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RELEVANCE OF SEAWATER AND SEDIMENT QUALITY ASSESSMENT

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Introduction

Water is the medium of any aquatic ecosystem, and so is for the sea also. Worldwide studies on seawater and sediment quality continue escalating day by day. Sea is the foundation of life on Earth, the assurance of our brighter living ahead.

Availability of clean seawater in the coastal regions, decline gradually with growing urbanization, speedy industrial advancements and climate change. Furthermore, contaminated seawater will adversely impact the environment and in turn human health. This is true with regard to our coastal ecosystems, globally.

Our ocean being our inheritance and we must safely handover this heritage to our forthcoming generations. For this commitment, seawater quality should be monitored and appraised along with the bottom sediment, and necessary measures should be taken for the marine environmental protection and conservation. It is important to assess seawater quality to ensure that it is harmless for marine life as well as for humans to come into contact. Also, it is appropriate to measure water quality to understand the environmental impacts which are harmful for the marine ecosystems. The fall of water and sediment quality in aquatic ecosystems has become a universal issue, and systematic monitoring and protection of water resources have become relevant vital topics.

Seawater Quality

Water quality comprises of all physical, chemical, and biological features that impact the valuable use of water. Any characteristic of seawater that leads to survival, growth, reproduction and proliferation of any valuable marine species, which touches the management choices and / or triggers environmental impacts, or reduces quality and safety of the produce can be considered as a water quality variable. The aim of water quality monitoring is to quantify the selected physical, chemical, and biological characteristics of water *via* statistically designed sampling. The data requirement is subject to the objectives of the monitoring survey. There are various ecological indicators which can proxy the physical, chemical, and biological characteristics of seawater sought after. The indicator selection also is need-based as per our objective of the study and type of required information. These indicators should have practical value and usefulness, i.e., they should have easiness for comprehension and be applicable both to managers and scientists with different educational backgrounds.

Other issues being alike, the marine life will be healthier, production will be more efficient, environmental impacts less, and product quality will be better in ecosystems with "good" water quality than in those with "poor" water quality. Information on water quality principles will help managers decide the potential of a body of water to produce the target species, to maintain or to improve water quality in the systems of consideration. Good water quality will minimize problems of fish stress and fish health, produce higher-quality fishery or cultured aquatic animal, reduce the environmental impacts, and realize more efficient production systems of greater profit as well as sustainability. Water quality does not become a key issue unless under intensive production systems or in embanked ecosystems where water flow is restricted or in seawater where anthropogenic pressures are high.

Information on the status of water quality is indispensable while making water quality management options. Although some general ideas about water quality can be obtained from visual observations, a much clear picture can be obtained from chemical and physical measurements. In order to properly sample, analyze, and interpret we need to have a general idea of water quality dynamics. As a general rule, you should only measure those variables that are important to your project /scheme /venture, that can be interpreted, and that can be altered through management interventions. Water analysis data information should be put into a beneficial use. Never measuring water quality, can lead to often highly inefficient management in critical situations. Hence there should be periodical monitoring of major water quality variables of importance, mostly applicable to Mariculture.

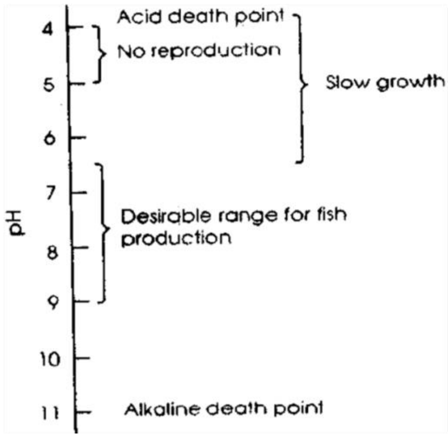
Major water quality variables and their dynamics

i. Temperature

- Water temperature is crucial for the growth, reproduction, and overall health of marine organisms. Change in atmospheric temperature affects water temperature and density. Warm water species prefer 25 -32°C.
- Water temperature affects chemical and biological processes marine life. The rate of chemical and biological reactions double with very 10°C rise in temperature. Hence the dissolved oxygen requirements of aquatic life are critical with temperature change. Extreme temperature changes lead to death.
- Fish and Crustaceans have poor tolerance to sudden change in temperature and they should not be removed from one water to another of substantially higher or lower temperature.
- Since the density of water decreases with increasing temperature above 4ºC, surface water can be so warm and light so that they do not mix with heavier deeper layers, causing depth-wise variability in water temperature. If there is no mixing of pelagic and benthic region, by wind or any other means, there can be thermal stratification in the ocean 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 plentiful, atmospheric convection, determining heat exchange between the ocean and atmosphere as well and as an indicator of long-term climate change.

