Marine Environmental Quality Assessments and Monitoring

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The marine environment refers to an environment where thewater bodiessuch as oceans, seas, bays, estuaries and others interface and intermingle, both way with the atmosphere and lithosphere, and also towards the sea from the mean high-tide mark and vice versa. The marine environmentis resultant of the physical, chemical, geological, biological and genetic factors contributing towards it.It also includes the various stages of associations, and featuresthatinterrelate and decide the productivity, status, and value of the marine ecosystem, the natural balance of the great bio-network.

Evaluating the environmental quality, by scrutinizing the disturbances in theecosystems, plus the reciprocations of its manifold constituents to different stresses and forces, is the means as well as the challenging need for the preparation and execution of appropriatemanaging strategies, restoration protocols, and conservation measures and practices. Hence, environmental monitoring becomes anintegral part of the environmental quality assessment.

The significance of water, sediment, and biota of the marine environment needspreservationin order thatthe environmental values are safeguarded. Environmental valuespoint towardsthe beneficial uses or the strength of an ecosystem. Beneficial uses are the usefulness of the environment beinggood for the communitygains, security, wellbeing, or aesthetic satisfaction. Ecosystem wellbeing is the natural healthy state of the environment itself and is evaluated in terms of the ecological constitution, utility, or ecosystem processes. Theecologicalstandards can be influenced by emissions/discharges and degeneration of the environment, or loss or damage of the natural habitats.

In this chapter, the focus is given totwo of the important constituents of the marine environment *viz.* the coastal and marine waters and sediment. The expression 'environmental quality' pertains to the extent of contents in water, sediment, or biota or changes in the physical/chemical characteristics of water and sediment compared to its natural state. The strength of comprehension of normal situations in the locality of a development / responsible activity proposal, and the sensitivity/adaptability of prevailing biota to the stresses exerted by the development, will powerfullyimpact the extent of assurance of success in the formulation of the environmental quality criteria and forecast of the environmental outcomes. This can be achieved by means of an environmental impact assessment (EIA) procedure.

The water and sediment quality of the marine environment is alsonaturally influenced by the biotic and abiotic factors of the ecological system. Various ecological variables can be used as key indices for the appraisal of water and sediment quality of the marine environment.The integrated monitoring and measurement of the selected indicators will bring light to the current status of the health of the concerned ecosystem. Continuous/periodical monitoring of the marine environment is essential for their quality assessment and maintenance.

In the traditional method of marine and coastal environmental monitoring, representative sampling sites are selected based on a statistical design to suit the data analysis. Water and sediment samples are collected from these sites using approved protocols. In addition, there are contemporarymeans that canexamine and estimate the environmental quality, pinpointingon biotic or abiotic parts, or both.When biotic components are incorporated in the evaluation and observation to judge the environmental quality, the aids used can varyfrom the individuals to the ecosystem, amid the ecological levels. Typical biological sensitivitycan also be gauged utilizing ecotoxicologcalmethodology, observation of physiological and behavioural responses in this regard. Whatever is the method of monitoring the environment, field-level sampling forms the first step in the assessment of the quality of the environment by quantifying selected indicator variables.

Water qualitywith reference to marine fisheries and mariculture
Water sampling

There should be no contamination during sampling and all the samples are properly sub-sampled and preserved to avoid/minimize changes in the water quality during storage. Niskin bottle sampler is used for collecting water samples from specific depths.

Fig 1 Niskin bottle sampler

Before sampling, the sampler and sampling bottles should beacid washed with 1N HCl in the laboratoryand washed twice with clean water. They should be rinsed with distilled water. Care should also be taken to avoid the sewage flush out fromthe boats/ships at the time of sampling.Proper sampling is of utmost importance. Take adequate number of samples to have representativesampling of the water body. Sampling should be contamination free to evadeinvalid results on analysis. Samples should be appropriately sub-sampled for the differenttypes of analyses as per researchable issue.

Toavoid/minimize changes in the water composition duringstorage,standard preservation methods are to be adopted. The collected samples are to be kept in ice box in the field and under refrigeration in the laboratory till analysis. Sample holding duration under preservation varies with analytical variables. The processing protocol should be meticulouslyfollowed for individual samples. For dissolved oxygen (DO), thesamples must be fixed immediately using Winkler's reagent onboard vessel itself. Samples for analysis of dissolved gases, pH and alkalinity must avoidatmospheric contamination during sampling and subsampling.

