Review of Some Water Quality Management Principles in Culture Fisheries

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Abstract: A review of some water quality management principles in culture Fisheries was carried out to provide fish culturist and environmental manager adequate knowledge to manage our fishery resources. Optimum fish production can be achieved only when the water quality is effectively managed. The required levels of physical and chemical characteristics of the culture medium, is necessary for fish culture. Some variables influence also water quality. Interactions between these variables can become complex and would require much more explanation. Salinity, conductivity, sediment, turbidity, dissolved oxygen, carbon (iv) oxide, pH, alkalinity, com compounds in water, estimation of nitrogenous compound, plankton , algae, light and dark method, plankton collection, plankton bloom and fish kill, pond productivity, harvest methods, carbon (iv) assimilation, carbon-14-fixation, nutrient uptake and chlorophyll are some water quality parameter reviewed to provide fish culturist and environmental manager adequate knowledge to manage our fishery resources.

Key words: Assessment and monitoring, chemical and biological, physical, productivity in fish ponds, water parameters

INTRODUCTION

Water is a simple chemical compound composed of two atoms of hydrogen and one atom of oxygen which bond covalently to form one molecule. It is known as the most complex of all the familiar substances that are single chemical compounds. It is an extraordinary substance which exists in the three states of matter (gaseous, liquid and solid states). In its pure state, water is colorless, odorless, insipid, freezes at 0ºC, has boiling point of 100ºC at a pressure of 760 mmHg, with a maximum density of 1cm^3 at 4ºC. It is thermally stable at temperatures as high as 2700ºC. Water is neutral to litmus, with a pH of 7 and undergoes a very slight but important reversible self-ionization.

Water quality plays a role in the distribution of fish (Welcomme, 1979). The importance of measuring physical, chemical and biological variables was considered at the Technical Consultation on Enhancement of Fisheries of Small Water Bodies in Harare (Marshall and Moses, 1994). The Physico-chemical characteristics of water are important parameters as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Moses, 1983).

Variability of water quality influences the toxicity levels of heavy metals on estuarine organisms as it affects the Physico-chemical composition of the ecosystem.

Water rising from market stalls and slaughter houses, streets washing and flushing of sewage which flow through drains into rivers altered the chemical composition of the water body thereby causing pollution (Ademoroti, 1996).

Optimum fish production can be achieved only when the water quality is effectively managed. The required levels of physical and chemical characteristics of the culture medium, is necessary for fish culture. The availability of food organisms (planktons) and the influence of naturally occurring substances such as dissolved oxygen, carbon dioxide, ammonium nitrite and hydrogen ions (H$^+$) are important factors affecting the growth and survival of cultured fish. The role of temperature, salinity and various pollutants in fish culture cannot be over looked. Thus, the water used for the cultivation of fish cannot yield maximum production, if the environmental conditions are not optimal for the growth of fish and other aquatic organisms. Therefore, there is the need to ensure that, these environmental factors are properly managed and regulated on a daily basis. This maintains these factors within a desirable range for the survival and growth of the fish.

The water body used for fish culture is an ecosystem consisting of biotic and abiotic factors. These factors interact to produce an exchange of materials. Functionally, four components can be recognized in the ecosystem:

- Inorganic and organic compounds in the environment (Abiotic component)
- Producers which synthesis food from inorganic and organic compounds (autotrophs)
- Consumers, which depend on food, synthesized by the autotrophs e.g., herbivores, carnivores and omnivores.
- Decomposers, which break down complex compounds in the process of feeding. Decomposition results in the release of substances usable by the producers e.g., bacteria and fungi. They are called saprophytes.

The producers, consumers and decomposers form the biotic factor in the aquatic ecosystem. Different trophic levels exist in such ecosystem. Aquatic plants occupy the first trophic level while herbivores and carnivores occupy the second and third trophic levels respectively. An organism in an ecosystem can occupy more than one trophic level according to the sources of energy assimilation. This chapter treats the chemical and physical analysis to determine the quality of water used in fish culture.

Water quality is one of the most overlooked aspects of pond management - until it affects fish production. Clay turbidity in ponds is one of the most common quality issues we address. However, several other variables influence water quality for fish including water temperature, phytoplankton, photosynthesis and pH, carbon dioxide, alkalinity and hardness. Additionally, water quality can be affected through the interaction of these factors. Temperature, turbidity light intensity, pH, dissolved ions such as NO_3 and PO_4 are reported to marshal the activities and composition of organisms (Mukhtar and Deeni, 1998). Organic waste dump caused environmental stress in coastal waters which resulted in the low landing of some important fisheries (Nweke, 2000). Size, structure and biomass of phytoplankton population and production are closely related to physico-chemical conditions of the water body (Mitchell-Innes and Pitcher, 1992).

Water temperature influences the onset of fish spawn, aquatic vegetation growth and the biological demand for oxygen in ponds. As water temperature increases, it holds less oxygen. Additionally, plants and animals use more oxygen due to increased respiration rates. These factors commonly result in less available oxygen for fish during the summer and fall months. Another temperature-related phenomenon is water stratification. This occurs in deeper ponds as increased ambient temperature causes a warm, less dense layer of water to stratify over a cool, dense layer of water. Most of the oxygen is produced in the warm surface layer of water and over time oxygen can be depleted in the cooler layer. These layers may not mix for a long period until a cold front or thunderstorm cools the surface layer allowing the two layers to mix. This is often referred to as "turn-over". The result is a sudden dilution of oxygen and a simultaneously increased demand for oxygen from decaying organic matter. This can cause severe fish kills.

Phytoplankton is microscopic plants that produce most of the oxygen and are the base of primary productivity in a pond. Phytoplankton depends on sunlight for photosynthesis and produce oxygen during the process. Phytoplankton use oxygen at night through a process called respiration. Extended periods of cloudy weather can cause a phytoplankton die-off, using oxygen during decomposition. If phytoplankton is too abundant in a pond, the amount of oxygen used during nighttime respiration can cause oxygen depletions for fish. Oxygen levels are usually lowest during the hour just before daylight. Ideal phytoplankton bloom in water should result in visibility between 12 and 30 inches. Anything less than 12 inches can compound the abovementioned problems and anything greater than 30 inches begins to lower pond productivity.pH is a measure of whether water is acidic or basic. Fish have an average blood pH of 7.4, so pond water with a pH close to this is optimum. An acceptable range would be 6.5 to 9.0. Fish can become stressed in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0. Fish growth is limited in water pH less than 6.5, and reproduction ceases and fry can die at pH less than 5.0. Death is almost certain at a pH of less than 4.0 or greater than 11.0. Pond water pH fluctuates throughout the day due to photosynthesis and respiration by plants and vertebrates. Typically,

pH is highest at dusk and lowest at dawn. This is because nighttime respiration increases carbon dioxide concentrations that interact with water producing carbonic acid and lowering pH. This can limit the ability of fish blood to carry oxygen.

Alkalinity is water's ability to resist changes in pH and is a measure of the total concentration of bases in pond water including carbonates, bicarbonates, hydroxides, phosphates and borates. These bases react with and neutralize acids, buffering changes in pH. Carbonates and bicarbonates are the most common and important components of alkalinity. A total alkalinity of at least 20 ppm is necessary for good pond productivity. Water with high alkalinity and similar hardness levels has a neutral or slightly basic pH and does not fluctuate widely.

Hardness is a measure of alkaline earth elements such as calcium and magnesium in pond water. Hard water has a higher concentration of alkaline earths. Calcium and magnesium are essential to fish for metabolic reactions such as bone and scale formation. Additionally, hardness and total alkalinity can affect pH through interaction with the carbon dioxide cycle.

