Qatar Univ. Sci J. (1999), 19:

PROGRESS OF OCEAN SCIENCES IN INDIA

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INTRODUCTION :

The Indian Ocean, unlike the Atlantic and the Pacific oceans which communicate to both north and south poles, is land-locked by the landmass of Asia on the north and does not extend into the cold climate regions of the northern hemisphere. It only communicates to the Antarctic Ocean and Antarctica in the south. In other words, the Atlantic and Pacific oceans are open oceans and the Indian Ocean is a closed ocean. Such a geographical orientation gives some unique features to the Indian Ocean.

The Indian Ocean can broadly be divided into two regions : north of the Equator and south of the Equator. The former includes the Arabian Sea and the Bay of Bengal. At its northernmost end, the Arabian Sea is connected with the Gulf and the Red Sea. The region south of the Equator is oceanic and hence the conditions of this region largely remain uniform.

The most important development in ocean research came in 1960 when the Government of India constituted an Indian National Committee on Oceanic Research (INCOR) to plan and coordinate an international programme in oceanography called the International Indian Ocean Expedition (IIOE). In this programme, 40 ships from 20 countries participated. The programme, which was co-sponsored by the UNESCO. lasted for five years (1960-1965). India became one of the active participants of this programme and played host to research vessels and scientists from different countries. The termination of this programme saw the birth of a new institution in the country the National Institute of Oceanography (NIO) on January, 1, 1966. Under the Council of scientific and Industrial Research (CSIR), this national institution is the premiere laboratory in the country to carry out ocean research in its totality. Over the years, the NIO has grown into a sizeable organisation. It has its Headquarters in Goa and three regional centres at Bombay, Cochin an Visakhapatnam with a staff strength of about 500 and conducts researches on practically all disciplines of oceanography. In 1975, the NIO commissioned the first Indian-built research vessel «Gaveshani». This vessel, after completing several hundred cruises in the Indian Ocean, was decommissioned in 1995. Gaveshani has surveyed nearly one million line kilometres in the sea and has worked at more than 10,000 stations resulting in the collection of a large volume of data and information on the Indian Ocean.

In 1981, another important development in the ocean sector was the creation of the Department of Ocean Development by the Government of India, under the direct

charge of the Prime Minister of India. The main objective of this Department was to promote speedy development of the ocean sector. In 1982, the Department formulated an «Ocean Policy Statement» which was discussed and approved by both Houses of the Indian Parliament. Soon after is creation in 1981, the Department launched the First Expedition to Antarctica. Deep Sea exploration of polymetallic (manganese) nodules began in December 1980 by NIO using the research vessel Gaveshani and in January 1981 the first sample of nodule was picked up from a depth of 5 km.

In March 1983, the Department of Ocean Development acquired a very sophisticated and highly advanced oceanographic research vessel «Sagar Kanya». This ship has so far completed more than 200 cruises including a number of international cruises to Australia and the Caribbean. Another multipurpose fisheries and oceanographic research vessel «Sagar Sampada» was acquired by the Department of Ocean Development in November 1984. It is well equipped for the exploration and exploitation of marine living resources. During the eighth five-year plan, the Department of Ocean Development has established a new institute named as the National Institute of Ocean Technology (NIOT) in Madras.

PROGRESS OF RESEARCH

From the important events and landmarks summarized above, it is clear that researches in the Indian Ocean are largely a post-independence activity. For India, oceanography is a young science. Systematic and organized work, began after the National Institute of Oceanography (NIO) came into existence in 1966. Thus, the total effort involved in this field is about 31 years. Oceanography is a multi-disciplinary science and it embraces all sciences. The studies carried out during the last 25 years fall into the following broad categories :

a) **Physical Oceanography or Physics of, the Oceans :** This science deals with the dynamics and kinetics of the sea; such as; ocean currents, ocean circulation system, waves regime, temperature and salinity distribution on in the water column, the water masses coming into the Indian Ocean from the Antarctic Ocean, Red Sea, Gulf and other regions.

b) **Chemical Oceanography :** Embraces the composition of sea water, distribution of oxygen and carbon dioxide in the sea, fertility of water (nutrients), quality of water, chemistry of the sediments, changes in the water quality by man-made activities (pollution), fresh water discharge into the sea, river run-off, sediment load and a host of other problems.

c) **Biological Oceanography :** Includes all living organisms of the sea both plants and animals including microorganisms (bacteria and other microbes). Floating plants called phytoplankton are primary producers which are consumed by small animal

organisms called zooplankton and these two in turn are consumed by higher forms of life such as fishes, crustaceans, mollusks and a variety of other animals forming a complex food cycle in the sea. Today India is one of the foremost countries in seafood production and also in the export of seafood to other countries.

