Study on the Physico-Chemical Parameters Present in Shrimp and Shrimp Culture Water for the Improvement of Sea-food Quality of Khulna Region, Bangladesh.

by

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A thesis submitted in partial fulfillment of the requirements for the degree of
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Dedicated

to

my beloved parents

Late Mir. Md Abu Bakker

&

Begum Khalada Bakker

Declaration

This is to certify that the thesis work entitled "Study on the Physico-Chemical Parameters Present in Shrimp and Shrimp Culture Water for the Improvement of Sea-food Quality of Khulna Region, Bangladesh" has been carried out by Mir. Md Fakker Uddin Ali Ahamed in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above research work or any part of the work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

This research provides guidance on how to develop shrimp quality in aquaculture. Aquaculture development is growing rapidly worldwide due to increasing demands of its products and limited production from Inland and marine capture fisheries. The research studied water of different sources which are used in shrimp culture. The results provided significant information and the values were compared with the current standard values or acceptable physico-chemical factors that affect the quality of shrimp culture water as well the quality of shrimp. The current state of knowledge on the acceptable limits of hazardous chemicals in water used for fisheries and aquaculture and the acceptable concentrations accumulated in the tissue of aquaculture products are also furnished. Shrimp and shrimp culture water were collected and tested from different locations or shrimp farms (Ghers), hatcheries and nurseries of Bagerhat, Satkhira and Khulna district. The farms were chosen and designated as 1-9 from Satkhira, 10-18 from Khulna and 19-27 from Bagerhat. Different parameters such as, pH, DO, BOD, Fe, salinity, hardness, turbidity and heavy metals were performed. DO, BOD, pH and salinity were measured on the spot after collecting the shrimp culture water from shrimp farms (Ghers), hatcheries and nurseries. Turbidity, hardness, NO_3^- and Fe were measured in the laboratory with spectrophotometer (DR-4000) in Fisheries office, Khulna. Heavy metals were measured atomic absorption spectrophotomer in atomic energy center, Dhaka, Bangladesh. The values of pH, BOD, salinity and hardness at different location of Bagerhat were found within standard limits in farms nos. 19 to 27 but DO was found to be high. The values of BOD and iron at different location of Khulna were found within standard limits in farms 10 to 18 but pH, turbidity, salinity, hardness, and DO were found to be high. The values of hardness, BOD and iron at different location of Satkhira district were found within standard limits in farms nos. 1 to 9 but pH, turbidity, salinity, and DO were found to be high. The values of nitrate in all farms at Satkhira, Khulna and Bagerhat district were low. The heavy metal such as Pb, Cr, Cd and Hg in shrimp culture water were found within standard limit in Satkhira district in farms nos. 1, 4 and 7 and heavy metal in shrimp were found within standard limit in farms nos. 1 to 9. The values of heavy metal Pb in shrimp for shrimp in farms nos. 11, 12,14,15,17 and 18 of Dumuria, Koyra and Paikgachha of Khulna district were found within standard limit but in farms nos. 10, 13 and 16 were high. The value of Hg in shrimp culture water for shrimp farms of Dumuria, Koyra and Paikgachha of Khulna district were

found in farms nos.10 to 18 within standard limit. The value of Cd in shrimp culture water for shrimp farms of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10, 12,14,15,17 and 18 within standard limit but in farms nos. 11, 13 and 16 were higher than standard limit. The value of Cr in shrimp culture water for shrimp farms of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10, 11, 12, 14, 15, 17 and 18 within standard limit but in farms nos. 13 and 16 were higher than standard limit. The values of heavy metals Pb, Hg, Cd, and Cr in shrimp for shrimp farms of Rampal, Mongla and Bagerhat main town of Bagerhat district were found within standard limit in farms nos. 19, 20, 21, 22, 23, 24, 25, 26 and 27. The quality of physico-chemical parameters in shrimp culture water at different locations at Bagerhat was found to be standard and the presence of heavy metals in shrimps at these locations was found to be within standard limit. The physico-chemical parameters such as pH, salinity, hardness, DO, BOD, NO_3^- Fe and heavy metals in shrimps and shrimps culture water of other areas should be maintain as like as Bagerhat.

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Chapter-I

Introduction

1.1 General

Frozen shrimps are most important of all Bangladesh export fishery proudest. Annual exports have increased from 180 M.T in 1968 to 86840 M.T. in 2007(BRAR-2007). This increase corresponds with the expansion of brackish water cultivation of shrimps. The export value in 1972 was approximately US$ less then 3 million but in 2007 it was 515 million which was the 2nd largest export item in our country. EU is the major export market importing 49% in 2007 and USA importing 40% in 2007 of the total quantity (BRAR-2007). In order to compete in the international market shrimp exporters must met physico-chemical standards set by importing countries. The shrimp industry in Bangladesh can be divided into four components post-larva production (hatchery), Nursery, grow-out (shrimp farming) and shrimp processing. Most important component to be considered in the environmental point of view is the shrimp farming because it has been originated from natural systems and has now been transformed to extensive, semi-intensive and to intensive culturing systems. The culturing systems have now grown beyond natural boundaries or carrying capacities of the farming areas. Semi-intensive and intensive farming systems use largely resources and energy sources, such as electricity and fuel to maintain farming system. The shrimp industry in commercial scale in Bangladesh has been developed by private sector with the initiative of the government.

Life cycle of shrimp

Shrimp mature and breed only in a marine habitat. The females lay 50,000 to 1 million eggs, which hatch after some 24 hours into tiny nauplii. These nauplii feed on yolk reserves within their body and then undergo a metamorphosis into zoeae. This second larval stage feeds in the wild on algae and after a few days metamorphoses again into the third stage to become myses. The myses already look akin to tiny shrimp and feed on algae and zooplankton. After another three to four days they metamorphose a final time into post larvae young shrimp having all the characteristics of adults. The whole process takes about 12 days from hatching. In the wild the post larvae then migrate into estuaries which are rich in nutrients and low in salinity. There they grow and eventually migrate back into open waters when they mature. Adult shrimp are benthic animals living primarily on the sea bottom [1].

Hatchery

Small-scale hatcheries are very common throughout Southeast Asia. Often run as family businesses and using a low-technology approach they use small tanks (less than ten tons) and often low animal densities. They are susceptible to disease but due to their small size, they can typically restart production quickly after disinfection. The survival rate is anywhere between zero and 90% depending on a wide range of factors including disease the weather and the experience of the operator. Green water hatcheries are medium-sized hatcheries using large tanks with low animal densities. To feed the shrimp larvae, an algal bloom is induced in the tanks. The survival rate is about 40%.Galveston hatcheries (named after Galveston, Texas, where they were developed) are large-scale, industrial hatcheries using a closed and tightly controlled environment. They breed the shrimp at high densities in large (15 to 30 ton) tanks. Survival rates vary between zero and 80% but typically achieve 50%.In hatcheries the developing shrimp are fed on a diet of algae and later also brine shrimp nauplii sometimes (especially in industrial hatcheries) augmented by artificial diets. The diet of later stages also includes fresh or freeze-dried animal protein, for example krill. Nutrition and medication (such as antibiotics) fed to the brine shrimp nauplii are passed on to the shrimp that eat those [2].

Nurseries

Many have nurseries where the post larval shrimp are grown into juveniles for another three weeks in separate ponds, tanks or so-called raceways. A raceway is a rectangular long shallow tank through which water flows continuously [3]. In a typical nursery there are 150 to 200 animals per square meter. They are fed on a high-protein diet for at most about three weeks before they are moved to the grow out ponds. At that time, they weigh between one and two grams. The water salinity is adjusted gradually to that of the grow out ponds. Farmers refer to post larvae as "PLs" with the number of days suffixed (i.e., PL-1, PL-2, etc.). They are ready to be transferred to the grow out ponds after their gills have branched, which occurs around PL-13 to PL-17 (about 25 days after hatching). Nursing is not absolutely necessary but is favored by many because it makes for better food utilization, improves the size uniformity helps utilize the infrastructure better and can be done in a controlled environment to increase the harvest. The main disadvantage of nurseries is that some of the post larval shrimp die upon the transfer to the grow out pond [2].

Farm system

In the grow out phase the shrimp are grown to maturity. The post larvae are transferred to ponds where they are fed until they reach marketable size which takes about another three to six months. Harvesting the shrimp is done by fishing them from the ponds using nets or by draining the ponds. Pond sizes and the level of technical infrastructure vary. Extensive shrimp using traditional low-density methods are invariably located on a coast and often in mangrove areas. The ponds range from just a few to more than 100 hectares; shrimp are stocked at low densities (2–3 animals per square meter or 25000/ha). The tides provide for some water exchange and the shrimp feed on naturally occurring organisms. In some areas, farmers even grow wild shrimp by just opening the gates and impounding wild larvae. Prevalent in poorer or less developed countries where land prices are low extensive produce annual yields from 50 to 500 kg/ha of shrimp (head-on weight). They have low production costs (US$1–3/kg live shrimp) are not very labor intensive and do not require advanced technical skills [4]. Semi-intensive does not rely on tides for water exchange but use pumps and a planned pond layout. They can therefore be built above the high tide line. Pond sizes range from 2 to 30 ha the stocking densities range from 10 to 30/m² (100,000–300,000/ha). At such densities artificial feeding using industrially prepared shrimp feeds and fertilizing the pond to stimulate the growth of naturally occurring organisms become a necessity. Annual yields range from 500 to 5,000 kg/ha, while production costs are in the range of US$2–6/kg live shrimp. With densities above 15 animals per square meter, aeration is often required to prevent oxygen depletion. Productivity varies depending upon water temperature thus it is common to have larger sized shrimp in some seasons than in others. Intensive use even smaller ponds (0.1–1.5 ha) and even higher stocking densities. The ponds are actively managed: they are aerated, there is a high water exchange to remove waste products and maintain water quality and the shrimp are fed on specially designed diets typically in the form of formulated pellets. Such produce annual yields between 5,000 and 20,000 kg/ha, a few super-intensive can produce as much as 100,000 kg/ha. They require an advanced technical infrastructure and highly trained professionals for constant monitoring of water quality and other pond conditions their production costs are in the range of US$4–8/kg live shrimp.

1.2 Background of the research topics

Shrimp farming is a highly profitable sector with enormous scope to increase foreign exchange and general employment in a developing country like Bangladesh. However shrimp farming needs to be conducted in a way that is socially acceptable, economically viable, technically appropriate and environmentally sound. The survival of farming system can be relatively high with higher anticipated profit (4, 5, 6, 7, 8 and 9). The growth or yield of shrimp depends on favorable water quality characteristics. In shrimp farming systems excess food, decal matter or sudden increase or decrease in algal or microbial populations may cause drastic changes in water quality parameters. A part from these physico-chemical parameters, such as, total salinity, pH, BOD, DO, Fe^{2+}, hardness, etc. plays a vital role in the growth of shrimp. In the present world people are aware of health in taking food. Fish is globally treated as the safest food for making up protein deficiency. In the fiscal year (2005-06) Bangladesh earned about Tk. 32000 million by exported fish and fish like items of which about Tk. 18184.2 million from Khulna region. It was known from different periodicals that due to salmonella and filth contamination, 19 containers of exported fish were sent back to Bangladesh in 2007 the value of which was 500 million. As we are not in a position to maintain the standard quality shrimp, we are loosing 1 US$ per pound from exported fish in comparison to that of India and Thailand. To improve the quality of the shrimps this research has been undertaken.

1.3 Objective of the study:

Various physico-chemical parameter such as, total salinity, pH, BOD, DO, turbidity, Fe, nitrate and hardness etc. play a vital role in shrimp culture. The objectives of this research are to measure total salinity, pH, BOD, DO, turbidity, Fe, nitrate, hardness and heavy metals in shrimp and shrimp culture water in order to improve the shrimp quality.

Chapter-II

Literature Review

Over the year, intensive shrimp aquaculture has become high revenue industry for many countries like Thailand, Sri Lanka, Taiwan, India, Philippines and Bangladesh. In shrimp aquaculture the main components are grow-out ponds comprising and hatcheries. The grow-out culture systems are mainly natural, extensive and semi-intensive to intensive in accordance with its operations [10]. Water is the most important factor for aquaculture. Selection of water source should be based on its suitability for efficient production of a high quality aquaculture product. Poor water quality may affect fish and shellfish health through impairment of development and growth or may degrade the quality of the product by tainting its flavor or by causing accumulation of high concentrations of toxic substances which could endanger human health. The importance of water quality has created a need for guidelines for determining the suitability of water source for use in this research. Temperature, turbidity, salinity, pH, DO, BOD, hardness, nitrogen compounds and iron are the basic physico-chemical properties. Because these physico-chemical properties of water also affect the growth of fish and shellfish. These parameters must be tested for in all potential water sources [11]. Physico-chemical parameters of water affect food consumption of reared shrimp [12] that may the reduce growth rates and final cultured biomass within a pond. Several authors studied how variations of water quality influences shrimp behavior [13] reported that alterations of salinity might influence F. paulensis consumption of ration. Miranda [14] and Santos [15] noticed an in hibitory effect on predation activities of F. paulensis when exposed to closed environments contaminated with ammonia and heavy metals respectively [16] registered lower growth of Litopenaeus vannamei in high salinities with reduction in food consumption, where as [17] working with the same species registered significant changes in food intake and food conversion rates for lower temperatures [16] reported significant variations on the growth of F. paulensis juveniles as a function of different physical-chemical parameters of water (i.e. temperature, and salinity), mainly due to changes of respiratory and excretory metabolism. Now a days, as a way to reduce feeding management expenses and keep acceptable pond water and bottom quality even spending more with personnel most shrimp are just using feed trays instead of broadcasting the ration through the entire grow-out pond guided by feeding tables. However, on both feeding schemes it is fundamental to have knowledge of how water quality influences food consumption [18].Generally the pond water at Samut Sakorn was poor as regards nitrogen and phosphorus. Levels of nitrogen were usually less than 0.1 ppm (nitrate, nitrite) and phosphate less than 0.7 ppm. At Surat Thani on the other hand, nitrogen values ranged from 7 to 9 ppm (nitrate, nitrite) and phosphate was less than 0.2 ppm on the one occasion when measurements were taken. This variation in nutrient levels at different localities indicates the use of different fertilizers. As was shown in the fertilization experiment reported above, water at Samut Sakorn benefited from a balanced fertilizer containing both nitrogen and phosphorus. It is likely that at Surat Thani, greatest benefits would be obtained with the use of super phosphate alone. One of the factors which make the use of fertilizers difficult in Thailand is the leakage of water from ponds. The leaking water carries away nutrients. There are two main causes of leaks; [19] holes in levees caused by burrowing crabs and [20] leaky sluice boxes. The expert and his counterpart found that leaks caused by crabs could be stopped by digging a trench in the levee and inserting sheets of polyethylene film in the trench. It is not known how long this protection will last. The cost of digging the trench is high, but if longer testing proves the plastic film to be worthwhile, it might be possible to install it in new ponds at a much lower cost. A small ditch and levee would be constructed initially, then the polyethelene film lay down, and finally the ditch widened and the plastic film covered with earth. The expert and his counterpart tried several ways of preventing sluice gates from leaking. They found that a sheet of cello Crete 60 cm wide fastened to the sides and bottom of the sluice box prevented leaks. The cello crete should be positioned adjacent to the sluice boards. Food and Agriculture Organization (FAO) reports that most species subject to capture fishing are overexploited and that the potential for increasing yields in the long term is extremely limited. Aquaculture is an attractive alternative to capture fisheries due to its potential for production expansion effective use of processing facilities and adaptability of production to market requirements. Facing the leveling of Production of capture fisheries, aquaculture has grown in production at an average annual rate of over 11 percent during 1990-94 according to FAO-reported trends. With this growth the World Bank has become increasingly involved in assisting and financing aquaculture project requests from member governments. This report is thus meant to help private and public sectors and lending institutions determine whether the water quality at a proposed aquaculture development site is acceptable. The need for such a guide has become important and necessary with the continued durations of water resources from increases in industrial and municipal wastewater discharges and agro-chemical use [21]. Water is the most important input for aquaculture and thus a key element in the success of these projects. Source water should be selected based on its suitability for efficient production of high quality aquaculture product. Poor water quality may impair the development and growth of fish and shellfish. It may also degrade the quality of the product by tainting the flavor or by causing accumulation of high enough concentrations of toxic substances to endanger human health. The importance of water quality along with the growth of the World Bank's involvement in aquaculture projects has created a need of a guide for determining the suitability of source waters proposed for use in these projects. It is the goal of this report to provide information useful to this end. This report reviews the quality standards for water and fish product, looks at the parameters of greatest importance to aquaculture, and discusses the scientific basis for these standards [22]. It can provide government officials, field technicians and task managers with necessary information to make informed judgments. The report also contains practical, step-by-step guidelines for use by task managers in determining whether the quality of the proposed source water will present a significant risk to the success of a project. The prescribed procedures would be of importance to site selection for any considered aquaculture enterprise and would also be of use to governments involved in formulating inland and coastal zone development plans that would include assessment of appropriate areas for the establishment of aquaculture facilities. Fish and shellfish health is very sensitive to water quality. Water quality criteria are based on studies of growth, behavior and health of different species in various waters. One set of parameters which affect fish and shellfish are the basic characteristics of natural water otherwise referred to as its physcio-chemical properties. These include properties such as turbidity, pH [23] and dissolved oxygen. For many of these properties, fish have a limited range in which they can grow optimally. Hence, screening the source water in respect to its physcio-chemical properties is an important initial step in assessing the source-water suitability to fish health. In any shrimp farming, management of water quality is of primary consideration particularly in ponds with higher stocking rates. Degradation of water quality is detrimental to shrimp growth and survival. Good quality water is usually defined as the fitness or suitability of the water for survival and growth of shrimp. Water quality is critical for survival health and growth of shrimps especially in semi-intensive and intensive shrimp culture systems and for the production of quality shrimp seed in the

Chapter-III

Description of Physico-chemical parameters

pH, salinity, turbidity, hardness, DO, BOD, NO_3^-, Fe and heavy metal are the basic physico-chemical parameters. Because these physcio-chemical properties of natural water affect the growth and health of fish and shell-fish, these parameters must be tested for in all potential water sources.

3.1 pH

The pH of water is its hydrogen ion concentration ($[H^+]$). It is expressed as the negative logarithm of the hydrogen ion concentration ($-\log [H^+]$).

Effect

The pH of water used in aquaculture can affect fish health directly. For most species, a pH between 7.5 and 9 is ideal. Below pH 6.5 species experience slow growth (19). At lower pH, the species ability to maintain its salt balance is affected [19] and reproduction ceases. At approximately pH 4 or below and pH 11 or above most species die [20].

The pH can also indirectly affect fish and shellfish through its effects on other chemical parameters. For example, low pH reduces the amount of dissolved inorganic phosphorous and carbon dioxide available for phytoplankton photosynthesis. Also at low pH, metals toxic to fish and shellfish can be leached out of the soil. At high pH the toxic form of ammonia becomes more prevalent. In addition phosphate, which is commonly added as a fertilizer, can rapidly precipitate at high pH [21]

Treatment

Low pH water is often treated using lime [29]. Alum can be used to treat high pH waters. In cases where the high pH problem is due to excess phytoplankton photosynthesis in waters with high alkalinity and low calcium hardness Gypsum can be added as a source of calcium. Another option is to kill off phytoplankton with algaecides but low dissolved oxygen conditions residual adverse effects of the algaecide and high costs may result [21].

3.2 DO (Dissolved oxygen)

Dissolved oxygen (DO) is a very basic requirement for aquaculture species. It is usually the first limiting factor to occur in pond culture. Dissolved oxygen is a complex parameter because its concentration is dependent upon many processes. In an aquaculture system the sources of dissolved oxygen are photosynthesis and reaeration from the atmosphere. The sinks include oxygen-consuming processes such as respiration from microbial life, fish, and plants and the degradation of organic matter by microorganisms (biological oxygen demand or BOD). These processes are influenced by other factors. Photosynthesis, respiration, the degradation of organic matter and the solubility of oxygen are all influenced by temperature. The type of fish life stage feeding practices level of activity and dissolved oxygen concentration also influence the respiration rate. In addition to temperature, oxygen solubility is also affected by salinity, barometric pressure and impurities. The most common cause of low dissolved oxygen in an aquaculture operation is a high concentration of biodegradable organic matter (and thus BOD) in the water. This is especially true at high temperatures. Hence BOD is possibly a more important parameter to dissolved oxygen than dissolved oxygen itself.

Effects

Dissolved Oxygen concentrations near saturation levels are generally healthiest for fish. Romaire [23] believes that growth is impaired if dissolved oxygen concentrations remain below 75 percent saturation for long periods and Colt and Orwicz recommend that dissolved oxygen be maintained at a minimum of 95 percent saturation for optimum growth. The following generalizations were derived for warm water pond fish. For dissolved oxygen concentrations approximately 1-5mg/L the dissolved oxygen is still high enough for survival however, long-term exposure results in slow growth. As dissolved oxygen gets be low 1 mg/L, it becomes first lethal after long term exposure and at lower dissolved oxygen, only small fish can survive short-term exposures [30]. At high oxygen concentrations, oxygen super saturation can contribute to gas bubble trauma. Although when combined with other gases, oxygen can cause gas bubble trauma. High oxygen concentrations alone do not result in gas bubble trauma but high dissolved oxygen concentrations occurring at times when water temperature increases rapidly can augment the phenomenon [24]. Oxygen super saturation occurs due to high dams, aerators and rapid photosynthesis when saturated groundwater is warmed naturally to ambient temperatures, or when saturated water is heated in hatcheries [31].

Guideline

Setting guidelines for dissolved oxygen for source water is difficult because dissolved oxygen in aquaculture operations is affected by many processes independent of the initial dissolved oxygen source-water. At the screening stage, the initial dissolved oxygen and BOD can be used to assess the ability of the source water to maintain proper oxygen levels. Other factors affecting dissolved oxygen concentration in the aquaculture operation can only be assessed and mitigated once the operation is running. DO should be considered as a minimum for source water. In addition the dissolved oxygen and BOD should be used together to assess the ability of the source water to maintain proper oxygen levels.

Treatment

Treatment of source water for low dissolved oxygen can be accomplished using aerators. These systems typically employ mechanical mixing in order to increase the surface area of the water exposed to the air and thus the transfer of oxygen. These can take many forms including running the water over baffles or employing power aerators such as paddlewheel aerators and spray aerators.

3.3 Salinity

Salinity is a measure of the total concentration of dissolved ions in water and measured in parts per thousand (ppt). Salinity varies depending on where the water source lies in the spectrum from seawater to freshwater. Typical salinity values are less than 0.5 ppt for freshwater, 0.5 to 30 ppt for brackish water and 30 to 40 ppt for marine water. In freshwater, the salinity and the elements contributing most significantly to salinity can vary depending on the rainfall and the geology of the area. Freshwater commonly contains relatively high concentrations of carbonate, silicic acid, calcium, magnesium and sodium [25]. The salinity of seawater varies depending on proximity to the coastline, rainfall, rivers and other discharges. The elements contributing most to the salinity of seawater however do not vary markedly. Chloride and sodium ions contribute most significantly with sulfate, magnesium, calcium, potassium and bicarbonate ions contributing to a lesser degree [32].

