Coastal Water Quality Index

Chapter 4

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"It is a curious situation that the sea, from which life first arose, should now be threatened by the activities of one form of that life"

Rachel Carson

Introduction

The coastal regions are unique because of their position at the interface of atmosphere, lithosphere and hydrosphere. This interaction creates a wide variety of complex habitats, which host a rich biodiversity, energy and mineral resources. Although coastal ocean covers ~10% of the total area of the ocean, it is estimated[25] that this system provides important ecological and economical services in the form of coastal protection, fisheries and other living and non-living resources. This has made the coastal areas centres of human activity for millennia. It is not by chance that virtually all of the world's major cities are located on coasts and an estimated ~50% of the world's population lives within the coastal regions [26]. The world population is estimated to be 9.8 billion in 2050, and 11.2 billion in 2100 (www.un.org). The increasing human population and rapid boom in industrialization are putting tremendous stress on the coastal systems for their everyday needs. Halpern et al (2008)[27], based on an ecosystem-specific, multi-scale spatial model indicated that no area is unaffected by human and large fractions of the ocean ecosystem (41%) are strongly affected. Consequently, the resources in the coastal ecosystem have become progressively depleted, in some places, to a point of no recovery. Therefore, gradual deterioration of the coast across the globe and the failure to restore the marine ecosystem, even after the cessation of human interference have demanded comprehensive and comprehensible ecological assessment from societal, economic and political heads.

2. India's coastline of about 7500 km spans nine maritime states and five Union Territories including two Island territories. It has 1208 island territories and an Exclusive Economic Zone (EEZ) of 2.2 million sq.km. India has also been allotted by the International

[25] Costanza R, De Groot R, Sutton P, et al. (2014). Changes in the global value of ecosystem services. Glob Environ Change, 26:152–158 (https://www.sciencedirect.com/science/article/abs/pii/S0959378014000685)

[26] Sharpe, M., 2005. The rising tide: combating coastal pollution. J Environ Monit. 7, 401-404

[27] Halpern,B.S,, Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., 2008. A global map of human impact on marine ecosystems. Science. 319, 948–952 (https://www.ncbi.nlm.nih.gov/pubmed/18276889)

Seabed Authority (ISA) an area of 1.5 lakh sq.km in the Indian Ocean for exploitation of seabed resources. India also has established interests in Antarctica.

3. Fishing is a major economic activity undertaken by India in the seas around it. 2.5 lakh vessels of various kinds are deployed on fishing activities, employing nearly 15 million people directly or indirectly. In addition to providing staple food to millions across the country, it also earns foreign exchange close to $6 billion. India is also prospecting for oil and natural gas in its EEZ. Nearly 20 percent of petroleum needs of India are extracted off shore. India has also been prospecting for oil in far flung corners of the world, extending her maritime interests beyond Indian Ocean into the Pacific and Atlantic regions. Like other countries, as resources on land reduce and with improvement of technology, India too will be looking to exploit its EEZ and the area allocated by ISA for poly-metallic nodules and other resources.

4. Bulk of India's trade is through sea and amounts to 90 percent of trade by volume and 70 percent by value. India has 12 major and 205 notified minor and intermediate ports. Under the National Perspective Plan for Sagarmala, six new mega ports will be developed in the country. The average throughput across the ports of India was about 100 million tonnes per month. A major part of the imports is crude oil and LNG, to meet energy needs of the nation. As the Indian economy and industry grows further, its energy needs would also grow. Indian shipping, ports and supporting industries would therefore play a pivotal role in India's future economic growth. But the downside is the pollution from the ships. The main sources of pollution from ships are:

- Oily-water discharge from ships.
- Tanker accidents.
- Garbage and Other Solid waste.
- Wastewater discharged from ships.
- Accidental spillage during terminal loading.
- Ballast-water discharged from ships at ports.
- Marine Machinery Exhaust.
- Anti-fouling Paints.
- Sound pollution

5. Each of these have a negative effect on one or the other component of the marine ecosystem. While the wastewater discharged from the ships can damage ecosystems, create algal blooms and pose significant human health risks, the garbage and other solid waste may become marine debris, and can then pose a threat to marine organisms, humans, coastal communities, and industries that utilize marine waters. Exhaust emissions from ships are considered to be a significant source of air pollution. The noise produced by ships can travel long distances, and marine species that may rely on sound for their orientation, communication, and feeding, can be harmed by this sound pollution. In fact, the Convention on the Conservation of Migratory Species has identified ocean noise as a potential threat to marine life.

