coral reefs are an integral part of the coastal environment in tropical areas of the Region.

Sublethal, chronic effects of pollutants may include retardation of growth, alteration of chemoreception in food-finding and mating, aberrant behaviour, physiological stresses affecting the vigour of organisms, and reproductive failure. An excess of nutrients may cause dense algal growths (abnormal blooms) that adversely affect higher forms of life such as fish and shellfish, and may lead to serious local oxygen depletion.

Biological and ecosystem effects monitoring has been subject to recent reviews (GESAMP 1981; ICES 1979). They both propose that a set of supplementary techniques be used, including fish diseases and deformations, abnormal blooms, aspects of primary production, plankton community studies. Microorganism studies can also be used.

It seems appropriate to discuss briefly the potential pollution effects of the different wastes considered in section 8, using a different division. Again, data from the Region are very limited and statements will often have to be based on results from other areas of the world ocean, following considerations by, for example GESAMP (1982).

9.3 Review of potential effects of various wastes

9.3.1 Domestic sewage

The main impact of untreated sewage disposal is to be expected in the vicinity of the outfall where turbidity can depress the primary production and the benthic community can be affected or smothered by sedimentation. At a distance the effect can be an enhancement of the biological communities due to the input of inorganic and organic nutrients. Discharge on shorelines can enhance seaweeds and intertidal species adapted to high nutrient levels. This will lead to a disturbance in the eco-dynamics which can imply a greatly reduced species diversity. The impact of this can be large on coral reefs. Dumping of untreated sewage in areas of limited water exchange can give rise to very serious environmental deterioration.

In relation to human health a major concern of sewage disposal is the transmission of infectious diseases, which can occur both as a result of bathing and consumption of marine produce. Several outbreaks of hepatitis, shigellosis and cholera in the United States and Europe have been attributed to swimming or shellfish consumption in sewage-contaminated areas. It is clear that this can also occur in the Region.

Dumping of untreated sewage and household refuse on beaches and in lagoons occurs in the Region and probably constitutes one of the most serious pollution problems in some parts of the Region.

9.3.2 Organochlorines

Fish and other marine organisms can take PCBs from water and food. The effects of PCBs on marine organisms have been observed in laboratory studies, using relatively high concentrations. Effects include mortality, retardation of growth, and impairment of reproduction in fish and invertebrates. PCBs also affect on human health and residues in marine food products could represent a public health problem, although there appear to be no confirmed cases of diseases due to this source.

DDT is known to have deleterious effects on the ecosystem, an important one being eggshell thinning in birds leading to much reduced reproduction. Marine organisms show considerable differences in sensitivity to DDT. For zooplankton the lethal concentration starts at 0.01 mcg/l; for fish at 0.1 mcg/l; phytoplankton crustaceans and molluscs are affected by concentrations above 1.0 mcg/l.

There are several other synthetic organic substances, e.g. hexachlorobenzene (HCB) mirex and toxaphenes. A common name for all these products is xenobiotics. It is likely that the continued use of PCBs and DDT in various parts of the tropics and southern hemisphere will lead to concern for parts of the marine environment and its products. The use of xenobiotics in the Region is also fairly widespread.

9.3.3 Metals

Many metals: Fe, Cu, Zn, Co, Mn, Cr, Mo, V, Se, Ni and Sn are known to be essentia nutrients and an insufficient supply of these elements will lead to deficienc diseases. However, exposure above a certain level may cause adverse effects. It i difficult to detect effects of metals on marine organisms in the field mainly because other waste materials are usually deposited together with the metals. Therefore controlled experimental studies in the laboratory and possibly in the field must be included in studies aimed at assessing effects of metals. The sensitivity of marine organisms is very variable, many benthic invertebrates for instance being very tolerant, and also depends markedly on the stage of development of the organisms. Effects of metal contamination from marine products on human health can be of concern, and have been extensively investigated in industrialized areas. Results suggest that there is no general threat to average consumption. The toxicity of metals is generally given in the order Hg>Ag>Cu>Zn>Ni>Pb>Cd>As>Cr>Sn>>Fe>Mn>Al>Be>Li. Five cases of poisoning of humans from toxic metals in marine food have been recorded in Japan, from Hg, Cd and Cr.

The few data available on metal concentrations in the Region do not suggest higher than average levels except perhaps for Cu in the northern upwelling area. This is, however, a perfectly natural cause. In general, concentration levels in marine food are not known. Such levels ought to be established, e.g. through a baseline study.