Effects

Salinity is tremendously important to fish which must maintain the concentration of dissolved salts in their bodies at a fairly constant level. Through the process of osmoregulation the fish expends energy in order to maintain this level. Each organism has a range of salinity in which it can grow optimally and when it is out of this range excess energy needs to be expended in order to maintain the desired salt concentration. This is done at the expense of other physiological functions if the salinity deviates too far from the optimum range.

Treatment

Salinity may be increased by adding gypsum or sodium chloride, though costs could be prohibitive. Due to its high solubility large increases in salinity can be obtained using sodium chloride. Generic rock salt can be used for this purpose. Gypsum is only soluble up to about 2 ppt and therefore is more appropriate for affecting smaller changes in salinity [33]. It should be noted that because increases in salinity cause particles to settle the effect of increased sedimentation rates must be considered in any treatment to increase salinity. Lowering salinity would require advanced treatment processes such as reverse osmosis and electro dialysis which are too expensive to be practical for most aquaculture operations.

3.4 Turbidity

Turbidity is a measure of light penetration in water. Turbid conditions result from dissolved and suspended solids such as clay and humus compounds or microorganisms such as phytoplankton. In source water it is primarily a result of erosion during runoff. Because of the significant contribution of erosion to turbidity caution should be used when taking source water from areas where current and future land use practices encourage erosion. Construction areas, deforested areas and cropland have relatively high rates of erosion while forest and grassland have lower rates of erosion [34]. In addition to turbidity from source water, turbidity may also come during the aquaculture operation. For example in the aquaculture pond turbidity can increase as a result of sediment re-suspension, biological activity, the addition of manure and feed and erosion of the pond slopes.

Effects

Turbid waters can shield food organisms as well as because gill damage and fish stress. It can also clog filters. Turbidity levels affect the light available for photosynthesis by phytoplankton and the growth of undesirable organisms. In ponds with organisms that depend upon phytoplankton for feed, turbidity must be at sufficiently low levels to allow the penetration of light for photosynthesis [35]. However, the turbidity must also be high enough to avoid the growth of undesirable rooted plants. The turbidity necessary for prevention of the growth of these plants can be typically provided by the Phytoplankton themselves. For ponds with organisms that derive a majority of their nutrition from feed inputs, light for phytoplankton growth is not imperative and therefore the turbidity can be higher. How ever, if turbidity is too high in these ponds photosynthesis can be inhibited significantly enough to reduce oxygen levels [36]. This can be remedied by using mechanical aeration at a rate such that oxygenation occurs without exacerbating the turbidity problem through suspension of sediment. Because many suspended solids will settle out in ponds or canals, another major concern besides turbidity itself is the around of suspended particles that can potentially settle out (that is, settable solids). Sediments from highly turbid source water may fill ponds and canals within a few months. They can contain large amounts of organic matter that exerts a high oxygen demand resulting in oxygen depletion. Sedimentation can also smother eggs of some species in ponds used for natural reproduction. Sedimentation of contaminated suspended particles is also of concern in areas affected by pollutants such as heavy metals and pesticides [37].

Guidelines

Lethal levels of turbidity have been shown to be 500-1,000 milligrams per liter (mg/L) for cold water fish [18]. Channel catfish have tested more tolerant with their fingerlings and adults surviving long-term exposures to 100,000 mg/L with behavioral changes occurring above 20,000 mg/L [38]. Recommended suspended solids concentrations for salmonid culture from different literature sources are less than 30 mg/L less than 80 mg/L and less than 25 mg/L.

Treatment

Colloids or very small suspended particles can be coagulated and precipitated by adding electrolytes such as aluminum sulfate (alum). While alum is very effective, it can cause other water quality problems by reducing alkalinity and pH. Lime can be added to counteract these effects. Turbidity caused by suspended clay can be precipitated by the addition of organics such as barnyard manure, cottonseed meal or super phosphate. However, organic matter is often difficult to obtain [39] and it exerts an oxygen demand when decomposing. Avoiding or addressing the source of turbidity is a better strategy than chemical treatments which require frequent application and may result in other water quality problems. Current methods of sediment control involve using sediment ponds or canals to remove the bulk of sediment before water enters the culture area, draining ponds and removing sediments periodically at the end of the growing season, or dredging undrinkable ponds. Sediments removed from aquaculture facilities may be considered an environmental hazard and hence be difficult and/or costly to dispose [40].

3.5 Hardness

Total hardness is a measure of the concentration of all metal cations with the exception of the alkali metals. Calcium and magnesium are the most common cations contributing to hardness in fresh water systems. To a much lesser extent, hardness also includes other divalent ions such as iron (Fe^{2+}) and barium (Ba^{2+}).Water is classified with respect to its hardness and softness. These categories were originally developed for municipal water treatment and thus have no biological relevance [41]. It should be noted that much of the concern about hardness in water treatment is with all the ions involved, while in aquaculture the concern is mostly with the calcium concentration.

Effects

Calcium is the most important component of hardness to aquaculture. It is necessary for bone and exoskeleton formation and for osmoregulation. Crustaceans absorb calcium from the water when molting and if the water is too soft their exoskeletons begin to soften and they may cease to molt. In addition, bone deformities and reduced growth rates may result if water is too soft. Hardness also affects aquaculture species and operations through its chemical interactions with other species in water. Calcium reduces the toxicity of metals, ammonia and the hydrogen ion. In addition, due to the higher on concentration in hard waters, suspended soil particles settle faster in hard water than soft water. For waters where alkalinity is high and calcium is low, photosynthesis may increase the pH to levels that are toxic to fish [42].

Guidelines

In general the most productive water for fish culture has roughly equal magnitudes of total hardness and total alkalinity. Hardness averages 6,600 mg/L in ocean water and therefore is not a problem in seawater or brackish water systems [43].

Treatment

Insufficient hardness is easily overcome. Calcium hardness can be raised by adding agricultural gypsum or calcium chloride. Gypsum is preferable because it costs less, is more readily available and does not affect alkalinity. Its disadvantages include the variable purity of agricultural gypsum (70-98 percent) and its slow reaction rate relative to calcium chloride [44].

3.6 BOD (biochemical oxygen demand)

The biochemical oxygen demand is a measure of the amount of organic compounds that be biologically oxidized by naturally occurring microorganisms in water [45]. It is important in aquaculture because the degradation of organic matter by microorganisms is a major sink for dissolved oxygen a parameter of fundamental importance to aquaculture.

Effects

As indicated earlier, the major concern of BOD is the potential for it to deplete oxygen to levels which are dangerous to fish. If source water contains a large amount of BOD, microbial growth will be enhanced especially at high temperature [46]. With this microbial growth and the corresponding degradation of organic matter oxygen will be consumed. This can lead to the depletion of oxygen in the pond and its associated effects on fish including death.

Guidelines

Like dissolved oxygen, it is difficult to establish guidelines for BOD that are dependent upon many processes. BOD indicates the rate of oxygen consumption in water over a 5-hours period. The optional range of BOD for cyprinid culture is recommended to be less than 8-15 mg/L .For waste water-fed ponds the recommended range of BOD concentrations is 10-20 mg/L [47].These guidelines can be used while taking into consideration factors such as the degree of aeration of the pond, seasonal temperature changes, expected photosynthesis and the solubility [48]. A judgment can then be based on the appropriate BOD level for source water.

Treatment

Two common options for treatment are potassium permanganate and aeration. Potassium permanganate chemically oxidizes organic matter thus reducing the BOD. However results are often mixed and the treatment is controversial because potassium permanganate is also an algaecide, it may further decrease oxygen levels by killing algae [49]. The lower oxygen levels are due to reduced photosynthesis and the decomposition of the dead algae. The most effective method for reducing BOD is providing oxygen through aeration, thus accelerating the degradation of the BOD by microorganisms. The methods of aeration are similar to aeration in dissolved oxygen treatment. For rapid removal, rigorous aeration to remove BOD can be followed up by a settling basin and a sand filter to remove the microorganisms and any other particulates [50, 51]. Another method which is less costly and less efficient is to use retention ponds in which the water is held for one or two days to allow settling and oxidation of the BOD.

3.7 Nitrate

Nitrate is the least toxic of the major inorganic nitrogen compounds. It is formed as the end product of the nitrification process and concentrations are generally higher than both ammonia and nitrite.

Effects

High levels of nitrate can affect osmoregulation and oxygen transport but toxic concentrations are much higher than for ammonia and nitrites [52, 53]. High nitrate levels can also result in eutrophication and excessive growth of algae and aquatic plants which might have a negative impact on culture species.

Treatment

Nitrate can be converted to nitrogen gas by the process of de-nitrification. It can then be removed by volatilization [54, 55]. These treatment systems can be difficult to run and are generally expensive.

3.8 Iron

Iron (Fe) is found in two oxidation states in natural systems. Ferrous iron (Fe^{2+}) is the reduced form and ferric iron (Fe^{3+}) is the oxidized form. The reduced form of the metal which predominates in non oxygenated (anoxic) waters is relatively soluble while the oxidized form which predominates in oxygenated waters is very insoluble [56]. The difference in solubility causes problems when using source water with high concentrations of reduced iron. If source water contains a lot of reduced iron, the iron will precipitate once the source water is oxygenated. The precipitate can then have deleterious effects upon the operation. Common sources of ferric iron are bottoms of large reservoirs during summer and deep ground water [21].

Effects

If waters which have high concentrations of reduced iron are used directly for filling aquaria or tanks for holding fish, the precipitates may occlude gills and cause stress or mortality. This is less of a problem in earthen ponds where the volume of water is greater and the iron precipitates near the inflow and does not harm fish. Channel catfish ponds can even be filled with water containing 20 to 50 mg/L of ferrous ion but such waters are not suitable for direct use in hatcheries [57]. In addition to the problems with precipitation, iron also encourages the growth of iron metabolizing bacteria which form an orange slime that can clog pipes, filter and other equipment [58].

Guidelines

Iron concentrations less than 0.5 mg /L would be appropriate for hatcheries of channel catfish and other warm water species while the optimal iron concentration for cold water hatcheries is less than 0.15 mg/L. Iron concentrations of less than 0.2 mg/L are recommended for cyprinid culture and concentrations of less than 0.1 mg /L are recommended for marine aquaculture systems. But Meade [59, 60] conservatively recommends a general standard of less than 0.01 mg/L.

Treatment

Ferrous iron can be removed with potassium permanganate ($KMnO_4$), but the procedure is seldom practical because potassium permanganate is toxic to phytoplankton and expensive. Orthophosphate is adsorbed by the precipitating ferric hydroxide, so ponds must often be fertilized after treatment [61].The simplest method for removing reduced iron is to retain water for one or two days in a holding pond, which will allow the reduced forms (ferrous iron) to naturally oxidize to the oxidized forms (ferric iron) precipitate and settle out. If rapid removal is necessary water can be vigorously agitated with mechanical devices or spilled through towers and then passed through a sand filter or settling basin. In small-scale operations, iron can be removed with filters and water softeners alone but this method is not practical for large scale aquaculture facilities [62].

3.9 Temperature Effects

Water temperature affects a multitude of important processes in aquaculture. Physiological Processes in fish such as respiration rates, feeding, metabolism, growth, behavior [63], reproduction and rates of detoxification and bioaccumulation are affected by temperature. Temperature can also affect processes important to the dissolved oxygen level in water such as the solubility of oxygen and the rate of oxidation of organic matter. In addition the solubility of fertilizers can be affected by water temperature [64, 65].

Guidelines

Each species has an optimum temperature at which its growth rate and heartiness are best. Growth will still occur at very close to the upper and lower lethal temperature limits; however, suboptimal temperature conditions cause stress which affects behavior, feeding, metabolism, growth and immunity to disease [66]. It is therefore preferable that water remain near optimum temperature and imperative that it never deviates beyond lethal limits. The guidelines are based on the conditions at which optimal growth rates occur.

Treatment

Since controlling the temperature of ponds in large-scale aquaculture facilities is often not practical sites should be selected in geographic regions which provide an ambient temperature conducive to the growth of marketable-sized products within a reasonable period of time [20].

3.10 Pb

The major sources of lead (Pb) to aquatic systems include atmospheric deposition of exhaust from vehicles, disposal of batteries, lead ore mine wastes, lead smelters, sewage discharge, highway runoff and agricultural runoff from fields fertilized with sewage sludge.

Environmental behavior and background levels

At pH 6 the lead ion (Pb^{2+}) and hydroxide species dominate. At higher pH, lead hydroxide and carbonate species begin to dominate [67]. Lead also commonly forms sulfate and carbonate precipitates. It also forms complexes with or precipitates. It also forms complexes with organic matter and particulates. Dissolved lead concentrations in the environment are generally low due to either precipitation of carbonate species or adsorption to particulate matter [68]. There is some evidence that lead forms organometallic compounds in natural systems which can accumulate in fish [69, 70]. The backgrounds levels of dissolved lead in surface waters rarely exceed 20 ppb [71]

Effects on fish and shellfish health

Chronic lead toxicity in aquatic organisms leads to nervous system damage while acute toxicity causes gill damage and suffocation [72]. Chronic lead toxicity is easily identified in fish by the blackening of the fins [73]. The toxicity of lead is dependent on the alkalinity, hardness and pH of the water. Toxicity is decreased by high alkalinity (that is, high calcium carbonate) because calcium carbonate competes for uptake at the gill surface [74]. The solubility of lead and thus its toxicity is lower in hard waters than in soft waters [75]. For the same reason, lead toxicity is higher at lower pH levels which would be common particularly at ponds bottoms and among benthos and nutrients [76].

Effects on bioaccumulation

Background levels are low in most marine products and unlikely to be a public health threat [77]. However mollusks are known to accumulate high concentrations of lead in polluted areas [33]. The half-life of lead in marine organisms is shorter than the half lives of other heavy metals. Lead in black-lip oysters has a half-life of 26 to 34 days. In 40 days mussels lose 33 percent of their accumulated. It is believed that the rate of lead depuration is dependent upon the initial exposure conditions and detoxification mechanism [78].Effects on human health. As mentioned earlier, fish and shellfish are not a major pathway for lead exposure to human populations. The effects which primarily arise from exposure to exhaust fumes include impaired neurological and motor development and damage to kidneys [79]. Severe lead poisoning can also occur in cases where lead-based paints are ingested.

Guidelines

The permissible level of lead in drinking water is also included for comparison. However, saltwater mussels (Mytilus edulis) have been shown to accumulate significant concentrations of lead in water with a concentration of 10 ppb, so it is questionable whether any of the criteria above questionable whether any of the criteria above are conservative enough for mollusks [80].

3.11 Hg

Mercury (Hg) naturally occurs in the environment as a result of the volcanic degassing of the earth's crust and weathering of mercury- rich geology. While water from areas rich in mercury ores may exhibit high local mercury concentrations, industrial processes, agriculture and the combustion of fossil fuel are the most significant sources of aquatic contamination. Common sources include caustic soda pulp and paper and paint manufacturing. Mercury is also used in batteries, dental amalgam, and in bactericides.

Environmental behavior

Mercury occurs in both inorganic and organic forms in water. Its most predominant forms in freshwater are hydroxide complexes and in saltwater as a chloride complex [81]. Mercury also exists as the mercuric ion (Hg^{2+}) and under anoxic conditions, as the neutral, reduced form (Hg). In soils it can precipitate out as stable mercuricsulphide [82]. Methyl mercury is formed by bacteria from mercuric ions under both aerobic and anaerobic conditions. It is this forms that bio-accumulates in fish and shellfish.

Background levels

Mercury levels in water are much lower than levels in sediments. Natural background concentrations average 0.1 mg/L dry weight in soils and 0.19 mg/L dry weight in sediments. Background levels for unpolluted waters fall in the range of 0.001 to 0.003 parts per billion (ppb) for lakes and rivers, 0.002 to 0.015 ppb for coastal waters, and 0.0005 to 0.003 ppb for the open ocean.

Effects on fish health

The lethal levels of mercury for fish range from 1 mg/L for tilapia to 30 mg /L for guppies and 2 mg/L for a crustacean (Cyclops abyssorum).

Effects on bioaccumulation

While methyl mercury accounts for more than 90 percent of the mercury found in fish at higher tropic levels it constitutes of the total mercury found in aquatic systems [83]. Methyl mercury is 1,000 times more soluble in fats than in water and concentrates in muscle tissue, brain tissue, and the central nervous system. Hence mercury levels in fish may be in excess of 10,000 to 100,000 times the original concentration in surrounding waters. The contaminant rises through the food chain and high concentrations of mercury accumulate in predators such as trout, pike, walleye, bass, tuna, swordfish and shark. In highly contaminated areas methyl mercury may be accumulated in smaller species which are lower in the food chain such as those found in aquaculture [83]. In addition to fish, aquatic invertebrates also accumulate mercury to high concentrations. Accumulation is fast while depuration is slow. Slightly contaminated shrimp slow to depurate mercury while contaminated oysters depurate rapidly. Unlike oysters, shrimp consume sediment dwelling organisms which may contain a higher proportion of methyl mercury than plankton and detritus in the water column. Mercury depuration in fish is also extremely slow. The half-life of methyl mercury in fish is estimated at two years [84].Levels of methyl mercury in fish have also been correlated with the age and size of the fish, the species, pH of the water, and mercury content of water and sediments [85]. However the processes affecting mercury behavior in the environment are too complex for prediction with the current state of knowledge.

Effects on human health

The general population does not face a significant health risk from mercury. Exposure is primarily through diet. In most foodstuffs mercury is largely in the inorganic form and at very low levels. Fish and fish products are the dominant dietary sources hence mercury is of greater concern in areas where fish and shellfish account for a major Cadmium proportion of the diet [86]. Very high levels (more than 1 mg/L wet weight) have been found in the flesh of fish from contaminated waters, resulting in bans on fishing, fish sale, and fish consumption in polluted areas. Groups of people with high fish consumption rates may accumulate blood-methyl mercury levels associated with a low risk of neurological damage in adults [87]. The health effects of mercury poisoning are essentially irreversible. Symptoms include numbness and tingling loss of vision and hearing delirium and disturbance of gait and speech [88]. Of particular concern is that methyl Mercury is almost completely absorbed from the intestine and stable in the body and circulates unchanged in the blood. It remains in the body for extended periods of time (biological half-life is estimated at 70-76 days in human and 200 days to two years in fish), penetrates easily through the blood-brain barrier and accumulates in the brain. Pregnant and nursing women are at a greater risk of adverse effects than the general population [89]. Methyl mercury easily penetrates the placenta and accumulates in the fetus [90] causing critical prenatal exposure which may lead to brain damage [91]. Because it is highly fat soluble methyl mercury also accumulates in mother's milk.

Guidelines

Because the concentrations which may present a public health risk are significantly lower than those that affect the health of the culture species the guidelines are based on the public health risks [92]. Because the chemical and biological interactions of mercury are so complex, it is not possible to calculate a single mercury criterion for source water that will produce aquaculture products with a mercury concentration less than those which present a risk to public health.

3.12 Cd

Cadmium (Cd) is a highly toxic metal which plays a role in a variety of industrial processes such as electroplating, nickel plating, smelting, engraving and battery manufacturing. It is also a constituent of easily fusible alloys, soft solder and electrodes for vapor lamps, photoelectric cells, nickel cadmium storage batteries, pigments and plastics. Inorganic fertilizers such as phosphate fertilizers, sewage sludge used on agricultural land and tailings from. Zinc mines are also important sources of cadmium contamination. Cadmium is usually found along with zinc in surface waters but at much lower concentrations [93]. Municipal sewage effluents and sludge are another important source of cadmium in aquatic environments.

Environmental behavior

The predominant form of cadmium in the environment is as the cadmium ion (Cd^{2+}). It also can complex with organic matter and particulates to a significant extent [94]. In anoxic sediments, cadmium precipitates as cadmium sulfide [95]. Unlike mercury, cadmium does not form organ metallic species.

Background levels

In general natural waters contain very low levels of cadmium unless they milk are polluted. For unpolluted waters of any type, cadmium concentrations generally range from 0.0 to 0.13 ppb. Saline water levels are less than 0.2 ppb in estuaries (less than 2.0 in estuarine sediments) and less than 0.15 ppb in coastal areas (less than 1.5 in sediments)

Effect on fish and shellfish health

The cadmium ion and some organic and inorganic complexes are toxic to fish. Acute toxic exposure of fish damages the central nervous system and parenchymatous organs. Chronic exposure adversely affects the reproductive organs of aquatic organisms, as well as maturation, hatchability and development of larvae [96, 97]. Continuation of exposure causes mortalities at concentrations considerably lower than the lethal count level (96-hour LCJ), probably because the efficiency of the cadmium detoxification mechanism in fish has a limited duration [98]. However, most of the cadmium which binds with solid particles ends up in sediments where its biological availability is limited and thus less toxic. Calcium also reduces the toxicity of dissolved cadmium, so it is somewhat less toxic in hard water [99]. Because carbon and cadmium compete for binding sites, higher concentrations of carbon dioxide may reduce the bioavailability and hence the toxicity of cadmium.

Effects on bioaccumulation

Some species have greater capacity for accumulation of cadmium than other species. Unlike mercury; accumulation rates for cadmium vary greatly among groups [101]. The bio-concentration factors (concentration in organism/concentration in water) for many species are on the order of thousands. For some mollusks and arthropods, [102,103] they are on the order of tens of thousands and on the order of hundreds of thousands for certain tissues (few of which are usually eaten by man). 30 Depuration is slow and incomplete, so animals contaminated in culture facilities are not commercially salvageable.

Significant levels of cadmium may be accumulated by bivalve mollusks and certain species of crustaceans [104]. In polluted waters, oysters, clams, cockles, and some species of crab (particularly in the brown meat) can accumulate significant amounts of cadmium. The Pacific oyster has exhibited consistently high concentrations of cadmium, [105] especially in China. Cadmium concentrations in shrimp and prawns are unlikely to be high. Although, studies of Penaeus japonicas have revealed high concentrations in areas where fin fish concentrations were comparatively low. In marine vertebrates, cadmium tends to accumulate in the kidneys leaving the concentration low in the axial muscle tissue.

Effects on human health

Cadmium is exceptionally persistent in humans [106] and even low levels of exposure may result in considerable accumulation over time especially in the kidneys [107]. The major symptoms of cadmium poisoning also known as itai-itai syndrome, are softening of the skeletal bones, pseudo-fractures of the bones, possible skeletal deformation, and kidney damage [108]. Sub clinical effects include liver and renal tubular dysfunction [109].Exposure is likely to vary among individuals depending on food preferences. Bivalve mollusks, some crustaceans, kidneys and livers of terrestrial animals, and tobacco are common pathways of cadmium exposure for humans [110]. While cadmium poisoning has not been known to occur as a result of consumption of fisheries products, significant concern exists over this possibility.

Guidelines

Meade's [111] cadmium criteria of 0.5 ppb for soft water and 5 ppb for hard waters are good for most aquaculture with the exception of mollusks. [112] Linear uptake of cadmium was recorded for mollusks growing in 5 ppb of hard saline water [113]. Therefore a more conservative upper limit of 0.5 ppb, regardless of the hardness is recommended for mollusks.

3.13 Cr

Chromium (Cr) is principally used in plating and chrome alloy production. Chromium is also used in pigments, paints, ceramics, textile dyes, fungicides, fireproof bricks and catalysts. Chromate compounds are also used for corrosion control in heating and cooling systems [114].