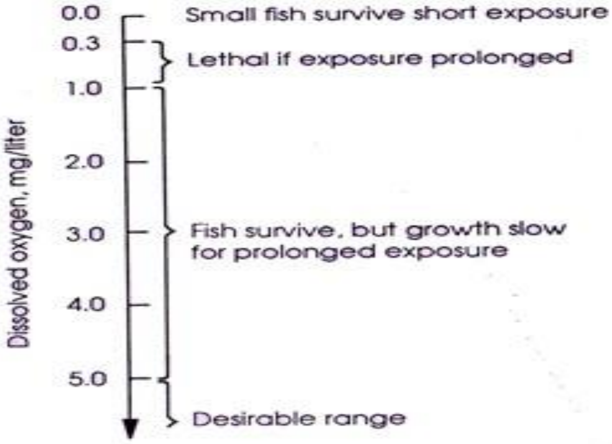
ii. pH

- The pH being the negative logarithm of the hydrogen ion (H^+) concentration, it indicates how acidic or basic a water is.
- Ideal pH levels in coastal and marine waters help in avoiding stress and disease in fish and other organisms for better production. Fish and Crustaceans are responsive to changes in pH.
- A pH of 7 is regarded as neutral. The lower the pH below 7, the more acidic the water is. The higher the pH above 7, the more basic or alkaline it is.
- Photosynthesis (removal of CO_2) increases the pH, while addition of CO_2 (by respiration or dissolution of atmospheric CO_2 in seawater) reduces 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 from this range can cause stress and disease in them. The acid and alkaline death points for fish and crustaceans are approximately pH 4 and pH 11 respectively, as shown below.



iii. Dissolved oxygen (DO)

- The aquatic organisms need oxygen to respire, and dissolved oxygen (DO) is a very important water quality parameter in the marine environment. The dissolved oxygen concentration being too low or too high can damage aquatic life and affect water quality.
- Free oxygen (O_2), is oxygen that is not bound as a compound. Dissolved oxygen is this free gaseous oxygen (O_2) dissolved in the water and remain within water.
- In a water body, the source of DO is mainly the atmospheric diffusion and photosynthetic activity. When photosynthesis exceeds respiration DO is more.
- The solubility of oxygen decreases with increased temperature and salinity. As depth increases DO will decrease.
- In shrimp farming, dissolved oxygen levels at the bottom is important, since shrimp spend a lot of time at the pond bottom.
- The ideal DO range for most fish species is 5 - 7 $mg1^{-1}$. Low DO can bring about stress, disease, and mortality in fish. Maintaining optimal DO levels is indispensable for the survival and growth of fish.



- During the daytime the aquatic plants including the phytoplankton produce oxygen by photosynthesis and hence levels of dissolved oxygen exhibit a diurnal cycle in aquatic ecosystems. The least concentrations of dissolved oxygen befall about dawn.
- During daylight, photosynthesis increase DO concentrations reaching the maximum in the afternoon. During the night, there is no photosynthesis but oxygen consumption is there by respiration.
- Cloudy weather can influence dissolved oxygen levels as photosynthesis is less that time due to partial blocking of sunlight.

- A phytoplankton bloom can reduce the DO level as the oxygen demand will be increased.
- Death and decomposition of phytoplankton in excess or any excessive organic matter decomposition will increase the oxygen demand and reduce the DO levels.

iv. Total dissolved solids and Salinity

- Salinity is the total concentration of all ions in a known quantity of water.
- The ions leading to salinity are Ca^{++}, Mg^{++}, Na^{++}, K^{+}, Cl^{-}, SO_4^{--} and HCO_3^{-}. The concentrations of these ions fluctuate significantly from water to water. Units of expression of salinity may be in milligrams per liter (ie., parts per million or ppm), but for high salinity, the expression is in grams of solute per kilogram of solution ie., parts per thousand (ppt).
- Salinity is of prime value for natural waters since it resolves what species of aquatic animals are present in that water body. The changes in salinity affect the growth and survival of these organisms.
- Salinity also affects with other water quality parameters since the ionic strength of a solution affects equilibrium constants for all chemical reactions.
- The total dissolved solids (TDS) concentration indicates the milligram per liter of dissolved organic and inorganic matter in a water sample.

