

Physicochemical and Biological Analysis of Effluents of Fish Processing Industries at Rupsha, Khulna; Potential Source of Hazards to the Coastal Environment



A Thesis

By

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In

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**Physicochemical and Biological Analysis of Effluents of Fish Processing
Industries at Rupsha, Khulna; Potential Source of Hazards to the Coastal
Environment**

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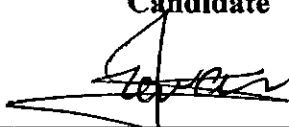
November, 2015

Declaration

Physicochemical and Biological Analysis of Effluents of Fish Processing Industries at Rupsha, Khulna; Potential Source of Hazards to the Coastal Environment

The results submitted in this thesis are entirely of the candidate's own investigations and no part of the results has been accepted for any degree, nor is it being concurrently submitted for any degree.

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Dedicated to

My Beloved Parents

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Abstract

Fish processing plants use huge amount of fresh water for processing purpose. After processing, these huge amounts of water are discharged to the nature. The present study attempts to represent the characteristics of effluent from fish processing industries and probable impacts on coastal habitat and fishery sustainability. Water samples were collected from three different zones adjacent to Rupsha River where waste water is discharged in. Considering distances from the river three zones (Zone 1, zone 2 and Zone 3) were evaluated. Samples were collected from nature, adjacent to the corresponding zones both at low tide and high tide. The periodic physicochemical analysis of effluent to assess the quality of effluent has been carried out in the laboratory. The parameters such as temperature, pH, TDS, TS, TSS, BOD, COD, chlorides, nitrate, bacterial count and plankton count of the water have been studied using international standard protocol. The physicochemical analysis reveals that all the samples are polluted having high chloride (14360 mg/l), BOD (62.37 mg/l) and TS (8000 mg/l) concentration which are higher than the permissible limits. The reading of the parameters of the discharged waste water are very high than the adjacent natural water bodies (BOD 2.67 mg/l, COD 9.34 mg/l). Among three different zones Zone 2 is more causative to pollution. This study concludes that waste water from fish processing industries becomes a threat not only to the aquatic lives but also for human habitat.

Key words: Fish processing industries, waste water, pollution, environment.



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CHAPTER ONE

INTRODUCTION

1. Introduction

Global production of shrimp has been in a steadily increasing trend over the last decade from 3 million tons to 4.2 million tons from 1992 to 2001 and this trend is expected to continue (FAO, 2002). In 2000, more than 60% of total world fisheries production underwent some form of processing (FAO, 2002). The most important part of the fish products destined for direct human consumption was fresh fish (a share of 53.7%), followed by frozen fish (25.7%), canned fish (11.0%) and cured fish (9.6%). Fresh fish increased in volume (live weight equivalent) from an estimated 28 million tons in 1990 to 52 million tons in 2000 with a corresponding increase in the volume of processed fish (frozen, cured and canned) from 43 million tons in 1990 to about 45 million tons in 2000. Freezing represents the main method of processing fish for human consumption, and had a 55% share in 2000. In developed countries, the proportion of fish that is frozen has been constantly increasing, and frozen fish has become the most common form of product, with a share of 40% of fish production. Considerable studies have been done on the characterization of the processed products as well as the different possible modes of utilization of fish (Garcia-Arias *et al.*, 1994; Espe *et al.*, 2001; Stepnowski *et al.*, 2004) and shrimp (Jeong *et al.*, 1991; Shahidi and Synowiecki, 1991; Benjakul and Sophanodora, 1993; Lee and Um, 1995; Chung *et al.*, 1996; Shahidi *et al.*, 1999; Mok and Song, 2000; Mok *et al.*, 2000) processing by-products.

However, the wastewater generated from fish and shrimp processing plants, the waste loads as well as the role of the wastes in environment have not been receiving enough attention since long. Characterization of the shrimp and fish processing wastewater is particularly important not only for the protection of the ecosystem but also for the sustainability of the fishery itself.

Dumping effluents into water bodies, such as rivers or lakes, creates a human health hazard but can also negatively disrupt the river and lake ecosystems. Increased organic matter (from the effluents) breaking down in the river reduces the amount of dissolved oxygen in the water body as the decomposition process uses up the available dissolved oxygen (Davies and Walker, 1986). Fish and other aquatic life need that dissolved oxygen in the water to live. The more biodegradable a waste is, the more rapid is the rate of its oxidation and the corresponding consumption of oxygen. Because of this relationship and its significance to water quality (dissolved oxygen levels in the water), the organic content of waste waters is usually measured in terms of the amount of oxygen consumed during its oxidation, termed the Biochemical Oxygen Demand (BOD).

Effluents heightens the levels of nutrients, increasing the bioavailability of nutrients, which can increase productivity of plankton near the effluents outfall (Munawar *et al.* 1993) and increase the chance of algal blooms.



Contaminants present in the effluents might be toxic for some already existing phytoplankton (Munawar *et al* 1993).

According to Bangladesh Frozen Food Export Association recently there are 145 numbers of onshore fish processing industries all over Bangladesh. Among them there are 34 industries situated at the bank of river Rupsha in Khulna District. Major part of the processed shrimp products come through these industries. Though Bangladesh Environment Association has a close inspection on the surrounding environment of the industries but very few numbers of industries follow their instructions, beside there are many flaws in the inspection system of the Association. These industrial effluents released into water directly after little or no treatments have added to the problem. Wastewaters released from different Fish Processing plants differ in composition because of the varietal management practices. As each fish processing plant has its own characteristics and standards, it is difficult to estimate the amount of waste water use and generate to the surrounding water bodies.

Seafood Processing Plants generate a high volume of effluent which increases as the amount of production increases. As the effluents are not as visible as other industries, people often are not concerned about the deleterious effects of the effluents. Slowly but steadily this negligence may turn into a fatal impact on environment.

Comprising all these it is essential to conduct a research on analysing the characteristics of shrimp and fish processing waste water and have a fine idea on the probable impacts on coastal habitat and fishery sustainability. If the impact can be understood clearly then it will be easier to have an effective way to mitigate the pollution level through adequate waste water management.

1.1. Objectives

- To analyse and discuss the characteristics of shrimp and fish processing wastewater.
- To identify the probable impacts on coastal habitat and fishery sustainability.

CHAPTER TWO

LITERATURE REVIEW

2. Literature Review

Any literature is hardly available regarding the magnitude of regional and global loads of effluents produced by the seafood processing industries and related impacts on ecosystem. Given the absence of any reliable estimate of the global production of seafood processing wastes and the waste characteristics, an attempt was made to analyse the approximate waste loads from the reported values of waste characteristics (e.g., quantities of different parameters per quantity of seafood processed) and the reported quantities of seafood processed.

The main inputs in a processing plant are whole fresh or iced fish and shrimp, water, ice, calcium hypochlorite and other chemicals, packaging materials and electricity plus liquid soap used during cleaning. The outputs are the fresh chilled fillet exported or consumed; swim bladders, removed from fish carcasses and processed separately into valuable product; skins of fishes like sharks and rays are processed into leather; remaining fats, red meat carcasses (with swim bladders removed) and fillets rejected on quality grounds that are either used for human consumption or made into fish meal or silage; wastewater of varying strengths, especially from the filleting and trimming processes, contains fat, oil and grease with blood, small pieces of fish and protein; waste heat from ice manufacture, chilling, and the cold room (to atmosphere). The outputs of the processing industries usually contain a large bulk of waste products. (I. Shahidul *et al*, 2004)

Generally, the head, shell and tail portions of shrimp are removed during processing and these account for approximately 50% of the volume of raw materials. Increasing production of inedible parts of shrimp, such as heads, shells and tails, is causing environmental problems as a result of uncontrolled dumping. The wastewater from seafood processing plants contains large amounts of organic matter, small particles of flesh, breeding, soluble proteins, and carbohydrates. (I. Shahidul *et al*, 2004)

Mauldin and Szabo (1974) reported that as much as 65% of the tuna is wasted in the canning process. The average daily waste flow was over 27,000 l/ton of fish, varying from 500–1550 mg/l of BOD; 1300–3250 mg/l of COD; and 17,000 mg/l of TSS of which 40% was organic. Steven (1981) surveyed the North Carolina seafood industry and stated that unloading, washing and separating ice, sorting grading and re-icing before shipping all constitute handling and sources of contamination from personnel. Results of the survey found that the average values for TSS was 2.4 mg/l, ash 1.11 mg/l, organic solids 1.30 mg/l and BOD 0.23 g/kg while water use was 1.5 l/kg of fish handled.

Shells and appendages may drop off during unloading, contributing large amounts of settle able solids to the waste load. Gills and body fluids and sand were also found to be part of the wastewater. Average BOD of rinse tank waste waters was 251 mg/l. Scales seemed to constitute the bulk of the solids in the effluent from the wash tanks surveyed. Scott *et al*. (1978) and Carawan (1991) reported

effluents loading at all stages of processing raw materials with a very high final bulk of wastes and the average value of waste loads.

Information provided by the Mississippi shrimp industry (Mississippi State University, 1998) indicates that Mississippi shrimp processors processed about 17,255 tons of shrimp in different months in 1998 with a corresponding production of 6277 tons of wet waste through all seasons of a year. On average, the waste bulk constituted 35% of the raw materials.

An even higher volume of waste production was reported by Yorio and Caille (in press) in fish processing industry in Argentina. They reported that the total waste generated in fish processing plants at five coastal cities in Argentina during the last decade (from 1989 to 2001) ranged 37,186–76,880 tons (average 49,786 tons) against total landings ranging 64,114–132,552 tons (average 85,838 tons); on average, waste bulk constituted 58% of the total landings.

Japan has an extensive background in processing fish into various food products. Japanese fish factories have calculated water use at 18–60 l/kg for the various types of plants. If the highest waste load and lowest volume are used for calculations of wastewater strength, the BOD could exceed 7000 mg/l for surimi processing.

However, average values calculated from Japanese fish factories indicated BOD's of 750 mg/l for tuna, 240 mg/l for frozen fish, and 205 mg/l for 'kamaboko' and 3625 mg/l for 'surimi'. Surimi, Kamaboko and fish meal plants would have BODs of 8204; 6776 and 18,400 mg/l respectively. Water use is about 3 l/kg fish or 273 l/kg surimi.

The stickwater comprises wastewater with the average BOD values ranging as high as 56,000–112,000 mg/l, and average solids concentrations, mainly proteinaceous, up to 6%. In most instances, stickwater is now evaporated to produce condensed fish solubles. Volumes have been estimated to be about 550 l/ton of fish processed.

Park *et al.* (2001) reported that in the commercial fishing industries of the Rhode Island, processing of squid and several types of finfish in fish processing facilities creates high levels of BOD in the waste water; typical BOD readings measured in the effluent of one seafood processing facility ranged 1000–5000 mg/l. Changes in processing methodologies coupled with increased landings of underutilized species and the desire to expand production have led to dramatic increases in the volume and strength of waste water discharged by several fish processing companies. The cleaning, separating, and packaging of underutilized species at these companies has resulted in the generation of a complex mix of solid organic material and contaminated wastewater. For example, squid ink is released into the waste stream during processing and is known to contain high concentrations of organic matters, including highly soluble proteins, which contribute significantly to excessive BOD loading (Shirai *et*

al., 1997). Waldon (1991) reported that the untreated effluents from shrimp processing plants cause low dissolved oxygen (DO) concentrations in the Bayou Grand Caillou, Louisiana that violate the water quality standards for DO criterion. The more important concern is that the untreated waste input high amounts of nutrients, such as nitrogen and phosphorus, which contribute to the eutrophication of coastal waters. This increase in primary productivity is one probable cause for the persistent hypoxic zone affecting much of the Gulf of Mexico during the summer months (Rabalais *et al.*, 1994, 1996).

Bagge-Ravn *et al.* (2003) demonstrated that the processing equipment of food industries harbors a microbial ecosystem both during production and after cleaning and disinfection. The micro flora is partly a reflection of the raw material used (fish and shrimp) and partly a reflection of the preservation parameters used in the products (e.g., NaCl and acid). *Pseudomonas spp.* and yeasts were identified after cleaning and disinfection in all of the four production environments investigated. In some of the products, these organisms may negatively influence quality. Yeasts have been identified as spoilage organisms of semi-preserved herring and *pseudomonads* may spoil aerobically stored cold-smoked salmon.

Therefore these organisms must be specifically targeted when developing cleaning and disinfecting procedures for these industries. Karunasagar and Karunasagar (2000) reported the occurrence of food-borne human pathogens such as *Listeria spp.* in fresh fish as well as processed fishery products. Rashid *et al.* (2000) in an investigation to identify the critical control points (CCPs) and the quality of exportable frozen shrimps from Bangladesh reported that the raw material bacterial load increased along the different steps of processing and it varied from 5.88% to 35.46%. They concluded that this increase was due to contamination from ice (703–2500 CFUml⁻¹), water (970–1800 CFUml⁻¹), contact surface of utensils (450–3570 CFUcm⁻²) and worker's hands (330–1985 CFUcm⁻²). The proliferation of shrimp microbial flora due to high temperature (>10°C) and considerable time elapse between two successive steps of processing also added to the increase in bacterial load. The bacterial load of 41.6% samples was below 106 CFUg⁻¹ while it was far below 106 CFUg⁻¹ in all the control samples. Zuberi *et al.* (1993) reported average (geometric) total aerobic plate count 2.4×10^6 CFUg⁻¹; MPN [most probable number] coliforms 94 g⁻¹; and MPN fecal coliforms 41 g⁻¹ in frozen shrimp. They also recorded pathogenic bacteria such as *Salmonella* in their samples. Cann *et al.* (1981) reported *V. parahaemolyticus* in processed shrimp being as high as 0.4×10^4 CFUg⁻¹ in Malaysian shrimp industry and suggested that Malaysian shrimp industry should launch control measures to meet the quality for processed shrimp.

CHAPTER THREE

MATERIALS & METHODS

3. Materials and Methods

3.1 Study area

Three zones were selected for the current study. The site was chosen according to various distance of discharging place from the industry facilities. The area was Zone 1, Zone 2 and Zone 3. Industries from Zone 1 directly discharge water into Rupsha River. There were ten industries in this Zone. Zone 2 has sixteen industries that discharge their effluents into Gop canal not more than 2 km away from the river. The Zone 3 has total eight industries that discharge water in Narankhali canal more than 2 km away from the river.

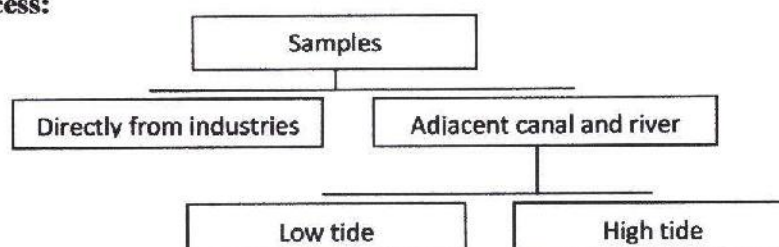
Five samples were taken out of ten from Zone 1. From Zone 2 total eight samples were taken out of sixteen and from Zone 3 total four samples were taken out of eight. All the samples were taken randomly.

Samples were taken from Rupsha River, Gop canal and from Narankhali canal both at the time of low tide and high tide. These two canals are directly linked with Rupsha River. All the samples were collected within June to August, 2015.

Table 1: Sampling design

Zones	Range	Total industries	Sampling industries	Sampling from adjacent nature
1	Discharge wastes directly to Rupsha river	10	5	Rupsha river (Low tide & High tide)
2	Discharge wastes to the adjacent canal which is <2km but >1km away from the river.	16	8	Gop canal (Low tide & High tide)
3	Discharge wastes into adjacent canal which is >2km away from the river.	8	4	Narankhali canal (Low tide & High tide)

Sampling process:



3.2 Parameter Analysis:

Eleven parameters were investigated from the collected samples. Samples collected from the selected area at seven days interval. Samples were taken at every high and low tide. Following parameters were analysed for the current study.