Environmental behavior and background levels

Under reduced conditions chromium is in the ion form, Cr^{3+}. Under oxidizing conditions such as those commonly found in an aquaculture operation, [115] it is in the hexavalent (Cr^{+3}) form. A large proportion of chromium in natural waters is found associated with suspended solids and sediment. In natural waters chromium typically has concentrations less than 5 ppb and they rarely get above 20 ppb [116]. Chromium cans also bioaccumulation in aquatic organisms.

Effects on fish and shellfish health

Chromium is highly toxic to aquatic organisms, especially in the hexavalent form. The toxicity of chromium is greater in soft, acidic water [117]. Therefore chromium poisoning is less of a problem in marine water and background levels are low in most marine organisms [118]. The 96-hr LC50 for salmonid fish ranges from 3.3 to 65 mg 1.38 for longer exposures it was found that a concentration of 13 ppb adversely affected the growth of rain bow trout. Chromium is not very toxic to humans. There is little evidence that significant exposure can occur via the ingestion of sea food products. There have been some incidences where large exposures via inhalation of salts caused lung cancer [119].

Chapter-IV

Experimental

Spectrophotometer (DR-4000) was used to measure turbidity, iron, nitrate and hardness, Digital pH meter was used to measured pH, Digital DO meter was used to measure DO and BOD, Digital Salinity meter was used to measured salinity and heavy metal such as Pb, Hg, Cd and Cr of shrimp and shrimp culture water were also measured from Atomic Energy center, Dhaka, Bangladesh.

4.1 Measurement of turbidity

The sample was collected in glass bottle and stored at 4°C for up to 48 hours.

Spectrophotometer (DR-4000 HACH) procedure for turbidity

By pressing the soft key under HACH program to select the stored program number for turbidity in FAUs by pressing 3750 with the numeric keys and then pressing ENTER. The display was showed HACH program- 3750. Then I used a set of matched sample cell and filled one of the clean Stoppard sample cell to the 10mL mark with deionizer water. Rinsing the other matched sample cell with sample. Then I was filled the sample cell to the 10mL mark with sample wipe the sides of both sample cells using a clean soft cloth. Placing the blank into the cell holders, close the light shield and pressing the soft key under ZERO. The display was showed: - 'O' FAU (Formazin Attenuation Unit). Gently invert the prepared sample several times. Immediately I was placed it into the cell holders and closed the light shield. Results in FAU turbidity were displayed.

4. 2 Measurement of hardness

The sample was collected in acid washed plastic bottle and adjusted the sample pH to 2 or less with nitric acid (about 5mL per liter). Before analysis, the sample was adjusted pH between 3 and 8 with 5.0 N sodium hydroxide standards solution.

Spectrophotometer (DR-4000) procedure for hardness

By pressing the soft key under HACH program to select the stored program for ultra-low range hardness by pressing 2000 with the numeral keys and then pressing enter. The display was showed: HACH program 2000. I was rinsed a plastic sample cell and the cap three time with the water to be tested. I was filled the plastic sample cell to the 25mL mark with sample and added the contents of one chlorophos phonazo solution pillow to the sample cell to mis. The sample cell was placed into the cell holder and closed the light shield. By pressing the soft key under zero. The display was showed '0' mg/L $CaCO_3$. I was removed the cell from the instrument and added one drop of CDTA reagent for ultra low range hardness to mix. The sample cell was placed into the cell holder to close the light shield and the result in μg/L as $CaCO_3$ was displayed.

4.3 Measurement of nitrate (NO_3^-)

The sample was collected in acid-washed plastic bottle and adjusted the sample pH to 2 with sulfuric acid. Before analysis the sample was adjusted pH to 7 with 5.0N sodium hydroxide.

Spectrophotometer (DR-4000) procedure for nitrate (NO_3^-)

By pressing the soft key under HACH program to select the stored program number for mid range nitrate by pressing 2520 with the numeric key and then pressing enter. The display was showed HACH program-2520. I was filled a sample cell with 10mL of sample and added the contented of one Nitra-Ver-5 Nitrate Reagent power pillow (The prepared sample). I was pressed the soft key under start timer to shake the cell vigorously until the timer beeped in one minute. When the timer was beeped, I was filled another sample cell with 10mL of sample to place the blank into the cell holder. By pressing the soft key under zero the display was showed 0.0 mg/L nitrate-nitrogen was displayed.

Spectrophotometer (DR-4000)

Wavelength Range: 190 to 1100 nm (DR-4000U), 320 to 1100 nm (DR-4000V) **Wavelength Accuracy:** ±1 nm, **Wavelength Reproducibility:** ±0.1 nm, **Wavelength Resolution**: 0.1 nm, **Wavelength Calibration**: Internal, automatic at power-up with visual feedback.

4.4 Measurement of iron (Fe)

The sample was collected in acid washed plastic bottle and adjusted the sample pH to 2 with Nitric acid. Before analysis the sample was adjusted pH to between 3 and 5 with 5.0 N Sodium hydroxide Standard Solution.

Spectrophotometer (DR-4000) procedure for iron (Fe)

By pressing the soft key under HACH program to select the stored program number for Iron (Fe) Ferrover method by pressing 2165. I was filled a clean sample cell with 10mL of sample and added the content of one Ferro-ver. Iron reagent powder pillow for 10mL sample to the sample cell (the prepared sample) swirl to mix. Now I was pressed the soft key under start timer. On the other side I was filled another sample cell (The blank) with 10mL of sample. When the timer beeps, I was placed the blank into the cell holder to close the light shield. Then I was pressed the soft key under zero. The display was showed: 0.000 mg/L Fe. At last I was placed the prepared sample into the cell holder to close the light shield and the result in mg/L Iron was displayed.

4.5 Measurement of pH, Salinity, DO and BOD

The water sample was collected in 1 liter beaker and pH was measured with the help of digital pH meter on the spot (shrimp farm, nursery and hatchery).DO and BOD of water were also measured with the help of digital DO meter on the spot.

4.6 Measurement of Lead. Mercury, Cadmium and Chromium

Heavy Metal like Pb, Hg, Cd, and Cr were measured from Atomic Energy Center, Dhaka. Bangladesh

4.7 Equipments and Apparatuses

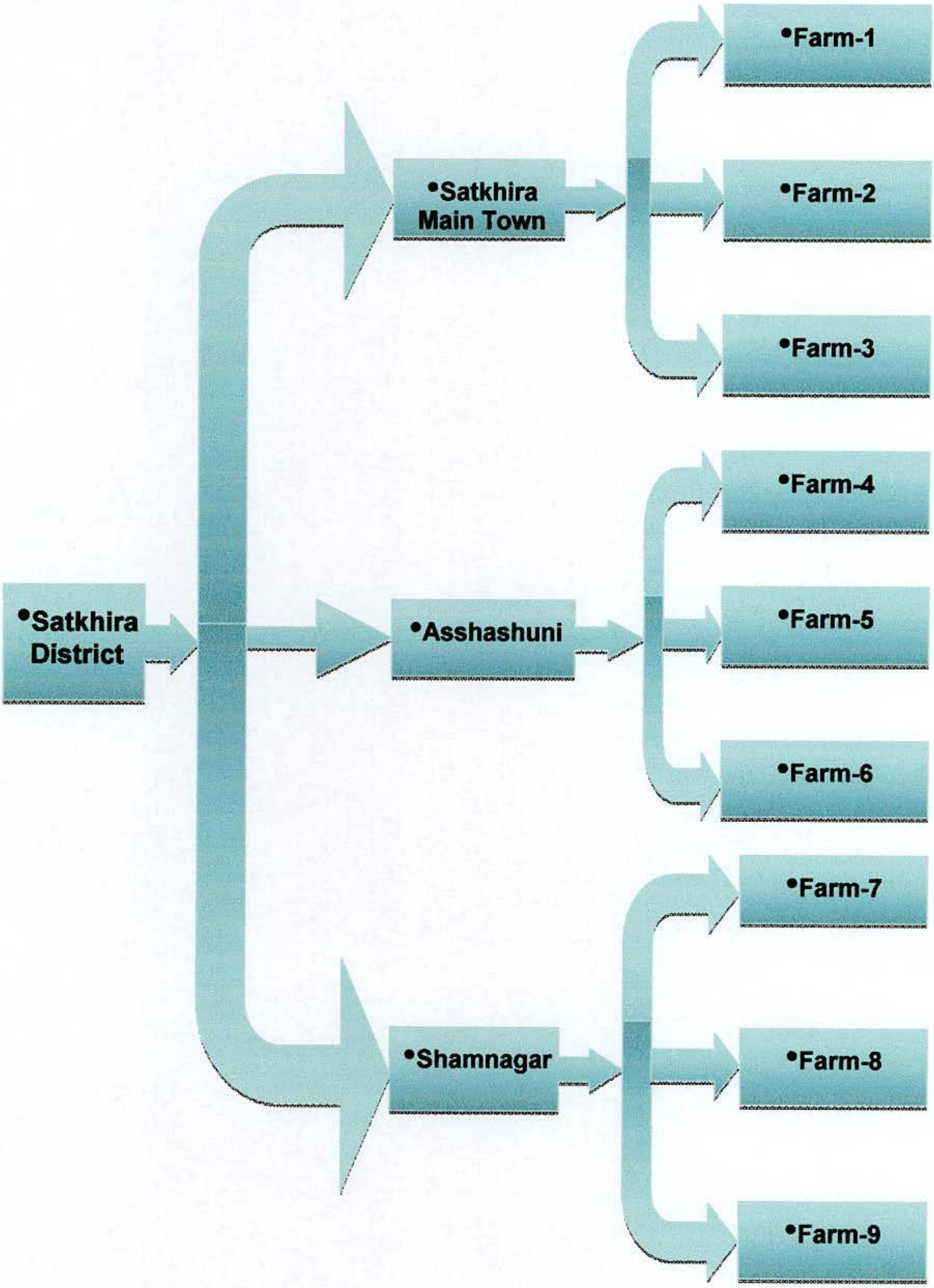
1. DR/4000 spectrophotometer
2. Digital PH meter
3. Digital salinity meter
4. Digital DO meter
5. Digital Thermometer
6. Micropipet
7. Buret
8. Beaker
9. Conical flax
10. Plastic bottle
11. Volumetric flax

12. Glass rod
13. Faunel
14. Ice box
15. Poly bag
16. Filter paper
17. Electric balance

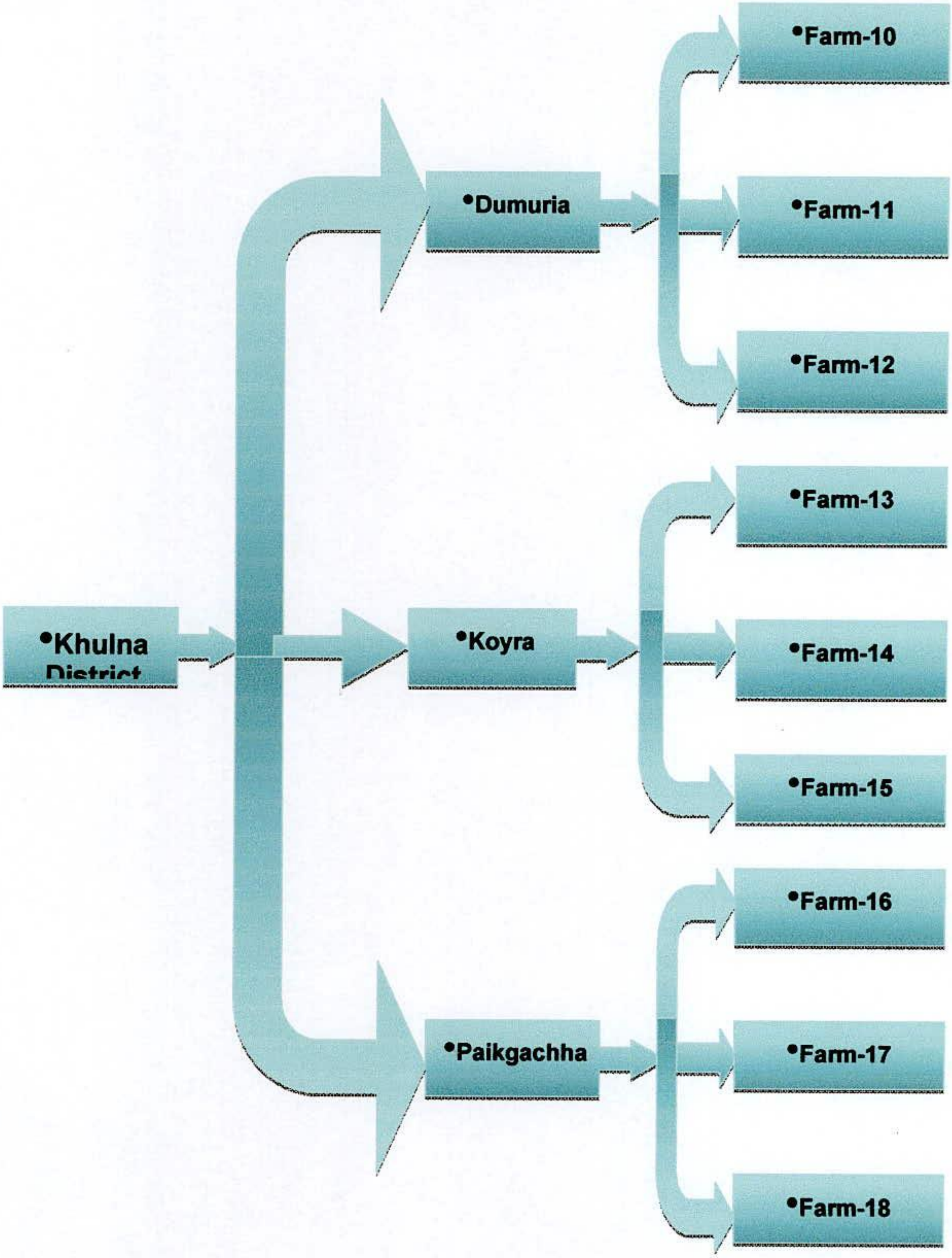
4.8 Chemicals and Materials

1. Sulfuric acid
2. Nitric acid
3. Hydrochloric acid
4. Sodium hydroxide
5. Amonium hydroxide
6. Chlorophos phonazo solution pillow
7. Sulfa-ver-4 reagent powder pillow
8. Nitra-ver-5 nitrate reagent power pillow
9. Ferro-ver. iron reagent powder pillow
10. 2.0 mL of mercuric thiocyanate solution
11. 1.0mL of ferric ion solution

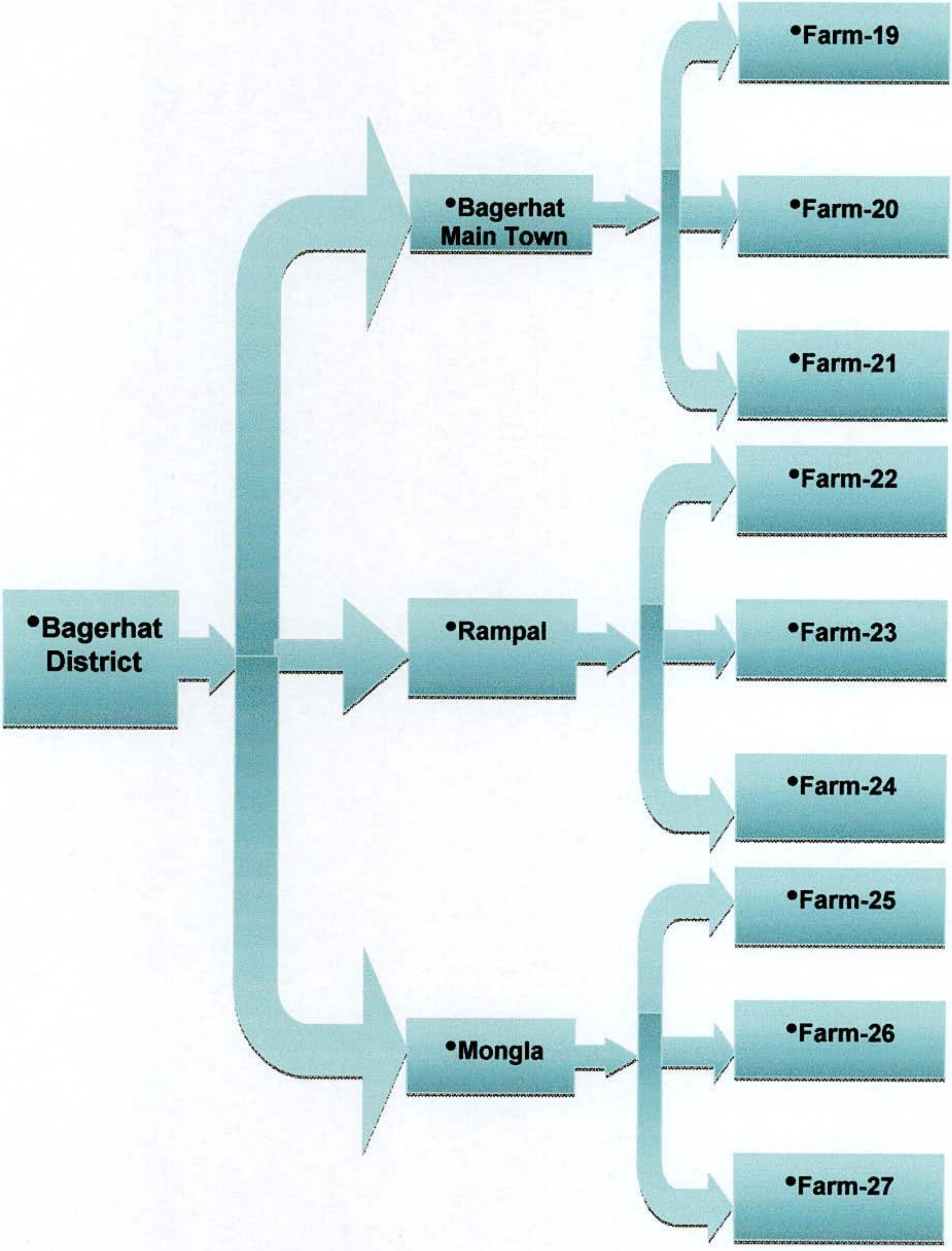
- **Experimental areas of Satkhira district**



- **Experimental areas of Khulna district.**



- **Experimental areas of Bagerhat district.**



Chapter-V

Results and Discussions

5.1 Experimental values of pH, NO_3^-, DO, BOD, Fe, salinity, turbidity, hardness and temperature of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat District.

Experimental values of pH, turbidity, salinity, NO_3^-, DO, BOD, Fe, hardness and temperature of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat District shown in Table-5.1.

Table 5.1: Experimental values of different parameters of shrimp culture water for farms of Satkhira, Khulna and Bagerhat District.

Locations	Parameters	pH	Turbidity	Salinity	Hardness	DO	BOD	Nitrate	Iron	Temp
	Unit	-	FAU	ppt	μg/L	mg/L	mg/L	mg/L	mg/L	°c
	Acceptable Range	7.5 – 8.9	20 - 30	10 - 35	100 - 500	>3	> 10	25 - 50	0.05 - 0.25	28-32
Satkhira	Farm No.-1	7.7	17	15	18	12.7	15.1	1.25	0.140	29.5
Main Town,	Farm No.-2	9.2	28	18	125	16.1	17.2	1.40	0.550	29.9
Satkhira	Farm No.-3	9.4	25	19	115	16.1	17.2	1.20	0.290	30.3
Assasuni,	Farm No.-4	8.0	55	13	15	13.5	18.5	1.20	0.043	28.3
Satkhira	Farm No.-5	8.5	46	10	14	15.5	22.0	0.60	0.027	28.3
	Farm No.-6	8.9	44	12	22	11.5	14.2	0.80	0.025	28.5
Shyamnagar,	Farm No.-7	7.9	60	13	159	10.5	12.5	1.60	0.095	27.9
Satkhira	Farm No.-8	8.8	70	15	425	15.6	15.8	0.90	0.125	28
	Farm No.-9	8.5	52	20	168	18.5	20.5	1.20	0.189	27.5
Dumuria	Farm No.-10	8.0	56	7	35	13.1	18.5	2	0.113	28.9
Khulna	Farm No.-11	7.9	28	10	9	15.2	23.7	1.9	0.200	29.6
	Farm No.-12	8.8	36	11	118	15.5	22.1	2.2	0.288	28.4
Koyra	Farm No.-13	8.7	17	10	72	12.5	17.8	2	0.199	27.9
Khulna	Farm No.-14	9.0	12	12	102	13.7	17.8	2	0.155	30.3
	Farm No.-15	8.5	12	10	115	12.5	16.5	1.8	0.105	28.3
Paikgachha	Farm No.-16	8.9	9	13	88	14.7	16.0	3.1	0.042	28.5
Khulna	Farm No.-17	9.0	15	12	112	14.2	15.8	2.8	0.82	28.1
	Farm No.-18	8.1	7	12	95	12.5	15.5	2.1	0.152	29.4
Bagerhat	Farm No- 19	7.5	25	12	110	14.5	15.8	0.3	0.056	33.8
Main	Farm No.-20	7.8	17	17	70	12.5	15.7	0.8	0.059	32.9
Town	Farm No.-21	7.8	22	18	85	12.7	14.5	0.7	0.109	30.4
Rampal	Farm No.-22	7.9	23	12	88	15.5	14.7	1.4	0.115	28.1
Bagerhat	Farm No.-23	8.2	25	15	92	13.5	14.0	0.6	0.092	28.6
	Farm No.-24	7.5	20	14	77	13.2	14.7	0.8	0.115	27.8
Mongla	Farm No.-25	7.7	22	13	60	14.8	14.0	0.8	0.105	28.7
Bagerhat	Farm No.-26	8.8	28	13	39	14.1	14.5	0.5	0.119	29.6
	Farm No.-27	8.5	16	15	45	17.5	22.5	0.3	0.08	28.3

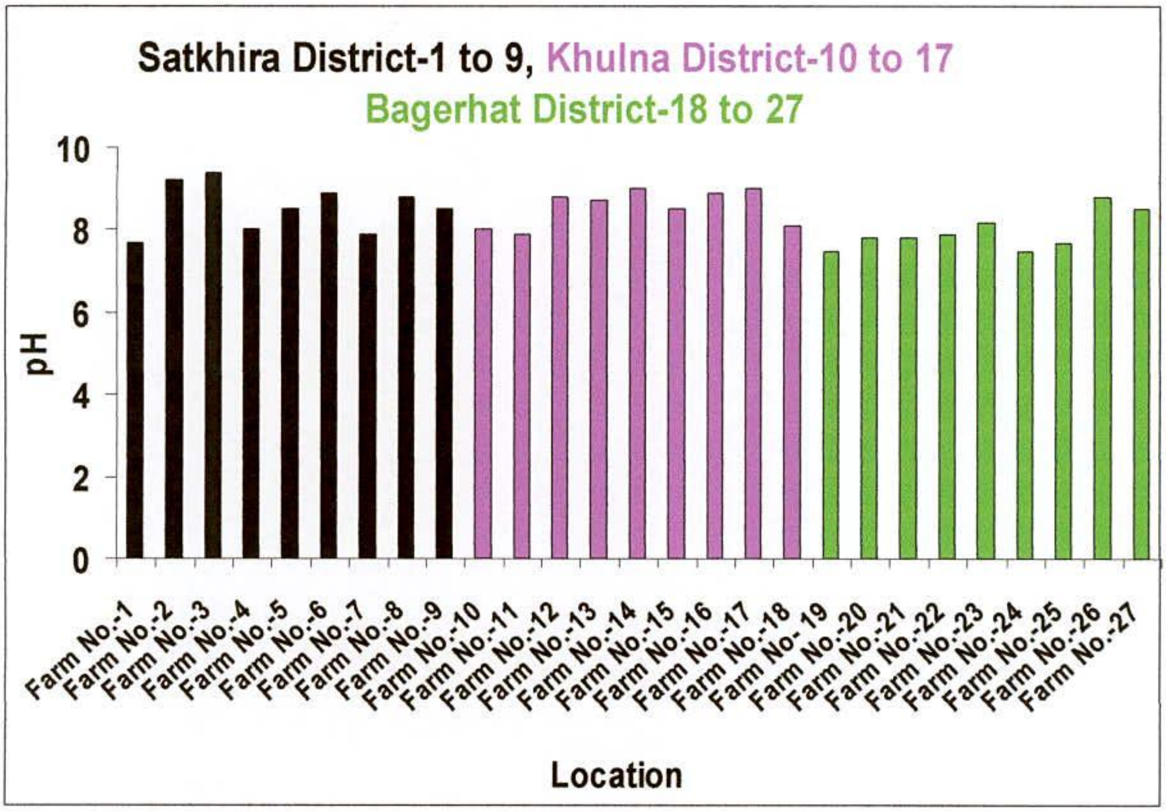


Figure 5.1: pH of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

It is observed from the figure 5.1 that the value of pH of shrimp culture water at different farms of Assasuni, Shyamnagar and Satkhira main town of Satkhira district were found within standard limit in farms nos. 1,4,5,6,7,8 and 9 but in farms nos. 2 and 3 were higher than standard limit. The higher values of pH in farms nos.2 and 3 may due to the addition limestone and urea in the farms. The value of pH of shrimp culture water at different farms of Dumuria, Koyra and Paikgachha of Khulna district were found in all the farms from figure 5.1 within standard limit. The value of pH of shrimp culture water at different farms of Bagerhat main town, Mongla and Rampal of Bagerhat district were found from figure 5.1 within standard limit.

