Unit 10: Physical, chemical and biological factors affecting productivity of ponds

Introduction

Water is the primary requisite for the existence and growth of aquatic animals. The elements present in water considerably influence the biological production in aquatic environment. The soil provides all these elements for biological production in aquatic environments. The quality of soil is important because of its influence on productivity and quality of overlying water. It has also has a great influence on construction and maintenance of pond bundles.

Quality

A satisfactory pond soil is one which part from being impervious to water, permits rapid mineralisation of organic water, adsorbs nutrients, loosely bound and releases them slowly over a long period of time. The ability of the pond to retain the required water level is also greatly affected by the physical characteristics of soil such as texture and porosity. Soil texture depends on relative proportion of particles of sand, silt and clay. Fine textured soils such as silly clay, clay loamy, silty-clay-loamy and sandy clay are more suitable for fish pond construction because of high water retention capacity. Gravelly and sandy soils having poor water retaining capacity and higher rates of seepage are not suitable for fish culture.

Physical factor

- **Texture of pond soil:** The proportionate composition of the mineral fraction of the soil particles (sand, silt and clay) is denoted by the texture of the soil and is an indicator of the water holding capacity of the soil. Pond soil for aquaculture should certain 35% clay.
- **Water:** The important physical properties of water are depth, temp and turbidity.
- **Depth:** Depth of water in a pond is most important since penetration of light to the bottom contributes in large to the pond productivity. Water layer below 3 to 4 meter in temperature countries and below 1.5 to 2 meter in tropical region have little significance in biological productivity. Shallow water gets warm up rapidly and provide optimum conditions for aquatic life. The primary production takes place from surface to a depth of 1 meter. However, fish ponds should not be too shallow in tropics, as extremely high temperature adversely affect production and may lead the fish mortality. A water depth of 1.5 to 2 meter is considered congenial (agreeable) from the point of biological productivity of a pond.
- **Temperature**

Temperature greatly influence the biological activities of fish notably their respiration, growth and reproduction.

Fish can perceive water temperature changes which are smaller than 0.1OC. Every species has its own characteristic optimum temperature range which might change seasonally. Fish is a cold blooded animal and unlike mammals and birds their body temperature is not internally regulated. Hence its body temperature varies with the temperature of water. This results in changes in metabolism. The temperature of water therefore has profound effect on the life.

The oxygen consumption of fishes increased with rise in temperature. At the same time, the amount of oxygen that water can dissolve and hold decreases with increase in temperature.

Ex : 10OC – 10.92 mg/l, 20OC – 884 mg/l, 30OC – 7.53 mg/l

Processes of fish such as growth and development. Several species have a wide range of temperature tolerance. However growth is usually optional within a limited range. The Indian major carps usually tolerate wide range of temperature, but thrive well in the temperature range of 18 to 38OC. lethal temperature limits for cold water species like trout and salmon is around 25OC. For carps and Tilapia, the lethal limits are around 40OC.

(Lethal – causing death, fatal – resulting in death)

Turbidity

Turbidity is a condition of water resulting from the presence of suspended matter. It may be due to suspended clay, silt and finely divided organic matter and plankton. It may be temporary due to rains, floods and drainage inflow or permanent an account of nature of soil and constant wind and wave action. Turbidity is measured by secchi disc visibility optimum secchi disc visibility in fish ponds is considered to be 40 to 60 cms.

Turbidity is an important binding factor in the productivity of a pond. Light can penetrate deeper into cleaner water and induce the growth of plants. Photosynthesis will be very much reduced in turbid waters. Turbid water gets heated up quickly and trap nutrients and cause siltation leading to ageing of pond. Turbidity suppresses or destroys planktonic organisms by suffocation. Waters containing > 400 mg/l of suspended solids (matter) are not productive.

Soil pH

The soil pH influences transformation of soluble phosphates, response of different nitrogenous fertilizers, adsorption and release of nutrients at the soil water interface including bacterial activity in soil and is maximum at neutral pH. The ideal pH is 6.5 to 7.5 for fish ponds.

Nitrogen

Nitrogen is required to stimulate primary production in aquatic environment. Soil is the main source of this element. However, a major fraction of this element remain in complex organic substances and bacterial degradation of organic matter present in soil cause the release of mineral nitrogen for utilization. The available nitrogen contents in the range of 25 to 50 mg/100 g is considered favourable for average production.

Phosphorous

Phosphorus is another element required for all aspects of cellular metabolism, respiration, cell division and growth, synthesis of protein and incorporation in all living tissues. The low status make this element as a limiting factor in biological production. The nature of phosphorous status of soils is generally low compared to other major elements and also due to reactive nature of phosphate ions, it becomes unavailable as insoluble phosphates. Due to these factors available soil phosphorus is considered for biological production rather than total phosphorus content of soil. The available soil phosphorus in the range of 3 to 6mg/100g is considered desirable for average productive soil.