9.3.4 Petroleum

There is ample evidence that oil spills can have effects on the marine ecosystem which are often of a temporary nature depending upon conditions (IMCO/UNEP 1982). Usually effects occur in the coastal zone. They appear to be limited in time in rocky shore areas where the physical erosion of the oil, for instance by active wave motion, is fairly strong. On sandy beaches where wave motion is weak, effects of oil drifting ashore from a spill can be of very long duration.

Effects on ecosystems can arise from toxicity, from smothering and clogging, and habitat destruction. Apart from acute toxic effects, sublethal (chronic) effects can also occur, such as interference with feeding and reproduction, abnormal growth and behaviour, susceptibility to predation. Changes in abundance and distribution of species may result. Generally the effects are more severe when the discharge of oil occurs in estuaries or coastal zones than when it occurs in the open sea.

Oil slicks at sea can have adverse effects on plankton, fish eggs and larvae of fish and benthic invertebrates (ICES, 1980). The long-term or ecological significance of these effects cannot as yet be assessed.

Marine food products can easily be tainted by oil contamination so as to become unacceptable for human consumption. Several such cases have been recorded. Crustaceans, fish, and molluscs exposed to oily conditions can acquire an oily taste, usually related to volatile compounds from oils and dispersants.

It is clear that oil pollution can be of serious concern in many parts of the Region. It is not possible to assess the influence of the contamination on the ecosystem level or on individual species or parts of the food web. However, effects on these levels may occur on a localized basis and the occurrence of other forms of oil pollution (tar balls, slicks) should be taken as warning signals. An active control and discharge policy is required (IMCO/UNEP, 1982).

A special concern in relation to oil pollution may be the effect on human health and the role of the polynuclear aromatic hydrocarbons (PNAHs) known to be carcinogenic to mammals. Fish and shellfish can concentrate PNAHs within their tissues when exposed to oil. However, they do not seem to retain these levels indefinitely, only some 1-10 per cent of the initial levels seem to remain some days after the exposure. On the basis of present scientific information it is not possible to say definitely how significant this threat to human health is, although it appears reasonable to assume that PNAHs accumulated from marine products would not at present cause cancer without additional exposure.

9.4 Other factors of concern

According to the GESAMP definition marine pollution is related to input of substances or energy. However, there are also other factors which need to be considered in relation to environmental degradation, which can be a natural process or induced by human activities. One such process of great concern for large areas of the Region is coastal erosion. This problem was specifically considered for Togo and Benin during an expert workshop in 1979 (United Nations, 1981). In Togo, erosion has had serious social and economic consequences, including: destruction of fishing villages; destruction and reconstruction of coastal roads; threats to tourism developments, both as regards hotel and other infrastructure installations, and as regards amenities. In Benin the construction of the port of Cotonou caused erosion of the coastline east of the port, and a permanent opening to the lagoon Lake Nokone, bringing about erosion in the channel and modification of the ecological balance in the lake.

Coastal erosion may be due to natural changes in the sedimentation conditions along the coast, including the effects of: sea-level variations; wind-generated waves; oscillations of the tidal cycle; changes in the natural sediment supply, for example due to climatic variations. Erosion may also be caused by human activities, e.g., river flow modifications through dam constructions; sand minnig, on the beach and offshore; the building of structures changing the shoreline morphology, e.g., jetties, piers, outfalls, breakwaters, ports and dredging for ports, urbanization of the coast. All these causes are discussed and exemplified through the cases of Togo and Benin in the workshop report (United Nations, 1981), where solutions to the problem are also discussed. For both nations the erosion is due to a combination of natural and man-induced causes.

In regard to the growing offshore oil exploitation, the influence of offshore constructions on the sea bed on the distribution of living resources and on local fishing activities will need consideration. It should be noted that exploration platforms can leave debris, drilling muds and other left-overs on the sea bed, which may also cause interference with fisheries. (GESAMP, 1977b).

Activities of mining, sand and gravel extraction will also influence the sea bed. These activities can give rise to an increased turbidity influencing the biological system by light reduction in the water. They can also bring about a release of contaminants contained in the sediments to the water column, such as metals, PCBs, DDTs, organic material (GESAMP, 1977b).

The ecosystem will in general be influenced by all these activities and processes. Erosion can have serious negative implications for the beach and nearshore ecosystems. Since these often play an important role in the development of offshore fish stocks as well, the consequences of coastal destruction can be far-reaching for marine ecosystems.