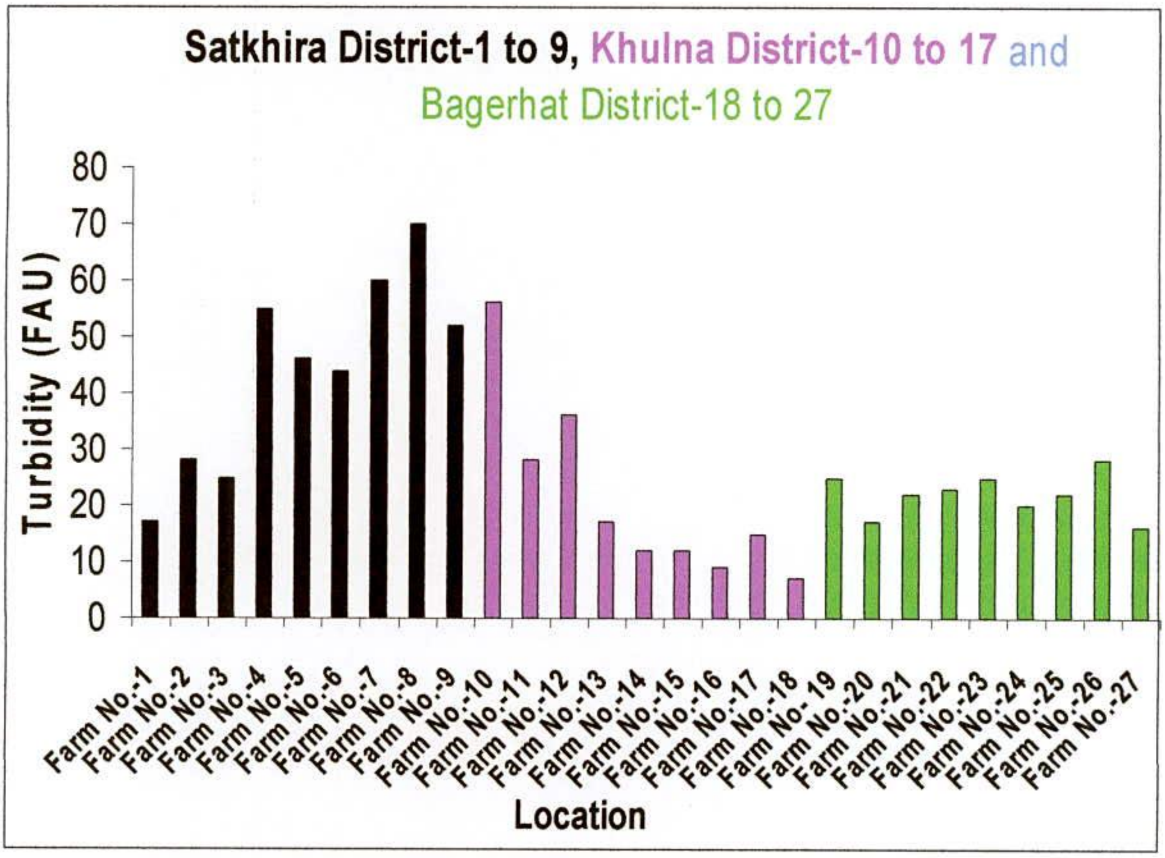


Figure 5.2: Turbidity of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

The value of turbidity of shrimp culture water at different farms of Assasuni, Shyamnagar and Satkhira main town of Satkhira district were found in farms nos. 1,2 and 3 from figure 5.2 within standard limit and in farms nos. 4,5,6,7,8 and 9 were higher than standard limit. The higher value of turbidity in farms nos. 4, 5,6,7,8 and 9 may due to exchanged their water every day. It is observed from the figure 5.2 that the values of turbidity of shrimp culture water at different farms of Dumuria, Koyra and Paikgachha of Khulna district were found high in farms nos. 10,11 and 12 and in ponds nos. 13,14,15,16,17 and 18 are lower than standard limit. The higher value of turbidity in farms nos. 10, 11 and 12 may due to exchanged their water every day. The values of turbidity of shrimp culture water at different farms of Bagerhat main town Mongla and Rampal of Bagerhat district were found from figure 5.2 within standard limit

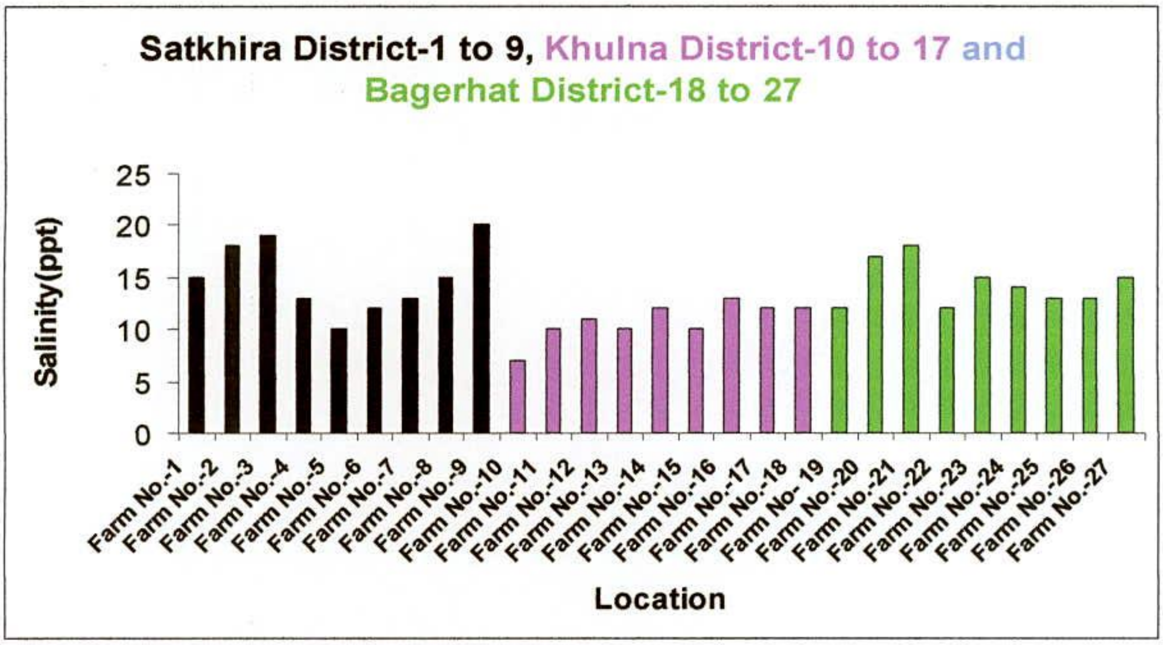


Figure 5.3 **Salinity of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.**

It is observed from the figure 5.3 that the value of salinity of shrimp culture water in all farms of Satkhira, Khulna and Bagerhat district within standard limit.

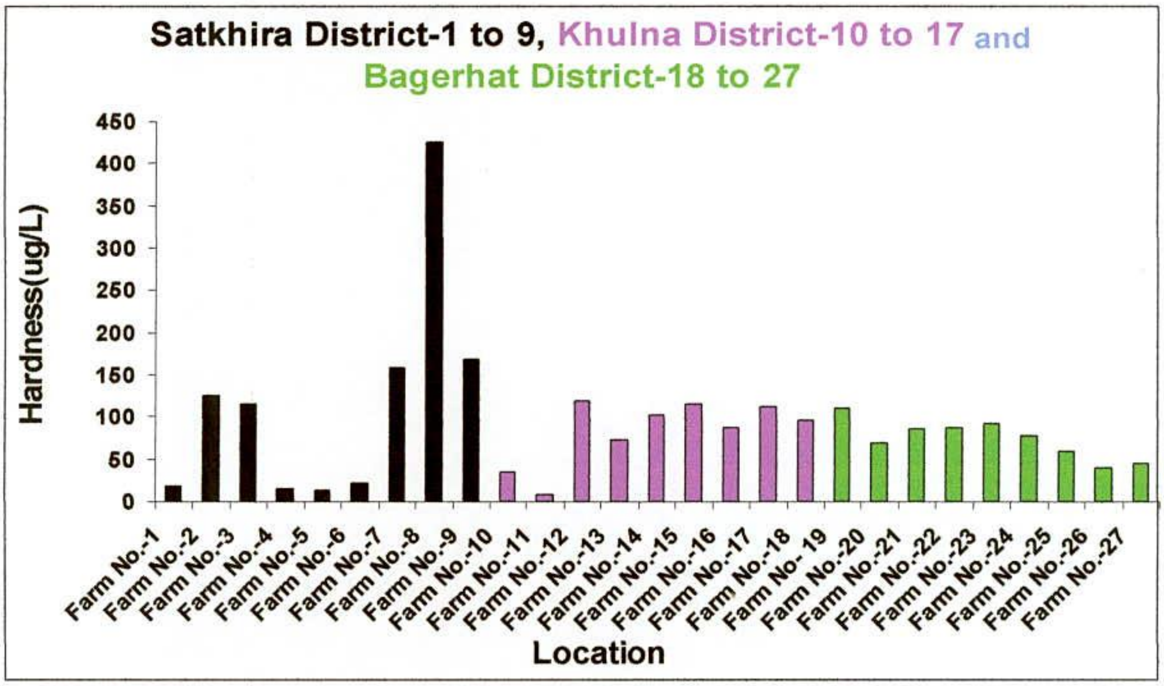


Figure 5.4 **Hardness of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.**

It is observed from the figure 5.4 that the value of hardness of shrimp culture water at different farms of Satkhira main town, Shyamnagar and Assasuni of Satkhira district were found within standard limit in farms nos. 2,3,7,8 and 9 but in farms nos. 1,4,5 and 6 are lower than standard limit. The lower values of hardness in farms nos. 1, 4, 5 and 6 may due to less then calcium. It is observed from the figure 5.4 that the values of hardness of shrimp culture water at different of Dumuria, Koyra and Paikgachha of Khulna district were found within standard limit in farms nos. 12, 14, 15 and 17 but in farms nos. 10,11,13,16 and 18 were lower than standard limit. The lower values of hardness in farms nos. 10,11,13,16 and 18 may due to less amount of calcium in the ponds. The value of hardness of shrimp culture water at different farms of Bagerhat main town, Mongla and Rampal of Bagerhat district were found low in all ponds from figure 5.4 The lower values of hardness in all farms may due to less amount of calcium in the ponds. If the hardness is lower, the growth rate of fish may be reduced. The hardness may be increased by adding agricultural gypsum or calcium chloride.

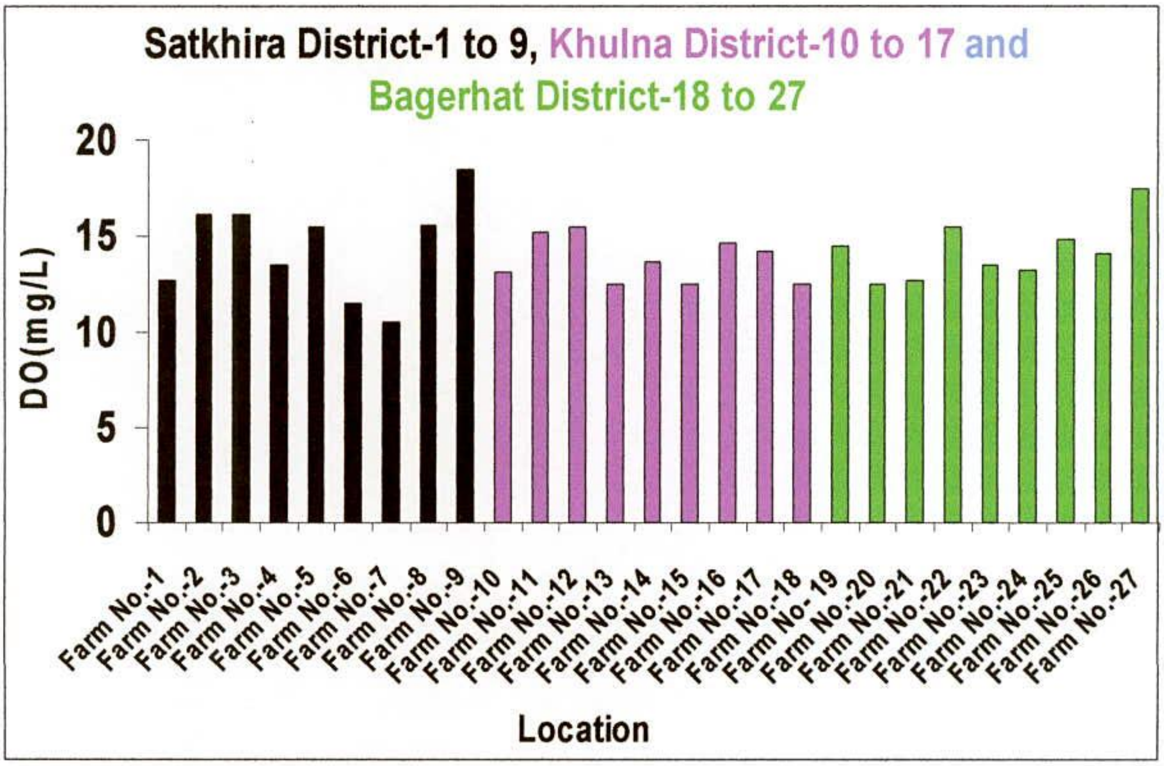


Figure 5.5 DO of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

The value of DO of shrimp culture water at different farms of Assasuni, Shyamnagar and

Satkhira main town of Satkhira District were found in all farms from figure 5.5 within standard limit. The values of DO of shrimp culture water at different of Dumuria, Koyra and Paikgachha of Khulna district were found in all farms from figure 5.5 within standard limit. The value of DO of shrimp culture water at different farms of Bagerhat main town, Mongla and Rampal of Bagerhat district were found in all ponds from figure 5.5 within standard limit

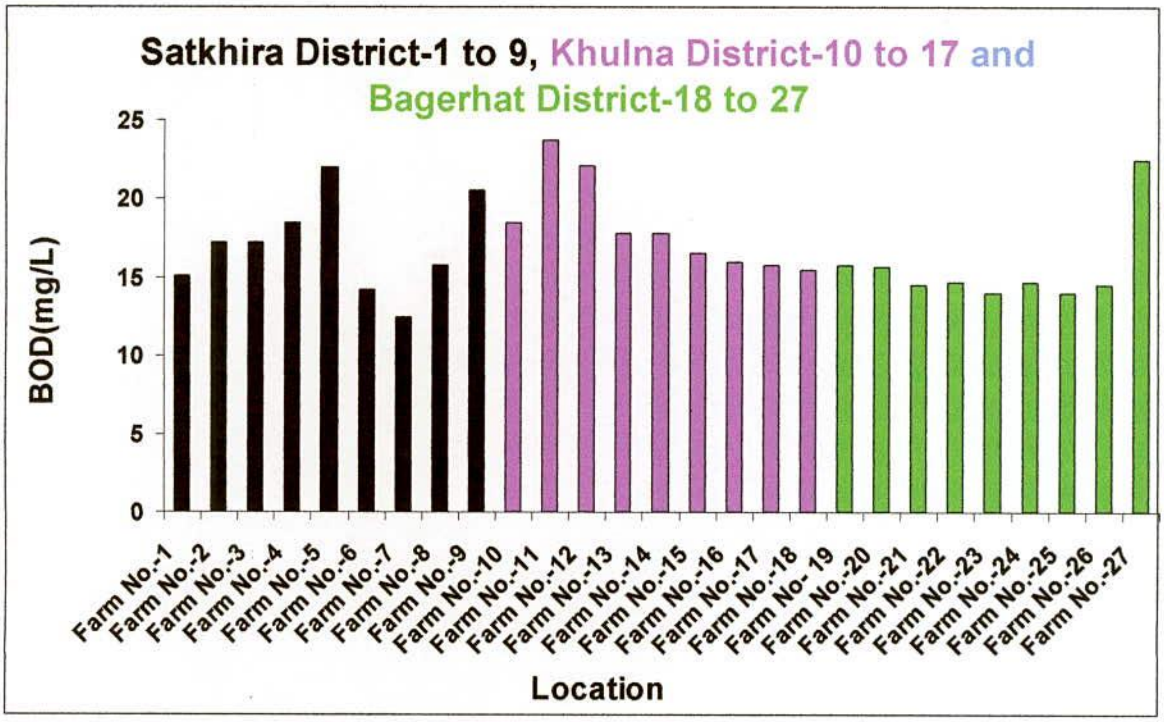


Figure 5.6 BOD of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

The value of BOD of shrimp culture water at different ponds of Assasuni, Shyamnagar and Satkhira main town of Satkhira district were found in all farms from figure 5.6 within standard limit. The value of BOD of shrimp culture water at different of Dumuria, Koyra and Paikgachha of Khulna district were found in all farms from figure 5.6 within standard limit. The value of BOD of shrimp culture water at different farms of Bagerhat main town, Mongla and Rampal of Bagerhat district are found in all ponds from figure 5.6 within standard limit.

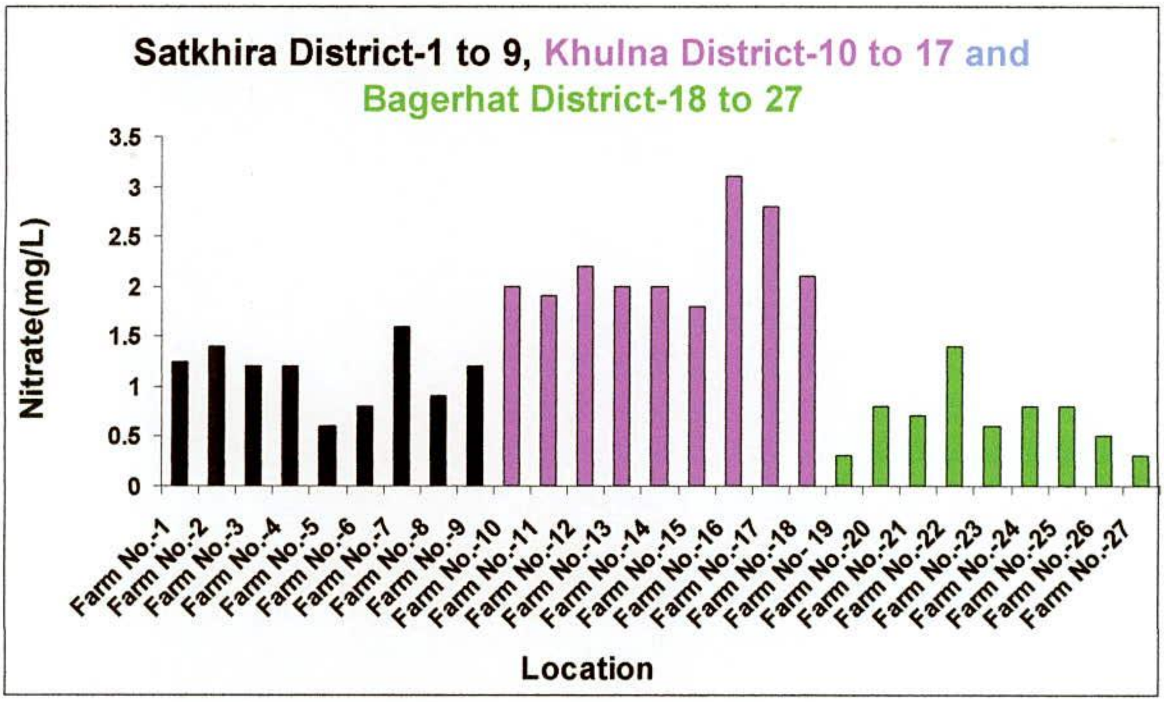


Figure 5.7 Nitrate of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

The value of nitrate of shrimp culture water at different farms of Assasuni, Shyamnagar and Satkhira main town of Satkhira district were found to be low in all farms from figure 5.7.The value of nitrate of shrimp culture water at different farms of Dumuria, Koyra and Paikgachha of Khulna district were found in all farms from figure 5.7 are lower than standard limit. The value of nitrate of shrimp culture water at different farms of Bagerhat main Town, Mongla and Rampal of Bagerhat district are found low in all the farms from figure 5.7. The lower values of nitrate may be due to the process of de-nitrification, which converted nitrate to nitrogen gas.