The article reviews some water quality management principles in culture Fisheries was carried out to provide fish culturist and environmental manager adequate knowledge to manage our fishery resources. Salinity, conductivity, sediment, turbidity, dissolved oxygen, carbon (iv) oxide, pH, alkalinity, nitrogenous compounds in water, estimation of nitrogenous compound, plankton, algae, light and dark method, plankton collection, plankton bloom and fish kill, pond productivity, harvest methods, carbon (iv) assimilation, carbon-14-fixation, nutrient uptake and chlorophyll are some water quality parameter reviewed to provide fish culturist and environmental manager adequate knowledge to manage our fishery resources.

DISCUSSION

Salinity: Salinity is defined as the total concentration of electrically charged ions in water. These ions are the four major cations - calcium, magnesium, potassium and sodium and the four common anions - carbonates (CO_3), sulphates (SO_4), chlorides (Cl) and bicarbonates (HCO). Other components of salinity are charged nitrogenous compounds such as nitrates (NO_3), ammonium ions (NH_4) and phosphates (PO_4). It is expressed in units of ppm; S%0 or ppt or g/L1(UNESCO/WHO/UNPP, 1992). In general the salinity of surface waters depends on the drainage area, the nature of its rock, precipitation, human activity in the area and its proximity to marine water (McNeely *et al.*, 1979).

Waters with salinity below 1‰ are fresh and waters with salinity higher than 1‰ are brackish/marine (Egborge, 1994). Salinity is the major environmental factor restricting the distribution of marine and lacustrine taxa, resulting in the paucity of species in brackish water (Ramane and Schlieper, 1971). Decline in littoral fauna species richness from the river mouth inwards occurs on reduction in salinity resulting to the reduction of stenohaline species and decrease in species diversity from sandy to mud substances.

Salinity of surface water is relatively uniform as it is generally well mixed by waves, wind and tides. However, variation of surface water salinity due to the effects of rainfall, evaporation, precipitation and other weather related factors are often observed. Salinity is considerably higher during dry season when sea water penetrates far up the rivers, than in wet season when rain water and flood from the Niger and Benue rivers drive the salt water back towards the sea. The Bonny River has high saline penetration from the Atlantic Ocean, which salinity fluctuates with the season and tide. Salinity is a major driving factor that affects the density and growth of aquatic organism's population in the mangrove swamp (Jamabo, 2008).

Conductivity: Conductivity is a measure of the ability of water to conduct an electrical current. The conductivity of

water is dependent on its ionic concentration and temperature. Distilled water has a conductivity of about 1 µmbos/cm and natural waters have conductivity of 20-1500 µmbos/cm (Abowei, 2010). Conductivity provides good indication of the changes in water composition particularly its mineral concentration.

Variations of dissolved solids in water could affect the relative quantities of the various components. There is a relationship between conductivity and total dissolved solids in water. As more dissolved solids are added, water's conductivity increases (Abowei, 2010). Conductivity of salt water is usually higher than that of freshwater because the former contains more electrically charged ions than the latter. The freshwater zone of the rivers of the Niger Delta can thus be said to be low in ions. The total load of salts of water is in direct relation with its conductivity. Conductivity is an index of the total ionic content of water, and therefore indicates freshness or otherwise of the water (Ogbeibu and Victor, 1995).

Conductivity of freshwater varies between 50 to 1500 hs/cm (Boyd, 1979), but some polluted waters reach 10,000 hs/cm. Seawater has conductivity around 35,000 hs/cm and above. The major constituents of the dissolved substances in water are calcium ion (Ca^{2+}), Magnesium (Mg^{2+}), hydrogen trioxcarbonate (iv) (HCO_3), trioxocarbonate (iv) (CO_3), trioxonitrate (v) (NO_3) and tetraoxophosphate (vi) (PO_4). They are the necessary constituents of aquatic animals which partly come from their food. Verheust (1997) stated that conductivity can be used as indicator of primary production (chemical richness) and thus fish production. Sikoki and Veen (2004) observed a conductivity range of 3.8 -10hs/cm in Shiroro Lake (Imo State) which was described as extremely poor in chemicals. They were of the view that fishes differ in their ability to maintain osmotic pressure, therefore the optimum conductivity for fish production differ from one species to another.

Sediment: Sediment is the loose sand, silt and other soil particles that settle at the bottom of a body of water. It can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice help to carry these particles to rivers, lakes and streams. Sediment strata serve as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity (Abowei and Sikoki, 2005). Sediment is also the major site for organic matter decomposition which is largely carried out by bacteria. Important macro-nutrients such as nitrogen and phosphorous are continuously being interchanged between sediment and overlying water (Abowei and Sikoki, 2005)

The type and intensity of agricultural land use determine sediment load which play a role in determining the insects which survive in a stream. Intensive agricultural land use produces modifications which reduce

the variety of macro-invertebrate taxa. Agricultural land drainage includes channelization of water courses and such drainage schemes can have a considerable impact on hydrology, sediment load, water temperature, chemistry and aquatic biology. Fish and benthos were less abundant in streams near farms than in those flowing through natural and clear-out forests and they stated that chemical contamination and sedimentation had caused the reduction. The comparison of historical and present day conditions indicates that modifications of the drainage basin have produced drastic effects on the stream which flows through the most intensively farmed basin.

Land activities may introduce large amounts of sediment into nearby streams and rivers. Sediment input may impact stream communities through a variety of direct and indirect processes, including reduced light penetration, smothering, habitat reduction and introduction of absorbed pollutants (pesticides, metals, nutrients). Sediment addition has been found to affect benthos. The effect of sediment addition is simply to reduce available habitat area. The structure of the sediments in the intertribal zone plays a major role in the distribution of the organisms that live in or on them. Benthic organisms show habitat preference for specific types of sediment. The Physico-chemical parameters of the sediments such as salinity, dissolved oxygen, pH, and organic carbon could also influence the occurrence and abundance of species distributed in them.

Mineral soils are often composed of inorganic particles of varying sizes called soil separates. The relative proportions of the various separate or size groups of individual soil grains in a mass of soil is referred to as soil texture. The soil texture specifically refers to the proportions of sand, silt and clay below 2000 μm (2 mm) in diameter in a mass of soil. Sand is generally coarse and gritty, silt is smooth like flour and clay is sticky and plastic when wet. The texture class determines the microbiological population of a soil and hence the biological and biochemical reactions taking place in such a soil.

Excess nutrients especially phosphates, sulphates and nitrates are classified as pollutants in waste water. Large tonnage of phosphate enters rivers and lakes through super phosphate fertilizer washed from soil and from chemicals used to improve the performance of detergents (Abowei and Sikoki, 2005). Phosphate is considered a pollutant principally because of Lake eutrophication resulting in algal bloom (Abowei and Sikoki, 2005). The presence of hydrocarbon has been shown to have adverse effect on phytoplankton community structure and abundance.

The granulometric and mass properties of lake and marine mud are similar, although lacustrine sediments at a given depth are typically finer grained than marine sediments because of lack of tidal currents and higher sedimentation rates. Problems linked to the toxicity of freshwater sediments are the subject of increasing attention on the part of water managers. The management of contaminated sediments becomes a crucial problem due to past and present industrial activities. Physically complex substrate types (leaves, gravel or cobble, macrophytes, moss, wood) generally support more taxa than structurally simple substrates (sand and bedrock).

Turbidity: Turbidity refers to the tendency for water to transmit light. The ability of water to transmit light is probably its most important attribute. Without it, photosynthesis would not be possible and, as a result, no life could exist in water. In addition, the sun, which provides the light, serves as a source of energy for evaporation, circulation and heat in the water body. If there is no cloud cover, the position of the sun determines the amount of light that is transmitted through the water with respect to that which is reflected. If the angle of incidence is less than 60º, only a small percentage of sunlight is reflected, and that, the percentage of sunlight reflected increase rapidly at angles above 60º. It is necessary to determine the amount of light penetration, particularly, in studies concerning photosynthesis.