Physical parameters:

1. Temperature
2. pH
3. Total solids
4. Total Dissolved Solids
5. Total Suspended Solids

Chemical parameters:

1. Chloride
2. Chemical Oxygen Demand
3. Biological Oxygen Demand
4. Nitrate

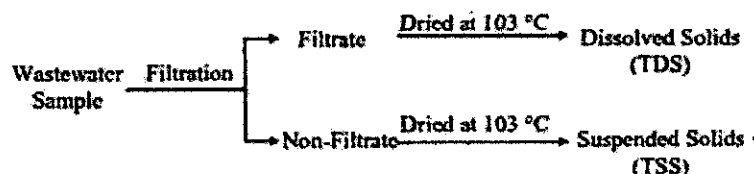
Biological parameters:

1. Bacterial load
2. Plankton load

3.2.1 Physical parameters:

1. **Temperature:** Temperature of the sample was measured instantly after collection by a glass thermo meter.
2. **pH:** pH was measured after collection by pH meter.
3. **Total Suspended Solids** 4. **Total Dissolved Solids** and 5. **Total solids**

All these three parameters were measured according to AOAC. The details have been shown in following flow chart.



3.2.2 Chemical parameters:

1. **Chloride:** Chloride was measured by titration method according AOAC (1976)

Calibration was done before every test.

Reagent:

- Acetic acid, Conc.
- Potassium Iodide, KI
- Sodium thiosulphate
- Starch indicator
- Distilled or Deionized water.

Procedure:

- Measuring out 200 ml of the water sample
- Add 5ml Acetic acid
- Add 1 gm of Potassium iodide and mix the solution
- Titrate the contains quickly against Sodium thiosalphate until the colour turns straw yellow.
- Add 2ml of starch to the conical flask. The colour turns blue
- Continue the titration until the sample turns colourless.
- Calculate the residual chlorine from titre value.

Procedure:

- Direct waste water was taken into a 500 ml beaker.
- For filtration fine filter paper of less than 2 micro meter pore size was used.
- Filtrate and Non-filtrate was collected.
- Filtrate and Non filtrate then dried at 103°C temperature in an oven.
- Dried filtrate then collected and weighted in an electric weight balance which is Total Dissolved Solids (TDS)
- Dried Non-filtrate then collected and weighted in an electrical weight balance which is Total Suspended Solids (TSS)
- The summation of TSS and TDS is known as Total Solids (TS).

2. Measurement of Biochemical Oxygen Demand (BOD)

BOD measurement was done according to AOAC (1976)

Reagent:

- **Manganous Sulphate ($\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$):** Dissolve 480g Manganous Sulphate tetra hydrate in distilled water and dilute to 1000ml.
- **Alkaline-iodide ($\text{NaOH} + \text{KI}$):** Dissolve 500g sodium hydroxide and 150g potassium iodide in distilled water and dilute to 1000 ml.
- **Sulfuric Acid:** H_2SO_4 (conc.)
- **Starch Indicator:** Prepare a paste of 0.5 g starch powder in deionized water. Add this paste into 100ml boiling water. Allow to boil for few minutes. Cool and then use.
- **Standard Sodium Thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$, 0.025 N)**

Procedure:

- Keep one bottle for determination of initial DO and incubate the samples at 20°C for five days.
- For determination of DO initially in the bottle (BOD bottle of 300 ml capacity) have to give 2 ml MnSO_4 + 2 ml Alkali-iodide + wait few minutes + 2 ml H_2SO_4 (conc.)
- 10 ml sample + 2 drop Starch $\rightarrow$ deep blue colour + add $\text{Na}_2\text{S}_2\text{O}_3 \rightarrow$ Water colour
- After five days determine the DO from the bottle which were kept in the incubator.
- Find out the difference between initial DO and after five days.

Calculation:

BOD= Initial DO - After five days DO

$$\text{DO} = \frac{y \times 200}{x} \text{ mg/l}$$

3. Measurement of Chemical Oxygen Demand (COD)

Method: Closed reflux method (AOAC, 1976)

Reagent:

- $\text{K}_2\text{Cr}_2\text{O}_7$: 12.259 in 1000 ml
- H_2SO_4 : 5.5g AgSO_4 in 543 ml
- **Ferron Indicator:** Dissolve 1.48g Phenanthroline monohydrate and 695 mg Ferrous Sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) and dilute to 100 ml with double distilled water.
- **Standard Ferrous Ammonium Sulphate:** 98g $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$, 20 ml H_2SO_4 (conc.) dilute to 1000 ml
- **Mercuric Sulphate (HgSO_4):** analytical grade

Procedure:

- 50 ml sample in flask, then 1g HgSO_4 and glass beads, add 5 ml H_2SO_4 reagent, then 25 ml $\text{K}_2\text{Cr}_2\text{O}_7$ reagent and setting with condenser + 70 ml H_2SO_4 reagent burvelt head over, then Heat 3-4 hours.
- After that 10 ml sample + 10 ml distilled water + 2-3 drop Feron indicator + add FAS from buratte, blue green to reddish brown

Calculation:

$$\text{COD} = \frac{(A-B) \times M \times 8000}{\text{ml sample}} \text{ mg/l}$$

Here, M = molarity of FAS

A = ml FAS used for distille water

B = ml FAS used for sample water.

4. Measurement of Nitrate-Nitrogen ($\text{NO}_3\text{-N}$) (DO mg/l)

Method: Nesslerization method (AOAC 1976)**Reagent:**

- Zinc Sulphate: 10g in 100 ml
- EDTA: 5g EDTA + 6 ml water + 1g NaOH = total volume 10 ml
- Nessler's Reagent: 5g HgI_2 + 3.5g KI + 8g NaOH in 25 ml + water = total 50 ml
- NH_4Cl (Standard ammonia solution): .7852g in 250ml (1000ppm)

Procedure:

- Prepare standard ammonium solution, 1000ppm, 100ppm, 10ppm, 1ppm, .1ppm, .3ppm, 0.03ppm, 0.05ppm, 0.07ppm ($S_1V_1=S_2V_2$)
- 50 ml standard sample in 0.5 ml ZnSO_4 and mixture, adjust the pH of the sample to 10.5 using 6N(.5ml) NaOH, wait few minutes, add 0.05ml EDTA, add 2ml Nessler's Reagent and mix well and wait few minutes.
- Measure absorbance at 420nm using 1cm cell with a reagent blank
- 50 ml sample in .5 ml ZnSO_4 and mixture, adjust the pH of the sample to 10.5 using 6N(.5ml) NaOH, wait few minutes, add 0.05ml EDTA, add 2ml Nessler's Reagent and mix well and wait few minutes.
- Measure absorbance at 420nm using 1cm cell with a reagent blank
- Concentration of $\text{NH}_3\text{-N}$ of samples can directly be derived from the calibration graph.

3.2.3 Biological parameters:**1. Microbial analysis****Total Plate Count**

Microbiological analysis was done according to the Bacteriological Analytical Manual of United States Food and Drug Administration (USFDA). Total Plate Count (TPC) or Standard Plate Count (SPC) was included in that research.

Laboratory Requirements**Materials**

- Autoclave machine
- Centrifuge machine, Electric balance
- Petri dish
- Solution mixer
- Bacteria isolating loops
- Refrigerator
- Bio-safety cabinet
- Micro-pipette, Tips and tips box

Reagents

- Peptone water
- Nutrient agar
- Distilled water

Laboratory work

Sterilization of equipments

Test tubes, Petri dishes, conical flask, plastic tips and other glassware were sterilized by autoclaving at a temperature of 121°C and a pressure of 15 pound per square inch for about 1 to 2 hours.

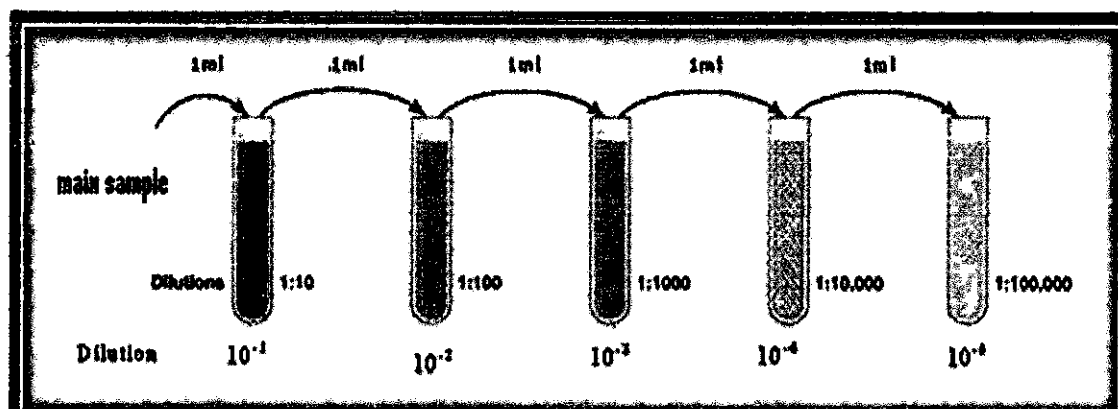
Media preparation

Media is being prepared by compounding require individual ingredients or, more conveniently, by adding water to a dehydrated product which contained all the ingredients. Practically, all media were available commercially in powdered form.

- Definite amounts of Plate Counting Agar (2.5 gm) were being accurately weighted
- These would take in separate volumetric flask (500ml) containing distilled water (half of the required volume)
- Then the final volume (500ml) being adjusted by pouring additional distilled water.
- Then the volumetric flasks keep in autoclave for sterilization. Autoclave has to be done at a temperature of 121°C for about 1 to 2 hours.
- After autoclave, the agar media was kept in the bio-safety cabinet/waterbath for 20-30 minutes for cooling and then transferred in required number of petridishes by 25ml volume for preparing plates.

Sample Preparation & Dilution (Water Samples)

1 ml of sample water was taken especially from the each sample and was transferred to cotton plugged bottle containing 9 ml distilled water. The sample was mixed properly by shaking the bottle carefully. Then the total amount became 10 ml. This made 1st decimal dilution (0.1). In this way five dilution tubes with the dilution strength, 10^{-1} through 10^{-5} were made (fig: 1).



Before filling the S-R cell with sample, the cover glasses were diagonally placed across the cell and then samples were transferred with a large bore pipette so that no air bubbles in the cell covers were formed. The S-R cell was let stunned for at least 15 minutes to settle plankton. Then plankton on the bottom of the S-R cell was enumerated by electronic microscope. By moving the mechanical stage, the entire bottom of the slide area was examined carefully. To achieve a random sampling, each time 3 fields were examined for each sample and an average of the counts had been recorded. The organisms thus counted, were expressed as cells per litter of the sample. From each sample 30 cells counts in 3 slides have been made to achieve random counts and an average of the counts has been recorded. Number of plankton in the S-R cell was derived from the following formula,

$$\text{Nos/ml} = \frac{C \times 1000 \text{ mm}^3}{L \times D \times W \times S}$$

Where, C = number of organism counted (in 100 cell out of 1000 cell)

L = length of each strip (S-R cell length) in mm

D = depth of a strip (whipple grid image width) in mm

W = width in mm

S = number of strips counted.

The number of cells per mm was multiplied by a correction factor to adjust the number of organisms per litre (APHA, 1976).

CHAPTER FOUR

RESULTS



4. Results and discussions

4.1. Chemical parameters:

Biological oxygen demand (BOD)

It measures the amount of oxygen requires by microbes for breaking down to simpler substances of the decomposable organic matter present in any water, wastewater or treated effluent. It is also taken as a measure of the concentration of organic matter present in any water. The greater the decomposable matter present, the greater the oxygen demand and the greater the BOD values (Ademoroti, 1996). The present study effluent shows BOD value as 52 mg/l in Zone 1, 62.37 mg/l in Zone 2 and 59 mg/l in Zone 3. Trivedi *et al.* (1986) observed the effluents of textile industry in the range from 320 mg/l to 720 mg/l. Low value of BOD is due to lesser quantity of total solids, suspended solids in water as well as to the quantitative number of microbial population (Avasan & Rao, 2001).

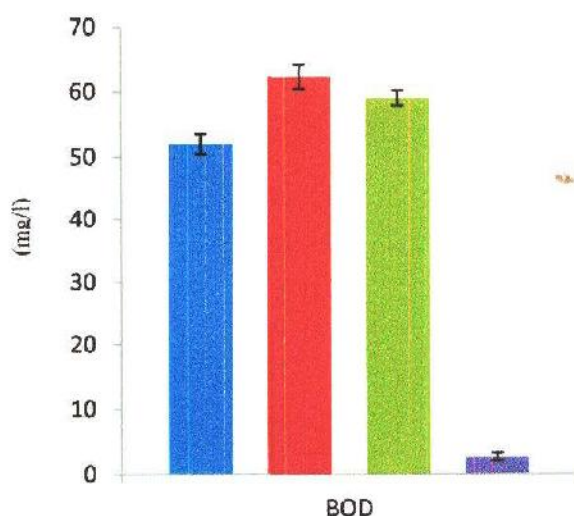


Figure 2: Inter zone biological oxygen demand during high tide.

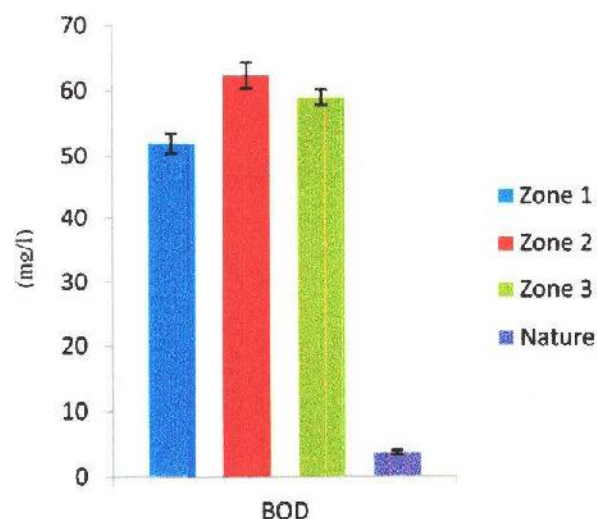


Figure 3: Inter zone biological oxygen demand during low tide.

During both in the high tide and low tide natural water source compiles significantly less ($P < 0.05$) amount of BOD than the waste water. Intra zone analysis showed zone 2 and zone 3 have significant differences of BOD amount. Zone 2 has the highest amount of BOD in waste water (85 mg/l). Excessive presence of organic matter in waste water is the presumed cause of high BOD value.

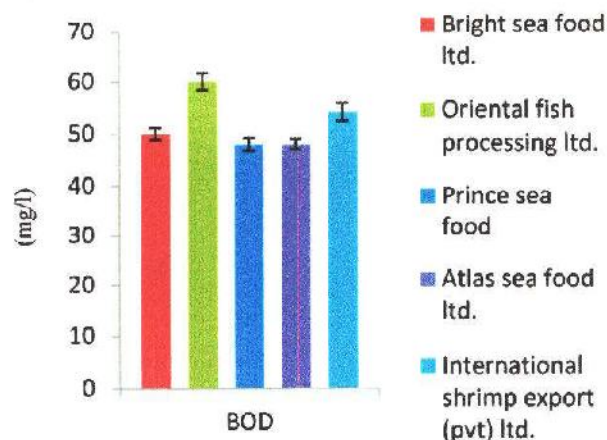


Figure 4: Intra zone biological oxygen demand, zone 1

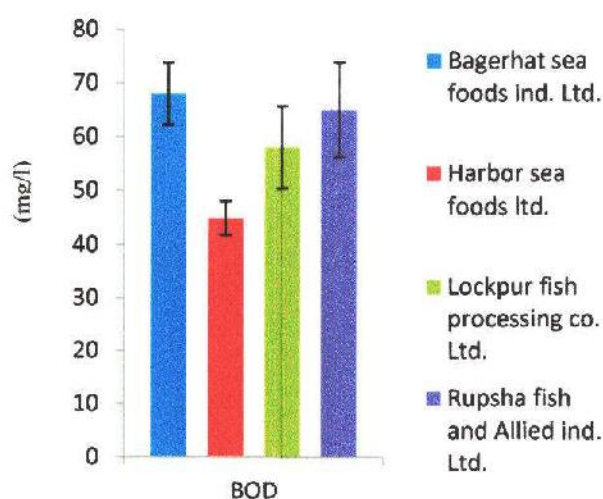


Figure 5: Intra zone biological oxygen demand, zone 3

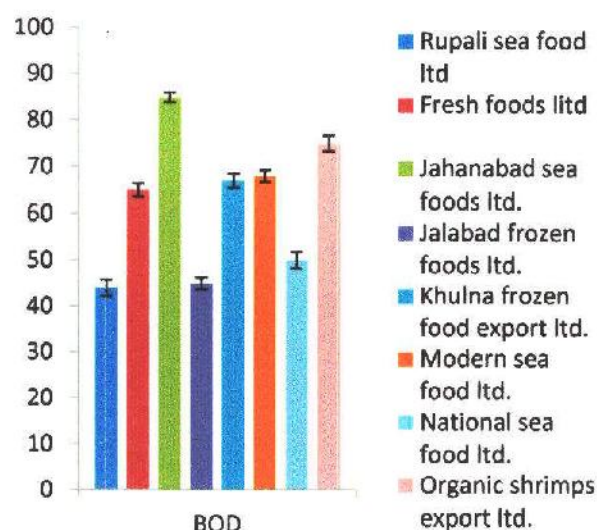


Figure 6: Intra zone biological oxygen demand, zone 2

Chlorides:

Fish processing industries use salt for preservation of food products; hence the content of chloride increased in discharged water. Beside, most of the industries use 200-700 ppm chlorine solutions to disinfect the waste water. Sometimes this range does not maintained strictly. The maximum value of chloride was recorded at Zone 1 (14360 mg/L) and minimum at Zone 2 (12125 mg/L). Kolhe and Pawar (2011) observed chloride of untreated effluent in dairy industry as 630 mg/L. Effluent from sugar mill showed 205 mg/L chloride content (Kolhe *et al.*, 2008). Excessive chlorinated water discharging is a major threat to aquatic environment.