9.5 Overall evaluation

The Region has very rich marine resources: fisheries and offshore oil and minerals which represent great amenity values for the benefit of the Region. The fisheries resources are probably fully exploited but the exploitation of non-living resources has only begun fairly recently.

The Region is facing environmental problems related to pollution; physical changes of the coast through erosion, which can be natural as well as induced by human constructions; exploitation of resources on a large scale without having access to fully developed management and control mechanisms. The seriousness of these problems vary. Unfortunately a satisfactory overall evaluation cannot be made on the basis of existing data, and few local assessments are available. The one by Osibanjo (1983) for Nigeria suggests that the problems are rather serious. Comparison between statements in reports from Regional workshops (IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan 1978, and the IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Africa, Tenerife 1983) suggests that the trends are not towards a general improvement.

It seems clear that the nearshore and coastal zone problems are the most pressing. In order to establish a basis for proper management and control, the existing data base must be improved both as regards information on environmental characteristics and information on contaminant levels in biota, sediments and possibly water. The environmental assessment and management projects of the Action Plan for the Protection and Development of the Marine Environment and Coastal Areas of the West and Central Africa Region, implemented through co-operation with United Nations agencies, will supply much relevant information (UNEP, 1982c). The objectives of these include: development of contingency plans in relation to emergency situations asscciated with oil spills and industrial installations (WACAF/1); training of regional scientists in marine pollution measurement, development of programmes for monitoring pollutants in the marine environment, and compilation of a data base on pollution and effects of pollutants (WACAF/2); research and training required to assume control over coastal erosion, formulation of a framework for the enforcement of coastal erosion control measures, and development of appropriate technologies and their application to the problems of coastal erosion (WACAF/3). Within WACAF/2, FAO has established a pollution analysis network which should supply data to allow an assessment of the level of pollutants in marine organisms. Intercalibration of sampling and analytical techniques will be organized and assistance to maintenance of equipment. Observations of oil slicks and tar balls will be organized through IOC, and microbial contamination of sea-water and shellfish will be investigatted by national laboratories following suggestions from WHO.

In addition to these projects, studies will be needed to provide basic information on coastal zone conditions, including temperature, salinity, water level variations, tides, currents and winds. Such information can be gathered without use or instalment of very sophisticated equipment (see for example GESAMP, 1980a). Observations can be carried out from boats, small ships, fishing vessels and harbour jetties. Long time series observations of sea surface temperatures from parts of the Region exist and have been used to investigate the influence of wind conditions on the temperature and the possibility of predicting the temperature development from meteorological data (e.g. Verstraete, 1983; Gallardo, 1983).

In order to make the best use of data collected at different parts of the coastline, information on measuring programmes and exchange of data between the institutions in the different ocuntries is very desirable. This may be organized on a bilateral basis or on a regional basis, through direct contacts and contacts via the relevant governmental institutions. This aspect also forms part of the WACAF programmes.

Finally, it seems appropriate to note that fairly lengthy periods of development and implementation are needed for programme components of the kind discussed above. Considerable experience has been gained in other regions, e.g. the Baltic Sea (ICES, 1977b; Melvasalo et al., 1981), and the whole North Atlantic area (ICES 1983a; Pawlak 1983). It should also be noted that the interpretation of the information gathered in various programmes should be used to formulate and implement management and control measures. For this an overall assessment on a regional or subregional basis can form a very valuable input (Melvasalo et al., 1981; ICES, 1983b).

10. SCIENTIFIC INFRASTRUCTURE

There is a great need for pollution-oriented studies of the marine environment in the Region. This includes basic research on the governing processes and characteristics of the environment.

There are relatively few marine laboratories and institutions in the Region engaged in conducting studies on the marine environment. The total number of such institutions exceeds 33 but only two or three of them are directly engaged in problems of marine pollution (UNEP-RS/PAC/UN-ECA/UNESCO, 1982).

National marine research in the Region appears to be carried out mainly in programmes related to fisheries. Most of the research is concerned with the coastal and nearshore zone, and related to the exploitation of marine resources as well as the protection of the marine environment. There are tendencies within universities to expand marine research, but a serious obstacle is the lack of both equipment and personnel (IOC, 1983).

The information collected in table 15 shows that types and scopes of research activities in the institutions of the Region are concentrated in marine chemistry, physics and biology, i.e. in areas of marine sciences closely connected with the problem of marine pollution. It means that there are favourable conditions for including this problem in the scientific programmes of these institutions. Aspects of the present status, the need for further developments and a rationale for this are further discussed in UNESCO (1981).