The simplest way to do this is with a secchi disc. This is a white porcelain disc measuring 30 centimeters in diameter. A line is fastened at the center and the disc is lowered until it disappears from sight. This depth is called the depth of visibility. The secchi disc is limited in its application due to inconsistency in observation and comparison of data. Each observer obtains different results because of individual variations in sight. Never the less, data seem comparable if the mean of many reading are taken. The secchi disc is almost obsolete due to the development of photoelectric cells. A light receptive surface is lowered to a given depth. The surface is monitored by, a meter giving the number of lumens of light being received. With such an instrument, it is possible to determine the continuous distribution of light intensity with respect to depth.

The color of water in the open is in the blue green portion of the spectrum. If a bottle of this water is held up to the light, it is colorless. How then does water obtain its color? If organisms and impurities are temporarily eliminated, it must be due to the way various visible light rays are affected by transmission through water. Absorption of light rays is one important factor. The wavelength of light in the visible spectrum range from 0.4 micron to 0.8 micron, with the shortest of the visible rays being violet and the longest being red. The degrees to which rays are absorbed by a substance depend on their wavelength, but in water, it is not a straight-line relationship.

Long, red rays are absorbed most, whereas blue and green rays are absorbed least. Thus a wavelength of about

0.5 micron is absorbed least, with increasing absorption of various wavelengths. Pond water appears blue or green. The complete absence of light in great depth is due to total absorption and scattering of light rays. Greenish or bluish waters are good for fishpond. Yellow or brown waters are not very good as they are acidic. They arise from Moore land or marshy ground. The color of natural water results from the unabsorbed light rays remaining from the incident light.

Transmission of light in water depends on the suspended particulate matter ranging in size from colloidal to coarse dispersions. In ponds, turbidity and color can result from:

• Colloidal clay particles entering with runoff.
• Colloidal organic matter originating from the decay of vegetation; and, Abundance of plankton.

For example, ponds in woody environment are strained with humus substances; while ponds used for intensive fish culture are turbid with plankton. Turbidity restricts light penetration and limits photosynthesis. Sedimentation of soil particles may smother fish eggs and destroy communities of bottom organisms. Turbidity in natural water exceeds 20,000 mg/L. Muddy waters have less than 200 mg/L. Turbidity resulting from plankton abundance is not harmful to fish. However, eutrophication is harmful to fish. Secchi disc is used for measurement of depth visibility. The more, the turbidity of water, the less, secchi disc visibility values.

Temperature: Temperature is defined as the degree of hotness or coldness in the body a of living organism either in water or on land (Lucinda and Martin, 1999). It is very important in waters because it determines the rate of metabolism of aquatic organisms. Temperature is measured insitu using any good mercury - filled Celsius thermometer or thermistor (APHA, 1995). Generally, the surface water temperature follows the ambient temperature and it is influenced by latitude, altitude, season, time of day, air circulation, cloud cover, substrate composition, turbidity, vegetation cover, water current and depth of the water body (Umeham, 1989). It is one of the most important external factors influencing fish production. Water used for the cultivation of fish cannot yield maximum production if the thermal conditions are not optimal for the fish and other organisms. Temperature has a considerable influence on the principal and vital activities of the fish, notably: Breathing, growth and reproduction. This is because they are poikilotherms (the body temperature of the fish varies with that of the environment).

Temperature is linked with dissolved oxygen. Temperature is inversely proportional to dissolved oxygen level. Each fish species is adapted to a range of temperature. These are the minimum and maximum temperatures that can sustain live fish. There is also an optimum temperature that corresponds to the maximum growth of the fish. This is the temperature for maximum production of the pond. Flush out all water and replenish pond water when extremely high temperature is noticed. Heater could be used for extremely low temperature. But, this condition is rare in the tropics.

The growth, feeding, reproduction and migratory behavior of aquatic organisms including fish and shrimps is greatly influenced by the temperature of water (Fey, 2006). Aquatic organisms have their own tolerance limits to temperature and this affects their distribution. Higher temperatures are recorded on the surface of river waters during midday and become low during the latter part of the night (Kutty, 1987). River water shows little thermal stratification because of the turbulent flow which ensures that any heat received is evenly distributed. Most tropical freshwaters have a stable temperature regime with seasonal variations between 20 - 30ºC (Adebisi, 1981).

The temperature of natural inland waters in the tropics generally varies between 25 – 35ºC (Alabaster and Lloyd, 1980). NEDECO (1980), described the Niger Delta as humid/semi-hot equatorial area).

Temperature affects physical, chemical and biological processes in water bodies which alter the concentration of dissolved oxygen and rate of photosynthesis (Boyd, 1979). Under stress from increased temperature, shallow water ecosystems can undergo a state of change, characterized by the rapid loss of macrophytes and subsequent dominance of phytoplankton (Mckee et al. 2003). Water temperature can strongly affect the feeding patterns, growth rates and breeding seasons of fish and shell fishes. The lives of most aquatic organisms (especially poikilotherms) are controlled by water temperature. Aquatic organisms including fish may be classified ecologically in several ways according to environmental tolerance as stenothermal (lower or narrow) or eurythermal (higher or broad) respectively.

Along with light and nutrients temperature plays an important role in determining, phytoplankton productivity in aquatic ecosystems. Increased temperature increases metabolic activities which can lead to death. Temperature influences water quality and the distribution and abundance of aquatic organism, (Prasad, 2000). In water hydrogen ion concentration is measured in terms of pH, which is defined as the negative logarithm of hydrogen ion concentration (Boyd, 1979). This concentration is the pH of neutrality and is equal to 7. When the pH is higher than 7 it indicates increasing salinity and basicity while values lower than 7 tend towards acidity i.e. increase in hydrogen ion concentration. Pure water ionizes at 25^0C to give a concentration of 10gl litre. Accurate measurement of pH may be taken insitu, using electronic glass electrode. However, APHA (1995) reported that pH measurements are affected by temperature in two ways;

mechanical effects caused by changes in the properties of the electrode and chemical effects caused by equilibrium changes.

Dissolved oxygen: The amount of dissolved oxygen in water is very important for aquatic organisms. Dissolved oxygen affects the growth, survival, distribution, behavior and physiology of shrimps and other aquatic organisms (Solis, 1988). Oxygen distribution also strongly affects the solubility of inorganic nutrients since it helps to change the redox potential of the medium. It can also determine whether the environment is aerobic or anaerobic.

The principal source of oxygen that is dissolved in water is by direct absorption at the air-water interface which is greatly influenced by temperature (Kutty, 1987). At low temperature more oxygen diffuses into the water. The solubility of oxygen in water is controlled by some major factors such as temperature, salinity, pressure and turbulence in the water caused by wind, current and waves. Surface agitation of water helps to increase the solubility of dissolved oxygen in water . In rivers and streams the turbulence ensures that oxygen is uniformly distributed across the water and in very shallow streams the water may be supper saturated (Abowei, 2010).

Oxygen concentration in water is controlled by four factors: photosynthesis, respiration, exchanges at the air-water interface, and supply of water to the water body or pond (Erez *et al.*, 1990). A major part of dissolved oxygen is observed to come from photosynthesis processes and only a small part originates from the atmosphere (Milstein et al., 1989). Boyd and Lichtkoppler (1979) reported that there is significant fluctuation in dissolved oxygen concentration during a 24 h period in waters of lakes and ponds. Dissolved oxygen is usually lowest in the early morning just after sunrise, increasing during daylight hour to a maximum in late afternoon and decreasing again at night. The magnitude of fluctuation is greatest in waters with high plankton bloom and least with those having low plankton abundance. Production of oxygen in cloudy day is less than on a clear or partly cloudy day (Swingle, 1968). Dissolved oxygen concentration of 5.0 mg/L and above are desirable for fish survival (Boyd and Lichtkoppler, 1979).

Low dissolved oxygen concentrations are known to be one of the major problems to faunal and floral survival in the aquatic environment. Low concentration of dissolved oxygen created anoxic condition within the Black and Baltic Sea (Saiz-Salinas, 1997). The problems of anoxia are the major causes of faunal depletion in aquatic ecosystems.