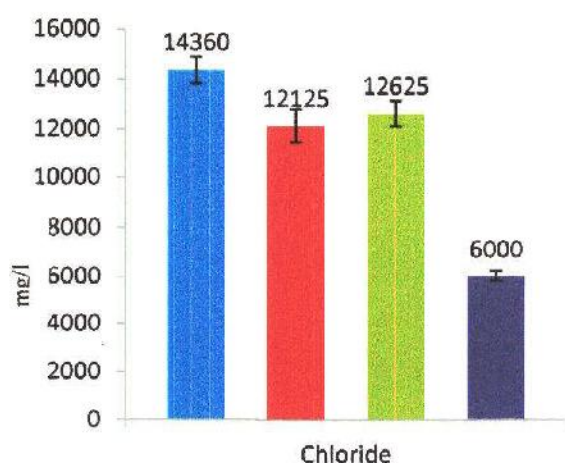


Figure 7: Inter zone amount of chloride during low tide.

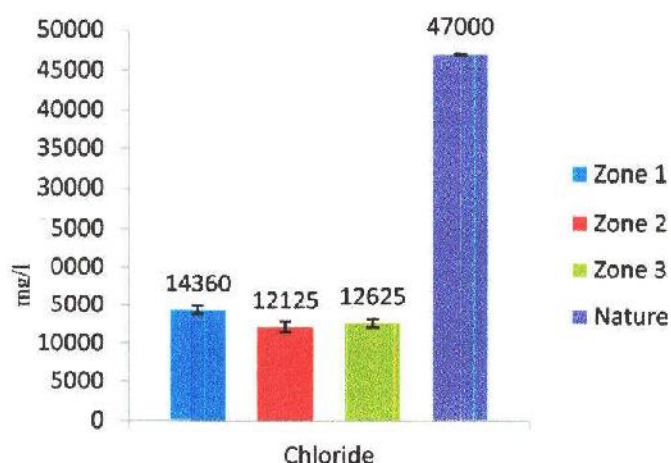


Figure 8: Inter zone amount of chloride during high tide.

Recommended chloride content in water for aquaculture fish and aquatic life is 0.01 mg/l. Fish can tolerate 0.37 mg/l. For surface irrigation 4-10 mg/l (Slight to moderate), >10 mg/l (Severe) is recommended (EPA, 1976). Zone 2 has a significant ($P < 0.05$) variation of chloride amount among the industries. Industries do not maintain the optimum use of chloride as disinfectants. This leads to a hazardous state of pollution.

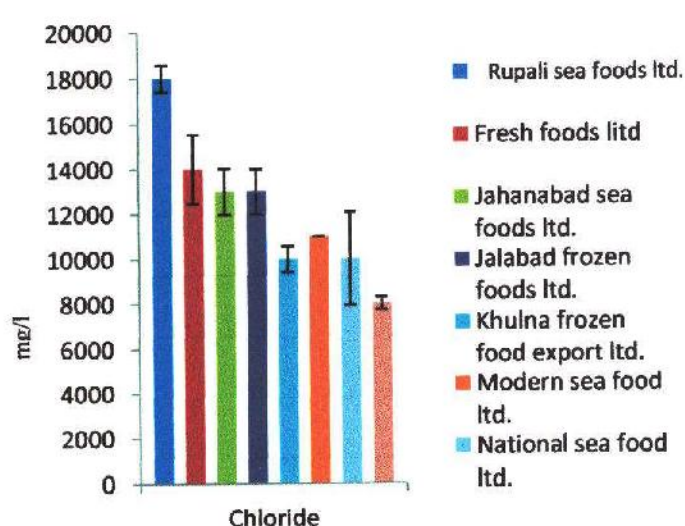


Figure 9: Intra zone amount of chloride, zone 2

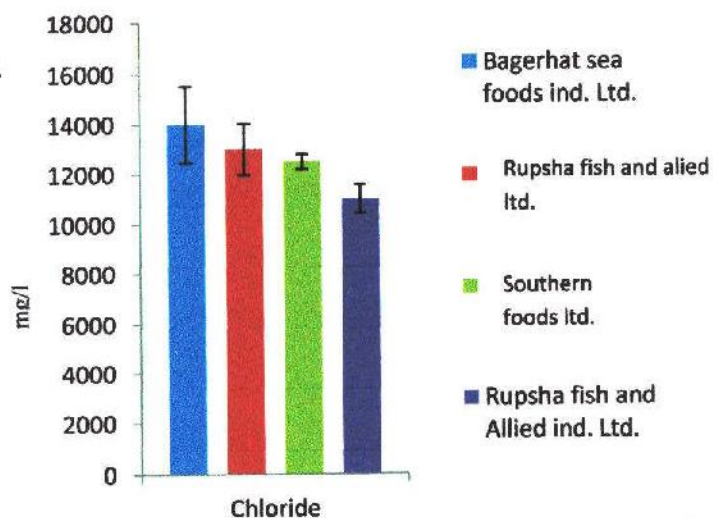


Figure 10: Intra zone amount of chloride, zone 3

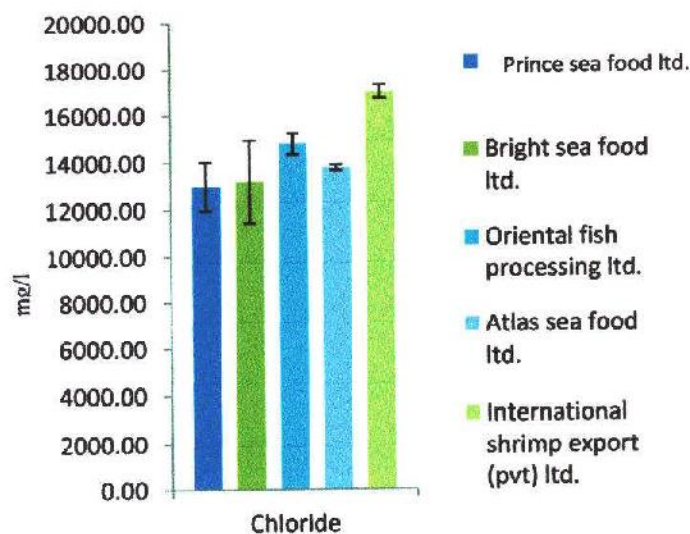


Figure 11: Intra zone amount of chloride, zone 1

Chemical Oxygen demand (COD)

It is the amount of oxygen required by organic matter for its oxidation by strong COD substance in water. The COD is a test which is used to measure pollution of domestic and industrial waste. The waste is measured in terms of equality of oxygen required for oxidation of organic matter to produce CO_2 and water. In present study the average value of COD was 13.6 mg/l in Zone 1, 16.82 mg/l in Zone 2 and 16.12 mg/l in Zone 3. The amount of COD in three zones significantly varies ($P < 0.05$) than adjacent natural water source. Kolhe *et al.* (2008) found value of COD 1230 mg/l in industrial effluent.

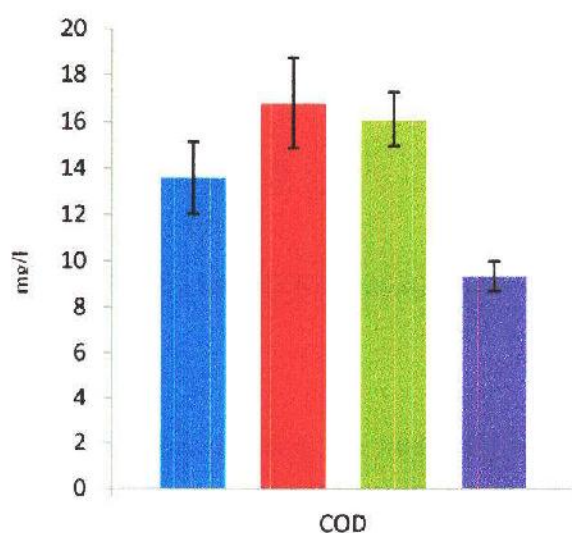


Figure 12: Inter zone COD amount during high tide.

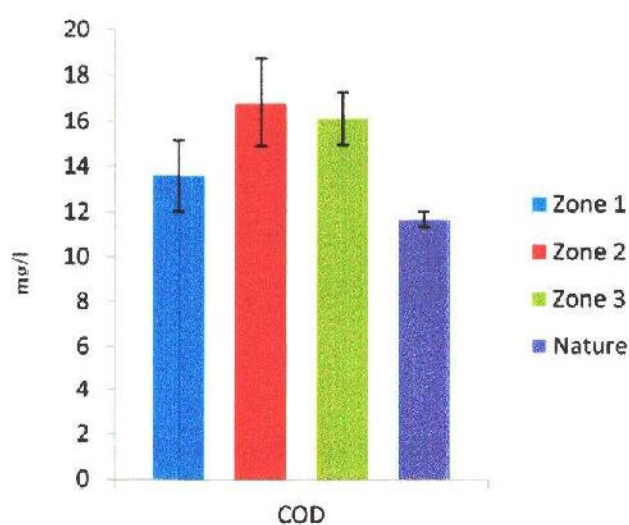


Figure 13: Inter zone COD amount during low tide.

This high value of COD in fish processing industries indicates that the waste water is highly hazardous for nature as it reduces the oxygen level in water thus making a threat for aquatic livings.

Intra zone analysis showed that zone 2 has significant ($P < 0.05$) variation in COD amount. This zone also has high amount of COD in waste water.

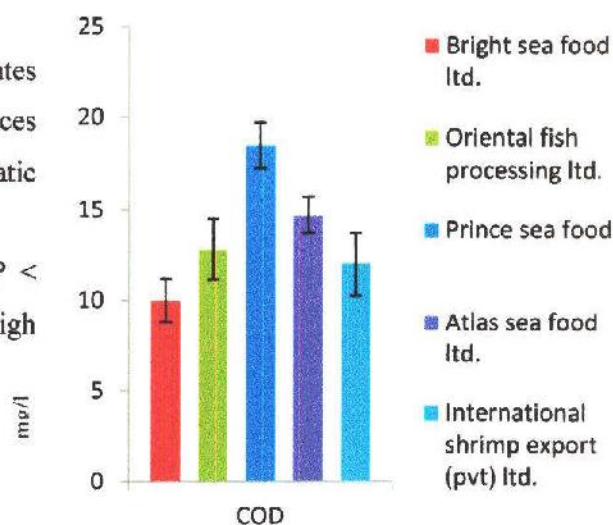


Figure 14: Intra zone COD amount, zone 1

Intra zone analysis showed that Zone 2 has significant variances ($P < 0.05$) in nitrate presence. Zone 2 has higher amount of nitrate in water than any other zones ranging from 130-166 mg/l.

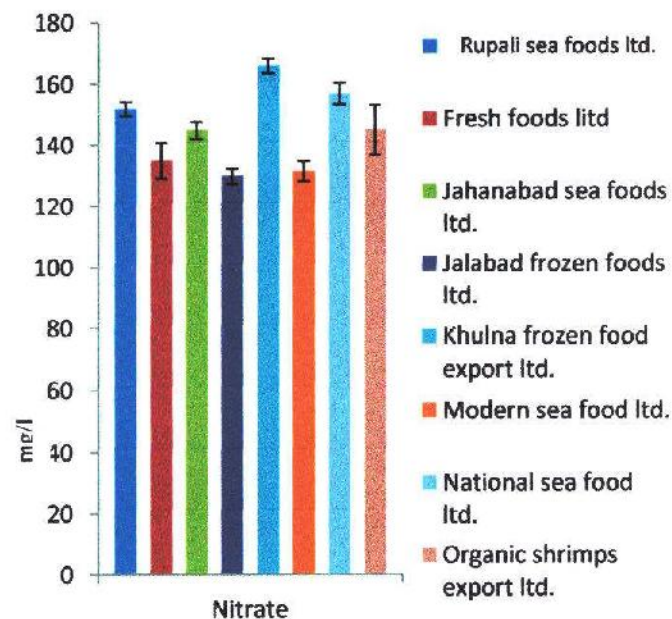


Figure 19: Intra zone nitrate presence, zone2

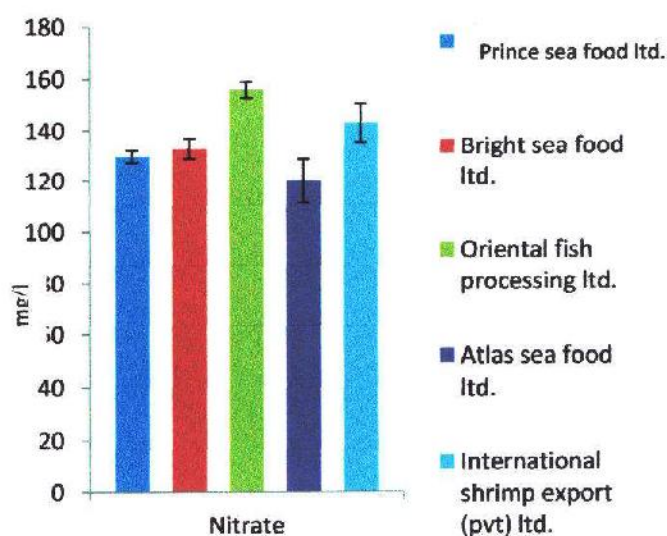


Figure 20: Intra zone nitrate presence, zone 1

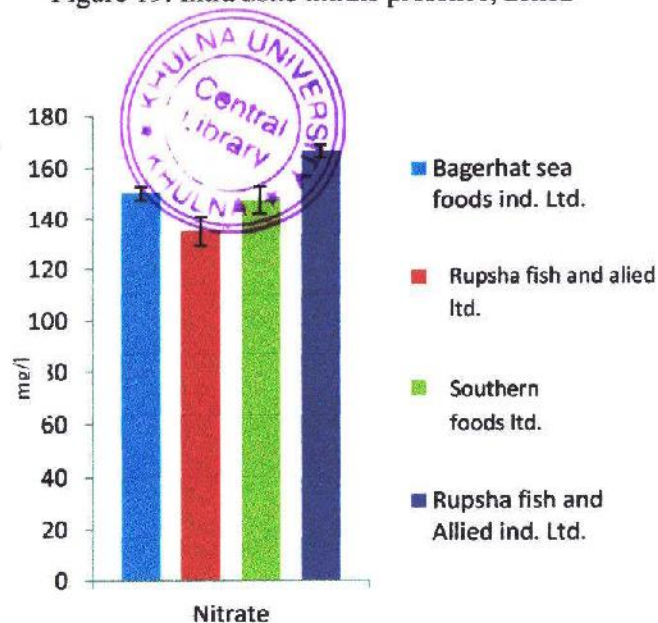


Figure 21: Intra zone nitrate presence, zone 3

4.2. Biological parameters:

Bacteria load:

Bacteria load is an essential indicator for determining the percentage of water pollution. Higher the presence of bacteria in water higher the water is polluted. But in three experimented zone it

was observed that load of bacteria is very low. It is because of chlorination. Zone 1 showed 4.9×10^1 cfu/ml which was the lowest and 6.0×10^1 cfu/ml in Zone 3 was the highest reading. Adjacent natural sources have higher count of bacteria. In general high levels of free CO_2 might be the reason for low pH values obtained in the water samples, which may consequently affect the bacterial counts.