6. The Indian subcontinent with its natural gradient in environmental features, complex oceanography (biannual reversal of surface currents) and unique geological history creates, a number of complex habitats, supporting a diverse biodiversity. Among various types of marine ecosystems in India, tidal mudflats, mangroves, estuaries, lagoons, beaches, marshes, vegetated wetlands and coral reefs have a major share. A total of 97 major estuaries, 34 major lagoons, 31 mangrove areas and 5 coral reefs have been mapped and identified in India for conservation and sustainable use. There are a total of 31 Marine Protected Areas (MPAs) in India, primarily in the marine environment, which cover a total area of 6271.2 km^2 with an average size of 202.1 km^2. East coast and Andaman and Nicobar Islands have adequate areas in the MPAs whereas the west coast and Lakshadweep Islands have poor representation. Also, another 100 PAs (10 in main Indian coast and 90 island PAs in Andaman and Nicobar) have terrestrial or fresh water ecosystems which constitute boundaries with seawater or partially contain marine environment.

7. The conservation of the marine ecosystems is largely linked to coastal zone management activities. However, like most coastal regions of the world, coastal areas of India are densely populated and ~30% of its human population is dependent on the rich exploitable coastal and marine resources. Further, three of the four megacities (Mumbai, Chennai and Kolkata) of India are located along the coast. With urbanisation on the rise, the coastal waters in India, apart from being affected by shipping, are getting heavily polluted also due to disposal of sewage, industrial wastes and agricultural runoff. During 2015, the estimated sewage generated from domestic sources was about 61,754 Million Litres per Day (MLD), of which 38,791 MLD (62%) of untreated sewage is released into the aquatic system (CPCB, 2016)[28]. There are about 490 large and medium scale industries located along the coast in addition to numerous small scale industries. It is estimated that

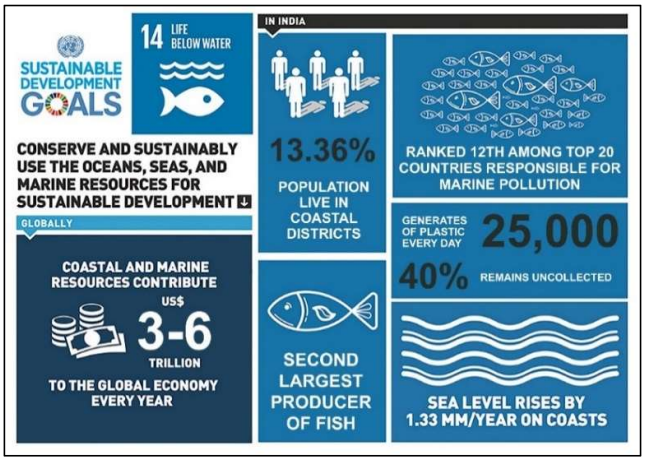
[28] CPCB 2016: CPCB Bulletin, Vol- I, July 2016. Central Pollution Control Board, Ministry of Environment and Forests, Govt. of India, Delhi, India. Available at: https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS9MYXRlc3RfMTIzX1NVTU1BUllfQk9PS19GUy5wZGY=

about 390 million tonnes of industrial effluents are annually discharged into the coastal waters[29] either directly or through the rivers. Moreover, the use of fertilizers and pesticides to enhance agricultural productivity appears to be increasing every year a fraction of which is ultimately washed into the coastal regions through runoff. Aquaculture, tourism and disposal of wastes from fishing trawlers and small ships are other sources of pollutants to the coastal system, all of which are adding to the stress on these ecologically sensitive and economically important ecosystems.

8. Waste management strategies seem to have failed to keep pace with the rapid urbanization and industrial growth along the coast. Though the sea has capacity to assimilate and degrade several pollutants arising from land-based sources, often even at low concentrations the pollutants accumulate in marine organisms. Over a period of time, depending on the nature of organism, it reaches to toxic levels in the organisms leading to their mortality. When the levels of pollutants reach beyond the assimilative capacity of the sea, the quality of the seawater reaches to the level of degradation when the entire biodiversity reaches to alarmingly low levels and fish production declines drastically. Monitoring the health of coastal waters is, therefore, highly essential to assess the status of pollution, to detect spatial or temporal changes of pollutant levels and to alert the planners and policy makers on levels of marine pollution.