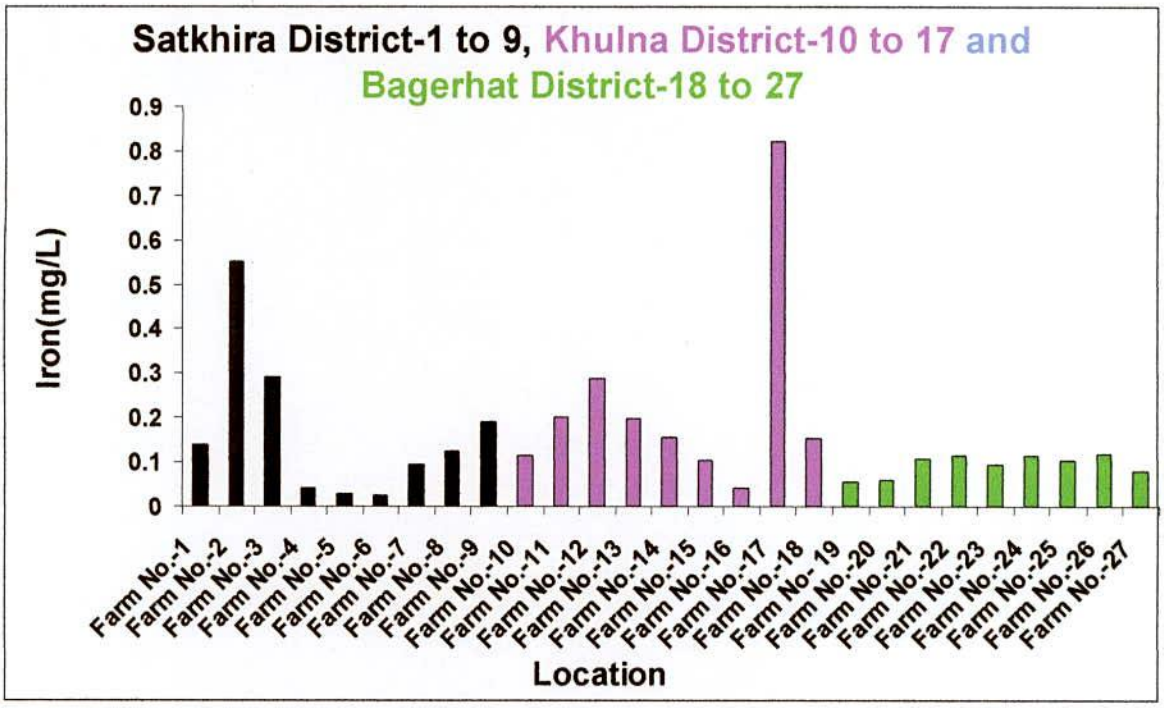


Figure 5.8 Iron of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

It is observed from the figure 5.8 that the values of Iron of shrimp culture water at different farms of Assasuni, Shyamnagar and Satkhira main town of Satkhira district were found within standard limit in farms nos. 4,5,6,7,8 and 9 but in farms nos. 1,2 and 3 are higher than standard value. Orthophosphate is observed by the precipitating ferric hydroxide and thus reduces the value of iron .The higher value of iron may be due to earthen pond where Orthophosphate is not absorbed. The values of Iron of shrimp culture water at different farms of Dumuria, Koyra and Paikgachha of Khulna district were found in all farms within standard limit. The value of Iron of shrimp culture water at different farms of Bagerhat main town, Mongla and Rampal of Bagerhat district are found in all farms from figure 5.8 within standard limit.

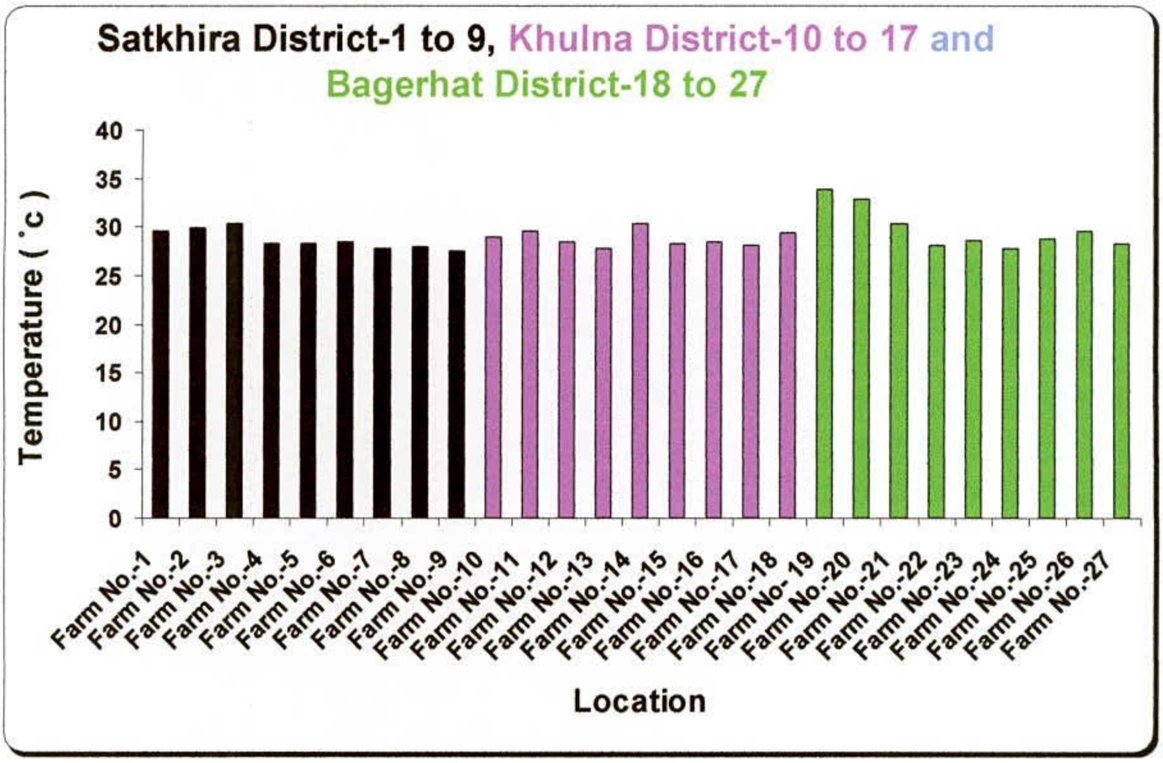


Figure 5.9 Temperature of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district.

The value of temperature of shrimp culture water at different farms of Satkhira, Khulna and Bagerhat district were found in all farms from figure 5.9 within standard limit.

5.2 Experimental values of pH, NO_3^-, DO, BOD, Fe, turbidity, salinity, hardness and temperature of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district.

Experimental values of pH, turbidity, salinity, NO_3^-, DO, BOD, Fe, hardness and temperature of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district are shown in Table 5.2.

Table 5.2: **Experimental values of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.**

Locations	Parameters	pH	Turbidity	Salinity	Hardness	DO	BOD	Nitrate	Iron	Temp
	Unit	-	FAU	ppt	µg/L	mg/L	mg/L	mg/L	mg/L	°c
	Acceptable Range	7.5 - 8.9	20 - 30	10 - 35	100 - 500	>3	> 10	25 - 50	0.05-0.25	28-32
Satkhira District	Nurseries No.- 1	7.9	10	15.1	31	11.5	12.8	0.42	0.06	28.7
	Nurseries No.- 2	8.1	8	14.3	45	10.1	12.5	0.82	0.09	28.9
	Nurseries No.- 3	8.0	12	14.2	49	12.0	12.9	0.75	0.15	31
Khulna District	Nurseries No.- 4	8.0	6	13.5	42	11.5	15.7	0.88	0.102	30.5
	Nurseries No.- 5	8.2	11	15.2	56	12.1	17.8	1.4	0.12	29
	Nurseries No.- 6	7.8	4	14.1	46	10.1	14.5	1.2	0.08	28.8
Bagerhat District	Nurseries No.- 7	7.8	7	13.2	55	9.5	14.5	1.0	0.08	28.4
	Nurseries No.- 8	7.9	12	14.3	35	12.1	15.8	0.88	0.05	29.5
	Nurseries No.- 9	8.2	4	15.3	48	10.5	13.7	0.75	0.08	29.6

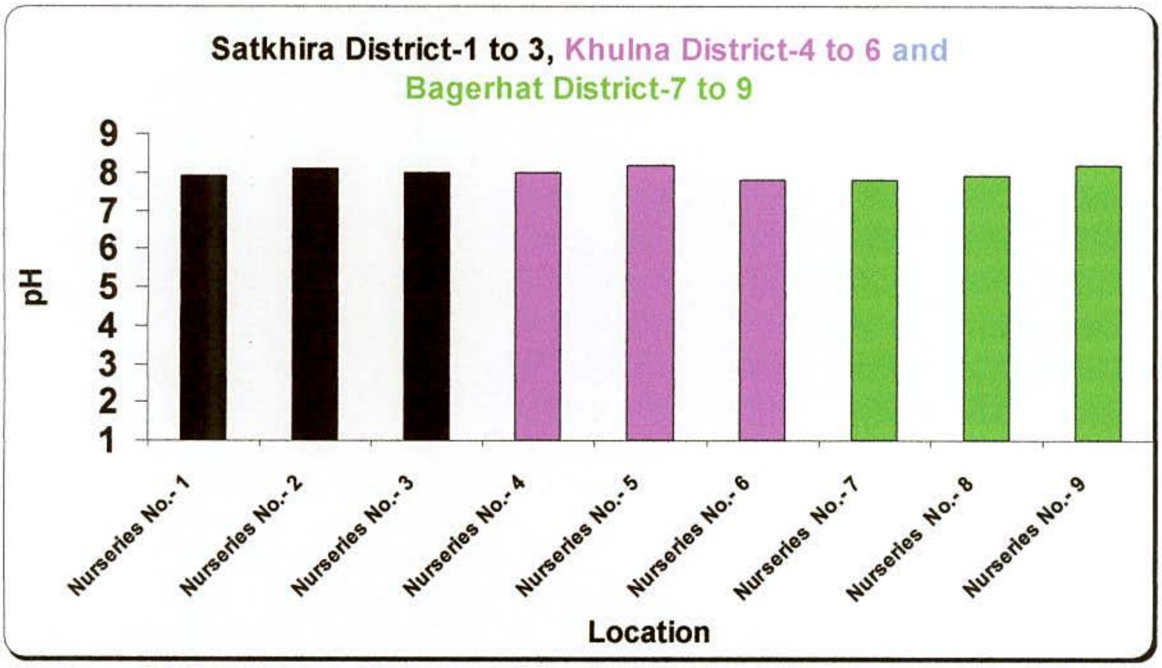


Figure 5.10 **pH of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.**

The value of pH of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found in all nurseries from figure 5.10 within standard limit.

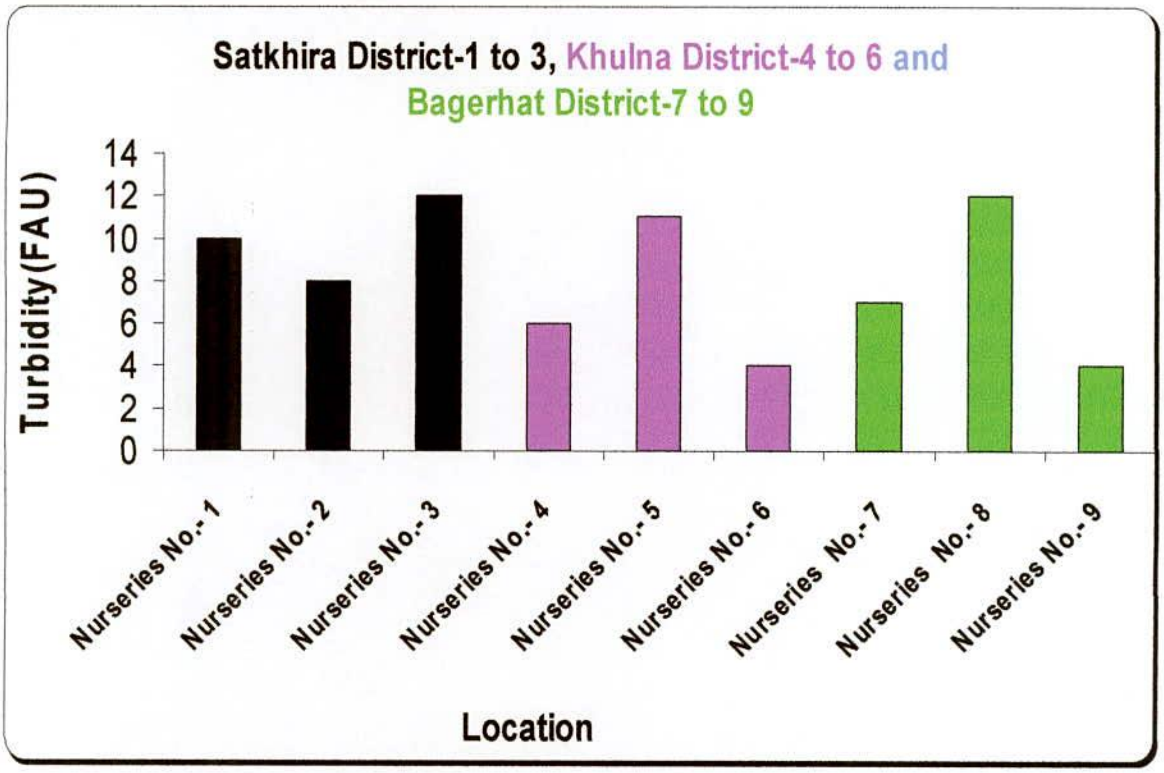


Figure 5.11 Turbidity of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The values of turbidity of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district are found low in all nurseries from figure 5.11. The lower value of turbidity in nurseries may due to use fresh water.

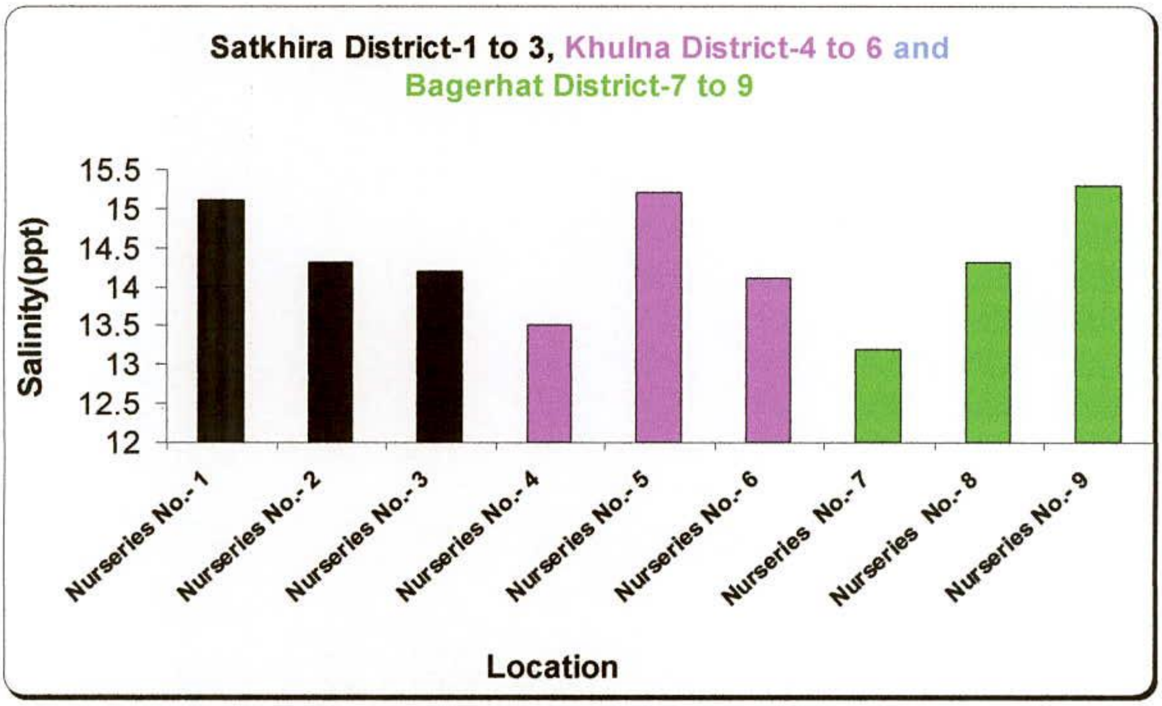


Figure 5.12 Salinity of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of Salinity of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found in all nurseries from figure 5.12 within standard limit.

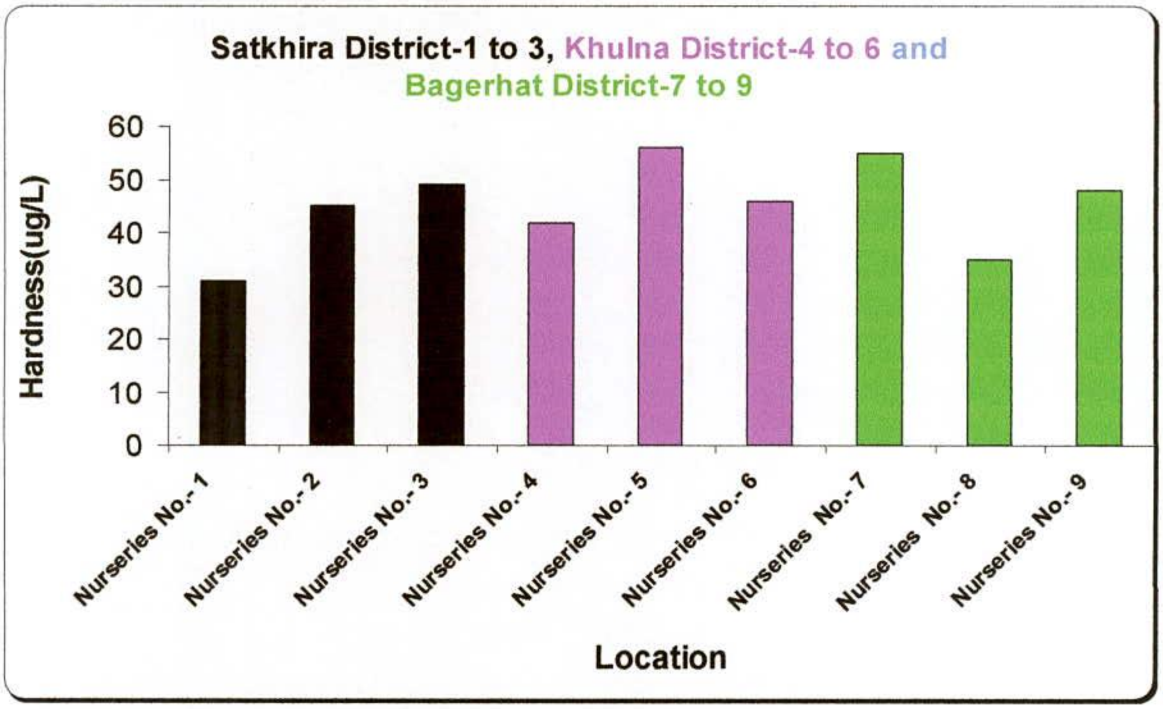


Figure 5.13 Hardness of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of hardness of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found low in all nurseries from figure 5.13. The lower values of hardness in nursery may due to less then calcium. If the hardness is lower the growth rate of fish may be reduced. The hardness may be increased by adding agricultural gypsum or calcium chloride.

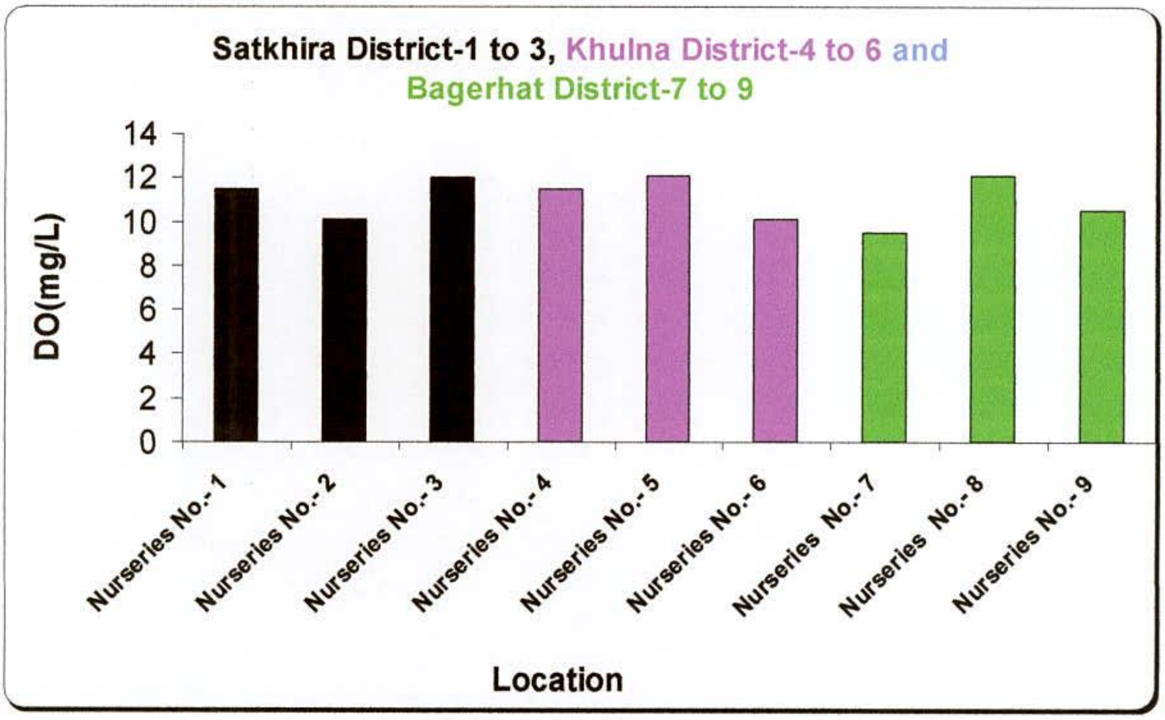


Figure 5.14 DO of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of DO of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found in all nurseries from figure 5.14 within standard limit.

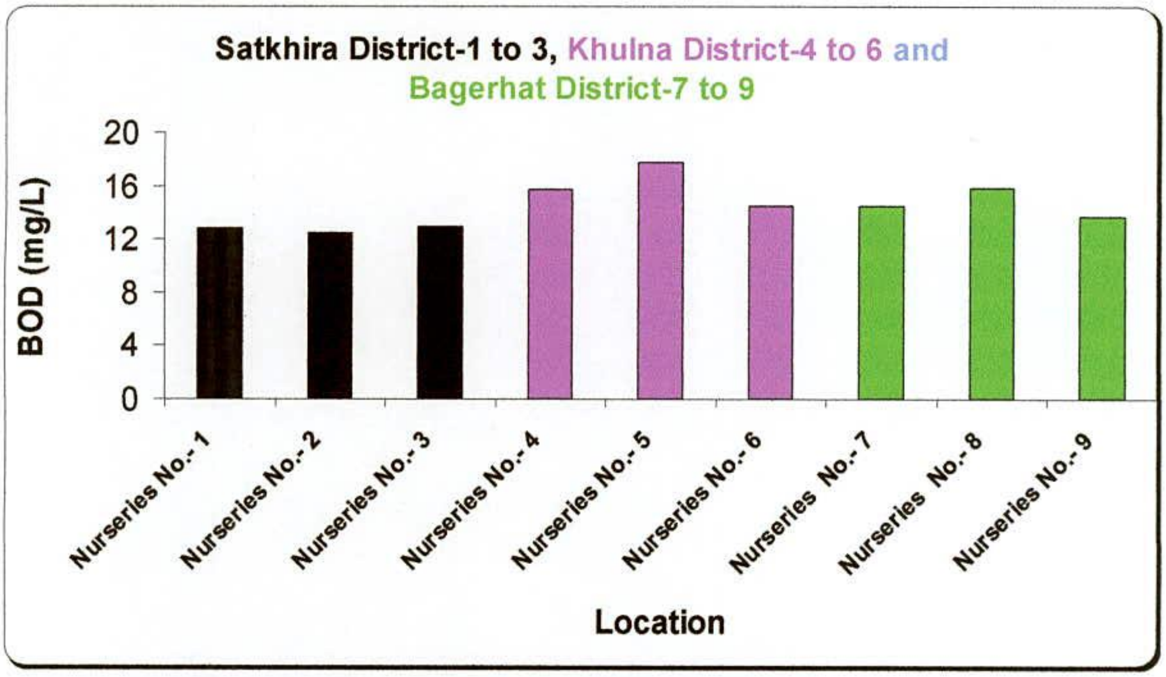


Figure 5.15 BOD of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of BOD of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found in all nurseries from figure 5.15 within standard limit.