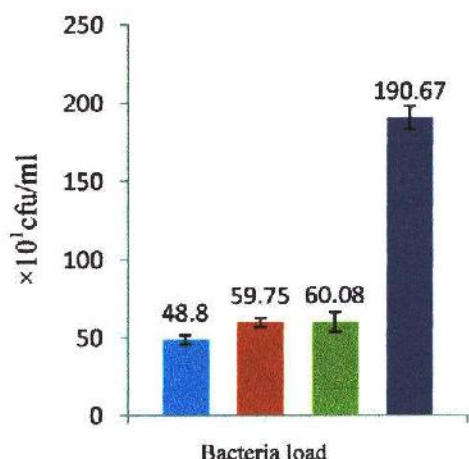


Figure 22: Inter zone bacteria load during low tide.

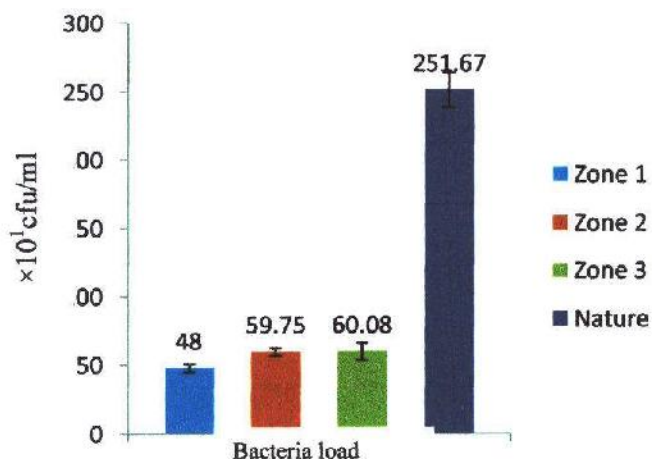


Figure 23: Inter zone bacteria load during high tide.

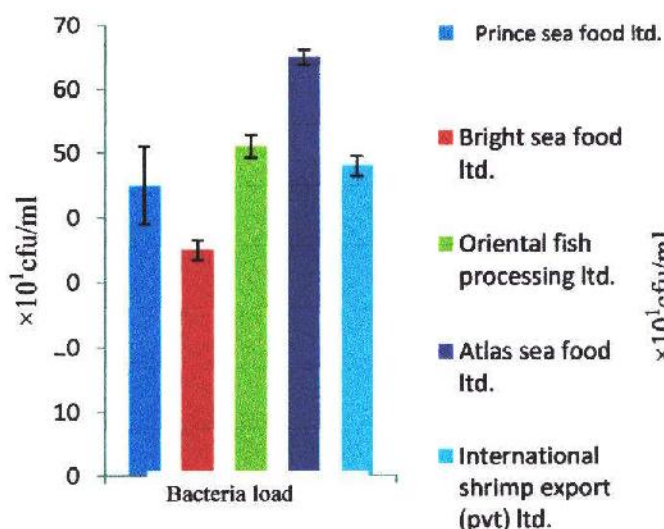


Figure 24: Intra zone bacteria load, zone 1

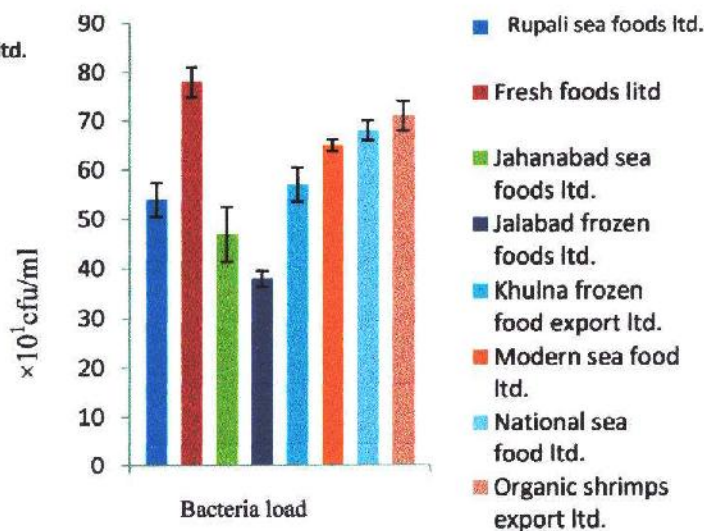


Figure 25: Intra zone bacteria load, zone 2

Bacteria count among industries in Zone 2 showed significant variation ($P < 0.05$) while zone 1 and zone 2 have less variation.

The acceptable limit of standard plate count of clean water is 10 cfu/ml. (ICMSF, 1988). None of the zones including nature do not obtain acceptable limit. Moreover, dumping water with low bacterial load may hamper the food web of nature.

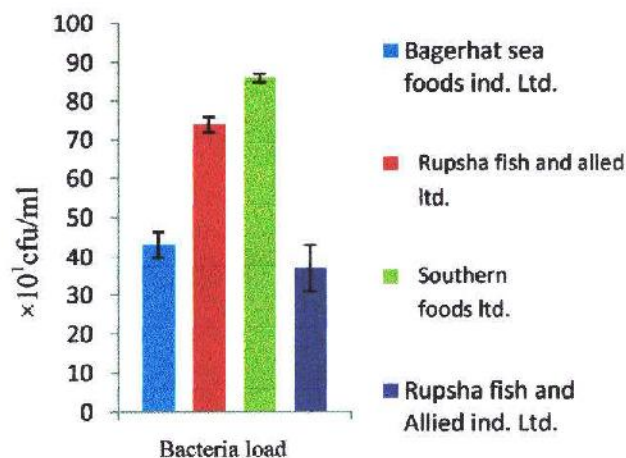


Figure 26: Intra zone bacteria load, zone 3

Plankton load:

Water disposed by fish processing plants has less load of plankton. In Zone 1 it was 64.2 nos/ml, Zone 2 was 58.25 nos/ml and Zone 3 showed 65 nos/ml. Plankton load was higher ($P < 0.05$) in nature during both at low tide and high tide. This low load in waste water may be caused by the excessive use of chlorine for purification. Intra zone analysis showed that zone 2 and zone 3 have diverse range of load. Plankton load is higher in zone 3 (65.00 nos/ml) among the three zones. P. Arunava *et al* in their 2008 study found 304400 nos/ml in Gulshan Lake, Dhaka and 251200 nos/ml in Bawniabad Dighi (Bangladesh). Comparing with their study present investigation sites showed less plankton load. Though nutrition level is very high in the waste water but huge amount of chlorine and TS might be the cause of less plankton load in waste water.

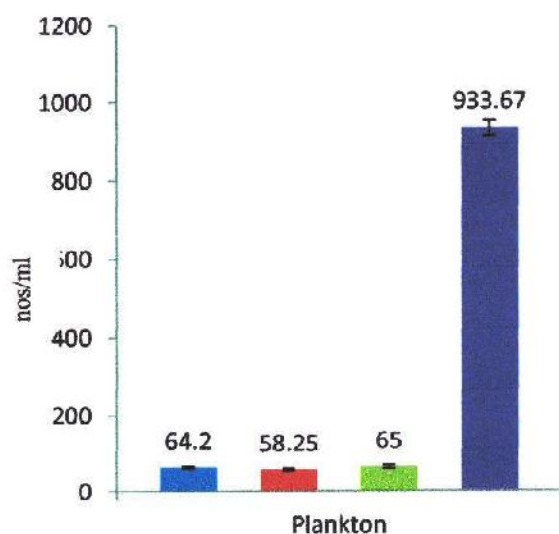


Figure 27: Inter zone plankton load during low tide.

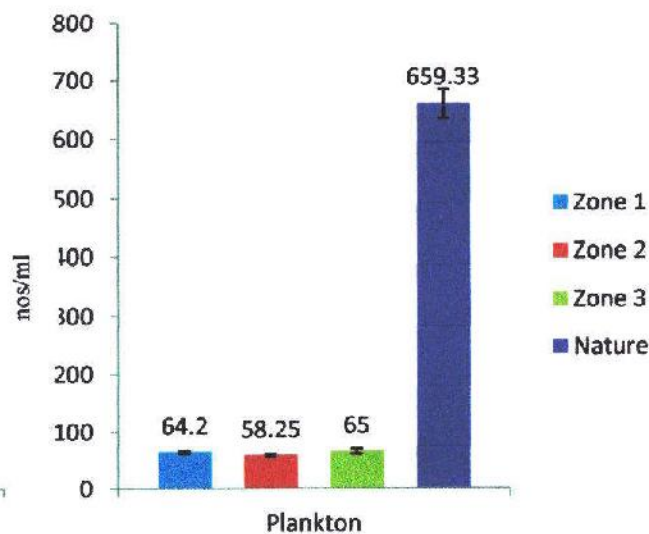


Figure 28: Inter zone plankton load during high tide.

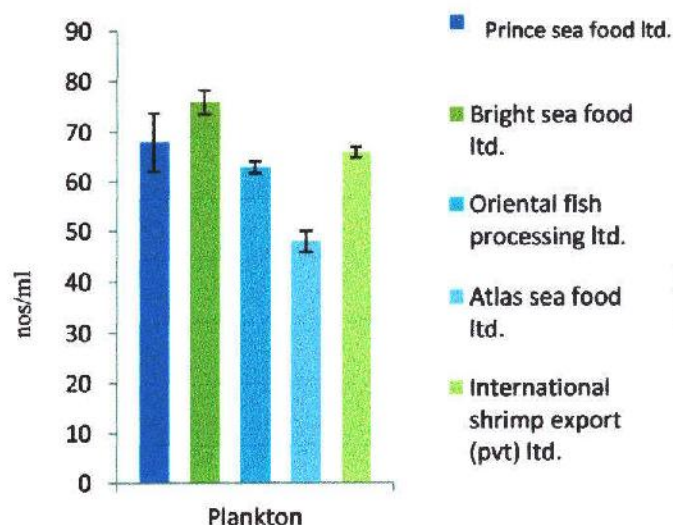


Figure 29: Intra zone plankton load, zone 1

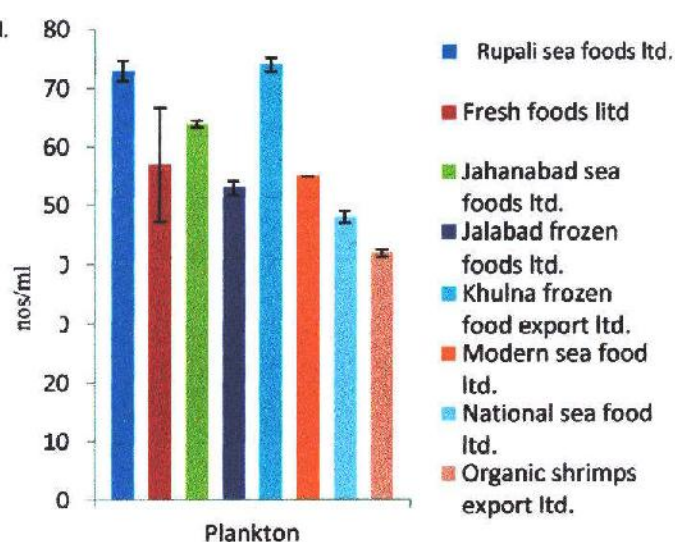


Figure 30: Intra zone plankton load, zone 2

Data analysis among industries within a single zone showed that plankton load in zone 3 significantly varies ($P < 0.05$). Zone 1 has less variation in plankton load.

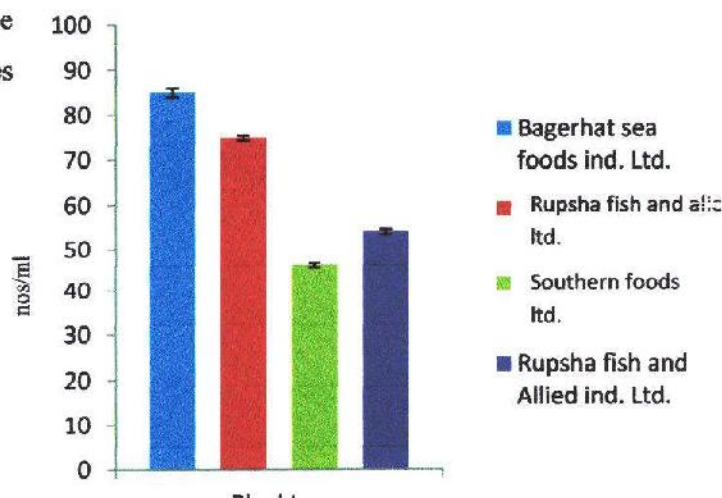


Figure 31: Intra zone plankton load, zone 3

4.3. Physical parameters:

Temperature:

Temperature is basically important for its effect on chemical reactions, reaction rate, aquatic life and the suitability of water for beneficial uses. In Zone 1 the average temperature was 31°C while temperature of Rupsha River water 31°C and 30°C at low and high tide respectively that showed significantly ($P < 0.05$) higher than that of nature. In Zone 2 the average temperature was 30.1°C while temperature of Gop canal at low tide was 31°C and high tide was 29°C. In Zone 3 the average temperature was 30.5°C while temperature of Narankhali canal water at low tide was 31°C and high tide was 30°C. The results indicate that some reactions could be speeded up, due to higher temperature, by the discharge of this wastewater

into stream. It will also reduce solubility of oxygen and amplify odor due to anaerobic reaction (Akan *et al.*, 2008).

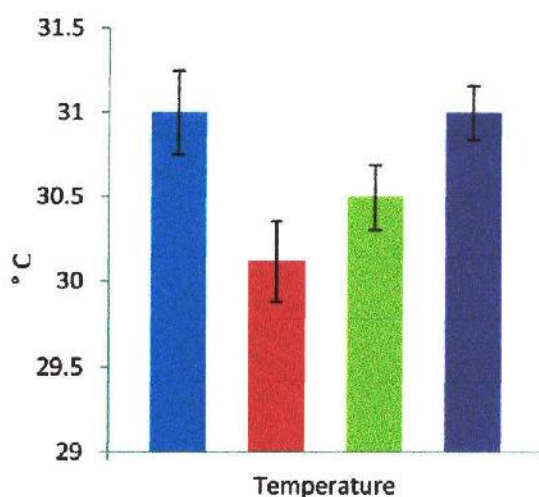


Figure 32: Inter zone temperature during low tide.

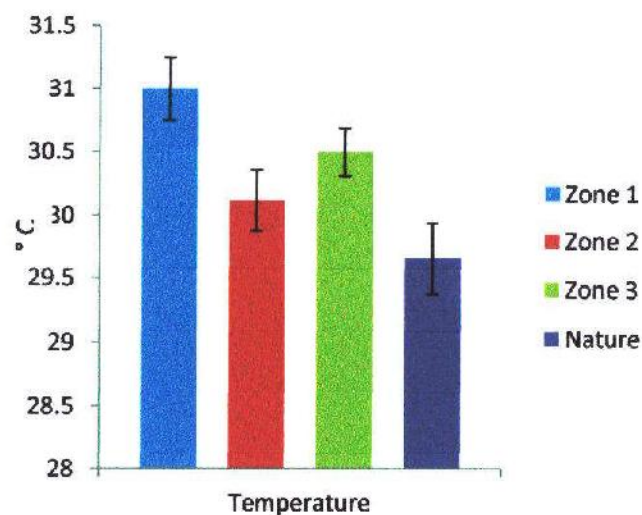


Figure 33: Inter zone temperature during high tide.