d) **Geological and Geophysical Oceanography :** This science deals with the non-living resources of the seabed such as the minerals including offshore oil and gas. Explorations in the Arabian Sea and Bay of Bengal have revealed vast deposits of different kinds of minerals in the seabed of our Exclusive Economic Zone (EEZ) and in the Indian Ocean (Beyond the EEZ).

e) **Marine Instrumentation and Ocean Engineering :** These two fields deal with the knowledge and development of different kinds of equipment and probes used from the ships for the study of different conditions of the ocean including the seabed. High technology and high sophistication are used in the deep sea, to keep the instruments and probes in working conditions. Oceanography is a highly risk-prone technology of probing the great ocean depths. In addition, there are innumerable problems to be studied in coastal areas for which a variety of instrumentation is required.

f) **marine Archaeology :** Exploration of the unique cultural heritage of India is of great educational value. For undertaking this task a Marine Archaeology Centre was established in NIO, Goa. The most significant results obtained by this Centre existed till 100 BC and is said to have been built by Lord Krisbna. The other discovery was the exploration of the port city of Poompuhar of the Chola kings at the mouth of the river Kavery. Both these got submerged into the sea in the past. Beside these, a number of shipwrecks have been identified underwater and a lot of treasures in the form of relics have been discovered.

g) **Data Centre :** The Indian National Oceanographic Data Centre (INODC) is housed in a separate building at NIO, Goa. It has excellent data deposition, retrieval and dissemination facilities with its linkages with all the important data centres in the world. High-speed computers are required both in the ships and in shore-based institutions to get the different types of data processed and used.

FOOD CHAIN COMPONENTS OF THE SEA

Commercially exploitable resources of the sea are the final links in the food chain starting from sun's energy and its conversion by plant communities into organic matter and ending up with exploitable fish, crustaceans and mollusks. This relationship has following components :

a) **Sunlight :** Like on land, sunlight is the

most important component for sustaining life in the ocean. Without sunlight, there can be no photosynthesis and no organic production or oxygen liberation by the unicellular microscopic plants collectively called «phytoplankton». These organisms make use of carbon dioxide and water in the presence of sunlight and synthesize a molecule of glucose with the liberation of oxygen as by-product, according to the well-known equation:

$$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2 \quad (1)$$

However, it must be noted that much of the sunlight falling on the sea surface gets absorbed as it penetrates into the sea. The intensity and depth of penetration depends on the transparency of water.

b) Nutrients : Growth of phytoplankton depends on the availability of inorganic substances such as nitrogen in the form of nitrate, nitrite and ammonia, phosphorous in the form of phosphate, silicon in the form of silicate and several other trace elements, minerals and metabolites, Thus, the most fertile areas of the sea are those which have an abundance of nutrients.

c) Upwelling : One of the important processes by which enrichment of the top-most layer occurs is called upwelling. Because of photosynthesis in the illuminated zone, the upper layers of water get impoverished with nutrients whereas the bottom waters always have high concentrations of nitrogen, phosphorus and silica. This water is always cold. Thus the main reservoir of nutrients in the ocean is the deep layer. In certain season, because of the convergence of the surface water, there is an influx of cold, nutrient-rich water from deeper layers to replace the upper layers. This phenomenon is called upwelling. Many areas of upwelling have been identified in the Indian Ocean. Enrichment of the areas adjoining the coast occurs by land drainage and river run-off during the monsoon months whereas in the open ocean the source of enrichment is only the upwelled water coming to the surface.

d) Phytoplankton : all floating, microscopic plant-life or drifting flora of the sea are included in this category. These form an assortment of green, blue-green, brown and yellow organisms collectively called algae or by a more appropriate name «phytoplankton». These organisms form the inherent richness of the sea. Most of the organisms either multiply vegetatively, i.e. by cell division or by the formation of spores. Phytoplankton constitute the basic source of food in the sea and the starting point of the food chain. These consumed by the floating and drifting animals which have a limited power of swimming called «zooplankton» Phytoplankton are also consumed by larger animals such as fish, crustaceans and mollusks etc. which are herbivorous and graze upon the floating plant life.

e) **Zooplankton :** Zooplanton form another assemblage of marine animals from the tiny one-celled protozoans to jelly fishes with tentacles several metres long. These are dominant constituents of the animal organisms in the sea. Unlike the phytoplankton which are non-locomotory and move at the mercy of waves, tides and currents, the zooplankton possess and ability to swim. However, their power to swim varies greatly with different animals. By virtue of their abundance and the intermediary role they play between phytoplankton and fish, the zooplankton are considered as the chief index of aquatic life at the next or secondary level of the food chain. The herbivorous zooplankton are efficient grazers of phytoplankton and have often been referred to as living machines transforming plant material into animal tissues. The predominant grazing animals of the sea are the crustaceans that swarm the sea as insects do on land. They constitute the main food items of the pelagic fish species and their larvae.