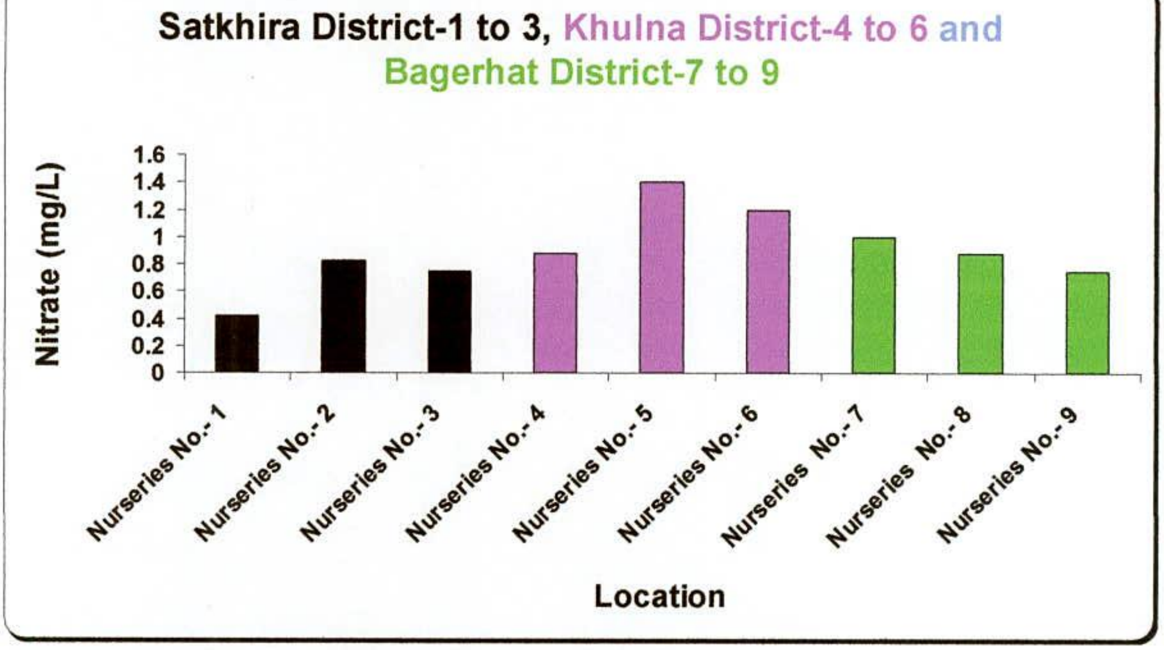


Figure 5.16 Nitrate of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of nitrate of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found low in all nurseries from figure 5.16. The lower values of nitrate may be due to the process of de-nitrification, which converted nitrate to nitrogen gas.

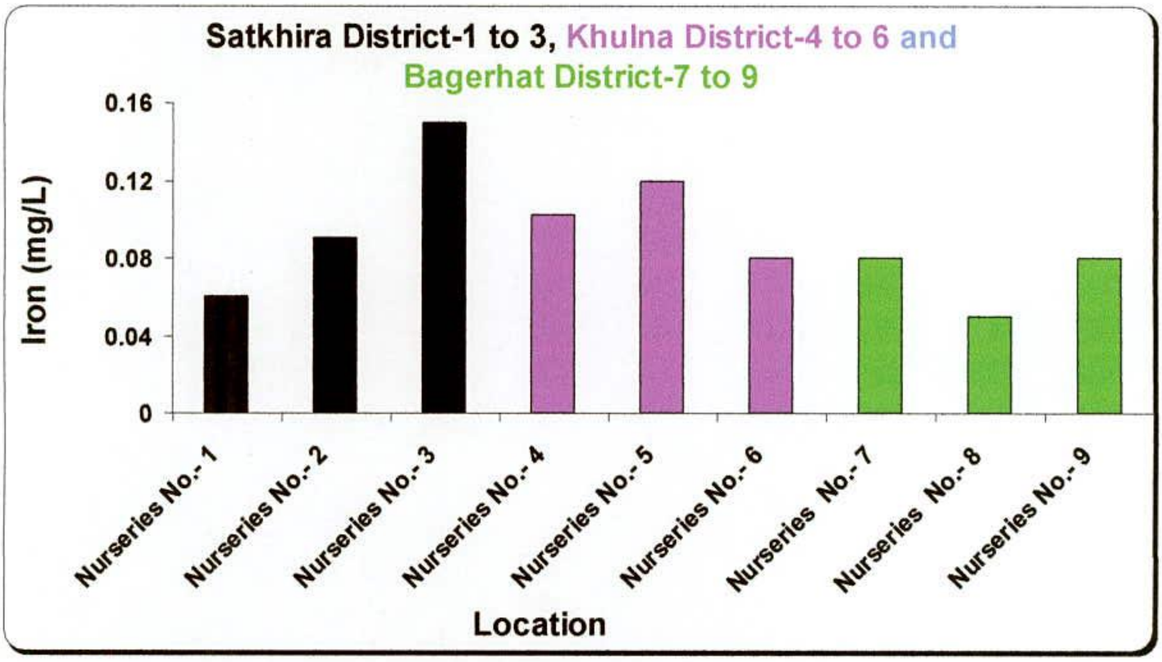


Figure 5.17 Iron of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of Iron of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found in all nurseries from figure 5.17 within standard limit.

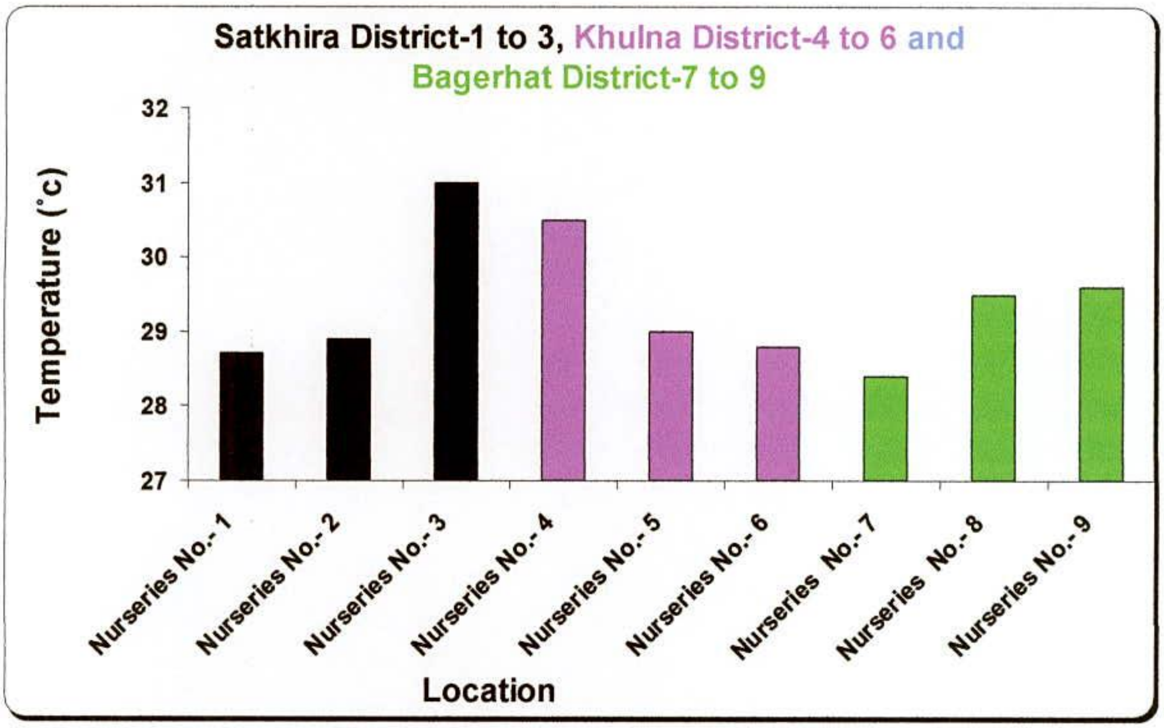


Figure 5.18 Temperature of shrimp culture water for nurseries of Satkhira, Khulna and Bagerhat district.

The value of temperature of shrimp culture water at different nurseries of Satkhira, Khulna and Bagerhat district were found in all nurseries from figure 5.18 within standard limit.

5.3 Experimental values of pH, $NO3^{-}$, DO, BOD, Fe, turbidity, salinity, hardness and temperature of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district.

Experimental values of pH, NO_3^{-}, DO, BOD, Fe, turbidity, salinity, hardness and temperature of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district are shown in Table 5.3

Table 5.3: Experimental values of pH, NO_3^-, DO, BOD, Fe, turbidity, salinity, hardness and temperature of shrimp culture water in hatchery of Satkhira, Khulna and Bagerhat district.

Locations	Parameters	pH	Turbidity	Salinity	Hardness	DO	BOD	Nitrate	Iron	Temp
	Unit	-	FAU	ppt	μg/L	mg/L	mg/L	mg/L	mg/L	°c
	Acceptable Range	7.5 - 8.9	20 - 30	10 - 35	100 - 500	>3	>10	25 - 50	0.05-0.25	28-32
Satkhira District	Hatchery No.- 1	8.5	14	22	55	8.6	10.5	1.2	0.08	28.6
	Hatchery No.- 2	8.7	10	25	53	7.7	9.5	1.5	0.09	28.9
	Hatchery No.- 3	8.3	13	23	46	8.9	10.1	0.8	0.08	30.4
Khulna District	Hatchery No.- 4	8.8	13	27	64	9.8	11.5	0.9	0.108	31.5
	Hatchery No.- 5	8.2	15	29	46	6.9	9.4	0.8	0.06	30.3
	Hatchery No.- 6	7.9	16	26	56	5.7	9	0.6	0.09	30.5
Bagerhat District	Hatchery No.- 7	7.9	15	25	49	7.8	9.5	0.9	0.05	29.5
	Hatchery No.- 8	8.2	17	24	69	8.4	9.9	0.7	0.08	28.9
	Hatchery No.- 9	8.9	10	25	68	6.3	8.9	1.4	0.09	29.4

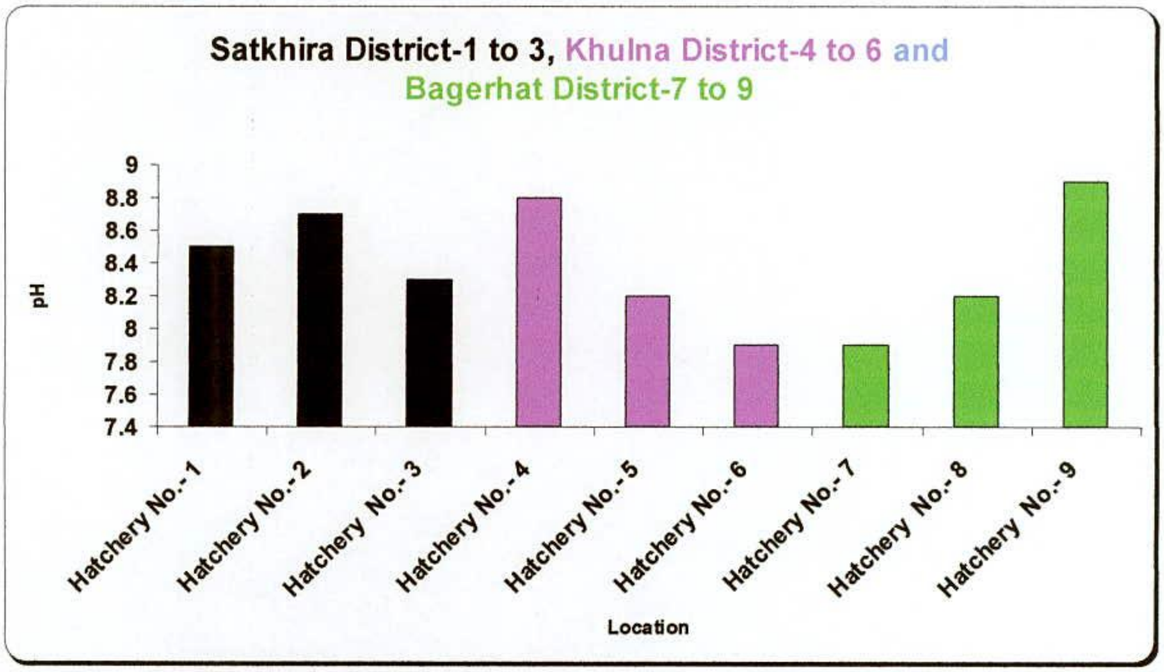


Figure 5.19 pH of shrimp culture water in hatchery of Satkhira, Khulna and Bagerhat district.

The value of pH of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.19 within standard limit.

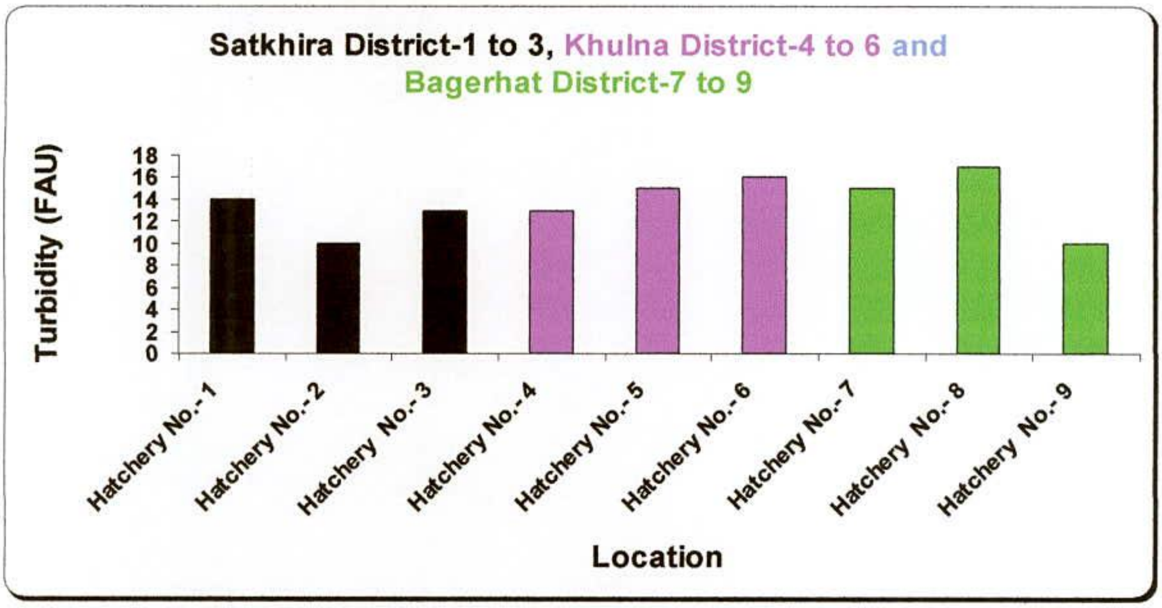


Figure 5.20 Turbidity of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of turbidity of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.20 within standard limit.

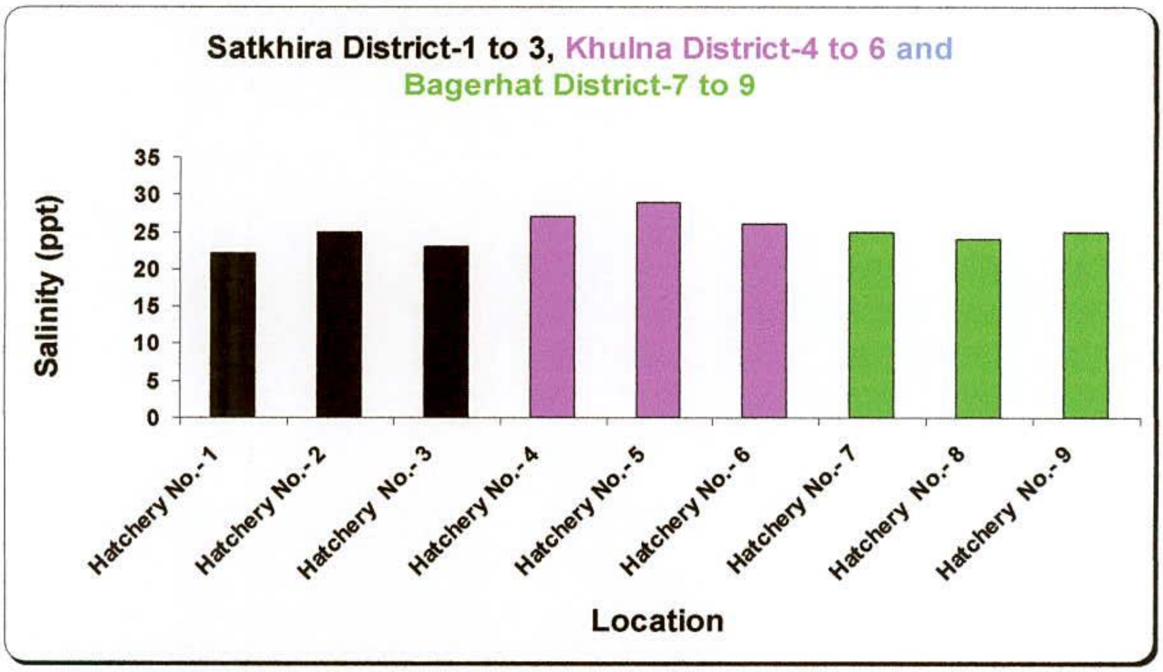


Figure 5.21 Salinity of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of salinity of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.21 within standard limit.

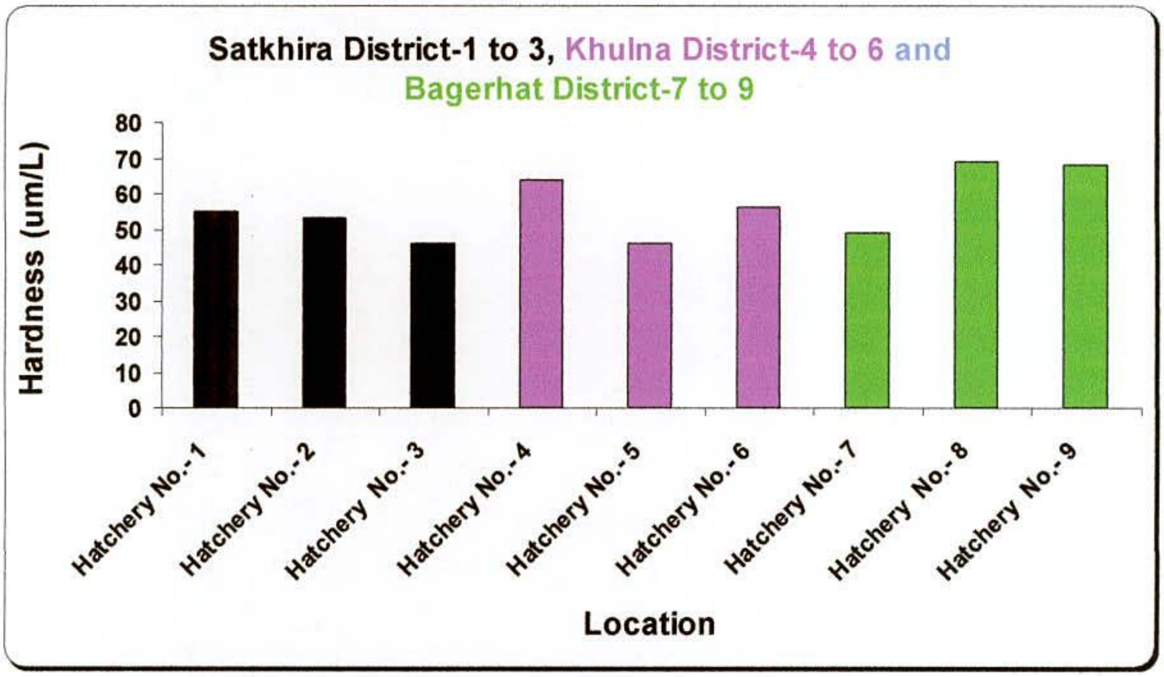


Figure 5.22 Hardness of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of hardness of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found low in all hatcheries from figure 5.22. The lower values of hardness in hatcheries may due to less then calcium. If the hardness is lower the growth rate of fish may be reduced. The hardness may be increased by adding agricultural gypsum or calcium chloride.

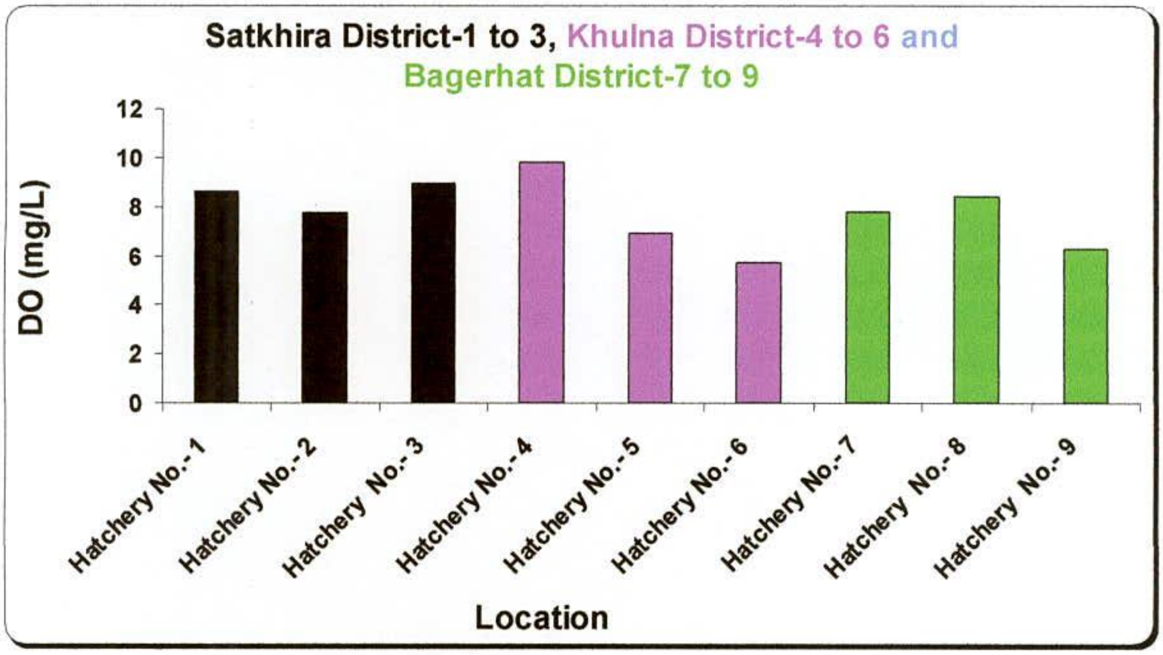


Figure 5.23 DO of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of DO of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.23 within standard limit.