Zone 2 showed slight variation ($P < 0.05$) in temperature. Other zones have no variation. Inter zone analysis also showed no significant differences ($P > 0.05$) between the zones and the natural water bodies.

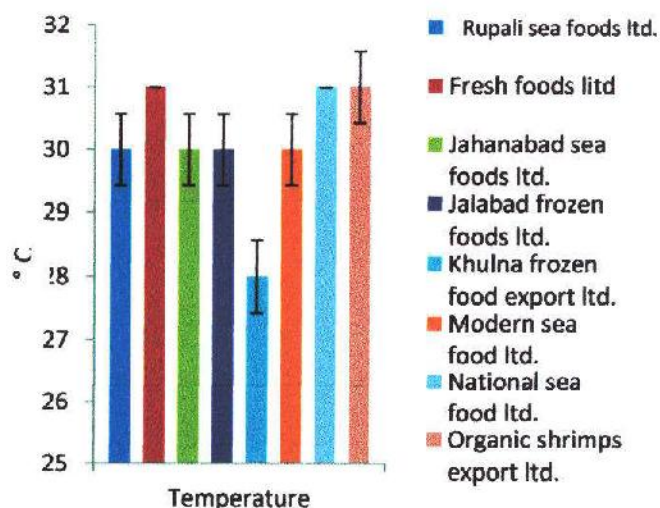


Figure 34: Intra zone temperature amount, zone 2

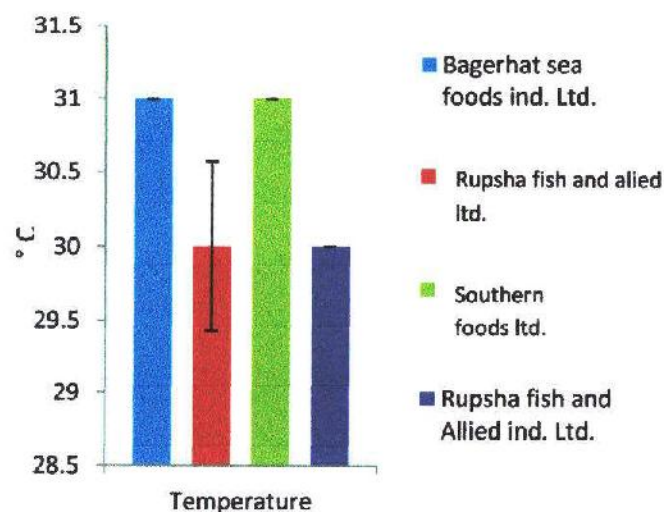


Figure 35: Intra zone temperature amount, zone 3

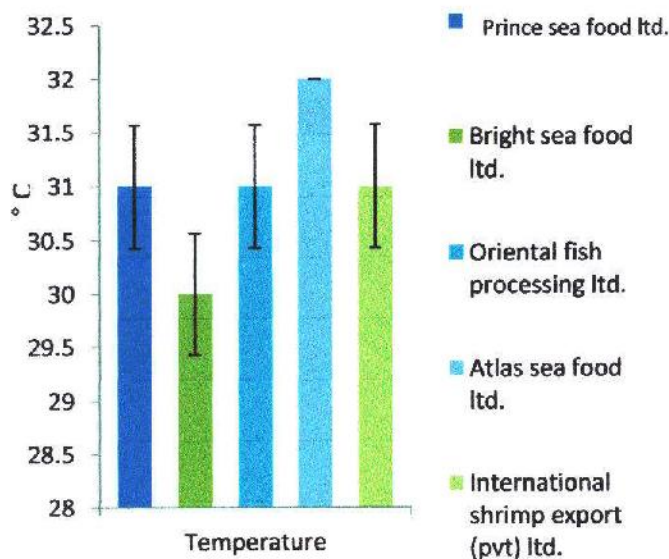


Figure 36: Intra zone temperature amount, zone 1

pH

pH is the measurement of intensity of acidity and/ alkalinity and measures the concentration of hydrogen ion in water. The pH determination is important objective in treatment of waste. Variation in pH values of effluent can affect the rate of biological reactions and survival of various organisms. Higher pH values (7.2) were recorded at Zone 1. Gop canal during low tide indicates highest pH value. It might be due to excessive use of pesticide to the adjacent cultivation land and homestead waste disposal. However, these values are in permissible limit. Thorat & Wagh (1999) observed the pH of the effluent sample as 8.4 in tannery industries. Rao *et al.* (1993) observed the pH of the textile industry effluent varied from 11.0 to 8.0. Kolhe *et al.* (2008) recorded the pH of Sugar industry untreated effluent as 6.5. High or low pH values in water have been reported to affect aquatic life and alter toxicity of other pollutant in one form or the other (DWAF, 1992).

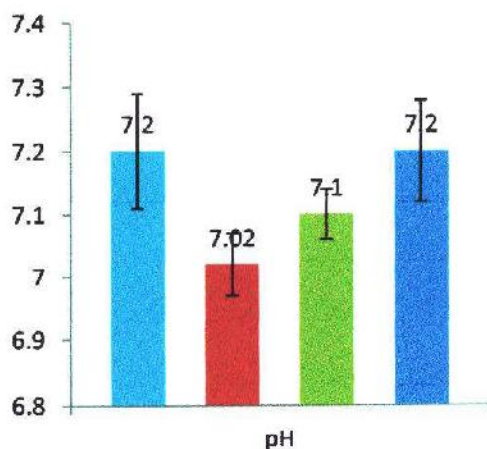


Figure 37: Inter zone pH during low tide.

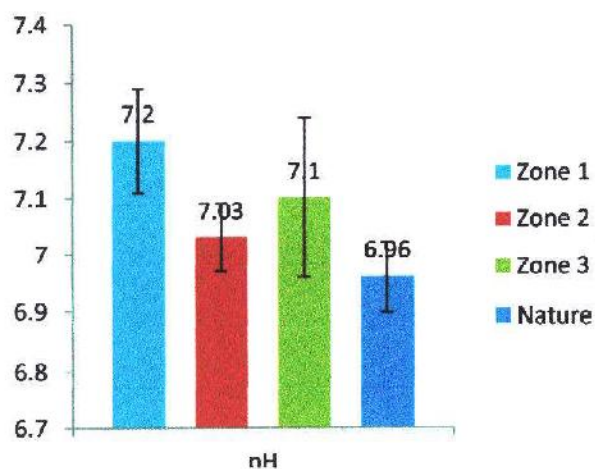


Figure 38: Inter zone pH during high tide.

Zone 2 showed significant variation ($P < 0.05$) among the industries in regard of pH value other than any other zones.

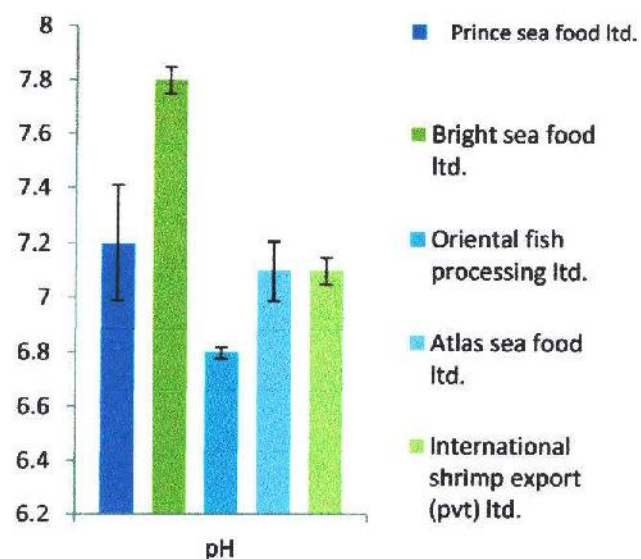


Figure 39: Intra zone pH amount, zone 3

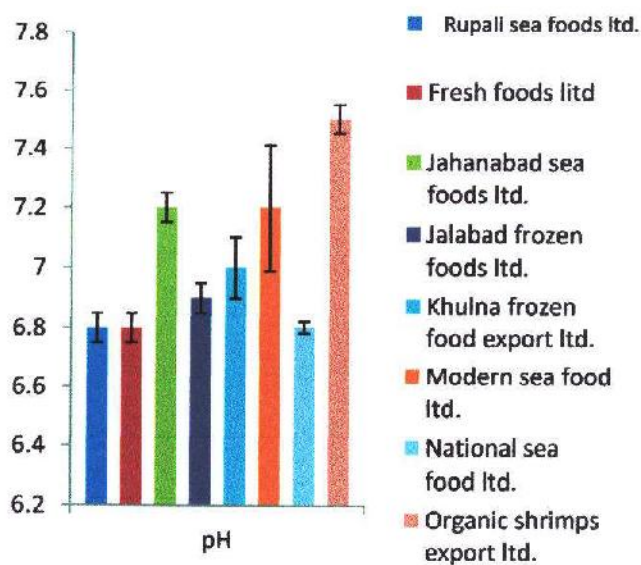


Figure 40: Intra zone pH amount, zone 2

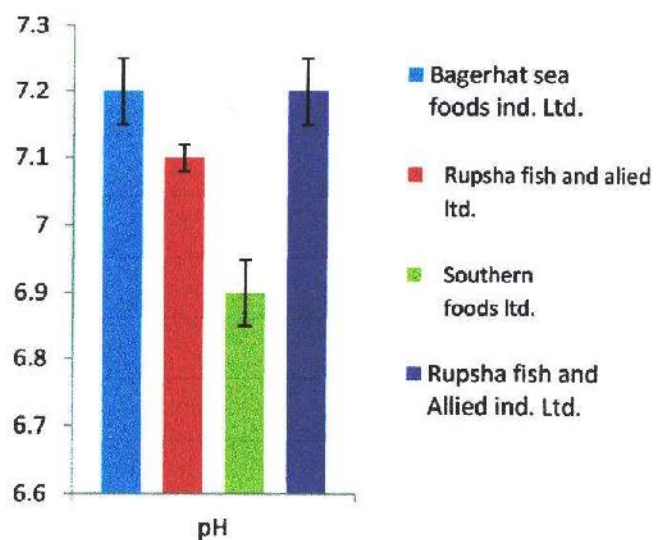


Figure 41: Intra zone pH amount, zone 1

Total dissolved solids (TDS)

The solid contained in the filtrate that passes through a filter with a normal pore size of 2 micrometer or less are classified as dissolved solids. Waste water contains high amount of dissolved solids. The size of colloidal particles in waste water is typically in the range from 0.01 to 1.0 micrometer. The average value of TDS in Zone 1 was 7208 mg/l in Zone 2 was 6931.25 mg/l and in Zone 3 was 6342.5 mg/l which is beyond the permissible values. This high value of TDS blocks sun rays and hamper the growth of phytoplankton. It may also cause lack of oxygen in water. Hosetti *et al.* (1994) reported that total dissolved solids in range 488 ppm in the waste water. Rao, *et al.*, (1993) studied textile industrial effluent and recorded total dissolved solid value ranges from 8500 mg/L to 10,000 mg/L.

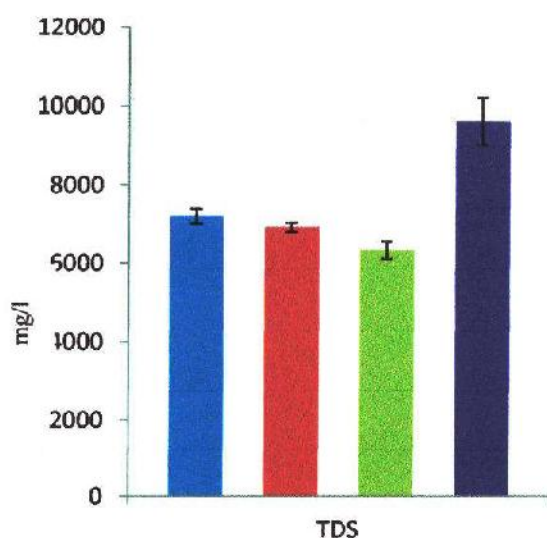


Figure 42: Inter zone TDS during low tide.

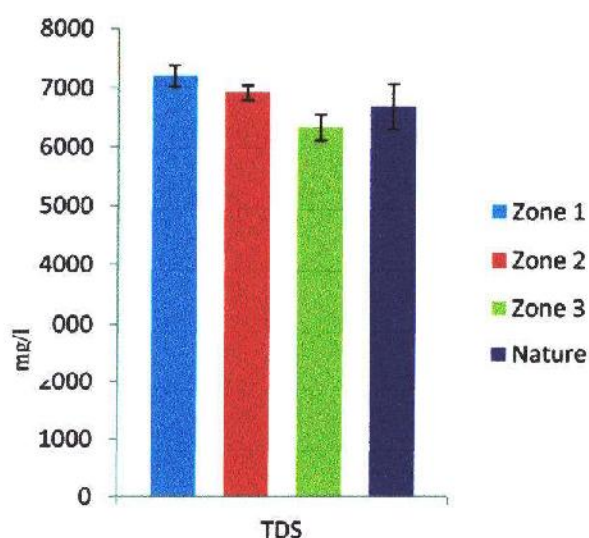


Figure 43: Inter zone TDS during high tide.

Analysis showed that zone 2 has significant variation among the industries in terms of TDS. Minimum value was found 6.2000E3 mg/l while maximum value was 7.8000E3 mg/l.

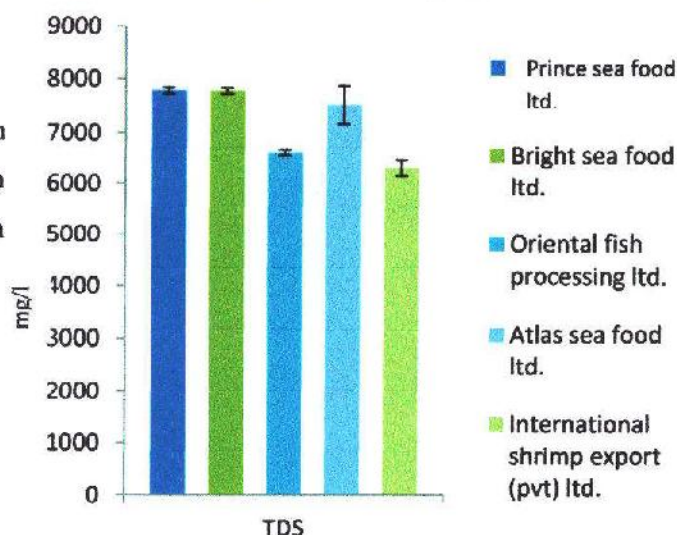


Figure 44: Intra zone TDS amount, zone 1



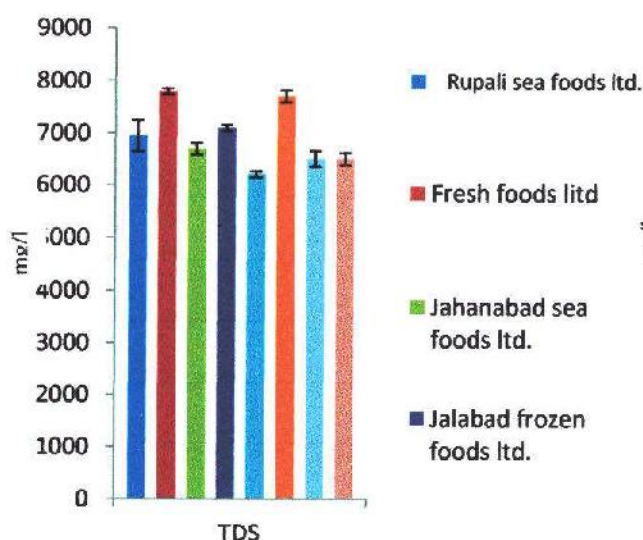


Figure 45: Intra zone TDS amount, zone 2

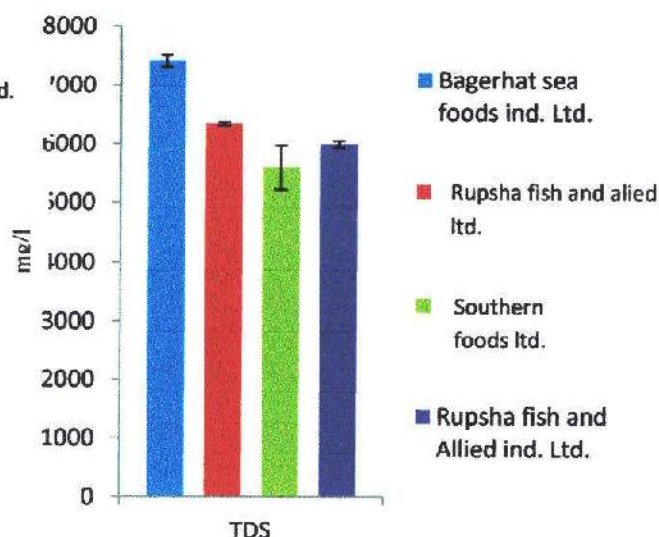


Figure 46: Intra zone TDS amount, zone 3

Total suspended solids (TSS)

Total suspended solids play an important role in waste water treatment. TSS test results are done routinely to assess the performance of conventional treatment processes and need for effluent filtration in reuse application. TSS is the samples under suspension and remains in water sample. In present study, the average value was 744.6 mg/L in Zone 1, 755.37 mg/L in Zone 2 and 760 mg/L in Zone 3. Avsan & Rao (2001) observed the TSS in sugar mill effluents as 220 to 790 mg/L. Significant variation ($P < 0.05$) can be seen between all the three zones and the adjacent natural water bodies. But during low tide the difference is higher.