EXPLOITED RESOURCES

a) **The Exclusive Economic Zone :** one of the most significant events that took place for establishing a new regime of the oceans in the recent past was the declaration of the Exclusive Economic Zone (EEZ) by India within the framework of the Third United Nations Conference on the Law of the Sea (UNCLOS III). This zone extends up to 200 nautical miles (sea miles) from each point of the coast and up to this distance around each island. The total area of the Indian EEZ is approximately 2.02 million sq. km. The EEZ has opened up new ventures for the exploration, exploitation and management of both living and non-living resources.

b) **Food Production by Capture :** During the last five decades, the increase in the capture fisheries was from 0.53 million tonnes in 1950-51 to 2.5 million tonnes in 1994-95, representing an annual growth rate of more than 9% . While the production was increasing steadily up to a level of 1.7million tonnes till 1984-85, it stagnated between 1.5 to 1.7 million tonnes for several years. Subsequently, within a span of 7 years, it showed a revival and the most recent figures of the last tow years show a promising trend. Of the 2.5 million tonnes, fish production by capture in the nineties was 2.2 million tonnes and the rest came by aquaculture. From these figures and from the estimated potential yield of 0-50m depth, it becomes clear that there is hardly any scops for further increase in the production form the coastal belt. The stagnation in marine fish production has led to the need for exploring new grounds and possibilities.

c) **Food Production by Aquaculture :** In India, fish and prawn culture in fresh water environments of Bengal and brackish waters of Kerala is an age-old practice and form the ways a change over seems to occur from capture to culture, using empirical methods, it is

difficult to ascertain where capture ends and culture begins. The potential and scope of cultivable species come under the groups of fishes, crustaceans, mollusks, seaweeds etc. Among the fishes, milkfish, mullets, Tilapia, eels, seabass and several others have a good potential for culture on a large scale. A few of the fishes noted above are being cultured at present. Among the shrimps, a phenomenal expansion has occurred in their culture. This is because of increasing demand of shrimps (prawns) for export and their high price in the world market. The annual growth rate in the global aquaculture production during the last decade has been more than 10% as against 3.2% in capture fisheries. According to FAO statistics for the year 1993, aquaculture accounted for 16% of the total world fish production. In India, the production of shrimps by aquaculture is 80,000 tonnes at an average yield of 700 kg/ha/annum.

d) **Seaweed Production :** Seaweeds, the larger and visible marine plant are one of the important living resources of the oceans. These are found attached to the rocks, corals and other submerged strata in the intertidal and shallow subtidal zones of the sea. About 624 marine algal species have been recorded form the Indian waters with a maximum number from Tamil Nadu. The yield of seaweeds from the Indian coast is only about 70,000 tonnes on a fresh weight basis as compared to the total world seaweed production of about 1821 x 10^4 tonnes (wet weight) annually. Seaweeds are important as food for human beings, feed for animals, fertilizer for plants and a source of chemical and drugs. Products of seaweeds such as agar agar, alginates and carageenans are being used in textiles, pharmaceutical, paper and pulp industries. The yield of seaweeds can be enhanced many times by cultivating them on coir and nylon ropes.

e) **Freshwater Supply :** In terms of population growth, the world supply of freshwater is dwindling very rapidly every year, and therefore, measures are being undertaken to augment drinking water from all sources. Desalination technology is one method to obtain freshwater from seawater. This is done by installing solar stills in isolated areas where there is no power supply. Seawater is brought into a chamber where heat of the sun rays makes the water boil and the vapours are condensed in another chamber as freshwater. There are other expensive methods such as flash distillation and electrodialysis to produce large scale freshwater from seawater. Such technologies are being employed in the Gulf countries. The most widely used desalination technology in India is «reverse osmosis». In this process, suitable osmotic membranes are used which reject salts and allow the water to pass through. Several plants of 50,000 to 100,000 litre capacities have been set up in Indian villages to supply water to the villagers.