Some of the scientific institutions available in the Region could be the basis for the training of local experts. In accordance with the recommendations of the Action Plan this training could include such areas as the use of analytical techniques for measuring pollutant concentrations, application of equipment to assess the effects of pollutants on human health, fishery resources, marine and coastal ecosystems and, of course, techniques used for the maintenance and calibration of research equipment. In addition, the teaching programmes could contain training in methods of establishing the environmental quality criteria and waste discharge regulations and methods for the analysis of coastal lagoons, estuaries and mangroves (UNEP, 1981).

There are several scientific institutions in some countries of the Region which have suitable conditions to train local experts and to invite for training groups of specialists from other countries of the Region. Such institutions are, first of all, in Nigeria, Ghana and Ivory Coast, but Senegal, Sierra Leone and the Congo also hold out promise in this field (table 15).

The WACAF programmes referred to above will form a basis for a proper research and training development.

It will be necessary to include the basic problems of marine environment and a preliminary acquaintance with the methods of marine pollution prevention in the teaching programmes of colleges and universities of the Region, in order to generate a truly regional expertise.

Table 15: Scientific and training facilities available in the WACAF Region (UNEP-RS/PAC/UN-ECA/UNESCO, 1982)

Zone	Country	Number of institutions	Type and scope of research activity	Research vessels or boats	Facilities for student courses	Facilities and space available for external students
	Mauritania	1	Oceanic physics, chemistry, biology	2	no	no
	Senegal	8	Oceanic physics, biology	at least 2 vessels, 2 boats	no	for 6 persons
Northern	Gambia	1	River research	3 - 4 boats	no	no
	Guinea	3	Marine biology and oceanography	?	?	?
	Sierra Leone	4	Physical, chemical, geological and biological oceanography	at least 1 vessel	yes	for 10-15 persons
	Ivory Coast	3	Fundamental oceanographic research, hydrology of lagoons and land waters	6 vessels, boats	yes	at least for 4-7 persons
Middle	Ghana	3	Physical, biological and chemical oceanography	3 vessels	no	no
	Benin	1	?	?	?	?

Table 15 (continued)

Zone	Country	Number of institutions	Type and scope of research activity	Research vessels or boats	Facilities for student courses	Facilities and space available for external students
	Nigeria	5	Biological, chemical and chemical oceanography; ecology of lagoons and estuaries; pollution monitoring and control	at least 3 vessels	yes	up to 20-25 persons
Middle	Cameroon	1	Marine biology and oceanography	no	yes	yes
	Gabon	2	Protection of environment	?	?	?
	Congo	1	Physical, chemical and biological (fishery - oriented) oceanography	1 vessel	yes	for 2-3 persons
Southern	Zaire	2	?	?	?	?
	Angola	2	Biology and oceanography	1 boat	?	?

SUMMARY AND CONCLUSIONS

There is a great abundance of living as well as non-living resources in the marine environment of the Region. This constitutes a very important subsistence base for the coastal nations. Other uses of the marine environment, e.g. for transportation and tourism, are of great significance for the income and development of the Region. Thus a proper control and management of the marine and coastal environment as an important economic asset is motivated beyond any doubt as a common interest of the countries in the Region.

The coastal zone is of great importance not only to the population of the Region, constituting about 40 per cent of the African population, but also plays a very significant role in the development and economy of adjacent land-locked countries, namely as an export/import link through the ports. The importance of the sea as a means of transport cannot be over-emphasized. This obviously calls for a great common interest in proper coastal zone management, at least as far as waterways and harbours are concerned.

The major sources of pollution in most of the countries of the Region result from human (domestic or municipal) waste and not from industrial sources. Estimates indicate that approximately 80 per cent of the pollution currently discharged to the coastal areas is attributable to people, and untreated waste on beaches and in the nearshore zone in many areas constitutes a really significant problem. Untreated and inadequately treated waste usually contain high concentrations of nutrients and micro-organisms. Nutrients may lead to eutrophication of coastal receiving waters and lagoons with various negative consequences (plankton blooms, oxygen depletion, fish kills, etc.). Depending on the type of carriers, micro-organisms discharged with sewage include various pathogenic forms which constitute a risk to bathers and to those who eat contaminated seafood (shellfish in particular). The basic zones of high risk connected with domestic pollution are located near big cities, beach hotels and recreational areas. A real public health threat is created at some of these sites due to uncontrolled sewage disposal.