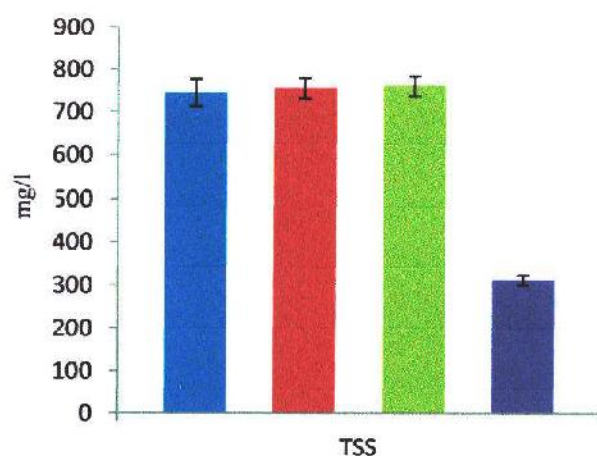


Figure 47: Inter zone TSS during low tide.

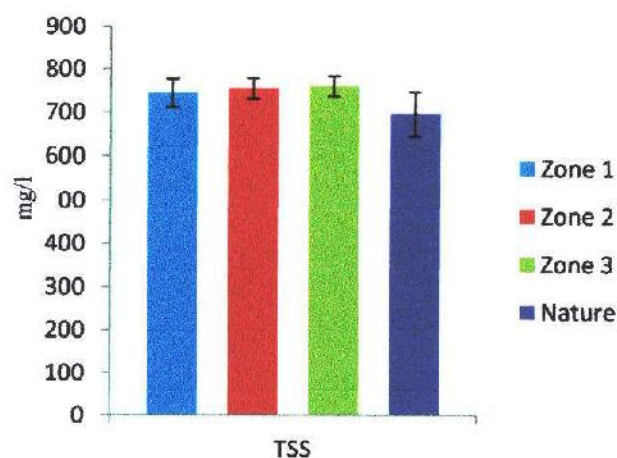


Figure 48: Inter zone TSS during high tide.

Intra zone data analysis showed that zone 2 has a high variation of the amount of TSS ranging from 543.33 mg/l to 950 mg/l. Zone 1 and zone 3 has less amount of TSS in its waste water in contrast to zone 2.

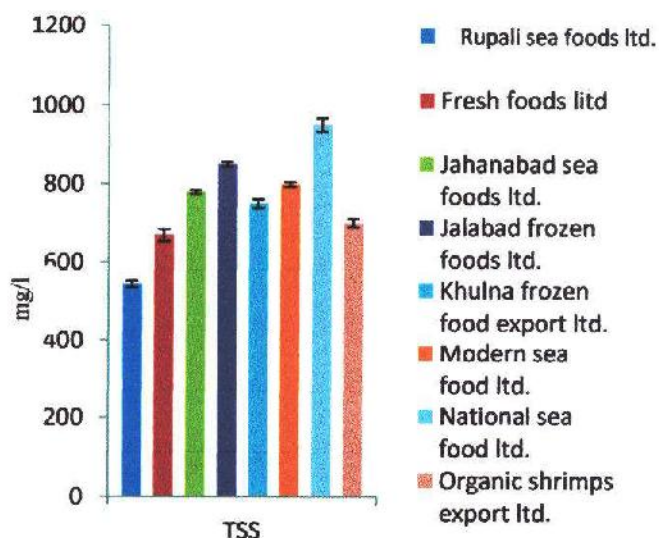


Figure 49: Intra zone TSS amount, zone 2

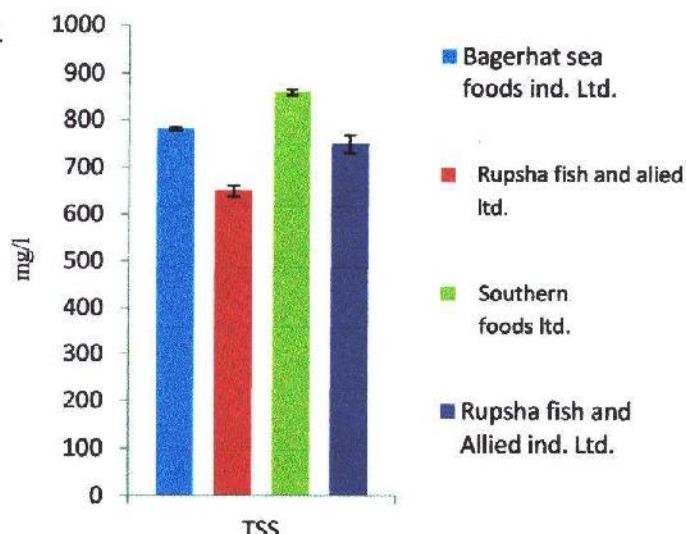


Figure 50: Intra zone TSS amount, zone 3

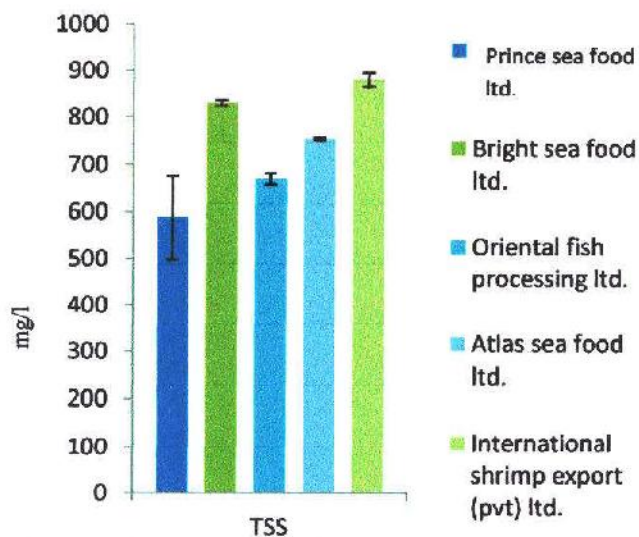


Figure 51: Intra zone TSS amount, zone 1

Total solids (TS)

Waste water contains variety of solid materials. After evaporation of unfiltered samples total solids were determined. The value ranges from 7980 mg/l in Zone 1 to 7125 mg/l in Zone 3. TS is higher in nature during low tide than the waste water but it is lower during high tide. Kolhe and Pawar (2011) found total solid 1310 mg/l in effluent in dairy industry. Higher TS in nature at low tide might be because of the other industries' disposal in the water.

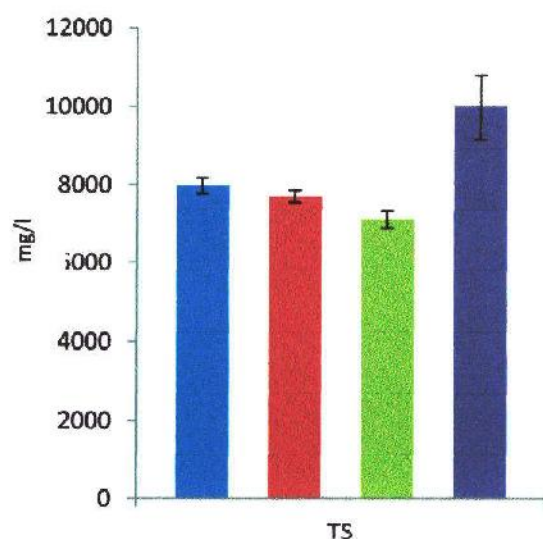


Figure 52: Inter zone TS during low tide.

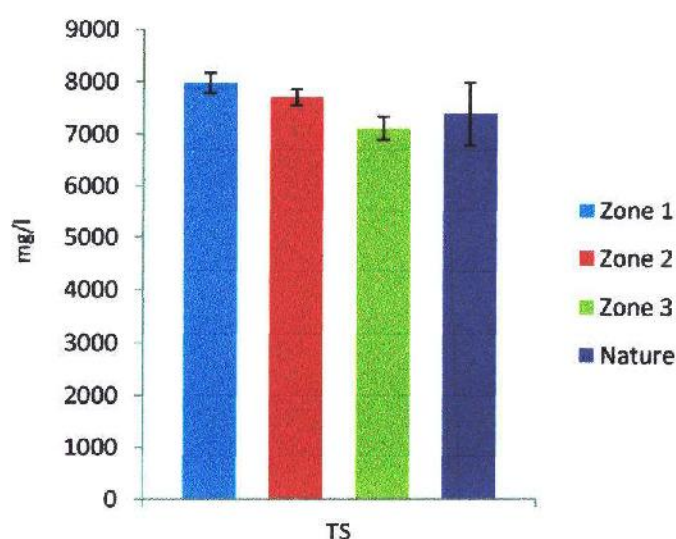


Figure 53: Inter zone TS during high tide.

Intra zone data analysis showed that zone 1 slightly has variation in total solids in waste water. Zone 2 and zone 3 have no variation.

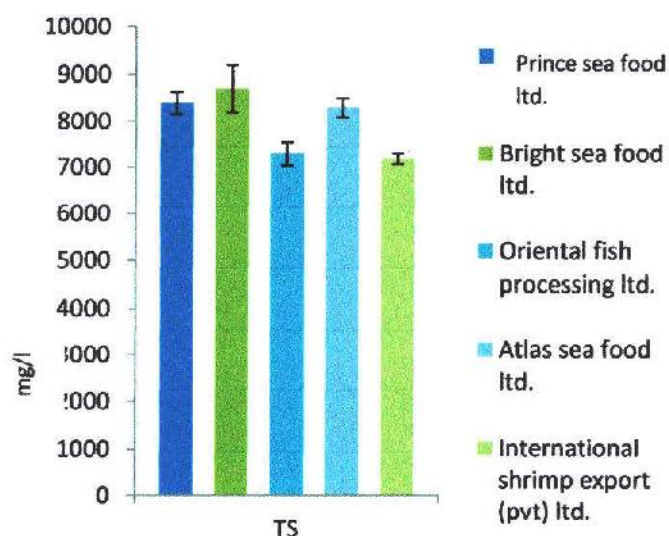


Figure 54: Intra zone TS amount, zone 1

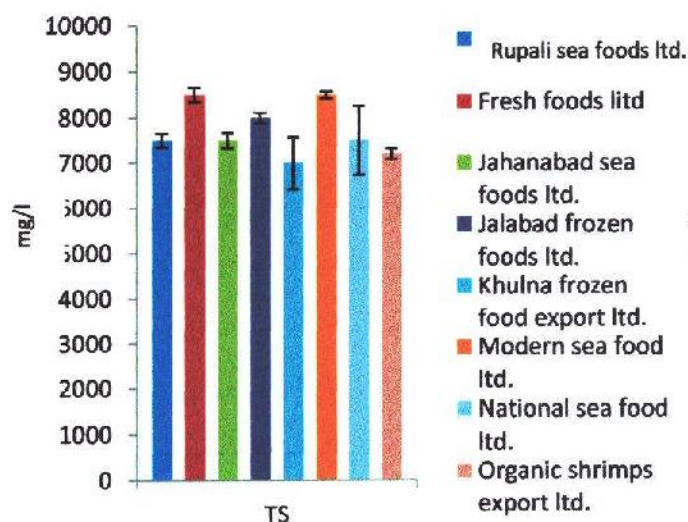


Figure 55: Intra zone TS amount, zone 2

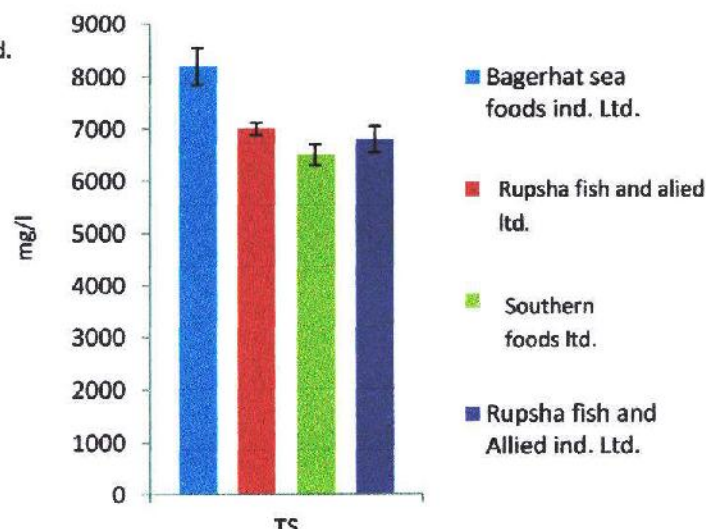


Figure 56: Intra zone TS amount, zone 3

Processing wastes are primarily organic in nature and therefore subject to bacterial decay. As a result, the oxygen concentration in the water is reduced with an increase in BOD. This can starve aquatic life of the oxygen it needs. Anaerobic decomposition of organic matters leads to the breakdown of proteins and other nitrogenous compounds. These chemical reactions release hydrogen sulphide, ammonia and methane which are potentially hazardous to the ecosystem and toxic to marine organisms in low concentrations. Nutrients resulting from decaying organic matter enhance plant growth and excessive plant growth together with oxygen depletion can lead to alterations in ecosystem structure and these are both features of eutrophication. (I. Shaidul *et al*, 2004.)

While comparing each other Zone 1 was found more polluted than other zones. Wastewater discharge from sewage and industries are major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem (Morrison *et al*, 2001; DWAF and WRC, 1995). The waste discharged from fish processing industries is degradable waste, though it is hazardous to microorganism in the nearby natural water sources. The extent of pollution was high as expressed by physicochemical properties. Analysis of industrial effluent discharge showed that the various parameters are beyond the permissible limit. These values are generally due to the decomposition of the proteinaceous matter and emission of ammonia compounds. The chloride content of industry is very high. This high chlorine concentrated water greatly affects surrounding water bodies. Debris and other solid organic objects should be removed since they usually float and affect the oxygen transfer to the water and also objectionable from an aesthetic point of view.

CHAPTER FIVE

CONCLUSION & RECOMMENDATION

Conclusion

Waste water from fish processing industries does not have any visual impacts on environment. For this reason environment degradation caused by the waste water from fish processing industries are far from conscious attention. Waste management is the pre requisite to set up an industry though this part is greatly neglected in our country. Present study reveals the unnoticed effects of the effluents from fish processing industries to the surrounding environment which are:

1. The discharge from the fish processing industries has a great effect on physicochemical parameters of the open water system such as
 - a. It increases chloride level much higher than the permitted level.
 - b. Nitrate level of the discharged area becomes higher, total solids, both suspended and dissolved, increases at the same area.
 - c. COD of the surrounding water body increases and BOD increase very high than permitted level.
2. Effluents of fish processing industries have great effects on growth and survival of aquatic microorganisms—plankton and bacteria.

Recommendation:

Further study need to be done in the minutes level of physicochemical parameter and its wide impact on environment. Cost effective water treatment facility should be developed. Awareness among the industrialists and local people should be created regarding to waste management and impact of untreated waste disposal on environment.

CHAPTER SIX

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Appendix

Table 2: Inter zone data analysis during high tide.