f) **Chemicals :** Seawater is 96.5% water and 3.5% salt. Of the 60 or more elements present in seawater, only a few are recovered commercially. Sodium chloride, bromine, magnesium and potassium are being recovered in industrial quantities from seawater. Since ancient times, one of the first large-scale industrial processes attempted by man was the manufacture of common salt from the sea by solar evaporation. The other elements recovered industrially are magnesium compounds, bromine, gypsum and potassium. To extract common salt, four sets of tanks are usually operated in sequence. The operation is designed to give maximum water evaporation, minimum leakage and least contamination by other precipitating compounds. To obtain magnesium metal form the sea water, magnesium hydroxide is first precipitated. This is converted to magnesium chloride which on electrolysis produces magnesium and chlorine. Both bromine and potassium are produced from brine after the common salt is removed by crystallisation and the resultant liquid is known as bittern.

g) **Bioactive Substances :** Of the 500 extracts of marine plants and animals screened so far in India, about 165 were found to be pharmacolcgically active. Perhaps the most significant property observed is the antifertility activity displayed by 4 species of seaweeds, 6 species of sponges, 5 species of soft and hard corals and 1 species of amphineuran mollusk. Other notable activities include antimicrobial, diuretic, nerve-stimulant and depressant, hypotensive, spasmogenic, spasmolytic, analgesic etc. These results obtained raise a promising hope that the seas around India may provide some very important drugs in the future.

h) **Minerals :** Whatever minerals are found on land also found in the seabed because seabed is just an extension of the land with the only difference that this land is covered with water. Heavy minerals called placers occur as black sand in several beach regions on both east and west coasts of India. These contain metals such as ilmenite, zircon, rutile, monazite, garnet etc. Western continental shelf is very promising for the formation of phosphorites (phosphorus deposits). It should be borne in mind that the ocean basin is classified as continental shelf which is a seaward-sloping surface of the continent extending into the ocean-basin called continental margin. Polymetallic nodules (black, potato-shaped lumps) cover a very large area of the sea floor. They carpet the sea floor of the open ocean. The first sample of nodules was collected in January 1981.

i) **Offshore Oil an Natural Gas :** Although the offshore oil and gas (hydrocarbons) come under the category of minerals, because of their importance, these are being described separately. India has mounted a major effort to increase its exploration,

exploitation and development capabilities for the offshore oil and gas during the coming years. This is being achieved by the efforts of several national organisations. The two agencies namely the Oil and Natural Gas Corporation Ltd., (ONGC) and the Oil India Ltd., (OIL) are largely responsible for most of the oil and gas production. The most important offshore oilfields are Bombay High, Bassein Gasfield and Godavari Basin. In 1993, the total oil production in India was 27 million tonnes (Mt) against a demand of 58.7 Mt. In 1995-96, the indigenous production was expected to reach 38.3 Mt mark because of the onset of production from three new Bombay High Oilfields namely Neelam, L-II and L-III and from the Godavari Basin, The latest 1996-97 production figures are 35 Mt. The demand of natural gas is growing faster than that of the oil and it is believed that if the 20th century has been the age of the oil, the 21st century will be the age of natural gas. New reserves of natural gas are being discovered at a very fast rate and at the present rate of depletion, if the reserves of crude oil are going to last for 50 years, those of the natural gas are likely to continue for the entire 21st century.

j) **Energy :** Of the several ingenious methods of obtaining energy from the sea such as tides, ocean thermal energy conversion (OTEC), salinity gradient, biomass conversion, ocean waves etc, the last one (ocean waves) has been found to be most promising for India. For tidal power plants, the Gulf of Kutch and the Gulf of Cambay in Gujarat and the Sundarbans areas in West Bengal, where the tidal range is large, have been found to be promising. Similarly, for the OTEC principle, which is based on the temperature difference in the water column, Tamil Nadu state has been considered suitable for India and it is the only state which has recognized that OTEC could possibly be an ideal substitute for the conventional methods of energy production in India. Power from the waves can be obtained by using the principle of oscillating water column (OWC) in which a chamber is exposed to wave action through an entrance at the side of the chamber. The air inside the chamber is pressurized and expands due to wave action and the air movement through an opening from or into the chamber is utilized to drive an air turbine. A survey of the wave climate along the coastline of India showed that the Kerala coast and the fishing harbor of Vizhinjam has an average wave power potential of 135 kw/m length of the wave crest. The plant was designed and constructed entirely by the Indian scientists and engineers. The average capacity of the power generation of the plant is 150 KW which fluctuates between 20 to 55 KW depending upon the wave climate. During the monsoon period (June to September), when the wave climate is maximum, the power generation reaches almost its full capacity.