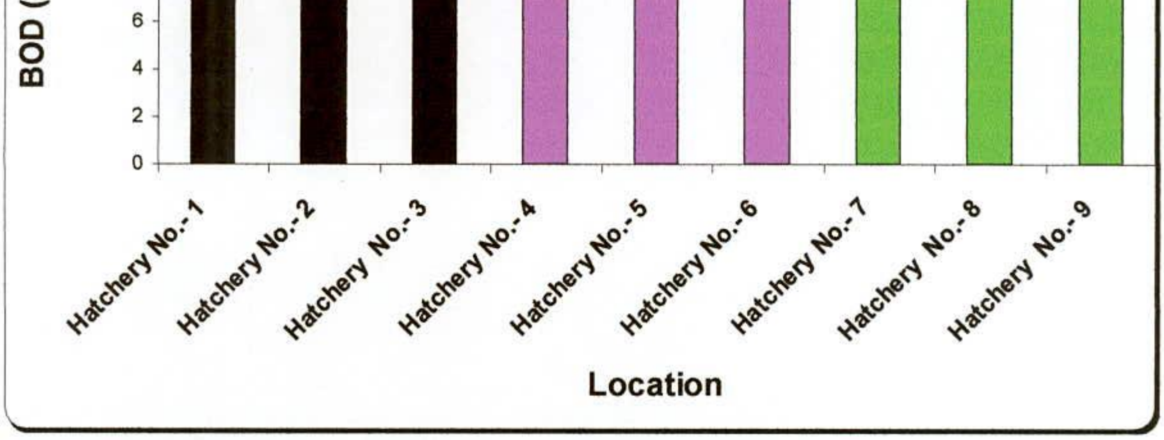


Figure 5.24 BOD of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat District.

The value of BOD of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.24 within standard limit.

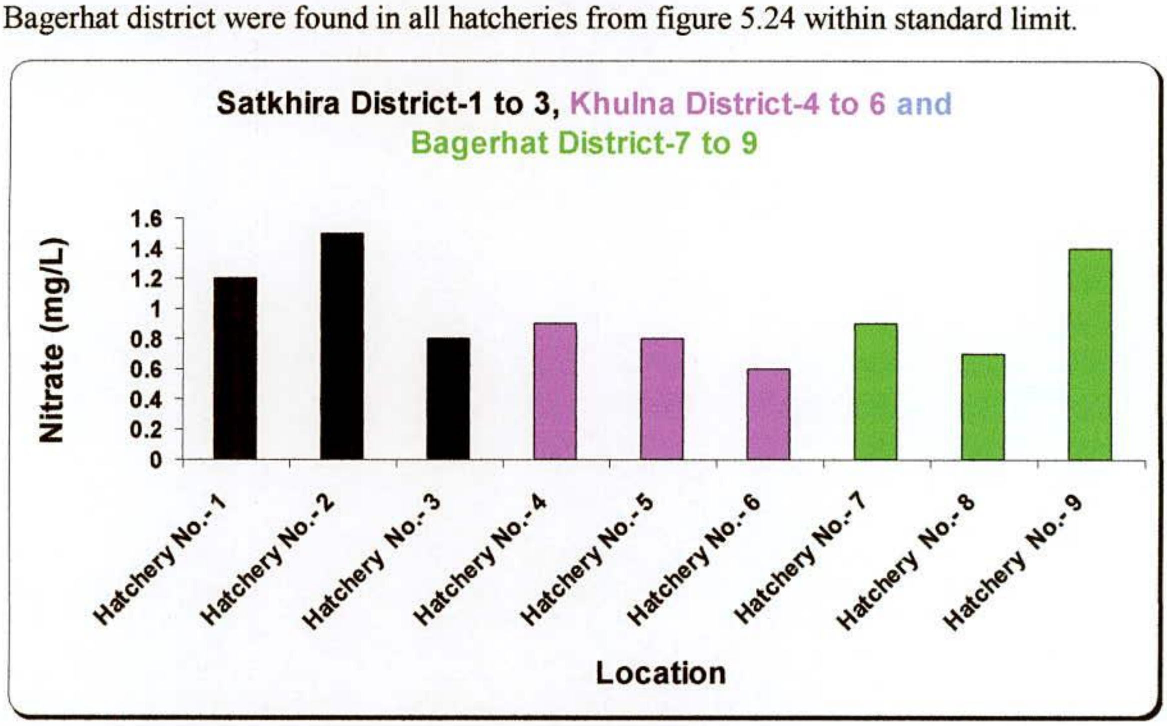


Figure 5.25 Nitrate of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of nitrate of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found low in all hatcheries from figure 5.25. The lower values of nitrate may be due to the process of de-nitrification which converted nitrate to nitrogen gas.

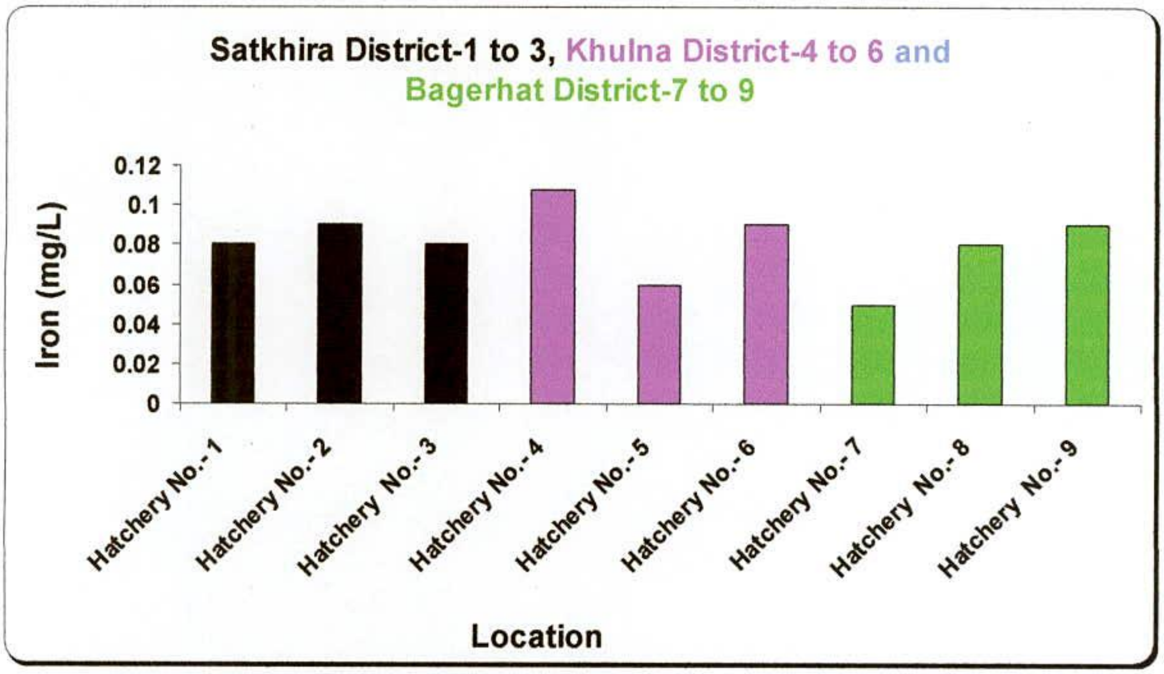


Figure 5.26 Iron of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of Iron of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.26 within standard limit.

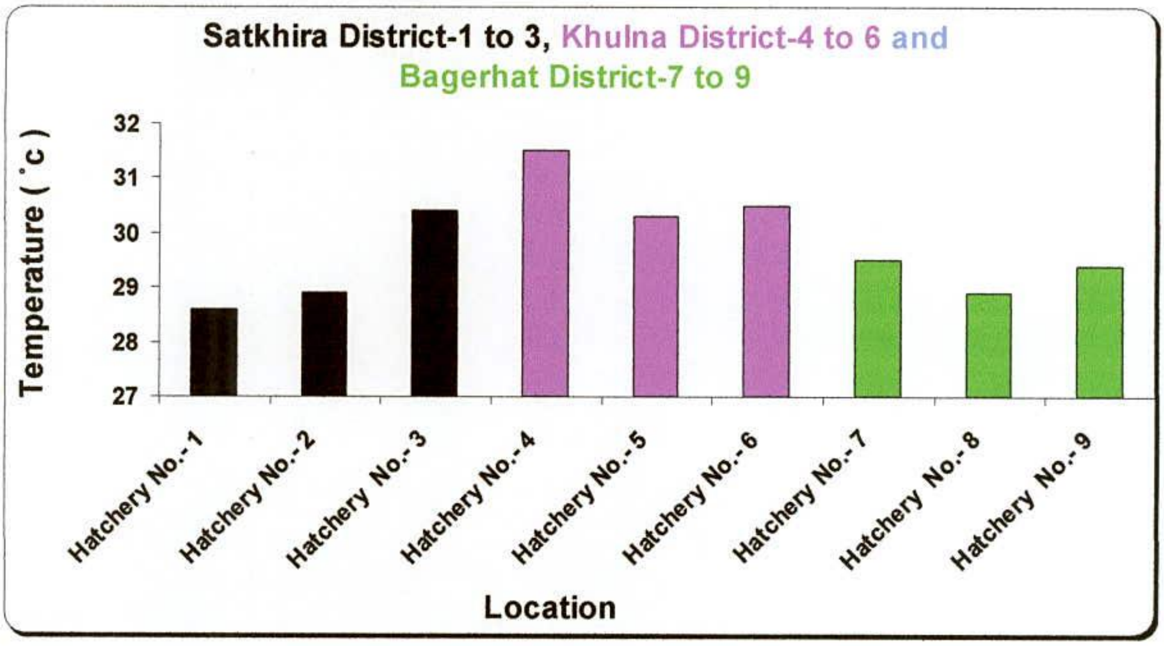


Figure 5.27 Temperature of shrimp culture water for hatchery of Satkhira, Khulna and Bagerhat district.

The value of temperature of shrimp culture water at different hatchery of Satkhira, Khulna and Bagerhat district were found in all hatcheries from figure 5.27 within standard limit.

5.4 Experimental values of heavy metals (Pb, Hg, Cd, and Cr) for shrimp culture water in shrimp of Satkhira, Khulna and Bagerhat district

Experimental values of heavy metals (Pb, Hg, Cd, and Cr) for shrimp culture water in shrimp of Satkhira, Khulna and Bagerhat district are shown in Table 5.4

Table: 5.4 Experimental values of heavy metals for shrimp culture water in shrimp of Satkhira, Khulna and Bagerhat district.

Locations		Pb (mg/kg)	Hg (mg/kg)	Cd (mg/kg)	Cr (mg/kg)
Satkhira district	Farm No-1	<10.0	<0.3	<0.3	<5.0
	Farm No-4	<10.0	<0.3	<0.3	<5.0
	FarmNo-7	<10.0	<0.3	<0.3	<5.0
Khulna district	Farm No-10	77.8±0.1	<0.3	23.0±0.7	11.9±2.4
	Farm No-13	105±5.56	<0.3	16.1±0.2	21.4±2.4
	Farm No-16	77.8±0.1	<0.3	22.8±0.9	16.7±2.4
Bagerhat district	Farm No-19	<10.0	<0.3	<0.3	15.0±0.65
	Farm No-22	19.5±0.85	<0.3	<0.3	<5.0
	Farm No-25	<10.0	<0.3	<0.3	<5.0

It is observed from the Table: 5.4 that the value of Pb in shrimp culture water for shrimp of Satkhira, Bagerhat and Khulna district were found within standard limit in farms nos. 1, 4,7,19 and 25 but in farms nos. 10, 13, 16 and 19 were higher than standard limit. The value of Hg in shrimp culture water for shrimp of Satkhira, Bagerhat and Khulna district were found in farms nos. 1,4,7,10,13,16,19,22 and 25 within standard from Table 5.4. It were found from table 5.4 that the value of Cd in shrimp culture water for shrimp of Satkhira, Bagerhat and Khulna district were found in farms nos. 1, 4, 19, 22 and 25 within standard limit but in farms nos. 10, 13 and 16 were higher than standard limit. The value of Cr in shrimp culture water for shrimp of Satkhira, Bagerhat and Khulna district were found in farms nos. 1,4,22 and 25 within standard limit but in farms nos. 10, 13, 16 and 19 were higher than standard limit from Table 5.4. The values of Pb, Cd and Cr in Khulna district may be due to drainage of a lot of industrial waste to the nearby rivers and canals. The mentioned metal may leached into or may directly be mixed when the rivers over flowed.

5.5 Experimental values of heavy metals (Pb, Hg, Cd, and Cr) in shrimp for shrimp of Satkhira, Khulna and Bagerhat district.

Experimental values of heavy metals (Pb, Hg, Cd, and Cr) in shrimp for shrimp of Satkhira, Khulna and Bagerhat district are shown in Table 5.5

Table: 5.5 Experimental values of heavy metals in Shrimp for shrimp of Satkhira, Khulna and Bagerhat district.

Locations		Pb (mg/kg)	Hg (mg/kg)	Cd (mg/kg)	Cr (mg/kg)
Satkhira Main	Farm No-1	<0.3	<0.03	<0.1	<0.1
town, Satkhira	Farm No-2	<0.3	<0.03	<0.1	<0.1
District.	Farm No-3	<0.3	<0.03	<0.1	<0.1
Assasuni,	Farm No-4	<0.3	<0.03	<0.1	<0.1
Satkhira District.	Farm No-5	<0.3	<0.03	<0.1	<0.1
	Farm No-6	<0.3	<0.03	<0.1	<0.1
Shyamnagar,	Farm No-7	<0.3	<0.03	<0.1	<0.1
Satkhira District.	Farm No-8	<0.3	<0.03	<0.1	<0.1
	Farm No-9	<0.3	<0.03	<0.1	<0.1
Dumuria,	Farm No-10	40±.5	<0.03	7±.56	<0.1
Khulna District.	Farm No-11	<0.3	<0.03	<0.1	<0.1
	Farm No-12	<0.3	<0.03	<0.1	<0.1
Koyra,	Farm No-13	70±5.56	<0.03	5±.3	8±.561
Khulna District.	Farm No-14	<0.3	<0.03	<0.1	<0.1
	Farm No-15	<0.3	<0.03	<0.1	<0.1
Paikgachha,	Farm No-16	37±.5	<0.03	7±.56	6±.06
Khulna District.	Farm No-17	<0.3	<0.03	<0.1	<0.1
	Farm No-18	<0.3	<0.03	<0.1	<0.1
Rampal,	Farm No-19	<0.3	<0.03	<0.1	<0.1
Khulna District.	Farm No-20	<0.3	<0.03	<0.1	<0.1
	Farm No-21	<0.3	<0.03	<0.1	<0.1
Mongla,	Farm No-22	<0.3	<0.03	<0.1	<0.1
Khulna District.	Farm No-23	<0.3	<0.03	<0.1	<0.1
	Farm No-24	<0.3	<0.03	<0.1	<0.1
Bagerhat Main	Farm No-25	<0.3	<0.03	<0.1	<0.1
town	Farm No-16	<0.3	<0.03	<0.1	<0.1
Bagerhat District.	Farm No-27	<0.3	<0.03	<0.1	<0.1

It is observed from the Table: 5.5 that the values of heavy metal (Pb, Hg, Cd, and Cr) in shrimp for shrimp of Satkhira main town, Assasuni and Shyamnagar of Satkhira district were found within standard limit in farms nos. 1 to 9. It is observed from the Table: 5.5 that the value of Pb in shrimp for shrimp in farms nos. 11, 12,14,15,17 and 18 of Dumuria, Koyra and Paikgachha of Khulna district were found within standard limit but in farms nos. 10, 13 and 16 were high. The value of Hg in shrimp for shrimp of Dumuria, Koyra and Paikgachha of Khulna district were found within standard limit in farms nos. 10 to 18 from Table 5.5. It were found from Table 5.5 that the value of Cd in shrimp for shrimp of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10, 12,14,15,17 and 18 within standard limit but in farms nos. 11, 13 and 16 were higher than standard value. The value of Cr in shrimp for shrimp of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10, 11, 12,14,15,17 and 18 within standard limit but in farms nos. 13 and 16 were higher than standard limit. It is observed from the Table: 5.5 that the value of heavy metals Pb, Hg, Cd, and Cr in shrimp for shrimp of Rampal, Mongla and Bagerhat main town of Bagerhat district were found within standard limit in farms nos. 19,20,21,22,23,24, 25, 26 and 27. The values of Pb, Cd and Cr in Khulna district may be due to drainage of a lot of industrial waste to the nearby rivers and canals. The mentioned metal may leached into ponds or may directly be mixed when the rivers over flowed.

Conclusion

Fish should be of sufficient size to be marketable and production should operate at a high enough rates to be profitable. The fish should be sufficiently healthy, so, disease or its risk is low. The fish should undergo examination for any specific symptoms based on the pollutants present. More general examination for diseases, stress or abnormalities should be performed. Recent research has pointed to the utility of biomarkers in assessing a potential effect of water quality on fish. The investigation involves the measurement of physico-chemical parameters of shrimp culture water and also in shrimp in different locations of Satkhira, Khulna and Bagerhat district. The values of pH, BOD, salinity, hardness and nitrate at different location of Bagerhat district were found within standard limits in farms nos. 19 to 27 but DO were found to be high. The values of BOD and iron at different location of Khulna district were found within standard limits in farms nos. 10 to 18 but pH, turbidity, salinity, hardness, DO and nitrate were found to be high. The values of hardness, BOD and iron at different location of Satkhira district were found within standard limits in farms nos. 1 to 9 but pH, turbidity, salinity, DO and nitrate were found to be high. The heavy metal such as Pb, Cr, Cd and Hg in shrimp culture water were found within standard limit in farms nos. 1, 4 and 7 and heavy metal in shrimp were also found within standard limit in farms nos. 1 to 9 of Satkhira district. The value of heavy metal Pb in shrimp for shrimp in farms nos. 11, 12,14,15,17 and 18 of Dumuria, Koyra and Paikgachha of Khulna district were found within standard limit but in farms nos. 10, 13 and 16 were high. The value of Hg in shrimp culture water for shrimp of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10 to 18 within standard limit. The value of Cd in shrimp culture water for shrimp of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10,12,14,15,17 and 18 within standard limit but in farms nos. 11,13 and 16 were higher than standard limit. The value of Cr in shrimp culture water for shrimp of Dumuria, Koyra and Paikgachha of Khulna district were found in farms nos. 10, 11, 12,14,15,17 and 18 within standard limit but in farms nos. 13 and 16 were higher than standard limit. The values of heavy metals such as Pb, Hg, Cd and Cr in shrimp for shrimp of Rampal, Mongla and Bagerhat main town of Bagerhat district were found within standard limit in all farms. Physico-chemical parameters in shrimp culture water at different locations of Bagerhat district were found to be standard and the presences of heavy metals in shrimps at these locations were found within standard limit.

The physico-chemical parameters such as pH, DO, BOD, NO_3^-, Fe, salinity and hardness in shrimps culture water of other areas should be maintain as like as Bagerhat district. The result obtains from this investigation will immense to help the shrimp cultivators to cultivate improved quality of shrimps. The country will be able to export safe and quality products and earned more foreign currency. It will be helpful to develop our economy and the products will be made a room in the global market.

Abbreviations and Acronyms

1. Ag	Silver
2. Al	Aluminum
3. As	Arsenic
4. ASP	Amnesiac shellfish poisoning
5. BCF	Bio-concentration factors
6. BOD	Biological oxygen demand
7. $CaCO_3$	Calcium carbonate
8. Cd	Cadmium
9. CFU	Colony forming units
10. Cl	Chlorine
11. CN	Cyanide
12. COD	Chemical oxygen demand
13. CO_2	Carbon dioxide
14. Cr	Chromium
15. Cu	Copper
16. DO	Dissolved oxygen
17. DSP	Diarrheic shellfish poisoning
18. DDT	Dichloro-diphenyl-trichloro-ethane
19. EU	European Union
20. FAO	United Nations Food and Agriculture Organization
21. Fe	Iron
22. HCN	Hydrogen cyanide
23. H_2	Hydrogen sulfide
24. Hg	Mercury
25. HOCl	Hypochlorous acid
26. $KMnO_4$	Potassium permanganate
27. LCSO	Lethal count level (50 years)
28. mg /L	Milligrams per liter
29. Mn	Manganese
30. MPN	Most probable number

31. WHO	World Health Organization
32. USEP	United States Environmental Protection Agency
33. NSP	Neurotoxin shellfish poisoning
34. Pb	Lead
35. PCB`	Polychlorinated biphenyls
36. ppb	Parts per billion
37. PSP	Paralytic shellfish poisoning
38. PTWI	Provisional tolerable weekly intake
39. ppt	Parts per thousand
40. Sn	Tin
41. TAN	Total ammonia nitrogen
42. TBT	Tri-butyl tin
43. TCDD	Tetra-chloro dioxin
44. TGP	Total gas pressure
45. FAU	Formazin Attenuation Units

Glossary

Actinomycetes: Any of an order (Actinomy cetales) of filamentous or rod-shaped bacteria, including the actinomyces (soil-inhabiting saprophytes and disease-producing parasites) and streptomyces.

Anthropogenic pollutants: Pollutants which come from human sources such as emissions from an industrial plant or pesticide emissions from agriculture. These pollutants are referred to as anthropogenic because they typically are associated with human activity. However, it is possible for some of them to come from natural sources.

Benthos: Organisms that live on or in the bottom of bodies of water.

Bioaccumulation factor (BCF): A measure of the extent to which a compound bioaccumulates in an aquatic species. It is calculated as (concentration of the compound in the body tissue) divided by (Concentration of the compound in the water).

Biological oxygen demand (BOD): The amount of dissolved oxygen used up by microorganisms in the biochemical oxidation of organic matter. Five-day BOD (BOD5) is the amount of dissolved oxygen consumed by microorganisms in the biochemical oxidation of organic matter over a 5-day period at 200C.

Cat ions: The ion in an electrolyzed solution that migrates to the cathode: a positively charged ion.

Chelating Agents: A compound that combines with a metal.

Chloracne: An eruption/inflammation of the skin resulting from exposure to chlorine.

Colony forming units: A measure of bacterial numbers which is determined by growing the bacteria and counting the resulting colonies.

Detritus: Loose material (as rock fragments or organic particles) that results directly from disintegration.

Divalent: Having a valence (combining power at atomic level) of two [e.g., Calcium (Ca^{+2})].

Hypoxia: Acute oxygen deficiency to tissues.

Ligands: A group, ion, or molecule coordinated to a central atom or molecule at a complex.

Most probable number: A measure of bacterial numbers in which the bacteria are serially diluted and grown. By identifying the dilution samples in which the bacteria grow, the number of bacteria in the original samples can be determined.

Necrosis: Localized death of living tissue.

Osmoregulation: The biological process of maintaining the proper salt concentration in body tissues to support life.

Parenchymatous: Related to the essential and distinctive tissue of an organ or an abnormal growth as distinguished from it supportive framework.

Physio-chemical properties of water: The basic physical and chemical properties of water in duding salinity, pH etc. Note this does not include concentrations of anthropogenic pollutants.

Red ox: Of or relating to oxidation- reduction.

