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SOME UNIQUE CHARACTERISTICS OF THE INDIAN OCEAN

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INTRODUCTION :

Morphologically, the Indian Ocean, unlike the Atlantic and the Pacific oceans, is land-locked on the north and does not extend into the cold climate regions of the northern hemisphere. It communicates to the Antarctic Ocean and Antarctica in the south. In other words, the Atlantic and the Pacific oceans are open oceans whereas the Indian Ocean is a closed ocean. Such a geographical situation causes asymmetry in its structure and circulation. This is evident from the occurrence of huge layers of extremely low oxygen water in the Arabian Sea and the Bay of Bengal. The landmass of Asia also affects the Indian Ocean climatologically by causing the seasonal changing monsoon, which in turn reverses the seasonally changing circulation over its northern part. Associated with the seasonally changing circulation, are the various upwelling areas, which get activated largely during one season which is the monsoon. This is in contrast to the other major upwelling areas in the world which are not synchronized with one season.

Another unique feature connected with the geographical and climatological situation is the formation of high salinity water in the Arabian Sea and even more extreme in the Red Sea and the Gulf. These water masses form a high salinity layer deep down in the Arabian Sea. This layer affects the circulation at intermediate depths drastically by preventing the water coming from the Southern part of the Indian Ocean (southern hemisphere) penetrating efficiently into the northern Indian Ocean.

The lowest oxygen concentrations (oxygen minimum layers) in the Indian Ocean occur in entirely different locations as compared to the other two oceans where the most pronounced oxygen minimum layers are found on the eastern side of the ocean, on both sides of the equator. In the Indian Ocean, it is found in the two northern bays, the Arabian Sea and the Bay of Bengal.

The meridional circulation of the Indian Ocean is similar to that occurring in an estuary where heavy water occurs at the bottom and spreads up to the extreme end of the bay and the light water in the upper layer gets confined to the mouth. Although only a part of the Indian ocean lies in the northern hemisphere, its own meridional circulation is initiated by the water masses coming from the Red Sea and the Gulf. Both these seas are relatively small, yet they have a very effective deep-reaching connection. The outflow of the Gulf water and of the Red Sea water is influenced by the Coriolis force leading to its spread into the Arabian Sea.

The Gulf is a shallow extension of the Arabian Sea. It is a closed sea with an area of 240,000 km^2 with a mean depth of 35 m and maximum depth varying between 90 and 100m along its north-eastern side near the coast of Iran. The total volume of water it contains is 7800 km^3 with an estimated residence time of 2.5 years. Although the Gulf forms a part of the Indian Ocean, it has only about a quarter of the species of plants and animals known from the Indian Ocean. Nevertheless, it still has the diversity as great as the Caribbean. As compared to the Indian Ocean and the Red Sea, the average organic productivity of the Gulf is much higher. This is because of the shallow nature of the Gulf where light penetration is high and this promotes a greater degree of photosynthesis.

The Red Sea is also a closed sea. It is a long, narrow body of water which separates the north-east Africa from the Arabian Peninsula. It has about 2000 km of navigable water connected with the Indian Ocean at the south and joins the Mediterranean Sea at the north by the Gulf of Suez. The Suez Canal was built by Ferdinand des Lesseps and opened in 1869. The canal offers a migration route between two biogeographic areas and this phenomenon has been termed as «Lessepsian Migration». Passive movement of animals along with many Red Sea species have penetrated into the Mediterranean; very few have accomplished a reverse migration.
The Red Sea lies 'between latitude 30°N and 12°30'N. The entire area is highly arid. Rainfall nowhere exceeds 18cm per year, and the coastal vegetation is of semi-desert in nature. The total surface area of the Red Sea is 4.5 x 10^5 km^2, while the volume is 2.51 x 10^5 km^3. Its average depth has been reported to be 491 m and the recorded maximum depth is 2350m. The southern coastal shelf of the Red Sea is shallow and it has actively growing coral reefs. All major tropical marine communities are represented in the Red Sea. Seagrasses are found in the shallow areas up to 70m depth. Fish are abundant while turtles, dugong and whales also inhabit the Red Sea. The last three groups are very important from the point of view of their global conservation.

ENVIRONMENTAL FEATURES

Physical

Form the point of view of water balance, the seas are defined as **negative** or **positive.** If the evaporation of water from the sea exceeds the «precipitation» and river run-off, it is termed as negative water balance. If, on the other hand, the precipitation and run-off exceed the «evaporation», It is called positive water balance.

The Indian Ocean as a whole is an ocean of negative water balance . it receives 6,000 km^3 of river run-off and 88,000 km^3 of precipitation. while its evaporation is 1,03,000 km^3 However there are some areas in the Indian Ocean such as the Bay of Bengal where the water balance is positive. The Arabian Sea is an area of negative water balance where on the whole the evaporation is more than its

precipitation. Highest evaporation occurs off the Arabian coast. It decreases steadily towards southeast. Along the southwest coast of India, there is a slight excess of precipitation over evaporation (>20cm).