SOURCES OF POLLUTION

Much of the pollution existing today in the Indian Ocean, as in all other oceans, originates from land. These include all biodegradable materials such as sewage, petroleum and its products, industrial wastes, pesticides and insecticides, heavy metals such as mercury, cadmium, lead, arsenic etc. The sea has great potential to break down almost all types of wastes by circulation, dilution, wave action and b the activity of microorganisms. However, some types of man-made changes are of much concern. For example, loading the sea with enormous volumes of biodegradable substances in which dissolved oxygen becomes a limiting factor. Sewage from large urban towns man-made materials e.g. polymers and plastic which do not degrade by bacterial activity and remain in the sea for a long time come under this category. Two of the world's largest oil tanker routes originate in the Gulf countries and about 654 Mt of oil are passed through the Arabian Sea. Thus the sources of oil pollution are tanker disasters, ballast water and bilge washings from the oil tankers after the oil has been delivered as cargo. Similarly, out of about 77,000 tonnes of pesticides and 125,000 tonnes of detergents used in India, 20 to 25% of these finally reach the coastal waters. A number of studies have shown that significant quantities of these get deposited as residue in fish, crustaceans and mollusks which through the food chain are transmitted to the human beings. Metal pollution when exceeds an optimum level can become highly dangerous because several metals are extremely toxic and these are transferred though the food chain from seafoods to human beings. Fortunately, metal pollution in the seas around India has not reached alarming limits but the potential threat it poses is enough to merit a dependable monitoring programme.

ENDANGERED ECOSYSTEMS

Of the several ecosystems such as seagrasses, salt marshes, mud-flats etc, two namely the mangroves and coral reefs are very important to mention here.

a) **Mangroves :** Mangroves are a cluster of tropical plants growing along the land-sea interface. They abundantly occur is estuaries and lagoons reaching upstream in the rivers up to a point where the water still has some salinity. They have lush growth along the coastline and around the islands of India and the area covered by them is 3,656 sq. km. Human-induced stresses on the mangroves have been enormous practically throughout the world. There are certain areas of mangroves which have been declared as reserves. Two mangrove areas namely the Sundarbans in West Bengal and on the Andaman Islands are noted for their beauty and greenery.

b) **Coral Reefs :** Coral reefs are unique, spectacular ecosystem of the tropical seas. In India, they are found as fringing reefs in certain areas of our coastline (Gujarat and Tamil Nadu) patch reefs in Maharashtra, Goa and Andhra Pradesh, on the islands (atolls) of Lakshadweep

which are all of coral origin and in the Andaman and Nicobar groups of islands. These have great aesthetic appeal and are sources of tourist attraction for scuba diving and underwater photography. They have large assemblage of plant and animal communities. In the past, large-scale destruction of coral reefs has occurred in India.

SPECIAL PROGRAMMES

Two programmes which began in the early eighties deserve special mention. One is the launching of the first expeditions to Antarctica and the other is the exploration of polymetallic nodules. The First Antarctic Expedition laid the foundation of polar research in the country which was non-existent earlier. As of date,18 expeditions have gone and returned and 19th has already landed. We have built two permanent stations in Antarctica namely «Dakshin Gangotri and Maitri» So far, more than 1200 personnel drawn from 48 organisations have participated in the expeditions. More than 500 publications in national and international journals have come out by the Indian scientists and 5 dissertations leading to Ph.D. degree have been accepted on different disciplines of Antarctic science.

In the second programme of polymetallic nodules, the NIO after surveying more than on million sq. km., demarcated a region of 30,000 sq. km. After several years of exploration on the abundance, grade and potential reserves of nodules in this region, two areas of 150,000 sq. km each were demarcated as «pioneer areas» One of these has been allotted to India by the International Seabed Authority for development and future exploitation.

OCEANS IN THE 21ST CENTURY

In the 21st century, the use of the oceans will be determined on the bases of social, cultural, environmental, recreational, economic, legal, national and international needs. Greater emphasis will be given on long-term «wise use of the ocean» and for the protection of the environment. More and more institutions in the country are likely to introduce curricula on marine science and related subjects at various levels of science educating. New and emerging uses will call for the development of new innovations and supporting technologies. Use of the research vessels will be greatly minimized and the ships will be largely used for the exploration of deep sea and seabed. Routine collection of data, both meteorological and oceanographic, will be undertaken by the data buoys with their direct link with the satellites to transfer data and information to a central agency. Continuous monitoring of the sea coast and its resources will be done by remote sensing, satellite imagery and data buoys. Environmental impact assessment will be required for each new environment -friendly technology under specific local conditions.

Different types of human uses of the ocean such as fishing, shipping, industry, recreation, living space, marine parks and protected areas will require new regulations and fresh administrative structure. There will be increasing pressure on warm water areas of the tropical seas for many activities. This is because these areas are known to have a quick turnover in most sea components. In the 21st century, we hope to use the ocean more wisely and judiciously so that future generations do not pay for our misdeeds.