The sewage disposal situation in parts of the Region is also a threat to further development of tourism. It also imposes restrictions on the use of marine products as well as constituting an additional health hazard in areas with inherent disease problems. Part of the solution to the problem lies in the application of proper disposal techniques, making use of the physical characteristics of the marine environment. However, treatment plants will also be necessary and it may be a major problem to develop effective techniques. At present the discharge of industrial pollution to estuaries, rivers and coastal areas of the countries does not appear to create a significant problem. However, rapidly increasing industrial development, particularly in the coastal areas and along the major rivers, will lead to an increase in the volume and diversity of industrial wastes discharged without adequate treatment into the marine environment. The analysis of development in the Region shows that pollution discharges are likely to increase significantly in the next ten years and are going to become rather important problems not only in localized areas where industry is concentrated, but along most West and Central African coasts.

Pollution by petroleum hydrocarbons is increasing in coastal waters and on beaches along the whole coast of the Gulf of Guinea and adjacent areas. Effects observed locally indicate that damage is being done to the coastal ecosystems and fishery resources. However, available information on this is very limited. It is still likely that a major part of the oil pollution is due to heavy maritime transport and associated operations rather than local exploration and exploitation. There are local exceptions to this, e.g. in Nigeria, the Niger Delta and Lagos Lagoon

The present levels of agricultural wastes, herbicides, pesticides and fertilizers discharged do not yet seem to constitute a major problem.

Available limited data suggest that sewage and oil products are major problems and indeed now produce significant pollution effects in localized beach and nearshore areas. The regional extent cannot be judged, but it appears that concerted action would be beneficial, with the nearshore zone as the primary objective.

The offshore and open sea areas of the marine environment of the Region cannot be considered as influenced by pollution at present.

It can be concluded that the trend of increasing pressure on the environment is continuing. The primary factors are: coastal pollution due to oil and sewage contamination; coastal erosion; and exploitation of living and non-living resources without enforcing control measures and management. This is partly due to lack of a proper data base. However, it is clear that remedial actions can be taken without waiting for such a data base to be developed.

Marine research in the Region needs to be strengthened. This process is to some extent under way, partly in relation to implementation of projects within the UNEP Regional Seas Programme for the West and Central African Region. The strengthening can be motivated by carrying out studies on the real problems existing in the nearshore and coastal zone. This is basic for the short-term development.

However, in order to obtain long-term solutions to the problems, attention must also be given to the environmental oceanographic characteristics and conditions in the offshore and oceanic zones. The nearshore and coastal problems should not be allowed to spread or be transferred further offshore. This will eventually happen if no remedial actions are implemented.

Monitoring of the pollution is required in order to establish baselines of concentration levels; identify specially threatened areas; and demonstrate the effects of management and control. This is clearly required in order to avoid inefficient or erroneous management and economic loss. It further points to the need to have national expertise for carrying out the programmes and interpreting the data. Interdisciplinary research should be encouraged from the start as well as a close liaison between those institutions carrying out the research and monitoring and those making management decisions. The environmental studies should be tailored to the needs. Unnecessary complications should be avoided. A discussion of these aspects in relation to coastal area development is presented in GESAMP (1980a, b).

Implementation of any programme will require funding, and a basic question is then what economic return there will be. This, of course, is related to the cost of environmental deterioration. It is usually difficult to give figures for this cost, or present definite convincing examples. There are many examples of the economic implications of erosion. Several examples can also be given of the implications of dam constructions and river regulations for the ecology of the delta and the loss of the local, coastal fisheries. In the Region, public health, and natural resources are being threatened. The cost of erosion due to improper constructions can clearly be estimated, and the cost of the loss of the local fisheries. However, how significant are such losses to the overall economy, when this is primarily based on mineral and oil exploitation, which is the direct or indirect cause of the loss of the fisheries? It may be difficult to estimate the potential cost of the public health threat due to pollution in areas where the public health threat due to other factors is already considerable. However, in such a situation additional unnecessary threats may have serious implications. On a wider basis, social considerations and society structure must be included in the cost-benefit and risk judgements.

A basic problem in all studies directed at investigating the human influence on the environment is to separate out the influence of natural variability. Environmental changes and deterioration cannot without reservation be ascribed to human influences. Effects of natural factors must be considered, which requires knowledge of the natural conditions and their variability. In areas of development and areas of concentrations of populations this aspect strongly supports the inclusion of environmental research as one integral part of the quest for overall socio-economic development.

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