Factors affecting the water quality
Temperature:
Water temperature is vital for the growth, reproduction, and overall healthof fishconcerned. Atmospheric temperature affects water temperature and density. The water temperature fluctuations can cause strain and disease in fish, leading to augmentedmortality and lesser growth rates. Tropical fishes have a preferenceof 25 -32°C. On the other hand, temperatefishesfavour 10 - 15°C.Extreme temperatures can cause mortality.
There is depth-wise variability in water temperature. Unless there is a mixing of pelagic and benthic region, by wind or any other means, there can be thermal stratification in the ocean, withdepth-wise decrease in temperature, especially in summer.Ocean temperature is useful for determining the location and variability of ocean currents and eddies, areas of upwelling where nutrients and ocean productivity may be abundant, atmospheric convection, determining heat exchange between the ocean and atmosphere as well and as an indicator of long-term climate change.

pH:
Optimal pH levels in coastal and marine waters help in avoiding stress and disease in fish and forbetter production. Fish are responsive to changes in pH.Photosynthesis (removal of CO_2) increases the pH, whereas addition of CO_2(by respiration or dissolution of atmospheric CO_2 in seawater) decreases the pH.The pH change can affect growth,reproduction, and overall health of fish and shell fish. The recommended pH range is 6.5 to 8.5. Variation fromthis range can cause stress and disease in fish.

Total alkalinity:
Total alkalinity quantifies the neutralization ability of water when there is an introduction of a strong acid into the water. The presence of salts of sodium, potassium, calcium and magnesiumcontaining ions of carbonates, bicarbonates, as well as hydroxidesin the water is usuallythe source oftotal alkanityin a water body. Total alkalinity below 20 ppm is considered as its critical for natural waters, the optimum range being 80-120 ppm.

The measurement of total alkalinity in an aquatic system is done by titration of its representative water samples withHCl or H_2SO_4 ie.,a strong acid. The titration is to be done in two consequent events in the same Erlenmeyer flask, keeping a white background underneath to

detect colour change easily. In the initial phase, use phenolphthaleinindicator to pH 8.3. In the second phase, addmethyl orange as indicator and titrate with further drops of acid to pH 4.2.The volume of acid used under each titration is quantified in terms of $CaCO_3$ equivalent value and the sum of the two together being the total alkalinity. The unit of total alkalinity is milligrams per liter of calcium carbonate (mgl^{-1} $CaCO_3$).

Salinity:
Salinity is the total concentration of all ions in aknown quantity of water. Salinity is an important attribute of natural waters that decides what species of aquatic animals are present in that water body. The changes in salinity affect the growth and survival of the concerned species.

Dissolved oxygen:
The aquatic organisms require oxygen to respire, and dissolved oxygen (DO) is a very important waterquality parameter in the marine environment. The ideal DO range for most fish species is 5 - 7 $mg1^{-1}$. Low DO canbring about stress, disease, and mortality in fish. Maintaining optimal DO levels is indispensable for thesurvival and growth of fish.

Dissolved carbon dioxide:
The concentration of carbon dioxide (CO_2) increases when respiration exceeds photosynthesis. Saturation of CO_2 occurs during early morning. When CO_2 enters fish blood it lowers the blood pH and reduces the ability of a fish's blood to transport oxygen. Favourable range of CO_2 concentration in water is < 5 mgl^{-1}.

Oxidation Reduction Potentialor Eh:
Oxidation reduction potential (ORP) is a measure of the proportion of oxidized to reduced substances in water. It is measured with respect to Hydrogen electrode(Eh). Eh range of natural waters 0.45 – 0.52 V. Appearance of Fe^{++} ion at 0.2 V coincides with depletion of oxygen in water. Below 0.2V, thetransformation of sulphate to sulphide occurs.

Nitrogenous compounds:
Nitrogenous compounds, such as ammonia-N, nitrate-Nand nitrite-N cause major water quality problems in marine environment and aquaculture. Toxicity with total ammonia-N (TAN) is very significant, with toxic levels causingmortality and reduced growth rates in fish. High levels of Total ammonia-N, nitrite-N, and nitrate-N can be toxic to fish and other aquatic organisms. The concentrationsgreater than 0.1 mg l^{-1} for TAN, 0.5 mg l^{-1} for nitrite-N and 100mg l^{-1} for nitrate-N are toxic.