In contrast to the Arabian Sea, the Bay of Bengal is a region of positive water balance. The average excess of precipitation is of the order of 70 cm annually. The total annual river run-off into the Bay of Bengal is about 2,000 km^3. The two seas occupy only 3% of the world ocean, but receive 9% of the global run-off which is 3 times greater per unit area than the rest of the oceans.

Monsoon

During the summer months (March to June), there is a northward movement of the sun. This creates enhanced solar heating of both land and water. The land has lower capacity to maintain heat than that of the water. Therefore, a strong land-ocean thermal contents in the region surrounding the Arabian Sea develops. Towards the end of May, the high temperature on land gives rise to low pressure over the sea which extends from Somalia to almost the entire Arabian Sea up to India. This low pressure attracts a huge flow of moist oceanic wind. The flow of this wind over the west coast of India is rather sudden. This leads the wind direction towards the coast, associated with a change in the weather and heavy rainfall known as the southwest (SW) monsoon. The monsoon hits the Kerala coast by late May or early June and then progresses in pulses towards northwest India by mid-July. The SW monsoon remains active over most of the country till September. Towards the end of September, it begins to withdraw. This is associated with the reversal of the wind over the landmass of India which is the beginning of northeast (NE) monsoon and the season of cyclones. With the weakening of SW monsoon, a shallow, low pressure area develops over the Bay of Bengal. This attracts the moist trade winds from the China Sea and the Bay of Bngal, which under the Coriolis effect enter into Tamil Nadu and adjacent areas producing copious rain. The NE monsoon thus accounts for 60% of the rainfall in the coastal regions of Tamil Nadu and its neighbouring areas from October to December.

Chemical

The enrichment of the Indian Ocean is largely governed by the annual cycle of monsoon. Surface layers, particularly along the coastal areas get their enrichment from the river discharge and land run-off which are maximum during the monsoon period. Deeper layer, on the other hand, get enriched by a process called upwelling when water from deeper layers, rich in nutrients and low in oxygen content , is brought to the surface. This process (upwelling) occurs both in the deeper parts of the ocean as well as in the coastal areas. The water masses of the north and south Indian Ocean are distinguished by their dissolved oxygen and nutrients as follows:

(a) those of the north have a low dissolved oxygen (less than 1 mll^{-1}) and are high in nutrients.

(b) those of the south have a high dissolved oxygen content (around 5 mll^{-1}) and are low in nutrients.

High concentrations of inorganic phosphate - phosphorous (PO_4-P) and nitrate-nitrogen (NO_3-N) are found in the northern Arabian Sea extending along the Saudi Arabian and Somalian coasts and along he coasts of Bangladesh, Myanmar (Burma) and Indonesian waters. In the central Indian Ocean, the values are low. The ratio between nitrate-nitrogen and phosphate-phosphors (N:P) in the upper 125 m of the Arabian Sea and the Bay of Bengal has been reported to be 6:1, while the normal oceanic value is 16:1 by atoms. Such a low ratio has been attributed to the reduction in nitrogen, because of denitrification associated with the advective transport of phosphorus from deeper layers.

Silicate values in the Indian Ocean are higher than those of either Atlantic or Pacific oceans. In the surface layers, the range in values is 0-3 µg-at/litre and in deeper parts the values are about 20 ug-at/litre/. These do not show andy irregularity and have been found to increase with depth.

Biological

The illuminated zone in the Indian Ocean, or the zone in which sunlight can penetrate, ranges from 40m and 140m. This layer is also called the euphotic zone or the compensation depth (the depth where the illumination is 1% of the surface). From the coastal waters to the offshore regions, this zone increases in depth. In all the productive areas, low transparency is found. These lie in the northern Arabian Sea, west coast of India and the African coast where the euphotic zone ranges between 40 to 60 m. In the northern Bay of Bengal and along the east coast of India, transparency is also low, about 60 m. This is because of the large scale influx of turbid riverine water into the Bay. In the southern part of the Indian Ocean, transparency is high and the euphotic zone ranges from 80 m to 140 m.

The range in the primary production within 100 m column of water is 0.001 to 6.5 g C m^{-2} day^{-1} (average 258 mg C m^{-2} day^{-1}). Areas of high productivity lie in the coastal waters and in the upwelling regions. The Arabian Sea and the Bay of Bengal are the two most productive regions of the Indian Ocean. The total column production in the Arabian Sea is 1.1 x 10^9 tonnes C $year^{-1}$. One-third of the total photosynthetic productivity of the Indian Ocean is contributed by these two regions.