v. Total Suspended Solids (TSS) and Turbidity

- Greater levels of total suspended solids and turbidity in the coastal and marine waters can restrict the sunlight diffusion into deeper layers. Turbidity is a measure of cloudiness in a solution, caused by suspended particles like clay, silt, plankton, and other microscopic organisms.
- Turbidity and TSS will reduce the growth and proliferation of aquatic plants and microalgae (the primary producers being the indispensable energy sources in the aquatic food chain), reducing photosynthesis and in turn reduce the DO availability in the system.
- Levels of total suspended solids above 100 $mg1^{-1}$ can cause a reduction in growth rates of aquatic organisms and a rise in fish mortality.

vi. Biochemical oxygen demand

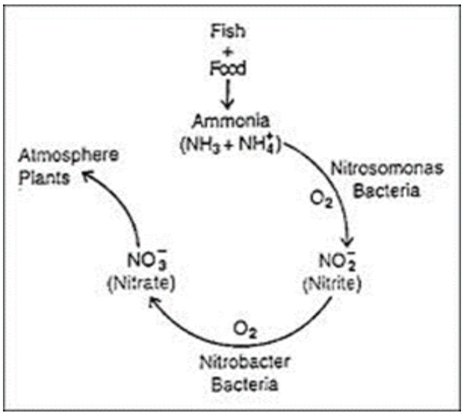
- The rate of oxygen consumption by the plankton and bacteria in a sample of will determine the biochemical oxygen demand (BOD).
- BOD is measured as the amount of dissolved oxygen consumed by the heterotrophic bacteria to convert available biodegradable organic matter into inorganic plant nutrients and carbon dioxide.
- When BOD exceeds 4 mg l^{-1}, the aquatic body experience of oxygen deficiency for the organisms of the ecosystem.

vii. Chlorophyll-a and Primary productivity

- The pigment Chlorophyll-a is an index of abundance of phytoplankton
- The term primary productivity denotes the rate of formation of organic matter by the phytoplankton. It is the rate at which new organic matter is added to the existing phytoplankton standing crop. It is expressed as grams of carbon per square meter or cubic meter/hr or per day or per year.
- Chlorophyll-a is the most abundant pigment in plants, algae, bacteria, cyanobacteria which are photosynthetic.
- It plays a key role in primary production in the process of converting light from the sun into energy.
- Satellites can detect chlorophyll concentrations in the oceans because it changes the color of the water.
- Chlorophyll-aspecific primary production varies by season and phytoplankton size.

viii. Inorganic Nutrients

- Dissolved inorganic nutrients are fundamental in preserving the biomass and energy balance in marine ecosystems. The dissolved inorganic nitrogen (DIN) (including the nitrate-N, nitrite -N and total ammonia-N), dissolved inorganic phosphorous (DIP) and dissolved silicates mainly implement the survival and dynamic progression of the marine organisms.
- The level of dissolved inorganic nutrients in water is affected by human activities as well as the *in situ* biogeochemical processes of ecosystem.
- The optimum levels of these nutrients improve production, productivity and also help in sustenance of the system. The levels in excess cause toxicity whereas the levels below optimum can impoverish the system.
- The changes in the N/P ratio, along with Si/N and Si/P ratios, can cause the growth and blooms of selective groups of phytoplankton and in turn alter the proportions of diatoms, dinoflagellates, and cyanobacteria to change the community structure.
- The optimal DIN:DIP ratio (N/P-ratio) for phytoplankton growth is 16:1 (based on molar concentrations) (Redfield ratio). Substantial deviations from 16 at low N/P-ratios indicate potential nitrogen limitation and at high N/P-ratios potential phosphorus limitation of phytoplankton primary production. This affects the biological state of the ecosystem, in particular the phytoplankton biomass, species composition and eventually food web dynamics.
- If DIN and DIP concentrations are in the ratio of between 10 and 20, there is not much deviation the Redfield ratio.
- Seasonal fluctuations in anthropogenic pressures and precipitation determine the seasonal and spatial distribution of nutrients in the water influencing ecosystem metabolism.
- The nitrogen cycle in the sea area is predominantly affected by both climate change and land-sea interactions in the coastal zone influenced by human activities. Consequently, nitrogenous compounds, such as ammonia-N, nitrate-N and nitrite-N can cause major water quality problems in marine environment and aquaculture.
- Higher than permissible levels of total ammonia-N (TAN), nitrite-N, and nitrate-N can be toxic to fish and other aquatic organisms. The concentrations greater than 0.1 mgl^{-1} for TAN, 0.5 mg l^{-1} for nitrite-N and 3 mg l^{-1} for nitrate-N are toxic.
- In aquatic system the ionized ammonia (ammonium ie., NH_4^+) is less toxic but unionized ammonia (NH_3) is highly toxic to aquatic life. Together, ammonium and ammonia is known as total ammonia nitrogen (TAN).
- Toxicity of TAN increases with increased pH and temperature. The sources of TAN are organic mineralization, fish feed and direct excretion from fishes. The oxidation of ammonia by nitrifying bacteria will provide the bioavailable forms NO_2 and NO_3 to the aquatic life.