Tainting or Off-flavor: When certain pollutants such as petroleum hydrocarbons accumulate in fish or shellfish to a level at which the flavor is affected. This makes the product undesirable for human consumption.

Zeolites: Any of various hydrous silicates that are analogous in composition to the feldspars, occur as secondary minerals in cavities of lavas, and can act as ion exchangers used fro water softening and as absorbents, and catalysts.

References

1 Acosta, B.O. and Pullin, R.S.V., 1991, "Environmental Impact of the Golden Snail (Pomaceasp.) on Rice Farming Systems in the Philip- Alapines."Proceedings of the International Center for Aquatic Resources Management (ICLARM) Con-ference. Manila, Philippines: ICLARM.

2 Taki, Y., Primavera, J.H. and Llobrera, J.A., 1985, Proceedings of the First

International Conference on the Culture of Prawns/Shrimps.SEAFDEC,Iloilo city Philippines . pp. 3-10.

3 APHA (American Public Health Association).1995, Standard Methods for Examination of Water and Wastewater. Washington, D.C.: APHA.

4 Avault, J.W., Bretonne, De.La. and Huner, J., V.1974.

5 Bailey, R.A., Clark, H.M., Ferris, J.P., Krause, S. and Strong, R.L., 1978, of the Environment. New York: Academic Press.

6 Banerjea, S.M. and Ghosh, A.N., 1963, "Soil Nu- Septrients and Plankton Production in Fish Ponds Available Soil Phosphorous." Indian Journal of Fisheries 10: 627-35.

7 Tucker, C.S. and Robinson, E. H., 1990. Channel Catfish Farming Handbook. New York: Van Nostrand Reinhold.

8 Biggar, J.W. and Riggs, R.I., 1974, Hilgardia 42: 383-91.

9 Black, E.A., 1991, "Coastal Resource Inventories:A Pacific Coast Strategy for Aquaculture Development." Pauw, N.De., Joyce, J., Aquaculture and the Environment. EuropeanAquaculture Society Special Publication 16.Ghent, Belgium.

10 Boyd, C.E., 1974, "LimeRequirementsof Alabama Fish Ponds."

11 Barraclough, S. and Funge-Smith, S.J., 1996, Some Ecological and Social Implications of Commercial Shrimp Farming in Asia, United Nations Research Institute for Social Development (UNRISD) Discussion pp. 74-78,

12 Bondad-Reantaso, M.G., McGladdery, S.E., East, I. and Subasinghe, R.P., Asia Diagnostic Guide to Aquatic Animal Diseases, chapter 4. FAO Fisheries Technical Paper 402/2, NACA/FAO 2001. ISBN 92-5-104620-4.

13 Boyd, C. E. and Walley,W.W., 1979, Water Quality in Warm water Fishponds. 1st printing. Birmingham, Ala.: Auburn University Press.

14 Boyd, C. E. and Walley, W.W., 1990, Water Quality in Ponds for Aquaculture. Birmingham, Ala.: Auburn University

15 Briggs, M.R.P. and Funge-Smith, S.J., 1996, "The Effects of Zeolites and Other

Alumino-silicate Clays on Water Quality at Various Salinities."Aquaculture Research 27: 301-11.

16 Bromage, N., Shephered, J., J. Shephered, and N.Bromage., 1988,"Fish, TheirRequirements and Site Evaluation." Intensive Fish Farming. Oxford: BSP Professional Books.

17 Buras, N., Duek, L. and Niv, M.S., 1985, "Reaction of Risk to Microorganisms in Wastewater."

18 Chautard, P., Avalle, O., Millous, O. and Vimaux, J.F., November 22, 2006, "Shrimp farming in the tropical zone" Brussels, Belgium; November 2003. In French. URL last accessed November 22, 2006.

19 Chakroborti, R.K., Ravichandran, P., Dolder, D.D., S.K. Mandal, S.K. and Sanfui, D., 1985, "Some Physio-chemical Characteristics of Kakdwip Brackish Water Ponds and Their Influence on Survival, Growth, and Production of Penaeus monodon (Fabricus)." Indian Journal of Fisheries pp. 224-35.

20 Clifford, H. C., 1985, Semi-intensive shrimp farming, pp. 13-40

21 Clifford, Henry C., 1994, "Semi-Intensive Sensation: A Case Study in Marine Shrimp Pond Management." Marine Biology pp. 14-19.

22 Draft report of the Consortium Programmed Shrimp Farming and the Environment, World Bank/NACA/WWF/FAO, June 21, 2002.

23 Encyclopedia of Food Science, Food Technology and Nutrition. "Fish Farming." 1882-87.

24 Bretonne, De La., L., Avault, L., J. W., R.0. and Smitherman, R. 0., 1969, "Effects of Soil and Water Hardness on Survival and Growth of the Red Swamp Catfish, Procambarus Clarkii, in Plastic Pools." Proceedings of the Southeastern Association of Game and Fish Commissioners 23: 626-33. Columbia, S. Carolina.

25 Dojlido, J. and Best, G.A., 1993, Chemistry of Water and Water Pollution. West Sussex: Ellis Horwood Limited.

26 DeWalt, B.R., May 2000, Social and Environmental Aspects of Shrimp Aquaculture in Coastal Mexico, paper presented at the Mangrove 2000 conference in Recife, Brazil.

27 D'Silva, A.M. and Maughan, 0.E., 1995, "Effects of Density and Water Quality on Red Tilapia (Oreochromis mossambicus X 0. urolepis hornorum) in Pulsed-Flow Culture Systems." Journal of Applied Aquaculture 5(1) pp. 69-75.

28 Data extracted from the FAO Fisheries Global Aquaculture Production Database for the seven commonly farmed species plus Pennaeus spp. The most recent data sets are for 2006 and sometimes contain estimates. Last accessed 2008-07-03.

29 Data extracted from the FAO Fisheries Global Aquaculture Production Database for freshwater crustaceans. The most recent data sets are for 2003 and sometimes contain estimates. Last accessed 2005-06-28.

30 Durum, W.H. and Haffty, J., 1961, "Occurrence of Minor Elements in Water." U. S. Geological Survey Circular 445. Washington, D.C.Duram Eisler, R., 1971. "Cadmium Poisoning in Fundulus heteroclitus (Pisces: Cyprinodontidae) and Other Marine Organisms." Journal of the Fish Research Board of Canada 28: 1225-34.

31 EIFAC (European Inland Fisheries Advisory Commission). 1964, Water Quality Criteria for Freshwater Fish: Suspended Solids. Technical paper 1.

32 European Union (EU). 1979, Directive on the Quality of Fresh Water Needing Protection or Improvement in Order to Support Fish Life. 79/659/EEC.Brussels: EU.

33 FAO, Land and Water Development Division: Bio-Physical, Socio-Economic and Environmental Impacts of Salt-affected Soils, 2000, URL last accessed 2005-08-23.

34 Fitzgerald, W.F., Clarkson, T.W., 1991, "Mercury and Monomethyl Mercury: Present and Future Concerns." Environmental Health Perspectives December 1996 pp. 159-66.

35 Fitzpatrick, R., Powell, B. and Marvanek, S., 2006, CSIRO Coastal Acid Sulphate Soils: National Atlas and Future Scenarios, Presented at the 18th World Congress of Soil Science (WCSS), June 9–15, 2006. URL last accessed 2007-10-12.

36 Forstner, U. and Wittman, G.T.W., 1981, MetalPollution in the Aquatic Environment. Berlin:Springer-Verlag.

37 Funge-Smith, S. G.T.W., Briggs, M., August 26 – 29, 2003, Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific, FAO RAP publication 2004/10. A PDF file of an abridged version presented at the workshop for "International Mechanisms for the Control and Responsible Use of Alien Species in Aquatic Ecosystems", Jinghong, Xishuangbanna.

38 Fumess, R.W. and Rainbow, P. S., 1990, Heavy Metals in the Marine Environment. Boca Raton, Florida: CRC Press.

39 Ghosh, A., Chattopadyay, G. N., Chakraborti, P.K., Edward, P. and Pullin, R.S.V., 1990, "Wastewater-fed Aquaculture." Proceedings of the International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India.Asian Institute of Technology, Bangkok, Thailand.

40 Gulf States Marine Fisheries Commission: Non-Native Species Summaries: Yellowhead Virus (YHV), 2003. URl last accessed 2005-06-23.

41 Gulf States Marine Fisheries Commission: Non-Native Species Summaries: White Spot Syndrome Baculovirus Complex (WSBV), 2003, URL last accessed 2005-06-23.

42 Hempel, E., Winther, U. and Hambrey, J., 2002, Can Shrimp Farming Be Undertaken Sustainably? , World Bank/NACA/FAO/WWF Consortium Program on Shrimp Farming and the Environment.

43 Hirono, Y., 1983, journal of the World Aquaculture Society 14, pp. 451-457

44 Hossain, Md. Z., Lin, C.K., 2001, Diversified Uses of Abandoned Shrimp Ponds - A Case Study in the Upper Gulf of Thailand. ITCZM Monograph No. 5, Asian Institute of Technology, Bangkok, Thailand; 2001. URL last accessed 2007-02-15.

45 Howard, P. H., 1991, Handbook of Environmental Fate and Exposure Data for Organic Chemicals.Vol. 3: Pesticides. Chelsea, Mich.: Lewis Publishers Inc.

46 Huguenin, J. E. and Colt, J., 1989, Design and Operating Guide for Aquaculture Seawater Systems.Amsterdam: Elsevier.

47 Indian Aquaculture Authority: Shrimp Aquaculture and the Environment - An Environment Impact Assessment Report, ch. 2; IAA report, April 2001.

48 Indian Aquaculture Authority: Shrimp Aquaculture and the Environment - An Environment Impact Assessment Report, ch. 6; IAA report, April 2001.

49 International Shrimp Action Network: Prawn to Trade, Prawn to Consume, 2000. URL last accessed 2007-08-20.

50 Isensee, A. R., 1978, "Bioaccumulation of 2, 3, 7, 8,-tetrachlorodibenzo-para-dioxin." Ecological Bulletin 27 pp. 255-62.

51 Japan External Trade Organization JETRO). 1996, Specifications and Standards for Foods and Food Additives. New York.

52 Joseph, M.M., 1990, Aquaculture in Asia. Karnataka, India: Asian Fisheries Society, Indian Branch.

53 Khan, M.A.Q., 1977, Pesticides in the Aquatic Environment. New York: Plenum Press.

54 Kleeman, J.M., J.R. Olson., R.E. and Peterson, R.E., 1988, "Species Differences in 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin toxicity and Biotransformation in Fish." Fundamental and Applied Toxicology 10 pp. 206-13.

55 Kumaran, M., Ravichandran, P., Gupta, B.P. and Nagavel, A., September 2003, Shrimp Farming Practices and its Socio-Economic Consequences in East Godavari District, Andhra Pradesh, India – A Case Study, Aquaculture Asia 8(3)

56 Lawson, T.B., 1995, Fundamentals of Aquacultural Engineering. New York: Chapman and Hall.

57 Lewis, R.R., Philipps, M.J., Clough, B. and Macintosh, D. J., 2003, Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture, World Bank/NACA/WWF/FAO Consortium Program on Shrimp Farming and the Environment.

58 Lloyd, R., 1992, Pollution and Freshwater Fish. West Byfleet: Fishing News Books.

59 Lobel, P.S., Mann, D.A. and Sancho, G., 1994, Pollution and Coastal Fisheries: How Much Do We Know? Washington, D.C.: Center for International and Strategic Studies.

60 Maceina, M.J. and Shineman, J.V., 1979, "Grass Carp: Effect of Salinity on Survival, Weight Loss and Muscle Tissue Water Content." Progressive Fish Culturist 41 pp. 69-73.

61 Macrae, R., Robinson, R.K. and Sadler, M.J., 1993, Encyclopedia of Food Science Food Technology, and Nutrition. London: Academic Press. MAFF (Ministry of Agriculture, Fisheries, and Food). 1989. Report of the Working Party on Pesticide Residues, 1985-1988. Food Surveillance pp.25. London: HMSO.

62 Malm, O., Pfeiffer, W. C., Souza, C. M. M. and Reuther,R., 1990, "Mercury Pollution Due to Gold Mining in the Madeira River Basin, Brazil." Ambio 19(1) pp. 11-15.

63 Manahan, S. E., 1991, Environmental Chemistry 5th ed. Chelsea, Mich.: Lewis Publishers.

64 Mance, G., 1987, Pollution Threat of Heavy Metals in Aquatic Environments. London: Elsevier.

65 Mantoura, R.F.C., Dickson, A. and J.P. Riley., 1978, "The Complexation of Metals with Hurnic Materials in Natural Waters." Estarine and Coastal Marine Science 6 pp. 387-408.

66 Mara, D. and Cairncross, S., 1989, Guidelinesfor the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture. Geneva: WHO.

67 Marques, L.C. and Andreatta, E.R., 1998, Efeito da salinidade sobre o consumo de ração, crescimento e sobrevivência de juvenis do camarão rosa Penaeus paulensis (Pérez-Farfante, 1967). In: Anis... Aquiculture Brazil. Recite, 2, pp.804.

68 Maryland, Department of the Environment. 1993, Code of Maryland Regulations: Water Quality.26.08.02. Annapolis, Md.

69 McClennan, C., 2004, White Spot Syndrome Virus – The Economic, Environmental and Technical Implications of the Development of Latin American Shrimp Farming, Master's Thesis, Tufts University.

70 McEwan, F.L. and Stephenson, G.R., 1979, the Use and Significance of Pesticides in the Environment. New York: Wiley.Mckay, L. R., and B. Gjerde. 1985. "The Effect of Salinity on Growth of Rainbow Trout." Aquaculture 49 pp.325-31.

71 Sturmer, L.N., Samocha, T.M. and Lawrence, A.L., 1992.Intensification of penaeid nurserysystems.Pages 232-346 in A.W. Fast and L.G. Lester, .editors. Culture of Marine Shrimp, Principles and Practices. Elsevier scientific publishing Company, Amsterdam, The Netherlands.

72 Metcalf, Eddy., 1991, Wastewater Engineering: Treatment, Disposal and Reuse 3rd ed. rev. by G. Tchobanoglous and F. L. Burton. New York:McGraw-Hill.

73 Milne, P.H., 1972, Fish and Shellfish Farming in Coastal Waters. West Byfleet: Fishing News Books.

74 Miranda, K.C.F., 1997, Efeito da amônia na sobrevivência e crescimento da camarão rosa Penaeus paulensis Péres-Farfante, 1967 (Crustacea:Decapoda), Tese de mestrado em Oceanografia Biológica, Fundação Universidade Federal do Rio Grande (FURG), Rio Grande, RS, Brazil.

75 Moore, J. and Ramamoorthy, S., 1984, Heavy Metals in Natural Waters. Berlin: Springer-Verlag.

76 Murphy, T.J., Mullin, M.D. and Meyer, J.A., 1987,"Equilibration of Polychlorinated Biphenyls and Toxaphene with Air and Water." Environmental Science and Technology 21 pp. 155-62.

77 Musselwhite, C., 1982, "Survey of Arsenic Concentrations in Rivers and Coastal Waters of the U.K." WRC 199-s. DOE Contract Report. Water Research Center, Medmeham, Berkshire.

78 NACA: Codes and Certification; Network of Aquaculture Centres in Asia-Pacific (NACA). URL last accessed 2005-08-19.

79 NACA/MPEDA: Shrimp Health Management Extension Manul, Network of Aquaculture Centres in Asia-Pacific (NACA) and Marine Products Export Development Authority (MPEDA), India; 2003.

80 Nauen, C.C., 1983, "Compilation of Legal Limits for Hazardous Substances in Fish and Fisheries Products." FAO Fish. Circ. 764:102. Rome: FAO.

81 Nunes, A.J.P., 1995, feeds dynamics of Southern brown shrimp Penaeus subtilis (Pérez-Farfante, 1967) (Crustacea, Penaeidae) under semi-intensive culture in NE Brazil. Tese de Mestrado em Aquaculture. Memorial University of Newfoundland, Newfoundland, Canada.

82 Owen, J., Shrimp's Success Hurts Asian Environment, Group Says, in National Geographic News, June 21, 2004; updated December 20, 2004. URL last accessed 2007-08-20.

83 Palmer, S.J. and Presely, B.J., 1993, "Mercury Bioaccumulation by Shrimp Transplanted to Lavaca Bay, Texas." Marine Pollution Bulletin 26:10.

84 Pastor, A., Hemandez, F., Peris, M.A., Beltran,J., Sancho, V.S. and Castillo, M.T., 1994. "Levels of Heavy Metals in Some Marine Organisms from the Western Mediterranean Area (Spain)." Marine Pollution Bulletin 28(1) pp. 50-53.

85 Peavy, H.S. and Rowe, D.R., 1985, Environmental Engineering. New York: McGraw-Hill.

86 Perry, W.G. and Avault, J.W., 1970, "Culture of Blue, Channel, and White Catfish in Brackish Water Ponds." Proceedings of the Southeastern Association of Game and Fish Commissioners 23:592-7. Columbia, S. Carolina.

87 Farfante, I. and Kensley, B. F., Paris, 1997, Penaeoid and Sergestoid Shrimps and Prawns of the World (Keys and Diagnoses for the Families and Genera); Editions du Museum national d'Histoire naturelle #175.

88 Petit, J., 1990, "Water Supply, Treatment, and Recycling in Aquaculture." In G. Bamabe, ed. Aquaculture. Vol. 1. New York: Ellis Horwood.

89 Phillips, J.H., Edward,P. and Pullin, R.S.V., 1993, "Developing-Country Aquaculture, Trace Chemical Contaminants, and Public Health Concerns."and "Wastewater-fed Aquaculture." Proceedings of the International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India. Asian Institute of Technology, Bangkok, Thailand.

89 Pillay, T.V.R., 1990, Aquaculture Principles and Practices. West Byfleet: Fishing News Books. 1992. Aquaculture and the Environment. New York: Halsted Press.

90 Piper, R G., McElwain, I.B., Orme, L.E.,.McCraren, J.P., Fowler, L.G. and J.R. Leonard., 1982. Fish Hatchery Management. Washington, D.C.:U.S. Fish and Wildlife Service.

91 Pullin, R.S.V., Rosenthal, H. and Maclean, J.L., 1993. Environment and Aquaculture in Developing Countries. Manila, Philippines: International Center for Living Aquatic Resources Management (ICLARM).

92 Reish, D. J., Kauwling, T.J., Mearns, A.J., Oshida, P., Rossi, S.S. Wilkes, F. G. and Ray, M.J., 1978. "Water Pollution: Marine and Estuarine Pollution." Journal of the Water Pollution Control Federation 50: 1424-69.

93 Rice. M.A., 1992. "Bivalve Aquaculture in Warm Tropical and Subtropical Waters with Reference to Salinity and Water Quality, Monitoring, and Post-harvest Disinfection." Tropical Science 32(2): 179-102.

94 Roberts. R.J., Shepherd, C.J., 1974. Handbook of Trout and Salmon Diseases. West Byfleet: Fishing News Books.

95 Robertson, L., Lawrence, A.L. and Castille, F., 1993, Interaction and salinity and feed protein levels on growth of Penaeus vannamei. J. Applied Aqua. 2 : (1), 43-54.

96 Romaire, R.P., 1985. Water Quality, Crustacean and Mollusk Aquaculture in the United States. Westport: AVI Publishing.

97 Rönnbäck, P., 2003, Critical Analysis of Certified Organic Shrimp Aquaculture in Sidoarjo, Indonesia, Swedish Society for Nature Conservation (SSNC), 2003. URL last accessed 2007-08-20.

98 Rosenberry, B., May 2005 The Rise and Fall of Chloramphenicol, Shrimp News,. Archived URL last accessed 2007-02-15.

99 Salomons, W. and Forstner, U., 1984. Metals in the Hydrocycle. Berlin: Springer Verlag.

101 Samocha, T.M., .Blacher, T. and Estrada, E., 2000, 4th Latin American Aquaculture Congress and Exhibition, October 25-28, 2000, ATLAPA Convention Center Panama.

102 Samocha T. M., Blacher, T., Cordova, J. and Wind, A.De., 2000, pp. 66-68.

103 Samocha T.M.,T Blacher, Cordova, J. and Wind, A. De.,2001.,Aquaculture,Annual Meeting of World Aquaculture society, January 21-25,2001,Orlando,FL

104 Santos, M.H.S., Cunha, N.T. and Bianchini, A., 2000, Effects of copper and zinc on growth, feeding and oxygen consumption of Farfantepenaeus paulensis post larvae (Decapoda: Penaeidae), J. Exp. Mar. Biol. Ecol., 247, 233-242.

105 Sawyer, C.N. and McCarty, P. L., 1978. Chemistry for Environmental Engineers. New York: McGraw Hill.

106 Sayler, G.S., Nelson, J.D. and CoUwell, R.R., 1975. "Role of Bacteria in Bioaccumulation of Mercury in the Oyster Crassostrea virginica." Applied Microbiology 30: 91-96.

107 Schmidt, U. and Huber, E., 1976. "Methylation of Organo Lead and Lead (II) Compounds to (CH3)4 Pb by Microorganisms." Nature 259:157-8. London, U.K.

109 Shereif, M.M., Mancy, K.H., 1995. "Organo." chlorine Pesticides and Heavy Metals in Fish Reared in Treated Sewage Effluents and FishGrown in Using Polluted Surface Waters in Egypt." Water Science and Technology 32 pp. 153-61.

110 Stickney, R.R., 1986. "Tilapia Tolerance of Saline Waters: A Review." Progressive Fish Culturist 48 pp.161-7.

111 Meade, J.W., 1989, Aquaculture Management. New York: Van Nostrand Reinhold 112

113 Sunda, W.G., Engel, D.W. and Thuotte, R.M., 1978. "Effect of Chemical Speciation on Toxicity of Cadmium to Grass Shrimp, Palaemonetespugio: Importance of Free Cadmium Ion." Environmental Science and Technology 12(4) pp. 409-13.

114 Suntio, L. R., Shiu, W. Y., Mackay, D., Seiber J. N. and Glotfelty, D., 1988. "Critical Review of Henry's Law Constants for Pesticides." Reviews of Environmental Contamination and Toxicology 108 pp. 1-59.

115 Svobodova, Z., Machova, R.L. and Vykusova, B., 1993. Water Quality and Fish Health.EIFAC technical paper no. 54. Rome: FAO.

116 Swann, L., 1993. "Water Quality Water Sources Used in Aquaculture." Water Quality Fact Sheet AS-486. Aquaculture Extension. Illinois-Indiana Sea Grant Program. Purdue University, West Lafayette, Ind.

117 Tacon, A.G.J.,2002 Thematic Review of Feeds and Feed Management Practices in Shrimp Aquaculture, World Bank/NACA/WWF/FAO Consortium Program on Shrimp Farming and the Environment.

118 Tanavud, Ch., Yongchalermchai, Ch., Bennui, A. and Densrisereekul, O., 2007 "The Expansion of Inland Shrimp Farming and Its Environmental Impacts in Songkla Lake Basin", Kasetsart J. (Nat. Sci.) 35, pp. 326–343; 2001.

119 Tarazona, J.V. and Munoz, M.J., 1995. "Water Quality in Salmonid Culture." Reviews in Fisheries Science 3(2) pp. 109-39.