Marine Ecosystems for Sustainable Development

9. The worsening of marine ecosystem is, in fact, rendering considerable economic loss and warrants serious attention of all – policymakers, administrators, scientists and people – towards properly managing the marine ecosystem. The issues related to the marine ecosystem are neither confined to any country or continent nor is it limited to the developing or the developed world. Therefore, the United Nations and other global institutions have been paying attention towards this problem since decades. United Nations has initiated several measures to coordinate the development of environmental policy by keeping the global environment under review and bringing emerging issues to the attention of the governments and the international communities for action. In this context, when the UN General Assembly in its 70th Session adopted an agenda, "Transforming the World: 2030 Agenda for Sustainable Development", one of the 17 goals, SDG 14, was



[29]C.P.R. Environmental Education Centre (http://cpreec.org/pubbook-costal.htm)

exclusively assigned to marine ecosystems. SDG 14 aims "to conserve and sustainably use the oceans, seas and marine resources for sustainable development". The deterioration of coastal waters has become a global occurrence, due to pollution and coastal eutrophication (overflow of nutrients in water), where similar contributing factors to climate change can affect oceans and negatively impact marine biodiversity. Effective strategies to mitigate adverse effects of increased ocean acidification are, therefore, needed to advance the sustainable use of oceans.

Need for Marine Water Quality Indices

10. To assess the impact of various anthropogenic activities and natural processes on the coastal ecosystem, it is necessary to monitor long-trends along the coastal waters for important environmental and biological parameters. Therefore, countries are regularly monitoring and assessing the quality of coastal waters. Such monitoring programmes generate large datasets for several coastal variables. Success of such monitoring programmes depends on the transfer of knowledge gathered or generated to the policy makers, non-technical water managers and the public in an easily understood format. This will allow them to take decisions on sound scientific basis. However, the task of simplifying the enormous abiotic and biotic data is not straightforward. The concept of a Water Quality Index (WQI) offers a useful framework to transform complex datasets into a compact form that can facilitate monitoring the health of the coastal waters and also aid in designing specific pollution prevention programs. Further, it allows determining whether goals such as compliance with pollution regulations or implementation of effective pollution control actions are being met.

Index for coastal waters in India

11. India has national and international obligations to prevent adverse effects to marine ecosystems caused by various anthropogenic activities. To help monitor long-trends along the coastal waters of the country, the Ministry of Earth Sciences (MoES), formerly the Department of Ocean Development (DOD) has been implementing a nationally co-ordinated research programme on, 'Coastal Ocean Monitoring and Prediction System (COMAPS)' since 1990. Under this programme, long term data was being collected at regular intervals using consistent methods that could be used to generate valuable knowledge about the ecosystem processes and could help environmental managers develop effective management plans. In 2010, review of the programme by an expert panel resulted in restricting the number of monitoring locations from 81 to 24. Further, COMAPS programme has been renamed as "Seawater Quality Monitoring (SWQM)". The primary objective of SWQM programme is systematic monitoring of seawater quality along Indian

coast at selected locations, identified based on the sources of marine pollutants. To achieve this objective, the National Centre for Coastal Research (NCCR) coordinates the monitoring activities with the participation of National institutes and academia. Under the programme – COMAPS/ SWQM - data on more than 25 parameters on physico-chemical, biological and microbiological characteristics of seawater and sediment are being seasonally collected and analysed using standard protocols. Water (surface, mid-depth and bottom) and sediment samples are being collected in each location at 0/0.5 km (shore), 2/3 km (nearshore) and 5 km (offshore) distance from the shore.

12. Coastal monitoring programme developed indices using several parameters based on the following categories[30]:

Category I: degree of nutrient enrichment;
Category II: direct effects of nutrient enrichment; and
Category III: indirect effects of nutrient enrichment

Developing a simple water quality index requires selecting one or two parameters from each category as indicators. Globally, Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorus (DIP) are the potential parameters identified for the assessment of eutrophication from Category I, surface Chlorophyll-a (Chl-a) as an indicator from Category II as it reflects the immediate response for enrichment of nutrients and bottom DO as an indicator from Category III because it is a critical parameter for sustenance of ecosystem diversity[31,30]. In the Indian context, disposal of sewage is the major threat to the coastal waters. The major fraction of sewage in India is released untreated or with minimal treatment (CPCB 2016)[28], consequently bringing enormous loads of organic matter along with pathogenic microbial population to the coastal waters. In the recent years, organic forms of nutrients were found to contribute more than 70% of total nutrient pools in the coastal waters. Hence, pollution monitoring programmes in India provide wider attention to total or organic form of nutrients rather than the inorganic forms i.e. DIN & DIP.