- Increased TAN will affect fish health and the major symptoms include increased oxygen consumption, damage of gills, histological changes, susceptibility to disease, reduced growth and the toxicity may lead to death. Aquatic autotrophs rapidly utilize ammonium ions, thus naturally preventing it from increasing to toxic levels.
- Nitrite-N originates as intermediary product of nitrification of ammoniacal N.
- The concentration of nitrite-N in water should not exceed 0.5 mg per litre.
- Nitrite-N is toxic to fish and shrimp because it forms methemoglobin, affects immune and circulation systems, and reduces the transfer of oxygen to cells.
- High chloride concentration reduces nitrite toxicity and so nitrite toxicity is less in brackish water.
- Nitrate-N is the end product of nitrification of ammoniacal nitrogen by aerobic autotrophs. Its higher concentrations may lead to inability to swim and reduced movement.
- The concentration of dissolved inorganic phosphorus in seawater (as dissolved orthophosphate, PO_4 -P) should be in the range below 0.05 mg $l^{-1}$and and the dissolved silicate as reactive Silicate (SiO_3-Si) should be in the range of 4 to 6 mg l^{-1}.

Marine Sediment

- Marine sediment is formed mainly from the weathered rock and soil. These particles get deposited at seafloor by way of action of wind, ice, rivers etc from the land to the ocean. There will also be the formation of detritus deposit of the remains of marine organisms, submarine volcanism products, chemical precipitates etc. in the seafloor. All areas of the seafloor hold some form of sediment. There are different types of sediments from different sources, and the quantity varies from place to place.
- Sediment is a key factor in aquatic environments, and many dissolved and suspended substances in water are derived from the sediment-water interactions.
- Sediment is the storehouse for many substances that get adsorbed in aquatic ecosystems.
- Substances stored in sediment can be released into the water through ion exchange, dissolution, and decomposition.
- Some of such substances are potentially hazardous and exposure to them can cause serious public health problems.
- Sediment analysis is an important tool for assessing the impact of human activity on the aquatic environment, as it can provide a long-term record of environmental conditions and support identification of trends over time.
- Monitoring the chemical concentrations and physical composition of these sediments provides information on how the environment is changing with the natural or anthropogenic processes.

Sediment Quality

- The physical and chemical characteristics of water are also 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

i. 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 texture can also influence the benthic dwelling organisms
- Sediment texture is one of the characteristics affecting the blue carbon storage by the sediment

ii. Sediment pH

- Weak alkaline soil reaction (pH 7-8) had been found to be ideal for good fish productivity. Culture systems with acidic soils are generally less productive than with alkaline soils. Sediment pH is less dynamic (more stable) compared to the water pH and this adds value to the role of sediment as a buffer in the system.

iii. Oxidation Reduction Potential (Eh) (Redox potential)

- Oxidation Reduction Potential (Eh) is a quantitative measure of the tendency of a system to oxidize or reduce susceptible points. When Eh is positive and high it is an oxidizing system. When Eh is negative and low it is a reducing system.
- The anoxic sediments have redox potentials below -0.2 V.

iv. Sediment 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 enable 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 above by 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 result in accumulation of organic detritus at the bottom.

Conclusion

Good water quality is a vital factor for sustainable healthy fisheries and productive aquaculture operations. Regular monitoring of key variables of water quality is essential for the management of the fishery and for the environmental protection. The participatory approach in environmental management is very relevant in the present 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 citizen co-operation to achieve environmental sustainability for economic productivity. This is an indispensable link for the development of citizen science.

Based on thorough assessment of marine / coastal environmental quality, by way of continuous /periodical monitoring, water and sediment 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 generate the formulation of guidelines / policy suggestions / models to mitigate / restore the coastal marine ecosystems positively.

SUGGESTED READINGS

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