Treatment	Zone 1	Zone 2	Zone 3	Nature
Temperature	31±0.25 ^b	30.12±0.24 ^{bc}	30.5±0.19 ^{bc}	29.66±0.28 ^c
pH	7.2±0.09 ^c	7.03±0.06 ^c	7.1±0.14 ^c	6.96±0.06 ^c
Chloride	14360±527.23 ^b	12125±682.92 ^b	12625±528.59 ^b	47000±83.33 ^c
TS	7980±197.16 ^c	7712±152.52 ^c	7125±220.92 ^c	7400±597.21 ^c
TDS	7208±182.77 ^b	6931±120.30 ^{bc}	6342±220.79 ^c	6700±385.14 ^{bc}
TSS	744.6±32.15 _c	755.42±24.07 ^c	760.42±23.22 ^c	696.67±50.16 _c
COD	1360±81.56 ^b	1682.5±51.92 ^a	1612.5±61.16 ^{ab}	9.34±46.63 ^c
BOD	520±18.64 ^b	623.75±29.60 ^b	590±27.92 ^b	2.67±6.45 ^c
Nitrate	136.4±3.92 ^b	145.21±2.79 ^b	149.92±3.86 ^b	76.33±4.81 ^c
Bacteria	48.8±2.83 ^c	59.75±2.75 ^c	60.08±6.37 ^c	190.67±7.36 ^b
Plankton	64.2±2.70 ^c	58.25±2.46 ^c	65±4.73 ^c	659.33±24.15 ^b

Appendix

Table 2: Inter zone data analysis during high tide.

Treatment	Zone 1	Zone 2	Zone 3	Nature
Temperature	31 ± 0.25^b	30.12 ± 0.24^{bc}	30.5 ± 0.19^{bc}	29.66 ± 0.28^c
pH	7.2 ± 0.09^c	7.03 ± 0.06^c	7.1 ± 0.14^c	6.96 ± 0.06^c
Chloride	14360 ± 527.23^b	12125 ± 682.92^b	12625 ± 528.59^b	47000 ± 83.33^c
TS	7980 ± 197.16^c	7712 ± 152.52^c	7125 ± 220.92^c	7400 ± 597.21^c
TDS	7208 ± 182.77^b	6931 ± 120.30^{bc}	6342 ± 220.79^c	6700 ± 385.14^{bc}
TSS	$744.6 \pm 32.15_c$	755.42 ± 24.07^c	760.42 ± 23.22^c	$696.67 \pm 50.16_c$
COD	1360 ± 81.56^b	1682.5 ± 51.92^a	1612.5 ± 61.16^{ab}	626.67 ± 46.63^c
BOD	520 ± 18.64^b	623.75 ± 29.60^b	590 ± 27.92^b	233.33 ± 6.45^c
Nitrate	136.4 ± 3.92^b	145.21 ± 2.79^b	149.92 ± 3.86^b	76.33 ± 4.81^c
Bacteria	48.8 ± 2.83^c	59.75 ± 2.75^c	60.08 ± 6.37^c	190.67 ± 7.36^b
Plankton	64.2 ± 2.70^c	58.25 ± 2.46^c	65 ± 4.73^c	659.33 ± 24.15^b

KV.66-Acc, No-23 988
 04.10.16

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Temp	zone 1	15	31.0000	1.00000	.25820	30.4462	31.5538	29.00	32.00
	zone 2	24	30.1250	1.19100	.24311	29.6221	30.6279	27.00	32.00
	zone 3	12	30.5000	.67420	.19462	30.0716	30.9284	29.00	31.00
	Nature in low tide	9	29.6667	.86603	.28868	29.0010	30.3324	28.00	31.00
	Total	60	30.3500	1.08651	.14027	30.0693	30.6307	27.00	32.00
pH	zone 1	15	7.2000	.38024	.09818	6.9894	7.4106	6.75	7.90
	zone 2	24	7.0250	.28047	.05725	6.9066	7.1434	6.70	7.60
	zone 3	12	7.1000	.14924	.04308	7.0052	7.1948	6.80	7.30
	Nature in low tide	9	6.9667	.19526	.06509	6.8166	7.1168	6.75	7.30
	Total	60	7.0750	.28496	.03679	7.0014	7.1486	6.70	7.90
Chloride	zone 1	15	1.4360E4	2041.98783	5.2723E2	13229.1848	15490.8152	10400.00	17500.00
	zone 2	24	1.2125E4	3345.63310	6.8292E2	10712.2630	13537.7370	6000.00	19000.00
	zone 3	12	1.2625E4	1831.10746	5.2859E2	11461.5698	13788.4302	10000.00	17000.00
	Nature in low tide	9	4.7000E3	250.00000	83.33333	4507.8330	4892.1670	4300.00	5100.00
	Total	60	1.1670E4	3937.83473	5.0837E2	10652.7494	12687.2506	4300.00	19000.00
TS	zone 1	15	7.9800E3	763.62856	1.9716E2	7557.1166	8402.8834	6800.00	9300.00
	zone 2	24	7.7125E3	747.19912	1.5252E2	7396.9855	8028.0145	6000.00	8800.00
	zone 3	12	7.1250E3	765.29852	2.2092E2	6638.7525	7611.2475	6100.00	8600.00
	Nature in low tide	9	7.4000E3	1791.64729	5.9721E2	6022.8180	8777.1820	6000.00	11000.00
	Total	60	7.6150E3	997.03884	1.2871E2	7357.4376	7872.5624	6000.00	11000.00
TDS	zone 1	15	7.2080E3	707.86601	1.8277E2	6815.9969	7600.0031	6000.00	8140.00
	zone 2	24	6.9312E3	589.36453	1.2030E2	6682.3832	7180.1168	6100.00	7900.00
	zone 3	12	6.3425E3	764.84253	2.2079E2	5856.5422	6828.4578	5000.00	7540.00
	Nature in low tide	9	6.7000E3	1155.42200	3.8514E2	5811.8640	7588.1360	5400.00	8400.00
	Total	60	6.8480E3	797.16404	1.0291E2	6642.0707	7053.9293	5000.00	8400.00
TSS	zone 1	15	7.4460E2	124.55165	32.15910	675.6256	813.5744	480.00	900.00
	zone 2	24	7.5542E2	117.95280	24.07701	705.6096	805.2238	530.00	980.00
	zone 3	12	7.6042E2	80.46621	23.22859	709.2909	811.5425	630.00	870.00
	Nature in low tide	9	6.9667E2	150.49917	50.16639	580.9828	812.3506	500.00	900.00
	Total	60	7.4490E2	117.60934	15.18330	714.5183	775.2817	480.00	980.00
COD	zone 1	15	1360.00	315.911	81.568	1185.05	1534.95	800	1970
	zone 2	24	1682.50	254.375	51.924	1575.09	1789.91	1100	1980
	zone 3	12	1612.50	211.880	61.165	1477.88	1747.12	1380	1910
	Nature in low tide	9	626.67	139.911	46.637	519.12	734.21	450	790
	Total	60	1429.50	438.551	56.617	1316.21	1542.79	450	1980
BOD	zone 1	15	5.2000E2	72.21001	18.64454	480.0114	559.9886	420.00	700.00
	zone 2	24	6.2375E2	145.02061	29.60221	562.5132	684.9868	420.00	880.00
	zone 3	12	5.9000E2	96.74239	27.92712	528.5328	651.4672	410.00	700.00
	Nature in low tide	9	2.3333E2	19.36492	6.45497	218.4481	248.2185	210.00	270.00
	Total	60	5.3250E2	170.24534	21.97858	488.5210	576.4790	210.00	880.00
Nitrate	zone 1	15	1.3640E2	15.18364	3.92040	127.9916	144.8084	105.00	160.00
	zone 2	24	1.4521E2	13.67314	2.79102	139.4347	150.9820	125.00	170.00
	zone 3	12	1.4992E2	13.39239	3.86605	141.4075	158.4258	125.00	170.00
	Nature in low tide	9	76.3333	14.43087	4.81029	65.2408	87.4258	50.00	90.00
	Total	60	1.3362E2	28.29271	3.65257	126.3079	140.9254	50.00	170.00
Microbs	zone 1	15	48.8000	10.98831	2.83717	42.7149	54.8851	32.00	67.00
	zone 2	24	59.7500	13.48187	2.75198	54.0571	65.4429	35.00	84.00
	zone 3	12	60.0833	22.07202	6.37164	46.0594	74.1072	25.00	88.00
	Nature in low tide	9	1.9067E2	22.08506	7.36169	173.6906	207.6427	150.00	218.00
	Total	60	76.7167	51.07525	6.59379	63.5225	89.9108	25.00	218.00
Plankton	zone 1	15	64.2000	10.48945	2.70836	58.3911	70.0089	44.00	80.00
	zone 2	24	58.2500	12.05873	2.46148	53.1580	63.3420	40.00	76.00
	zone 3	12	65.0000	16.39845	4.73382	54.5809	75.4191	45.00	86.00
	Nature in low tide	9	6.5933E2	72.47586	24.15862	603.6235	715.0432	580.00	752.00
	Total	60	1.5125E2	217.21321	28.04211	95.1379	207.3621	40.00	752.00

Table 3: Inter zone data analysis during low tide.

Treatment	Zone 1	Zone 2	Zone 3	Nature
Temperature	31±0.25 ^c	30.12±0.24 ^c	30.5±0.19 ^c	31±0.16 ^c
pH	7.2±0.09 ^c	7.02±0.05 ^c	7.1±0.04 ^c	7.20±0.08 ^c
Chloride	14360±527.23 ^b	12125±682.92 ^b	12625±528.59 ^b	6000±200.00 ^c
TS	7980±197.16 ^c	7712.5±152.52 ^c	7125±220.92 ^c	10000±816.49 ^b
TDS	7208±182.77 ^c	6931.2±120.30 ^c	6342.5±220.79 ^c	9633.3±592.54 ^b
TSS	744.6±32.15 ^b	755.42±24.07 ^b	760.42±23.22 ^b	313.33±10.76 ^c
COD	1360±81.57 ^b	1682.5±51.92 ^a	1612.5±61.16 ^{ab}	11.66±30.35 ^c
BOD	520±18.64 ^b	623.75±29.60 ^b	590±27.92 ^b	3.67±18.40 ^c
Nitrate	136.4±3.92 ^b	145.21±2.79 ^b	149.92±3.86 ^b	108±4.83 ^c
Bacteria	48±2.83 ^c	59.75±2.75 ^c	60.08±6.37 ^c	251.67±12.80 ^b
Plankton	64.2±2.71 ^c	58.25±2.46 ^c	65±4.73 ^c	933.67±19.80 ^b

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Temp	zone 1	15	31.0000	1.00000	.25820	30.4462	31.5538	29.00	32.00
	zone 2	24	30.1250	1.19100	.24311	29.6221	30.6279	27.00	32.00
	zone 3	12	30.5000	.67420	.19462	30.0716	30.9284	29.00	31.00
	Nature in low tide	9	31.0000	.50000	.16667	30.6157	31.3843	30.00	32.00
	Total	60	30.5500	1.03211	.13325	30.2834	30.8166	27.00	32.00
pH	zone 1	15	7.2000	.38024	.09818	6.9894	7.4108	6.75	7.90
	zone 2	24	7.0250	.28047	.05725	6.9066	7.1434	6.70	7.60
	zone 3	12	7.1000	.14924	.04308	7.0052	7.1948	6.80	7.30
	Nature in low tide	9	7.2000	.24495	.08165	7.0117	7.3883	6.90	7.60
	Total	60	7.1100	.28899	.03731	7.0353	7.1847	6.70	7.90
Chloride	zone 1	15	1.4360E4	2041.98783	5.2723E2	13229.1848	15490.8152	10400.00	17500.00
	zone 2	24	1.2125E4	3345.63310	6.8292E2	10712.2630	13537.7370	6000.00	19000.00
	zone 3	12	1.2625E4	1831.10746	5.2859E2	11461.5698	13788.4302	10000.00	17000.00
	Nature in low tide	9	6.0000E3	600.00000	2.0000E2	5538.7992	6461.2008	5000.00	6800.00
	Total	60	1.1865E4	3605.77808	4.6550E2	10933.5287	12796.4713	5000.00	19000.00
TS	zone 1	15	7.9800E3	763.82856	1.9716E2	7557.1166	8402.8834	6800.00	9300.00
	zone 2	24	7.7125E3	747.19912	1.5252E2	7396.9855	8028.0145	6000.00	8800.00
	zone 3	12	7.1250E3	765.29852	2.2092E2	6638.7525	7611.2475	6100.00	8600.00
	Nature in low tide	9	1.0000E4	2449.48974	8.1849E2	8117.1555	11882.8445	5000.00	14000.00
	Total	60	8.0050E3	1441.65101	1.8611E2	7632.5821	8377.4179	5000.00	14000.00
TDS	zone 1	15	7.2080E3	707.86601	1.8277E2	6815.9969	7600.0031	6000.00	8140.00
	zone 2	24	6.9312E3	589.36453	1.2030E2	6682.3832	7180.1168	6100.00	7900.00
	zone 3	12	6.3425E3	764.84253	2.2079E2	5856.5422	6828.4578	5000.00	7540.00
	Nature in low tide	9	9.6333E3	1777.63888	5.9254E2	8266.9191	10999.7475	7500.00	12200.00
	Total	60	7.2880E3	1366.06797	1.7635E2	6935.1072	7640.8928	5000.00	12200.00
TSS	zone 1	15	7.4460E2	124.55165	32.15910	675.6256	813.5744	480.00	900.00
	zone 2	24	7.5542E2	117.95280	24.07701	705.6096	805.2238	530.00	980.00
	zone 3	12	7.6042E2	80.46621	23.22859	709.2909	811.5425	630.00	870.00
	Nature in low tide	9	3.1333E2	32.30712	10.76904	288.4939	338.1668	270.00	370.00
	Total	60	6.8740E2	188.66931	24.35710	638.6615	736.1385	270.00	980.00
COD	zone 1	15	1360.00	315.911	81.568	1185.05	1534.95	800	1970
	zone 2	24	1682.50	254.375	51.924	1575.09	1789.91	1100	1980
	zone 3	12	1612.50	211.880	61.165	1477.88	1747.12	1380	1910
	Nature in low tide	9	882.00	91.055	30.352	812.01	951.99	740	990
	Total	60	1467.80	369.744	47.734	1372.28	1563.32	740	1980
BOD	zone 1	15	5.2000E2	72.21001	18.64454	480.0114	559.9886	420.00	700.00
	zone 2	24	6.2375E2	145.02061	29.60221	562.5132	684.9868	420.00	880.00
	zone 3	12	5.9000E2	96.74239	27.92712	528.5328	651.4672	410.00	700.00
	Nature in low tide	9	3.3667E2	55.22681	18.40894	294.2156	379.1177	250.00	420.00
	Total	60	5.4800E2	145.84287	18.84114	510.2990	585.7010	250.00	880.00
Nitrate	zone 1	15	1.3640E2	15.18364	3.92040	127.9916	144.8084	105.00	160.00
	zone 2	24	1.4521E2	13.67314	2.79102	139.4347	150.9820	125.00	170.00
	zone 3	12	1.4992E2	13.39239	3.86605	141.4075	158.4258	125.00	170.00
	Nature in low tide	9	1.0800E2	14.50000	4.83333	96.8543	119.1457	90.00	125.00
	Total	60	1.3837E2	19.42562	2.50784	133.3485	143.3848	90.00	170.00
Microbs	zone 1	15	48.8000	10.98831	2.83717	42.7149	54.8851	32.00	67.00
	zone 2	24	59.7500	13.48187	2.75198	54.0571	65.4429	35.00	84.00
	zone 3	12	60.0833	22.07202	6.37164	46.0594	74.1072	25.00	88.00
	Nature in low tide	9	2.5167E2	38.40573	12.80191	222.1454	281.1879	190.00	296.00
	Total	60	85.8667	73.11390	9.43896	66.9793	104.7540	25.00	296.00
Plankton	zone 1	15	64.2000	10.48945	2.70836	58.3911	70.0089	44.00	80.00
	zone 2	24	58.2500	12.05873	2.46148	53.1580	63.3420	40.00	76.00
	zone 3	12	85.0000	16.39845	4.73382	54.5809	75.4191	45.00	86.00
	Nature in low tide	9	9.3367E2	59.42011	19.80870	887.8923	979.3410	855.00	980.00
	Total	60	1.9240E2	315.00827	40.66739	111.0247	273.7753	40.00	980.00