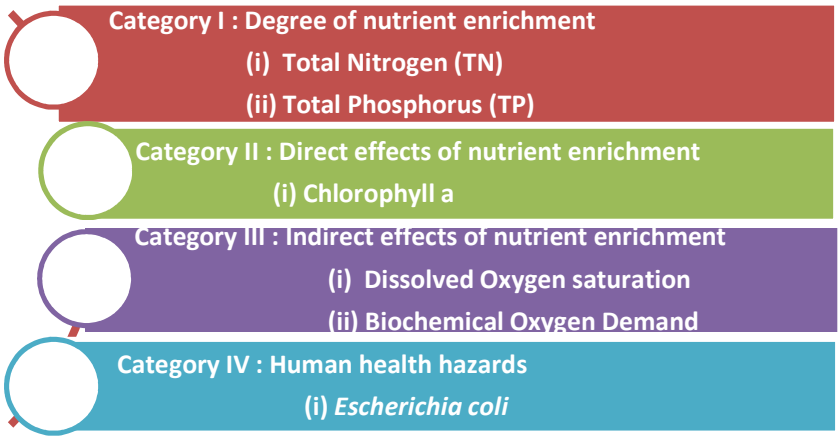
13. An index developed for the Indian coastal waters without considering total nitrogen (TN), total phosphorus (TP) and bacterial loads (in particular faecal coliforms) would be an underestimation of the water quality. For this reason, along with the above listed categories, faecal coliforms were considered as an indicator under Category IV:

[30] US EPA, NCCR, 2012. National Coastal Condition Report IV 334. doi:EPA-620/R-01/005

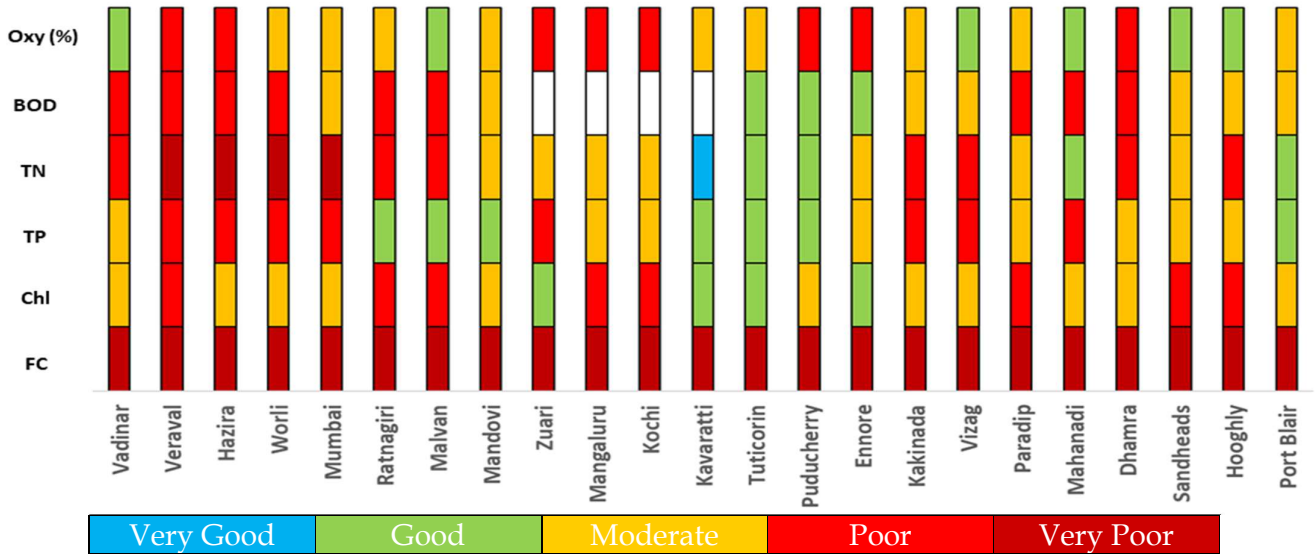
[31] OSPAR Procedure, 2005. Synergies between the OSPAR Comprehensive Procedure, the integrated set of OSPAR Ecological Quality Objectives (EcoQOs) for eutrophication and the EC Water Framework Directive OSPAR Commission

Human health hazards to the index calculation. **Figure 4.1** gives the parameters used by NCCR[32] for compiling water quality indices for the sites.

Figure 4.1. Parameters considered for calculating WQI



Based on threshold value, **Figure 4.2** below gives the grades of the different indicators at different monitoring locations.