The amount of oxygen needed to completely decompose the organic matter present in the water to simplest molecules, carbon (iv) oxide and water is known as the Biochemical Oxygen Demand (BOD) of the water.

Higher BOD increases the degree of pollution. When the organic loading of the aquatic environment becomes abnormally high, the BOD far exceeds the available oxygen. Biochemical oxygen demand is used as a measure of the quantity of oxygen required for oxidation of biodegradable organic matter present in a water sample by aerobic and anaerobic biochemical action.

Biochemical Oxygen Demand (BOD) is thus one of the measures of organic loads in an aquatic system as well as an indicator of levels of organic pollution (Bagariano, 1992). However, low BOD levels water support high organic enrichment. Clerk (1986) reported that BOD range of $\geq 2 \leq 4$ does not show pollution while levels beyond 5 mg/L is indicative of serious pollution. Water bodies with BOD levels between 1.0 and 2.0 mg/L were considered clean; 3.0 mg/L fairly clean; 5.0 mg/L doubtful and 10.0 mg/L definitely bad and polluted.

Like any other element, in-group six of the periodic table, oxygen is an electron acceptor and oxidizing in nature.

$$2 \text{ mg} + O_2(g) \rightarrow 2 \text{ mg}^{2+} + O^{2-} \text{ (s)}$$
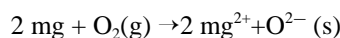
Oxygen is slightly soluble in water and combines directly with hydrogen to yield water.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O_{(L)}$$
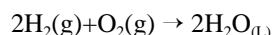
Obtaining sufficient oxygen is a greater problem for aquatic animals than terrestrial animals for two reasons: Oxygen has a low solubility in water, consisting only about 0.5 % of seawater compared to approximately 21 % in air. The percentage is slightly higher in fresh water but variable. The diffusion of oxygen is much slower in water than in air. Most aquatic animals must therefore actively move water across the exchange surfaces. If the water remained still, the oxygen in the vicinity of the exchange surfaces would soon be depleted and would not be renewed by diffusion fast enough, to sustain the animal.

A fish moves water into the mouth across the gill filament and out behind the operculum. A lobster keeps water current moving through small openings near the leg bases into the gill chamber beneath the carapace, and out near the head.

Pond fish can die if exposed to less than 0.3 mg/L of dissolved oxygen for a long period of time. The recommended minimum concentration of dissolved oxygen to sustain fish for long periods is 1.0 mg/L. However, concentrations from 5.0 mg/L are adequate in fishponds. Tropical fishes are more tolerance to low dissolved oxygen than temperate fishes. For instance, the tilapias, carps and cat fishes can tolerate dissolved oxygen levels of less than 1 mg/L. Some of these fishes have accessory organs capable of sustaining the fish out of water for many hours. There are also cases where fishes can survive in complete absence of oxygen. Fluctuations in dissolved oxygen levels affect fish growth.

Dissolved oxygen values are highest in the afternoon and lowest towards evening. The cloudy weather can cause low dissolved oxygen levels (Boyd, 1979). Oxygen super saturation causes gas embolism. Tsadik (1984) reported that fluctuating dissolved oxygen retarded the growth rate of *Oreochromis niloticus.*

The level of dissolved oxygen in ponds can be controlled by increased oxygenation of the pond water via beating the surface water with sticks and hands. Mixing of water by electrical agitators and compressed air supply is also ok. Water entering the pond can be made to cascade and splash down. This increases the oxygen supply in the pond. Excess fertilization and blooms should be avoided because it can result in eutrophication. This can lead to oxygen depletion, particularly in the night when respiration super cedes photosynthesis.
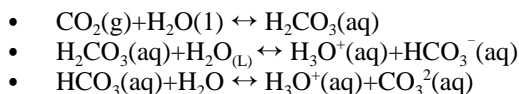
The solubility of oxygen in water varies with temperature. Dissolved oxygen content reduces sharply with increase in temperature. In large water bodies where thermal stratification takes place, there is stratification in oxygen. This shows oxygen profile of the water. The distribution of dissolved oxygen is "orthograde" when the water temperature decrease with depth and oxygen content remaining constant in an oligothrophic water body. But, when the water is eutrophic and oxygen concentration levels decrease steeply with depth in the hypolimnion, the distribution of dissolved oxygen is said to be heterogate.

Dissolved oxygen can be determined by using the dissolved Oxygen Meter or Winkler Method. The Oxyguard Modle MKll field oxygen meter is commonly used. The procedure for the Winkler Method involves filling oxygen bottles (125-300 mL) with water samples and fixing immediately with manganese sulphate and alkaline potassium iodide solution. A brown precipitate formed is shaken and dissolved with concentrated sulphuric acid solution. A 100mL of this solution is pipette into a 250 m l conical flask. The solution is titrated with sodium thiosulphate solution (0.25 N) using starch as an indicator, until a colorless solution is observed. The reading are calculated as:
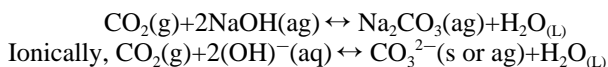
Calculated dissolved Oxygen (O_2 mg/L)
= (Mititrant)(N)(8)(1000)/ sample vol. in mL

Carbon (iv) oxide: Carbon forms two important oxides, namely carbon (iv) oxide (CO_2) and carbon (ii) oxide (CO), The atmosphere contains 0.03% by volume of carbon (iv) oxide. A small percentage of carbon (iv) oxide is also present in the dissolved form in water. In the combined form, it is present mainly as metallic trioxocarbonate (iv) in the earth crust, especially in lime stone regions and coral reefs.
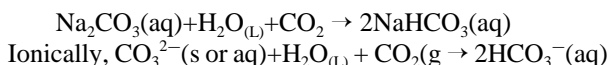
Carbon (iv) oxide is not very active chemically. It dissolves in water to form trioxocarbonate (iv) acid (soda water). This is a weak dibasic acid, which ionizes slightly:

- $CO_2(g) + H_2O(1) \leftrightarrow H_2CO_3(aq)$
- $H_2CO_3(aq) + H_2O_{(L)} \leftrightarrow H_3O^+(aq) + HCO_3^-(aq)$
- $HCO_3(aq) + H_2O \leftrightarrow H_3O^+(aq) + CO_3^{2}(aq)$

On heating, trioxocarbonate(iv) acid decomposes to form water and carbon (iv) oxide. It reacts directly with alkalis to yield trioxocarbonate (iv) oxide.

$$CO_2(g) + 2NaOH(ag) \leftrightarrow Na_2CO_3(ag) + H_2O_{(L)}$$
Ionically, $CO_2(g) + 2(OH)^-(aq) \leftrightarrow CO_3^{2-}(s\ or\ ag) + H_2O_{(L)}$

In the presence of excess CO_2, the trioxocarbonate (iv) oxide reacts with CO_2 to produce hydrogen trioxocarbonate (iv).

$$Na_2CO_3(aq) + H_2O_{(L)} + CO_2 \rightarrow 2NaHCO_3(aq)$$
Ionically, $CO_3^{2-}(s\ or\ aq) + H_2O_{(L)} + CO_2(g \rightarrow 2HCO_3^-(aq)$

Solution of alkalis absorbs carbon (iv) oxide readily and is frequently used to remove it from a mixture of gases.Carbon (iv) oxide neither burns, nor support combustion of most substances. The intense heat produced by burning magnesium, however decomposes carbon (iv) oxide to release oxygen for further oxidation of magnesium. The products of the combustion are carbon deposit and white magnesium oxide ash.

$$CO_2(g) + 2\ mg(s) \rightarrow 2\ mg\ O(s) + C(s)$$
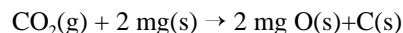
If the gas is passed over red-hot carbon, it is reduced to carbon (ii) oxide. This reaction is reversible and is of great commercial importance.

$$CO_2(g) + C(s) \rightarrow 2CO(g)$$
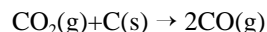
Carbon (iv) oxide is more soluble in water than oxygen. One volume of carbon (iv) oxide dissolves in an equal volume of water. The solubility of carbon (iv) oxide is higher at lower temperatures. Carbon (iv) oxide can exist in water as bicarbonate or carbonates in the dissolved or bound form, depending on the $_pH$ of the water. Acidic waters have high levels of dissolved CO_2; while alkaline waters are free from dissolved CO_2. Water is classified as soft, medium or hard, depending on the amount of bound CO_2. When the bound CO_2 is less than 5 mg/L (25 mg of $CaCO_3$), the water is soft. But, when the bound CO_2 is 5-22 mg/L (100 mg $CaCO_3$), it is medium. The water is described as hard when the bound CO_2 is above 22 mg/L.