Total Suspended Solids (TSS) and Turbidity:
High levels of total suspended solids and turbidity in the coastal and marine environment can reduce light penetration, affectingthe growth of aquatic plants and algae (essential energy sources in the aquatic food chain). High levels oftotal suspended solids (> 100 $mg1^{-1}$) can cause a reduction in growth rates and a rise in fish mortality.

Marine Sediment
Marine sediment isany deposit of insoluble particle, mainly rock and soil constituents, carried over from land region to the ocean by wind, ice, and rivers, plus the remains of marine organisms, submarine volcanismproducts,chemical precipitates from seawater, and matter from outer space that accumulate on the seafloor. All areas of the seafloor hold some form of sediment. There are different types of sediments from diverse sources, and the quantity of accrued sediment varies from place to place.

Sediment sampling
Sediment can be sampled using a grab. Usually Van Veen grab is used for this purpose. Van Veen grab having a sampling area of 0.1 $m^2$is a standard device for sediment sampling. This is aproficientsoft sediment sampler which can be used for a variety of sediments occurring in the coastal near shore as well as the marine areas. It is consistent and easy to runand it has broad-spreadrelevance, so that data comparisonof other regionsis possible.

Fig 2. A Van Veen grab

Sample should be representative of the area sampled. Collect at least four replication samples from a station. Pool these replicate samples in a wide basin. The pooled sediment is mixed meticulously. Then quartering is done, taking away the opposite quarters as shown below.

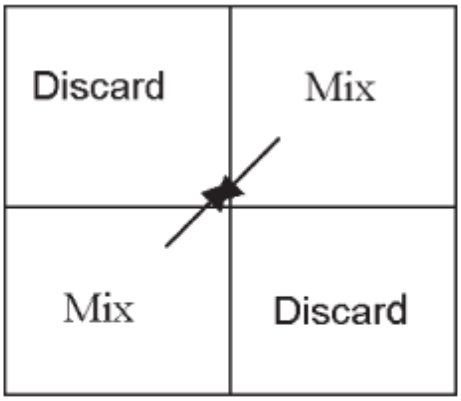

Fig 3Quartering of sediment sample

Quartering is done till a substantial quantity i.e.,around 500 g sediment is obtained. Collect in heavydutyplastic bags with self sealing facility.

Sediment processing

Do not store the sediment in wet condition for more than oneday. Wet samples should be kept under refrigerationif storage is needed in the wet stage for more thanone day. Then air-dry the sediment in shade in wellventilatedplaces. To reduce drying time, oven dryingcan be done at 50-60°C. (Temperature should not beincreased above 60°C since it will cause loss ofnutrients). Then pulverize the sediment gently bybreaking clods using a pestle and mortar. (Do not over grind the sediment so as to break the sand particles, which will cause errors in textural analysis). Thensediment samples can be stored in well-labelled,capped plastic bottles or heavy-duty plastic bags. Atthis stage, the sample is ready for analysis. While storing, storein a dry place.

Sediment Quality

The physical and chemical characteristics of water are influenced by the characteristics of bottom sediments. The bottom sediments provide food and shelter for the benthic organisms and also act as a reservoir of nutrients for the growth of benthic algae which constitute food for aquatic organisms. The sediment also functions as a buffer and governs the storage and release of nutrients into the water. It serves as a biological filter through the adsorption of organic residues of food, excretory products and algal metabolites. The sediment holds high bacterial load which helps in decomposition and mineralization of organic deposits at the bottom. The nature and decomposition of sediment have important roles on the balance of coastal ecosystems and also in the inorganic and organic nutrients present in the coastal and marine water.

Factors affecting sediment quality

Sediment texture:

Sediment texture is the relative proportion of size of the mineral particles (sand, silt and clay). Sediment of sandy loam to silty clay texture is fairly good in productivity on aquaculture point of view.

Sediment pH:

Weak alkaline soil reaction (pH 7-8) had been found to be good forgoodfish productivity. Culture systems with acidic soils are generally less productive than with alkaline soils.