14. The quality or accuracy of any WQI method relies on the definition of thresholds for selected indicators. Thus, the establishment of thresholds for each indicator should be robust and logical. For compiling the WQI for seawater, NCCR has adopted the methodologies of Integration and Application Network, Center for Environmental Science, University of Maryland used for the development of Eco Health Report Cards[33]. The main objective for deriving the WQI using the SWQM data was to find out the spatial extent of anthropogenic impacts (i.e. sewage and domestic discharges) on the coastal water

[32] Seawater Quality at Selected Locations along Indian Coast – Status Report (1990-2015), Ministry of Earth Sciences, Government of India

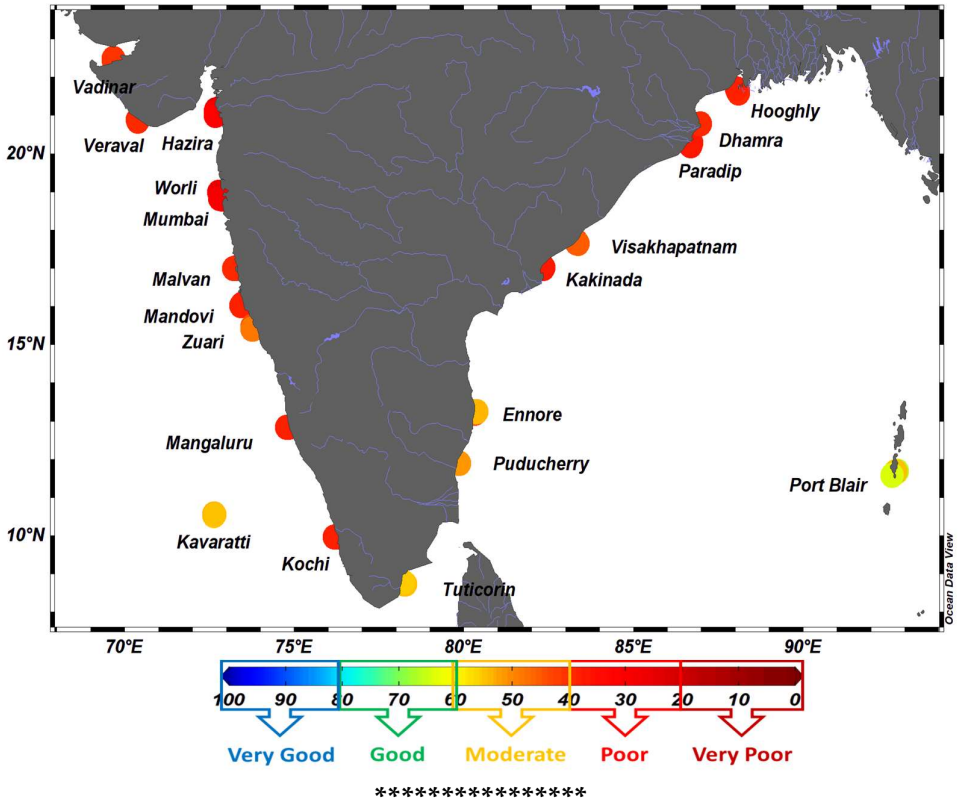
[33] Eco Health Report Cards (https://ecoreportcard.org/)

quality, hence SWQM/COMAPS dataset of all the stations (ranging from hotspots, 0.5 km, 2.0 km & 5.0 km) from each monitoring location collected during the recent years (2011-2015) were considered to derive thresholds for each indicator. Multiple thresholds were used to score indicators based on a gradient of healthy to unhealthy conditions by diving the data in equal percentiles. Cumulative scores for each parameter were converted to 0-100% grading scale and reported as WQI.

15. In respect of the aggregate index, WQI at Vadinar, Veraval, Hazira, Worli, Mumbai, Malvan, Mangaluru and Kochi along west coast; Kakinada, Paradip and Dhamra along the east coast obtained 'Poor' status. Stations viz. Zuari, Tuticorin, Puducherry, Ennore were found to be in 'Moderate' condition. In general, based on the WQI, 11 out of 21 locations were found to be in 'Poor' condition, and the remaining locations were in 'Moderate' condition. Locations at Port Blair and Kavaratti were found to be in 'Moderate' and 'Good' condition.

16. WQI were developed for each station and five years' average index for each station were used for the preparation of location wise WQI maps **(Figure 4.3)**.

Figure 4.3. Water Quality Index map for the period 2011-2015



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