Medium waters are low in calcium and magnesium. Increase in free CO_2 results in the decrease of dissolved oxygen in natural waters. Tropical fishes can tolerate CO_2 levels over 100 mg/L. But the ideal level of CO_2 in fishponds is less than 10 mg/L. Apart from being the by-product of respiration and source of carbon fixation (photosynthesis), CO_2 combine with haemoglobin instead

of oxygen. This can reduce oxygen supply in pond organisms.

In the determination of carbon (iv) oxide; bubble, the unknown gas through lime water (calcium hydroxide). If the gas is carbon (iv) oxide, the limewater turns milky due to the precipitation of insoluble calcium trioxocarbonate (iv).

$$Ca(OH) (aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O_{(L)}.$$
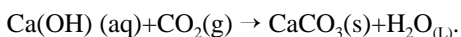
Continue bubbling more of the gas through the solution. The milkiness should disappear leaving a clear solution. This is because carbon (iv) oxide reacts with insoluble calcium trioxocarbonate (iv) to form soluble calcium hydrogentrioxocarbonate (iv).

$$CaCO_3(s) + H_2O + CO_2(g) \xrightarrow{Heat} Ca (HCO_3)_2 (aq).$$
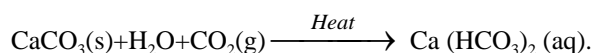
Heat the clear solution. It should become milky again due to the decomposition of soluble calcium hydrogen trioxocarbonate (iv) to form insoluble calcium trioxocarbonate (iv).

$$Ca(HCO_3)_2 (aq) \rightarrow CaCO_{3(s)} + H_2O_{(L)} + CO_2(g)$$

Water with a pH above 8.31 seldom contains sufficient carbon (iv) oxide. Therefore, the quantity of base required to raise the pH of a water sample to its end point using phenolphthalein is approximately equivalent to the carbon (iv) oxide content of the sample. Water containing carbon (iv) oxide can be titrated with either standard NaOH or Na_2CO_3 using the indicator, phenolphthalein. One mole of CO_2 reacts with one mole of NaOH. Titration is conducted with a NaOH So1^{-N}1 mL, which equals 1mg of CO_2. The equivalent weight of CO_2 is 44. Therefore, 1/44N solution is required for the titration with NaOH. One molecule of CO_2 reacts with one molecule of Na_2CO_3.

One molecular weight of Na_2CO_3 equals 2 equivalent weight. The equivalent weight of CO_2 is 22. Therefore, 1/22N (0.045N) solution is required for the titration with Na_2CO_3. If it is desired that 1mg of Na_2CO_3 equals 1mg of CO_2, it is easier to use a sodium trioxocarbonate (iv) (Na_2CO_3) for the titration because sodium trioxocarbonate (iv) is a standard. Therefore there is no need to standardize its solutions provided the solutions are carefully prepared.

Samples for the analysis of CO_2 are collected with airtight bottles. Titration is also carried out in an airtight laboratory condition. A pink color resulting from the addition of phenolphthalein indicates absence of CO_2 in the sample. When it is colorless, the presence of CO_2 in the sample is confirmed.

Calculation: Estimate 8.51 mL of 0.045N Na_2CO_3 for a 100 mL sample, using phenolphthalein indicator:(0.0454 mL Na_2CO_3) (8.51 mL of Na_2CO_3) = 0.386 Meg of 0.386 Meg of Na_2CO_3 = 0.386 mg of CO_2
(0.386 meg of CO_2) (22.0 mg of CO_2 per meg) = 8.49 Meg of CO_2
8.48 mg of CO_2 1000 mL/L = 84.9 mg/L of CO_2
CO_2 in mg/L = 1 mL of (Na_2CO_3) (N) (2) 100.

Sample vol in mL: It can also show that 1ml of 0.0454N Na_2CO_3 equals 9.99 mg/L of CO_2 when used to titrate 100 mL sample. Therefore, the burette reading in milliliter multiplied by 10 gives an estimation of CO_2 in mg/L when 100 mL samples are titrated with 0.0454 Na_2CO_3.

Reagents: Phenolphthalein indicator solution: Dissolve 0.5 g of phenolphthalein in 50 mL of 95% ethyl alcohol and add 50 mL of CO_2 distilled H_2O. Add 0.454 HNa_2CO_3 drop wise until a faint pink color reappears to remove all traces of CO_2 from the indicator.

Standard sodium trioxocarbon (iv) ((0.0454N) Na_2CO_3): Dry a few grams of anhydrous Na_2CO_3 at 1400°c and cool in desiccators. Dissolve 2.407 grams of Na_2CO_3 and dilute to 1000 m l with CO_2 free distilled water. This standard solution should be renewed each day. If desired, it can be standardized against a standard solution of dilute acid such as hydrochloric acid and tetraoxosulphate (vi) acid.

Procedure: The same procedures used for collecting samples of dissolved oxygen can be used. The analysis for carbon (iv) oxide should be made within 2 or 3 h after collection. To minimize exposure to air, siphon a portion of the sample into a 100 mL graduated cylinder through a flexible tube which discharges at the bottom of the cylinder. Let 50 or 75 mL of water overflow from the cylinder and then carefully remove the tube. Remove excess sample from the cylinder with a pipette. Add 4 drops of phenolphthalein indicator solution. If the sample turns pink, the pH is above 8.31 and free carbon dioxide is absent.

If the sample remains colorless it contains free CO_2. Samples containing CO_2 are titrated rapidly with 0.0454N Na_2CO_3 solution. Stir gently with a stirring rod. A faint pink color, which remains for 30 seconds, marks the end point. Samples supersaturated with CO_2 loose CO_2 to the air. For accuracy, titrate a portion of the sample and quickly add the volume of titrant used in the first titration and continue the titration to the end point. Calculate the CO_2 concentration.

pH: In order to avoid, the inconvenience of using negative indices; and to accommodate the wide range of H^+(aq) and OH^-(aq), concentration which are commonly encountered in acid-base reactions, Sorensen devised the

pH scale in 1909. He defined the $_pH$ of a solution as the negative logarithm of the hydrogen ion concentration to base 10.

The degree of acidity or alkalinity of pond water can be measured using:

- pH scale
- Universal indicators
- pH meters

The pH scale ranges from 0 to 14. The pond water is neutral when the pH is exactly 7. This means that the solution contains an equal concentration of H^+ and OH^- ions. Substances with a pH of less than 7 are acidic. This contains a higher concentration of H^+ ions than OH^- ions. Substances with lower pH are more acidic t. Substances, with a pH more than 7 are basic. This contains a higher concentration of OH^- ions than H^+ ions. Substances with higher pH are more basic. A universal indicator is made up of a mixture of various indicators which function at different pH ranges. By series of successive color changes, it can indicate pH values from 3 to 11. These pH changes can be easily determined by comparing the colors obtained with that of the standard given. Litmus is a substance that turns red when in contact with acidity and blue when in contact with basicity.