The total photosynthetic, productivity in the Indian Ocean ranges from 3-6 x 10^9 tonnes C $year^{-1}$ with an average of 4.42 x 10^9 tonnes C $year^{-1}$ or 258 mg C m^{-2} day^{-1} or 94 g C m^{-2} $year^{-1}$. Relative rates of primary production in the three world oceans are as follows :

Production

		Oceans		
		Pacific	Atlantic	Indian
Daily	mg C M^{-2} day^{-1}	127	190	258
Yearly	g C M^{-2} $year^{-1}$	46.4	69.4	94

The total zooplankton biomass for the Indian Ocean has been estimated to be about 5.2 x 10^8 tonnes $year^{-1}$ and secondary production computed from the zooplankton biomass ranges between 5-10 mg C m^{-2} day^{-1}. For the entire Indian Ocean it amount to 69.27 x 10^6 tonnes Carbon $year^{-1}$ or 1.5 tonnes Carbon km^{-2} $year^{-1}$.

Tertiary production calculated as 10% of the secondary production amounts to 6.93 x 10^6 tonnes $Carbon^{-1}$ year. Using a factor 10, the live weight of tertiary production (fish stocks) would be 69.3 x 10^6 tonnes. Assuming that 25% of the total stock can be safely exploited without depleting the stocks, the potential yield of fish etc., from the Indian Ocean would be of the order of 17.3 million tonnes. Of this, about 2.2 million tonnes is obtained annually in India. All other countries in the Indian Ocean collectively contribute to about 3 million tonnes annually. The estimate of potential yield has been made on a theoretical basis with the assumption of several factors, and therefore it may be on the higher side. Nevertheless, multi-fold increase in sea food is still possible from the Indian Ocean.

Geological

Measurements of the magnetic field in the Indian Ocean showed that the floor of this ocean is spreading at the rate of about 2 cm $year^{-1}$. This implies that the Indian Ocean is about 10^8 years old. One of the most prominent features of the Indian Ocean is its seismically active, rugged and inverted Y shaped Mid-Indian Ridge, which is cut by numerous north-northeast trending fracture zones. The seismic Ninety-Degree East Ridge, 4800 km long and the Chagos-Laccadive Plateau are the unique features of the indian Ocean. In between the topographic highs of the Indian Ocean, there are a good number of deep basins.

Sediment cones and abyssal plains with the thickness exceeding 1.5 - 2.5 km are present in many areas of the Indian Ocean. In parts of the Ganges cone, the sediment thickness exceeds 12 km. The most extensive sediments in the Indian Ocean are the calcareous sediments which occupy the Mid-Indian Ridge. The other sedimentary facies are (a) terrigenous clay, adjacent to the major river basins (b) silicous clay and oozes in the equatorial and southern latitudes influenced by high biological productivity (c) brown and red clay in deep areas outside the productivity belt (d) regions of terrigenous sediments which are small in terms of areas but its volume exceeds 70% of the total sediment of the Indian Ocean.

The following materials have been mapped in the indian Ocean (1) hard rocks (volcanic and limestone) on topographically high areas in the Mid-Indian Ridge (2) manganese nodules in the deep basins (3) ilmenite placers in the coastal areas of many countries (4) silicic volcanic ash in

the eastern Indian Ocean adjacent to the Indonesian Archipelago. Manganese nodules of the Indian Ocean for the first time were lifted by the Indians from the research vessel R.V. Gaveshani on January 26, 1981. The scientists of the national Institute of Oceanography (NIO) Goa, played a major role with the present author on board the vessel as Chief Scientist. The cruise was planned from Goa to mauritius and its return via the Central Indian Ocean to Goa.

Conclusion

The account summarized above gives the essential features of the Indian Ocean to indicate that the Indian ocean is in many ways an unique ocean and it significantly differs from the other two major oceans namely the Pacific and the Atlantic. Some of its broad features are as follows:

1. It is not an open ocean because its northern boundaries are closed with landmass of Asia. Unlike the other two oceans which communicate to both north and south poles, it communicates only to the south pole.
2. It has two other seas at its northern end - the Gulf and the Red Sea, both these are also closed seas.
3. The Arabian Sea - one of the components of the Indian Ocean - is influenced by the waters of the Gulf and the Red Sea. Oil traffic originating from the Gulf largely follows the Arabian Sea route resulting in the highest concentrations of both floating and dissolved hydrocarbons as compared to any other sea in the world.
4. High salinity water in the Arabian Sea coming from the Gulf and the Red Sea remains distinct for a long time during the year and the prevalence of oxygen minimum layer in deeper parts of the Arabian Sea and Bay of Bengal remaining distinct are the other important features.
5. Reversal of wind direction and the sea currents leading to the phenomenon of the annual cycle of monsoon over the Indian sub-continent is another unique feature in the Indian Ocean.
6. In the upper 125 m. high concentrations of phosphate-P and nitrate-N in the Arabian Sea and Bay of Bengal lead to anomalous ratio of N:P in the Indian Ocean.
7. High primary (organic) production in the Indian Ocean gives rise to high secondary and tertiary production rates.
8. Rugged, seismically active floor of the Indian Ocean, with prominent ridges and deep basins, contains a variety of sediments.