Organic Carbon:

Organic carbon is the most important factor determining the fertility status of soil/sediment. Organic carbon content originates in sediment due to the presence of organic matter. Organic matter contains 58% carbon. The soil organic matter binds soil particles which help the soil to maintain favourable conditions to facilitate aeration and permeability. It increases the water-holding capacity of soil and serves as a reservoir of the chemical elements that are essential for aquatic productivity. It helps in reducing soil alkalinity and acts as a buffer against rapid changes in pH. It serves as a source of energy for the growth of benthic microorganisms and helps in dissolving minerals to be absorbed by the growing plants. Biogeochemical processes undergoing in the bottom sediments tend to release nutrients into the water aboveby bacterial action on the sediments. Organic cycling in shallow brackish water systems is governed by the rate of conversion of living tissues into detritus and secondarily the rate of conversion of detritus into dissolved organic and inorganic forms of nutrients of which the former is faster. Secondary levels results in accumulation of organic detritus at the bottom.

Sediment colour:

Sediments exhibit a wide range of colour and when covered long enough with water they often develop darker shades of the original colours. A brown crust at the soil-water interface is a good sign, since it indicates that there is dissolved oxygen at the interface. A jet blackcolour at the sediment-water interface is undesirable since it reveals the absence of dissolved oxygen. When dissolved oxygen is depleted in the surface layer, compounds of ferrous iron form to produce black colour. In most pond bottoms, a jet black layer will occur a few centimetresbelow the sediment surface. Hydrogen sulphide is produced only in highly reduced black mud, but not all black mudis sufficiently reduced to produce H_2S.Sometimes reddish precipitates can be seen

on the bottom in shallow waters. This is more common in acidic systems with acid sulphate soils. Positive correlation is seen between fish production and organic carbon and it is found that 1.5% to 2.5% of organic carbon in sediment showed high fish production potential.

Conclusion

Good water quality is a key factor for sustaining fisheries healthy and productive in aquaculture operations.Factors such as temperature, pH, dissolved oxygen, nitrogenous compounds, total suspended solids*etc.* can affect water quality and fish health. Regular monitoring of these factors is necessary for the management of the environmental situations. The participatory approach in environmental management is very relevant in thepresent level culture systems. For 'environment management', we don't directly 'manage the environment'.It is human behaviour and actions that have an impact on the environment are to be altered with citizenco-operation to achieve environmental sustainability for economic productivity.

Based on thorough assessment of marine / coastal environmental quality, by way of continuous /periodical monitoring, water quality indices or ecosystem health indices can be derived from the generated dataset during the process, reflecting the current status of the environment. These indices can result in the formation of guidelines / policy suggestions to manage the environmental situation positively.

The Driver-Pressure-State-Impact-Response (DPSIR) methodrefers to asupplestructureuseful for decision-makers in relating human activities with the state of the environment (Fig 4). Drivers mean the growth in terms ofpopulation and socio-economic statusin societies and the resultant altered lifestyles, patterns of consumption, and outlines of production. Drivers get reflected in anthropogenic actions which may knowingly or unknowinglyforce the environment to bear Pressures. Alterations in the State of the environment may be brought about by the pressures put forth by the community. The State is the situation of the biotic and abiotic constituents of the environment in a selected ecosystemexpressed as the physical, chemical, and biological variables unique for that ecosystem. Changes in the features and performance of the environmentwill influence the services provided by the selected ecosystem andthe wellbeing of the peopledependent therein.

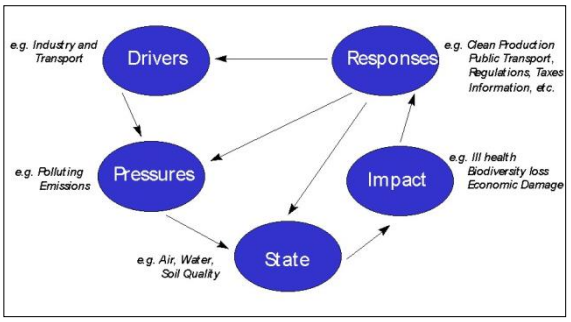

Fig 4 The DPSIR Framework

Ecosystem goods and/or services denote ecosystem functions/processes that openly or circuitouslyhelppeople in their societal/fiscal drivers, or hold the future potential to do so. In Response to the consequences on the services provided by the selected ecosystem or their seeming values, decisions are taken by the environmental managers. These responses includesole or group action plans formulatedbypeople and the government to avoid, recompense, restructure, or acclimatize to alterations in the status of the environment. Appropriateevaluation and observationplansfor the environmental status at the ecosystem planeneeds a deepunderstandingregarding the services delivered by the ecosystem selected forscrutiny, as well as a detection of its significancespanning the manifold dimensions (e.g., environmental, societal, cultural and fiscal).

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