These methods of measuring the pH, is not very accurate. A pH meter is an electrical device with electrodes that are very sensitive to hydrogen H^+ and hydrogen (OH^-) ions. It can measure the pH of very dilute solutions as well as that of colored and opaque liquids. The colorimeter also measures pH. Colorimeters have discs with different range of pH. There are two compartments. One tube with sample water is kept in the left compartment. The other tube with the indicator is kept in the right compartment. The color disc is then rotated until the two colors match. The value can then be red.

pH higher than 7, but lower than 8.5 is ideal for biological productivity while pH lower than 4 is detrimental to aquatic life (Abowei, 2010). Most organisms including shrimps do not tolerate wide variations of pH over time and if such conditions persist death may occur. Therefore, waters with little change in pH are generally more conducive to aquatic life. The pH of natural waters is greatly influenced by the concentration of Carbon (IV) oxide which is an acidic gas (Boyd, 1979). Phytoplankton and other aquatic vegetation remove carbon (IV) oxide from the water during photosynthesis, so the pH of a water body rises during the day and decreases at night (Boyd and Lichtkoppler, 1979). Rivers flowing through forests have been reported to contain humic acid, which is the result of the decomposition and oxidation of organic matter in them hence has low pH.

In the open ocean the pH of sea water falls within limits of 7.5-8.4 (Riley and Chester, 1971). Waters with low total alkalinity often have pH values from 6.5-7.5 before day break, but when phytoplankton growth is high, afternoon pH values may rise to 10 or even more (Beasley, 1983). Changes in the acidity of water can be caused by acid rain, run-off from surrounding rocks and waste water discharges (Ibiebele *et al.*, 1983). Waters with pH values of 6.5 to 9.0 are considered best for fish production, while the acid and alkaline death points are 4.0 and 11, respectively. Low pH values or acidic waters are known to allow toxic elements and compounds such as heavy metals to become mobile thus producing conditions that are inimical to aquatic life (Gietema, 1992).

Alkalinity: Alkalinity can be separated into bicarbonate, carbonate and hydroxide. The total titrable bases in water expressed as equivalent $CaCO_3$ are referred to as total alkalinity. In most waters bicarbonate (HCO_3^-), carbonates (CO_3^-) and hydroxides (OH^-) are the major bases. Others are silicates, phosphates, ammonia and various compounds. The amount of acid required for the standard tetraoxosulphate (iv) acid used is 0.02N. Results of alkalinity titration can be expressed as total alkalinity or as individual components of alkalinity such as hydroxide, carbonate and bicarbonate alkalinity.

Alkalinity can be determined using:

- Phenolphthalein (p)
  Measure out 100 mL of filtered sample into a conical flask. Add 10 drops of phenolphthalein indicator. If sample turns pink, add H_2SO_4 N/50 from burette until the color disappears.
  Calculation:
  P = titration x 10 ppm as $CaCO_3$
- Methyl orange (m)
  If sample does not turn pink with phenolphthalein, add 3 drops of methyl orange.Triturate with N/50 H_2SO_4, stirring continuously until color changes from yellow to orange
  Calculation:
  M = Titration $\times$ 10 ppm as $CaCO_3$

Nitrogenous compounds in water: The nitrogenous compounds often present in water are trioxonitrate (v), nitrogen (iv) oxide and ammonia. Trioxonitrate (v) and nitrogen (iv) oxides are among several oxides of nitrogen. The formation of these oxides by the direct combination of nitrogen and oxygen requires very high temperatures. Because of the large amount of energy required for their formation, these oxides of nitrogen are readily inter convertible, and are easily decomposed of their elements. Ammonia is a hydride of nitrogen. In nature, ammonia is produced when nitrogenous matter decays in the absence of air. The decomposition may be brought about by, heat or putrefying bacteria. As a result, small traces of

ammonia may be present in the air. However, because of its great solubility in water, it rapidly dissolves in rainwater and finds its way into the soil where it may be converted into other compounds.

Trioxonitrate (v) ion (NO_3^-), nitrogen (iv) oxide ion (NO_2^-) and ammonium ion (NH_4^+) are products from the accomplishment of nitrification by two different groups of bacteria functioning in sequence. The first group converts ammonium ions to nitrogen (iv) oxide ions, and the second group converts this nitrogen (iv) oxide ion to trioxonitrate (v) ion. The trioxonitrate (v) ion released into the water by bacteria, can be picked up by, the roots of aquatic plants.

Most of the trioxonitrate (v) ion in the root is quickly incorporated into organic nitrogen compounds and then stored in the cell vacuoles or transported to other parts of plant body through the vascular tissue. The nitrogen compounds in the plant body may eventually be broken down to ammonia by decomposers when the plant dies or when an animal that consumed the plant dies or excrete it.

Ammonia as products of biological processes can be related to pollution of the water. Over fertilization or enrichment of the ponds, incomplete degradation of faecal matter and feed remnants cause high ammonia levels in fishponds. Un-ionized ammonia (NH_3) is toxic to fish but the ammonium ion (NH_4^+) is not toxic. Un-ionized ammonia is highly toxic at levels less than 1 mg/L. Tropical species can withstand higher toxicities. Mead (1985) reported that unionized ammonia was 300-400 times more toxic than NH_4^+. The effect of toxicity is higher at higher pH.

Estimation of nitrogenous compounds: Of the several procedures adopted in ammonia determination, the simplest is the direct pesslerization method. This employees the use of colorimeter. The other intermediate products, trioxonitrate (v) and nitrogen (iv) oxide are all estimated calorimetrically using the Bausch and Lomb Mini Spectro Kits. Nitrogen (v) oxide is present in natural waters only in small quantities. It has been found to be toxic to fish, as NO_2 combines with haemoglobin, and forms methylhaemoglobin causing the brown coloration of blood (Russo *et al.*, 1981).

The presence of chloride ions and calcium inhibits nitrogen (iv) oxide toxicity. (Grawford and Allen, 1977). In contrast, ammonia and nitrate toxicity increases at lower pH levels (Russo *et al.*, 1981). EIFAC (1986) therefore recommended that levels of pH, calcium content (bicarbonate hardness) and chloride content (salinity) should be indicated when reporting on nitrogen (v) oxide concentrations. Wickins (1981) suggested that nitrogen (iv) oxide concentration in hard fresh water pond should not exceed 0.1 mg NO_2^- N/L and in salt water 1.0 mg NO_2^-N/L.

Plankton: The word plankton was derived from a Greek verb meaning "to wander". It is referred to those pelagic forms, which are carried about by the movement of the water rather than their own ability to swim. These organisms are called planktonts. The plants of the plankton are phytoplankton, the animals, and zooplanktons.

Some planktonts can only float passively, unable to swim. Others are quite active swimmers but are so small that swimming does not move them far compared to the distance they are carried by the water, but serves chiefly to keep them afloat; alter their level, obtain food, avoid capture, find a mate or set up water current for respiration. Although the majority of planktonts are small, mainly of microscopic size, a few are quite large. For example, the tentacles of *Physala* sometimes extend 15 m through the water, and there are Scyphomedusa, which grows to over 2 m in diameter.

Terms in wide use for referring to different components of plankton include the following:

- **Macro plankton:** Large planktonts visible to the unaided eye, retained by a coarse net (gauge), with mesh aperture of approximately 1mm. Exceptionally large planktonts are sometimes termed *Megaloplanktonts*.
- **Micro plankton:** Planktonic organism less than 1mm in maximum dimension but retained by a fine-mesh plankton net (gauge 21) mesh aperture approximately 0.06 mm.
- **Nanoplankton:** Organisms too small to be retained by fine-mesh bolting silk (less than 60 mm) but larger than 5 mm maximum dimension.
- **Ultra plankton:** Planktons less than 5 mm maximum dimension.
- **Epi plankton:** Plankton of the epipelagic zone i.e., within the uppermost 200 m.
- **Pleuston:** Passively floating organisms living at the air - sea interface, partially exposed to air and moved mainly by the wind.
- **Neuston:** Small swimming organisms inhabiting the surface water film.
  Epineuston on the aerial side; *Hyponeuston* on the aquatic side Bathyplankton: These are plankton of deep levels.
- **Hypoplankton:** Plankton living near the bottomProtoplankton: Pelagic bacteria and unicellular plants and animals.
- **Seston:** Finely particulate suspended matter.
- **Holopankton (Permanent plankton):** Organisms whose entire life span is planktonic.
- **Meroplankton (Temporary plankton):** Planktonic organisms passing through a pelagic phase, which is only part of the total life span. For example, planktonic spores, eggs or larva of nektonic or benthic organisms.