Organic carbon

Bacterial activity depends on the carbon content of the soil utilising it as a source of energy. In fish ponds, the process of sedimentation and decomposition of organic matter takes place and as a result various nutrients are released from complex organic forms to simple inorganic compounds. The unproductive nature of both newly constructed ponds and order ponds are mainly due to the low and high organic carbon content of the soil respectively. Organic carbon content in the range of 0.5 to 1.5% is considered is ideal for average fish production.

Water

Dissolved oxygen, pH, Carbon dioxide (CO2), Ammonia (NH3), alkalinity, dissolved organic matter etc., are the important chemical properties of water.

Dissolved Oxygen: (Do)

The most common kind of deficiency in water is lack of dissolved oxygen usually caused by decay of organic matter.

Even though oxygen is a major component (20.95% of air) but is sparingly soluble in water. The solubility has inverse ratio with temperature. There is a well known diurnal (24 hrs) variation in DO during day due to active photosynthesises, DO can increases reaching peak in the afternoon. (from dusk to dawn). T here is gradual decrease in DO content.

DO depletion

Main cause of depletion is organic matter load and its decomposition. Usage of high dose of organic manure should be done carefully. Second cause is algal bloom die off.

Prolonged exposure to sub lethal concentration of oxygen is harmful to fish which more often go unnoticed. Feed consumption, growth, feed conversion and disease resistance are reduced in sub lethal concentration under culture conditions.

Do needs of different sps.

The rate of respiration (O2 consumption) varies with species, size, activity, temperature, nutritional status etc., Younger fishes being more active consume more O2 than starved ones. If oxygen concentration in water is high fish tend to consumer more oxygen.

A minimum concentration of 5 mg/l is sufficient for warm water fishes, while 9 mg/l is required for cold water sps. (For short periods even if DO falls by 2-3 mg/l below the minimum levels fishes won't die). Experiments have shown that flucations of DO both below and above the optimum range has adverse effects on growth, appetite, feed conversion.

Fishes with accessory respiratory organs like in species clarias, Heteropneustus, channa, Anabas etc., can survive in poorly oxygenated waters. Tilapia species can survive well at DO concentration as low as 1 mg/l .

Methods of increasing DO

a) Aerators – Increase air-water interface water bubbles into small- more surface area.
b) Pumping fresh water
c) Splashing water surface

pH – puissance dihydrogen (Concentration of Hydrogen)

The pH or hydrogen ion concentration is often used as an index of water conditions in fish pond. The pH is defined as the negative logarithm of hydrogen ion concentration. The substances dissolved in water gives it an acid, neutral or alkaline reaction.

The pH value varies between 0 & 14. While a pH of 7 indicates a neutral reaction. pH above 7 shows an alkaline reaction and below 7 an acid reaction. Alkaline or neutral water is more productive than acid water. Water with pH ranging from 6.5 to 9.0 is most suitable for fish culture. In waters more acidic than pH 6.5 or more alkaline than pH 9.5 for long period, reproduction and growth will be diminish. Water more alkaline than pH 9.5, CO2 becomes unavailable. Acid waters also affect fish indirectly by its adverse affects on fish food organisms.

Carbon dioxide (Co2)

CO2 is highly soluble in water, but it is only a minor constituent of atmosphere (0.03% of air). The major sources of CO2 in water are from the decomposition of organic matter and respiration of aquatic animals and plants. Plants use CO2 for photosynthesis and release oxygen. Accumulation of CO2 generally takes place in the night.

CO2 occurs in water in 3 closely related forms, namely (a) free CO2 (b) bicarbonate ion (HCO3) (c) Carbonate ion CO3 (band C are band form)

The concentration of free CO2 usually does not exceed 20mg/l. However, it may be as high as 50mg/l in organically polluted water. High concentration of free CO2 interfaces with respiration in fishes leading to mortality. Fish can tolerate high concentration of CO2 if the DO concentration is high.

CO2 is not highly toxic to fish. Concentration between 50-100 mg/l can cause respiratory stress. Between 100-200mg/l CO2 is fatal. Most spp. will survive for several days when concentration is upto 60 mg/l, provided dissolved oxygen is plenty.

Organic matter

Organic matter is present as living plankton, suspended particles of decaying organic matter (detritus) and dissolved organic matter, BOD (Biochemical oxygen demand) is frequently mentioned in connection with organic matter in water.

BOD

The Biochemical oxygen demand is used up oxygen by unstable organic matter for its stabilization in water brought about by aerobic bacteria. For Aquaculture waters. BODs should be 20 ppm, incubation for 5 days difference between initial DO and final DO give BODs is 20 ppm.