- **Micronekton:** Terms sometimes applied to euphausids, mysids and other strongly swimming animals of intermediate size, which are generally regarded as part of the macro plankton.
- **Tychopelagic plankton:** Organisms of benthic habit, which occasionally become stirred up from the bottom and carried into the water.

Algae: The vast majority of all algae fall within four phyla:

- Cyanophyta (blue-green algae)
- Chlorophyta (green algae)
- Phaeophyta (brown algae)
- Rhodophyta (red algae)

The abundance of these groups in a water body depends on climate, water depth and other factors.

Cyanophyta: The blue green algae are inconspicuous but are found almost everywhere in brackish and saltwater environments. They are simple in form with prevalent filamentous characteristics. An individual filament is microscopic, but occurs in clusters of many individuals. These algae appear to be the most primitive and oldest. They have tremendous tolerance to variation in salinity and are able to live in areas of low light intensity. High or low salinity, prolonged exposures to the atmosphere and extreme temperatures do not seem to prohibit growth of blue green algae. They commonly occur in leathery mats or mould shaped structures called *stromatolites*.

Chlorophyta: The green algae are not abundant in salt waters but are dominant in fresh waters. Most salt-water forms are microscopic. However, a few of these are fairly small and difficult to identify with the unaided eye. Most salt-water green algae can be recognized by their color, although some calcareous varieties have a chalky appearance. They are major contributors to bottom sediments in shallow tropical areas. Such genera as *Halimeda*, *Penicillus* and *Udotea* are particularly abundant. They are rather large (several centimeters high) and have specialized holdfasts to anchor themselves.

Phaeophyta: The brown algae are the most totally marine, with only three fresh water forms. Marine forms are large and make up the bulk of coastal seaweeds in mid and high latitude waters. Their characteristic brownish color is due to a special pigment that masks the color of chlorophyll. The *Kelps*, the largest and most complex of the algae are included in this group. Within this order are Macrocystis, Nereocystis and

Pelagophycus: They are the largest algae and form commercial kelp. Some of the seaweeds are edible. They are fed to live stock. The most valuable product of the

brown algae is algin, a compound found in the cell walls. Algin is an absorbent material, which is used as an emulsifier or film forming colloid in ice cream, cosmetics, paints, drugs and latex.

Rhodophyta: More species of red algae are present in the sea than all other algae combined. They are present in a variety of forms. Many are massive calcareous forms. Red algae as a group exist at the greatest depths. They can live in such depths because of their ability to utilize the deep penetrating light rays in the blue and violet end of the spectrum for photosynthesis. Red algae live in shallow water. One of the largest families of the red algae is the *corallinaceal* or *coralline* algae, which is calcareous. This group includes: two general forms, an encrusting and nodular type and one, which is jointed. Many species of these *coralline* forms are associated with reefs and other tropical areas. Algae can also be classified based on their distribution in water column into phytoplankton and periphyton. The phytoplankton is floating while the periphytons are attached algae. The periphyton can be classified into Epolithon (attached to stones), Epipelion (attached on mud surface), Spisammon (attached on sand), Eixylon (attached on decayed wood) and Epiphylon (attached on living aquatic macrophytes).

Plankton collection: The most widely used apparatus for collecting plankton is plankton net. Despite variation in pattern, it consists essentially of a cone of bolting silk or equivalent material mounted on a ring or hoop to which are attached thin rope bridles spliced on a smaller ring by means of which the net can be shackled to a towing robe or warp.

Qualitative sampling of the surface waters is carried out by towing the net slowly behind a boat, at one to three knots for ten minutes. If all the water is filtered through the net (assuming no clogging of mesh by phytoplankton), the volume of water filtered can be calculated using the formula:

$$V = pr^2L$$

where, r = the radius of the hoop at the front of the net; L = the distance through which the net is hauled.

Hauls of this type are often used to assess the quantity of plankton in a given water column, but there are inaccuracies. The nets have been modified with fitted flow meters. These nets also collect the larger zooplanktons.

A quantitative method of sampling plankton populations is to centrifuge a small water sample and count the plankton in it. Although it is better to examine the plankton alive; examination is delayed for the preservation of the sample. Lugols iodine (10 g of iodine added to 20 kg and increased to 200 mL of H_2O plus 20 g acetic acid) or ten percent neutral formalin is used as

fixative. The preservative is added in the ratio of 1:100 mL.

In a rough field method, developed for estimation of plankton, 50 L of water are collected from different sections of the pond. These are filtered through an organdi or a muslin ring net with a 2.45 cm diameter glass specimen tube tied to the lower narrow end of the net. Add a pinch of common salt to water in the tube. Detach the tube from the net. Within 15-20 min of post salt addition, the plankton settles at the bottom of the tube.

If the resultant sediment is from 6.4 to 8.5 mm of the tube, 50,000 to 75,000 spawn/ha can be stocked in the pond. The animal or plant nature of plankton is differentiated by, either a pace brownish (zooplankton) or greenish (phytoplankton) color. The plankton in the tube can be fixed in 2% formalin for detailed study. It can be concentrated into the Sedgwick - Rafter counting chamber. Carefully position the cover glass over the chamber without forming an air bubble. The glass diagonally across the chamber and slowly rotating the cover glass as the sample is introduced from the pipette.

Place the counting chamber beneath the microscope, select a random microscope field, identify and count planktons seen within the ocular micrometric grid using appropriate keys. Repeat this procedure at least ten times.

Calculation: The Sedgwick Rafter counting chamber contains 1.00 mL (50 mm long, 20 mm wide $\times$ 1mm deep).

No of planktons per mL = 1000Tx /AN

where,
T = Total number of plankton counted
X = concentrate volume (m l)
A = Area of grid in (mm)
N = Number of grids employed
1000 = Area of the counting chamber, n (mn^2)

In well managed ponds, with high nutrient concentrations; there is a dense algal growth. Such ponds have denser algae communities than unmanaged ponds and other natural waters.

Plankton blooms and fish kill: Fertilization may not be the only reason for eutrophication or excessive growth of planktons in pond water surface. The growth of certain species of blue green algae such as *Microcystis*, *Anabaena Tracheiomona* and the dinoflagellate, *Gymnodinium* form dense scums in surface waters. These are not in any way due to fertilization. Such growth can be the primary cause of fish kill in ponds. Dense growths of these algae absorb heat from the sunlight, causing a sharp rise in temperature of surface waters.

This rise causes a shallow thermal stratification because light wind stiffed on only top waters. The heavy concentration of algae prevents the penetration of light for photosynthesis to depths below 1m. This causes anoxic condition in the deep areas, resulting in fish kills. The water becomes brown in colour with most of the plankton dead. No soluble phosphate is present in the top layer. The kills may have resulted from lack of oxygen and high concentration of free carbon dioxide.

Phytoplankton scum can be controlled by, avoiding excessive concentrations of phytoplankton scum especially *microcystis* on surface waters of fishponds. When such sums appear, dissolved oxygen should be measured daily to ensure that oxygen is present in depths below 1.3 m.

Light penetration and distribution of dissolved oxygen in ponds can be facilitated with copper tetraoxosulphate (vi) in one or two applications, a week. The quantity of copper tetraoxosulphate (vi) $(CuSO_4)$ in waters with 25ppm hardness is 800 g/ha surface area. The disadvantage is that, it adds to the total Biochemical Oxygen Demand (BOD) in the water. Nutrients may later recycle and cause heavy scum. Biological control using herbivores (plankton feeding fishes) appear more promising.