Hydrogen Sulphide (H2S)

Fresh water fish ponds should be free from hydrogen sulphide. H2S is produced by chemical reduction of organic matter that accumulates and forms a thick layer of organic deposit at the bottom.

Unionized hydrogen sulphide is toxic to fish, but the ions resulting from its dissociation are not very toxic 0.01 to 0.5mg/l – lethal to fish and any detectable concentration of hydrogen sulphide in water creates stress to fish.

Rectification of H2S

1) Frequent H2O exchange to prevent building up of hydrogen sulphide in the water.
2) When pH of water is increased by liming, the toxicity of hydrogen sulphide decreases.
3) Potassium permanganate (6.2 mg/l) can be used to remove H2S (1 mg/l) from water.

Ammonia (NH3)

The major source of NH3 to water is decomposition of organic manure, feed and excretion by fishes. Ammonia occurs in 2 forms unionized Ammonia (NH3) . and Ionized Ammonia (NH4). Ammonia refers to combed concentration of unionized and ionized Ammonia (NH3 + NH4). Only the unionized Ammonia is toxic to fish.

- 0.02 to 0.05 mg/l – safe concentration for many tropical fish species
- 0.05 to 0.4 mg/l – sub-lethal effects depending on the species
- 0.4 to 2.5 mg/l – lethal to many fish species.

Measures to maintain safe NH3 level, Normally high DO2 and high CO2, the toxicity of Ammonia to fish is reduced

1) Aeration
2) Healthy phytoplankton population removes NH3 from water.
3) Biological filters (convert NH3 to NO2)
4) No excess feeding (go for high protein feed)
5) Excessive liming should be avoided.

6) Water exchange

Total Alkalinity

The term total alkalinity refers to the total concentration of bases in H2O expressed in mg/l of equivalent calcium carbonate. Even though small amounts of carbonates of magnesium, sodium and potassium may slightly influence the alkaline reserve for all practical purposes. It can be expressed as the calcium content of the water in most waters.
Total Alkalinity is a measure of productivity of a pond. Productive waters have alkalinity values upto 100 ppm or 100 mg/l.

- < 20 mg/l stress to fish
- 20-300 mg/l ideal for fish
- 300 mg/l stress to fish.

Biological factor

Biological factors of water which influence fish production are tied up with the capacity of the surrounding environment to supply essential food to cultured species. They are therefore concerned only with rearing operations where no supplementary food is given and the energy requirements are met through the phytoplanktonic primary production. Photosynthesis which transforms mineral salts into carbohydrates under the influence of light given the energy necessary for the development of plants. The biomass of phytoplankton various seasonally in general reaching its highest levels in spring and summer. The density is highest in superficial layers of water (0-10m) and deceases with depth. The appearance of different populations is linked in part to the characteristics of the surrounding water temperature, turbidity and depletion of nutrient.

- The diseases in fishes and prawns are caused by bacteria, virus, fungi, protozoa and crustacean parasites. These parasites enter into the pond along with water, fish or prawn seed and nets from other infected ponds.
- Excess growth of aquatic weeds in fish pond is not a good sign in aquaculture systems. Weeds utilize the nutrients and compete with desirable organisms.

- **Estimation of productivity**

It is estimated by estimating the primary production to refer to the rate of synthesis of organic matter from the inorganic constituents of watery by the plants (phytoplankton) in the presence of sun light. Organic production by plants is the first step in trapping energy by living beings from non-living natural resources and hence called primary productivity. The methods followed are Dark and light bottle method and C techniques.

Light and Dark bottle method (Garden and Gran, 1930)

The amount of oxygen liberated by phytoplankton during photosynthesis is considered as a of primary production. Water samples are collected in three BOD bottles namely light, dark and control at depths at which productivity as to be measured. Zooplanktons are removed by filtering through plankton net (300 ....). Water samples is the control bottle is immediately fixed by using Winkler's fricatives. The dark bottle is wrapped with aluminium foil and kept in a black bag to protect from light. The light and dark bottles are then suspended on to a raft and anchored. The bottles are incubated for a period of 4 to 6 hrs between dawn to midday or between midday to sunset in the respective depths from where productive measurement need to be carried out. After incubation period, the bottles are taken out and fixed with Winkler's fricatives. The oxygen content in the sample is determined by using Winkler's method (other method of Do estimation can also be used)

Primary production is carried out as follows.

Let the initial oxygen level be IB

Let the final oxygen level be DB

Let the oxygen level in light bottle be LB

Net oxygen production = LB-IB

Gross production of oxygen = LB-DB Let 't' be the time kept for incubation

Gross primary productivity (LB-DB)x1000x0.375 = ------------------------------ = mgc/m3/hr 1.25xt

Net primary productivity (LB-IB)x1000x0.375 = ------------------------------ = mgc/m3/hr 1.25xt