Pond productivity: This is the rate at which photosynthesis takes place. The rate at which photosynthesis occurs is the real measure of productivity. Such a measure must include a time factor. The actual amount of green plants, the standing crop, is not a true measurement of productivity, but it is related to it. The biomass of photosynthetic organisms indicates productivity, but the opposite is not always true. The productivity of a pond may be high, but the standing crop may not reflect this because of a high rate of consumption by herbivores.

It is necessary for fish culturists to know the rate of production for any given fishpond. This rate can be measured in various ways. These involve chemical changes in the water due to variations in production. In order to measure productivity, it is necessary to determine either the actual amount of organic matter formed during photosynthesis, or the utilization of other constituents necessary for photosynthesis.

The most commonly used index of productivity is the dissolved oxygen content of the water. Oxygen is produced along with organic matter during photosynthesis, and it is produced in quantities directly related to the rate of organic production. Determinations of the amount of oxygen produced over a given period of time, therefore, provide close approximations of productivity.

Since the photosynthetic reaction is diurnally controlled by the position, presence or absence of the sun,

it is necessary to collect samples for productivity determination over a 24-h period at 3-h intervals. This provides a good measure of the change in production related to the sun's position.

Primary production is the increase in plant biomass over a period, plus any loss during that period. It is the total quantity of new organic compounds synthesized by photosynthesis. Primary productivity may be given as net or gross. Net primary productivity represents the total amount of new organic matter synthesized by photosynthesis less the amount the organic matter used for respiration.

Hydro biologists, to estimate plankton abundance, have used many different techniques; only a few methods are commonly used in fish culture. The harvest method, carbon (iv) oxide assimilation, carbon-iv-fixation, chlorophylla, primary productivity by light and dark bottles are possible methods of measuring phytoplankton abundance. Zooplankton can be measured by direct enumeration. Approximate estimates of total plankton can be obtained by particulate organic matter analysis, or in many ponds, from secchi disc visibility.

Harvest method: This is to measure the actual growth of a producing biomass. In this method, a small area, for example, a square meter, is surveyed and all plants are collected, weighed, and replaced in their original position. The procedure is repeated at selected time intervals. The growth of the producing biomass with time is the productivity. Such a method is merely an estimate. It only accounts for benthic production in shallow areas. The removal and replacement of plants alter their growth rate.

Carbon (iv) oxide assimilation: As oxygen is produced during photosynthesis reactions, carbon (iv) oxide is assimilated. It is therefore, possible to determine plant productivity by measuring changes of CO_2 content. pH changes reflect changes in various carbonates. With 0.002 pH units, small changes can be detected. However, because of the decrease in pH with temperature increase, it is necessary to distinguish pH changes due to temperature from those caused by CO_2 uptake.

Actually, HCO_3^-, and CO_3^{2-} all may provide carbon for conversion of organic matter during photosynthesis. The buffering capacity of saltwater may tend to mask changes in hydrogen ion concentration in saltwater ponds. For this reason, a fairly large uptake of CO_2 is necessary to produce enough pH change to give accurate measurements.

Another problem that exists is the precipitation of calcium trioxocarbonate (v). In an area where this occurs, it is not possible to use CO_2 uptake as a production index unless inorganic carbonate changes can be distinguished.

The concentration of various species in the carbon (iv) oxide-carbonate system shows significant diurnal

changes, which are directly related to photosynthesis. Free carbon (iv) oxide is present during respiration at night but disappears, as photosynthesis takes place during the day. The total carbonate, particularly HCO_3^-, follows a predictable relationship in the daytime during a 24-h period.

Carbon -14-fixation: A slight modification of the carbon (iv) oxide technique is the use of the radioactive carbon-14-isotope (^{14}C). A quantity of radioactive carbonate is added to a known volume of water. The plants suspended in water continue to photosynthesize for a period of time, after which the water is filtered and the organisms retained. A Geiger counter is then used, to measure the radioactivity in the organic tissues. In order to have a precise measure of the actual uptake of ^{14}C by the plants, a "dark" sample from the same water is also checked for ^{14}C content and the difference between the two samples represent the total production for that period of time. The ^{14}C method is the most sensitive technique for measuring net production, but it does not provide any data on respiration.

Nutrient uptake: The loss of nutrient elements such as phosphorous and nitrogen to organic matter through photosynthesis is also a measure of productivity. Water samples are collected periodically and analyzed for the nutrient elements. This method is not error free because some phosphorus are lost to inorganic precipitate and living organisms, and some recycled through excretion or decay of dead tissue.

Chlorophylla: The phytoplankton in pond water is concentrated by filtration through a membrane filter. The pigments contained in the phytoplankton are extracted in acetone and the concentration of chlorophyll (a) is determined spectrophotometrically. A close relationship exists between the concentration of chlorophyll (a) in water and the total abundance of phytoplankton (Boyd, 1979).

The absorbance of the pigment extract measured at 633, 645 and 630 mm are used to calculate chlorophylls a, b and c, respectively. The Optical Density (O.D) reading at 750 mm serves as a correction factor for turbidity. This reading at 750 mm is subtracted from each of the pigment optical density values of other wavelengths before they are used for calculations. The concentrations of the chlorophylls are calculated by inserting the optimal densities in the following equations.

$$C_a = 11.64\ D_{663} - 2.1\ D_{645} + 0.10\ D_{630}$$
$$C_b = 20.97\ D_{645} - 3.9 D_{663} - 3.66 D_{630}$$
$$C_c = 54.22 D_{630} - 14.81\ D_{645} - 5.53 D_{663}$$

where, C_a, C_b, C_c = concentration of chlorophyll a, b, c respectively in the extract, mg/L and D_{663}, D_{665}, D_{630} = optimal densities (with a 1cm light part) at the respective

wavelength. When the concentration of pigment in the extract has been calculated, the amount of pigment per unit volume of sample is calculated as follows:

$$\text{Chlorophyll a (mg/m}^3) = C^a \times \frac{\text{volume of extract L}}{\text{volume of sample M}^3}$$

Chlorophylls b and c (mg/m^3) are similarly calculated for the extracts.

Light and dark bottles method: The method involves taking water samples containing a natural plankton population in glass bottles and exposing the bottles to light in the euphotic zone. In a parallel experiment, a portion of the initial sample is held in a dark bottle for the same length of time and at the same temperature as the illuminated samples.

The initial O_2 content (IB) of the sample is determined by the Winkler's method. The difference between this concentration and the concentration found in the water from the illuminated bottle after a suitable period of exposure (LB) is a measure of net evolution of O_2 due to photosynthesis. This difference is not necessarily equal to the true photosynthesis of the plants enclosed in the LB as oxygen consumed by the respiration of the plant cells. It is more common with the dark and light bottle technique to measure gross photosynthesis. This is done by water and oxygen remaining in a dark bottle (LB-DB).

Such a difference is assumed to be equal to the total respiration occurring in the illuminated bottle over the same period of time and if added to the net value obtained over the same period of time and the LB-IB above, a measure of the gross photosynthesis from the relationship.

Calculation:
Gross photosynthesis
      = net O_2 evolved + O_2 used for respiration
      = gain in LB + Less in DB
      = (LB – IB) + (IB - DB)
      = LB – DB
Gross production
      = (LB – DB) x 375 mL M^3/h
      = T (hrs)
Respiration
      = (IB-DB) $\times$ 375 mg/ LM^3/h x RQ (1.0) = T (h)

CONCLUSION

Salinity, conductivity, sediment, turbidity, dissolved oxygen, carbon (iv) oxide, pH, alkalinity, nitrogenous compounds in water, estimation of nitrogenous compound, plankton, algae, light and dark method, plankton collection, plankton bloom and fish kill, pond productivity, harvest methods, carbon (iv) assimilation, carbon-14-fixation, nutrient uptake and chlorophyll culturist and environmental manager adequate knowledge to manage our fishery resources are some water quality parameter reviewed to provide fish.

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