Table 4: Intra-zone data analysis, zone 1

Treatment	Achia sea food ltd.	Bright sea food ltd.	Oriental fish processing ltd.	Atlas sea food ltd.	International shrimp export (pvt) ltd.
Temperature	31.00±0.57 ^c	30.00±0.57 ^c	31.00±0.57 ^c	32.00±0.00 ^c	31.00±0.57 ^c
pH	7.20±0.21 ^c	7.80±0.05 ^b	6.80±0.02 ^c	7.10±0.11 ^c	7.10±0.05 ^c
Chloride	13000±1026.30 ^c	13200±1743.50 ^c	14800±450.92 ^c	13800±115.47 ^c	17000±288.67 ^c
TS	8400±230.94 ^{bc}	8700±503.32 ^b	7300±251.66 ^c	8300±208.16 ^{bc}	7200±115.32 ^c
TDS	7800±57.73 ^b	7800±57.73 ^b	6600±57.73 ^c	7540±364.96 ^b	6300±152.75 ^c
TSS	588±88.75 ^c	830±5.77 ^{abc}	670±11.54 ^{abc}	755±2.88 ^{abc}	880±15.27 ^a
COD	1850±87.36 ^a	1000±1.15 ^c	1280±5.77 ^{bc}	1470±40.41 ^b	1200±57.73 ^{bc}
BOD	480±36.05 ^c	500±46.18 ^c	600±57.73 ^c	480±10.00 ^c	540±10.00 ^c
Nitrate	130±2.51 ^{bc}	133±4.04 ^{bc}	156±3.05 ^b	120±8.66 ^c	143±7.50 ^{bc}
Bacteria	45±6.02 ^{bc}	35±1.52 ^c	51±1.73 ^{ab}	65±1.15 ^a	48±1.52 ^{bc}
Plankton	68±5.85 ^b	76±2.30 ^b	63±1.15 ^b	48±2.08 ^c	66±1.00 ^b

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Temp	Achia sea food ltd.	3	31.0000	1.00000	.57735	28.5159	33.4841	30.00	32.00
	Bright sea food ltd.	3	30.0000	1.00000	.57735	27.5159	32.4841	29.00	31.00
	Oriental fish processing ltd.	3	31.0000	1.00000	.57735	28.5159	33.4841	30.00	32.00
	Atlas sea food ltd.	3	32.0000	.00000	.00000	32.0000	32.0000	32.00	32.00
	International shrimp export (pvt) ltd.	3	31.0000	1.00000	.57735	28.5159	33.4841	30.00	32.00
	Total	15	31.0000	1.00000	.25820	30.4462	31.5538	29.00	32.00
pH	Achia sea food ltd.	3	7.2000	.37383	.21572	6.2718	8.1282	6.80	7.54
	Bright sea food ltd.	3	7.8000	.10000	.05774	7.5516	8.0484	7.70	7.90
	Oriental fish processing ltd.	3	6.8000	.05000	.02887	6.6758	6.9242	6.75	6.85
	Atlas sea food ltd.	3	7.1000	.20000	.11547	6.6032	7.5968	6.90	7.30
	International shrimp export (pvt) ltd.	3	7.1000	.10000	.05774	6.8516	7.3484	7.00	7.20
	Total	15	7.2000	.38024	.09818	6.8894	7.4106	6.75	7.90
Chloride	Achia sea food ltd.	3	1.3000E4	1777.83888	1.0263E3	8584.1002	17415.8998	11600.00	15000.00
	Bright sea food ltd.	3	1.3200E4	3019.93377	1.7435E3	5698.0686	20701.9314	10400.00	16400.00
	Oriental fish processing ltd.	3	1.4800E4	781.02497	4.5092E2	12859.8264	16740.1736	14300.00	15700.00
	Atlas sea food ltd.	3	1.3800E4	200.00000	1.1547E2	13303.1725	14296.8275	13600.00	14000.00
	International shrimp export (pvt) ltd.	3	1.7000E4	500.00000	2.8867E2	15757.9311	18242.0689	16500.00	17500.00
	Total	15	1.4360E4	2041.98783	5.2723E2	13229.1848	15490.8152	10400.00	17500.00
TS	Achia sea food ltd.	3	8.4000E3	400.00000	2.3094E2	7408.3449	8393.6551	8000.00	8900.00
	Bright sea food ltd.	3	8.7000E3	871.77979	5.0332E2	8534.3790	10866.6210	7700.00	9300.00
	Oriental fish processing ltd.	3	7.3000E3	435.88989	2.5166E2	6217.1895	8382.8105	6800.00	7600.00
	Atlas sea food ltd.	3	8.3000E3	360.55513	2.0816E2	7404.3314	8195.6686	7900.00	8600.00
	International shrimp export (pvt) ltd.	3	7.2000E3	199.74984	1.1532E2	6703.7939	7896.2061	6970.00	7330.00
	Total	15	7.9800E3	783.62856	1.9716E2	7557.1166	8402.8834	6800.00	9300.00
TDS	Achia sea food ltd.	3	7.8000E3	100.00000	57.73503	7551.5862	8048.4138	7700.00	7900.00
	Bright sea food ltd.	3	7.8000E3	100.00000	57.73503	7551.5862	8048.4138	7700.00	7900.00
	Oriental fish processing ltd.	3	6.6000E3	100.00000	57.73503	6351.5862	6848.4138	6500.00	6700.00
	Atlas sea food ltd.	3	7.5400E3	632.13923	3.6496E2	5989.6791	9110.3209	6880.00	8140.00
	International shrimp export (pvt) ltd.	3	6.3000E3	264.67613	1.5275E2	5642.7589	6957.2411	6000.00	6500.00
	Total	15	7.2080E3	707.86601	1.8277E2	6815.9989	7600.0031	6000.00	8140.00
TSS	Achia sea food ltd.	3	5.8800E2	153.72703	88.75434	206.1209	969.8791	480.00	764.00
	Bright sea food ltd.	3	8.3000E2	10.00000	5.77360	805.1586	854.8414	820.00	840.00
	Oriental fish processing ltd.	3	6.7000E2	20.00000	11.54701	620.3172	719.6828	650.00	690.00
	Atlas sea food ltd.	3	7.5500E2	5.00000	2.88675	742.5793	767.4207	750.00	760.00
	International shrimp export (pvt) ltd.	3	8.8000E2	26.45751	15.27525	814.2759	945.7241	850.00	900.00
	Total	15	7.4460E2	124.55165	32.15910	675.8256	813.5744	480.00	900.00
COD	Achia sea food ltd.	3	1.8500E3	151.32746	87.36895	1474.0818	2225.9182	1680.00	1970.00
	Bright sea food ltd.	3	1.0000E3	200.00000	1.1547E2	503.1725	1496.8275	800.00	1200.00
	Oriental fish processing ltd.	3	1.2800E3	10.00000	6.77350	1255.1586	1304.8414	1270.00	1290.00
	Atlas sea food ltd.	3	1.4700E3	70.00000	40.41452	1296.1104	1643.8896	1400.00	1540.00
	International shrimp export (pvt) ltd.	3	1.2000E3	100.00000	57.73503	951.5862	1448.4138	1100.00	1300.00
	Total	15	1.3600E3	315.91138	81.56797	1185.0541	1534.9459	800.00	1970.00
BOD	Achia sea food ltd.	3	4.8000E2	82.44998	36.05551	324.8656	835.1344	430.00	560.00
	Bright sea food ltd.	3	5.0000E2	80.00000	46.18802	301.2690	898.7310	420.00	580.00
	Oriental fish processing ltd.	3	6.0000E2	100.00000	57.73503	351.5862	848.4138	500.00	700.00
	Atlas sea food ltd.	3	4.8000E2	17.32051	10.00000	436.9735	523.0265	470.00	500.00
	International shrimp export (pvt) ltd.	3	5.4000E2	17.32051	10.00000	496.9735	583.0265	530.00	580.00
	Total	15	5.2000E2	72.21001	18.64454	480.0114	559.9886	420.00	700.00
Nitrate	Achia sea food ltd.	3	1.3000E2	4.35889	2.51661	119.1719	140.8281	127.00	135.00
	Bright sea food ltd.	3	1.3300E2	7.00000	4.04145	115.6110	150.3890	126.00	140.00
	Oriental fish processing ltd.	3	1.5600E2	5.29150	3.05505	142.8552	169.1448	150.00	160.00
	Atlas sea food ltd.	3	1.2000E2	15.00000	8.66025	82.7379	157.2621	105.00	135.00
	International shrimp export (pvt) ltd.	3	1.4300E2	13.00000	7.50555	110.7062	175.2938	130.00	156.00
	Total	15	1.3640E2	15.18364	3.92040	127.9916	144.8094	105.00	160.00
Microbs	Achia sea food ltd.	3	45.0000	10.44031	6.02771	19.0648	70.9352	36.00	57.00
	Bright sea food ltd.	3	35.0000	2.64575	1.52753	28.4276	41.5724	32.00	37.00
	Oriental fish processing ltd.	3	51.0000	3.00000	1.73205	43.5476	58.4524	48.00	54.00
	Atlas sea food ltd.	3	65.0000	2.00000	1.15470	60.0317	69.9683	63.00	67.00
	International shrimp export (pvt) ltd.	3	48.0000	2.64575	1.52753	41.4276	54.5724	45.00	50.00
	Total	15	48.8000	10.98831	2.83717	42.7149	54.8851	32.00	67.00
Plankton	Achia sea food ltd.	3	68.0000	10.14889	5.85947	42.7888	93.2112	57.00	77.00
	Bright sea food ltd.	3	76.0000	4.00000	2.30940	66.0634	85.9366	72.00	80.00
	Oriental fish processing ltd.	3	63.0000	2.00000	1.15470	58.0317	67.9683	61.00	65.00
	Atlas sea food ltd.	3	48.0000	3.60555	2.08167	39.0433	56.9567	44.00	51.00
	International shrimp export (pvt) ltd.	3	66.0000	1.73205	1.00000	61.6973	70.3027	64.00	67.00
	Total	15	64.2000	10.48945	2.70836	58.3911	70.0089	44.00	80.00



Table 5: Intra-zone data analysis, zone 2

Treatm ent	Cosmos sea food ltd	Fresh foods ltd	Jahanabad sea foods ltd.	Jalabad frozen foods ltd.	Khulna frozen food export ltd.	Modern sea food ltd.	National sea food ltd.	Organic shrimps export ltd.
Tempe rature	30±0.57 ^b _c	31±0.00 ^b	30±0.57 ^{bc}	30±0.57 ^{bc}	28±0.57 ^c	30±0.57 _{bc}	31±0.00 ^b	31±0.57 _b
pH	6.8±0.05 _c	6.8±0.05 ^c	7.2±0.05 ^{bc}	6.9±0.05 ^c	7±0.10 ^c	7.2±0.2 _{1^{bc}}	6.8±0.02 ^c	7.5±0.05 _b
Chlorid e	18000±5 77.35 ^a	14000±15 27.50 ^{ab}	13000±10 26.30 ^{abc}	13000±10 00.00 ^{abc}	10000±5 77.35 ^{bc}	11000± 0.00 ^{bc}	10000±20 81.60 ^{bc}	8000±28 8.67 ^c
TS	7500±15 2.75 ^c	8500±152 .75 ^c	7500±173. 20 ^c	8000±115. 47 ^c	7000±57 7.35 ^c	8500±7 6.37 ^c	7500±763 .76 ^c	7200±11 5.32 ^c
TDS	6950±30 1.38 ^b	7800±57. 73	6700±115. 47 ^{bc}	7100±57.7 3 ^{ab}	6200±57. 73 ^c	7700±1 15.47 ^a	6500±152 .75 ^{bc}	6500±11 5.47 ^{bc}
TSS	543.33± 8.81 ^f	670±15.2 7 ^c	780±5.00 ^c	850±5.77 ^b	750±11.5 4 ^{cd}	800±5.7 7 ^{bc}	950±17.3 2 ^a	700±10. 40 ^{dc}
COD	1680±5. 77 ^b	1850±87. 36 ^{ab}	1800±61.1 0 ^{ab}	1950±15.2 7	1400±11. 54 ^c	1700±1 5.27 ^b	1880±5.7 7 ^a	1200±57 .73 ^c
BOD	440±12. 58 ^c	650±28.8 6 ^b	850±30.00 a	450±17.32 c	670±5.77 b	680±5.7 7 ^b	500±46.1 8 ^c	750±5.7 7 ^{ab}
Nitrate	152±2.3 0 ^{ab}	135±5.77 ^b _c	145±2.88a _{bc}	130±2.51 ^c	166±2.30 a	131.67±3.33 _{bc}	157±3.51a	145±8.1 4 ^{abc}
Bacter ia	54±3.46 ^c _d	78±3.05 ^a	47±5.50 ^{dc}	38±1.52 ^c	57±3.46b _{cd}	65±1.15 _{abc}	68±2.08a ^b _c	71±3.05 _{ab}
Plankto n	73±1.73 ^a	57±9.81 ^{ab} _c	64±0.57 ^{ab}	53±1.15 ^{bc}	74±1.15 ^a	55±0.00 _{bc}	48±1.00 ^{bc}	42±0.57 _c

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
temp	Cosmos sea food ltd	3	30.0000	1.00000	.57735	27.8159	32.4841	28.00	31.00
	Fresh foods ltd	3	31.0000	.00000	.00000	31.0000	31.0000	31.00	31.00
	Jahanabad sea foods ltd	3	30.0000	1.00000	.57735	27.5159	32.4841	29.00	31.00
	Jalabad frozen foods ltd	3	30.0000	1.00000	.57735	27.5159	32.4841	29.00	31.00
	Khulna frozen food export ltd	3	28.0000	1.00000	.57735	25.5159	30.4841	27.00	29.00
	Modern sea food ltd	3	30.0000	1.00000	.57735	27.5159	32.4841	29.00	31.00
	National sea food ltd	3	31.0000	.00000	.00000	31.0000	31.0000	31.00	31.00
	Organic shrimps export ltd	3	31.0000	1.00000	.57735	28.5159	33.4841	30.00	32.00
	Total	24	30.1250	1.19100	.24311	29.6221	30.6279	27.00	32.00
pH	Cosmos sea food ltd	3	8.8000	.10000	.05774	8.5516	7.0484	6.70	8.90
	Fresh foods ltd	3	8.8000	.10000	.05774	8.5516	7.0484	6.70	8.90
	Jahanabad sea foods ltd	3	7.2000	.10000	.05774	6.9516	7.4484	7.10	7.30
	Jalabad frozen foods ltd	3	8.9000	.10000	.05774	8.6516	7.1484	6.80	7.00
	Khulna frozen food export ltd	3	7.0000	.17321	.10000	6.5897	7.4303	6.80	7.10
	Modern sea food ltd	3	7.2000	.37363	.21572	6.2718	8.1282	6.80	7.54
	National sea food ltd	3	8.8000	.05000	.02887	8.6758	8.9242	6.75	8.85
	Organic shrimps export ltd	3	7.5000	.10000	.05774	7.2616	7.7484	7.40	7.80
	Total	24	7.0260	.28047	.05725	6.8068	7.1434	6.70	7.60
Chloride	Cosmos sea food ltd	3	1.8000E4	1000.00000	5.7735E2	15515.8623	20484.1377	17000.00	19000.00
	Fresh foods ltd	3	1.4000E4	2645.75131	1.6275E3	7427.5894	20572.4106	12000.00	17000.00
	Jahanabad sea foods ltd	3	1.3000E4	1777.83888	1.0283E3	8584.1002	17415.8898	11500.00	15000.00
	Jalabad frozen foods ltd	3	1.3000E4	1732.05081	1.0000E3	8697.3473	17302.6527	12000.00	15000.00
	Khulna frozen food export ltd	3	1.0000E4	1000.00000	5.7735E2	7515.8623	12484.1377	9000.00	11000.00
	Modern sea food ltd	3	1.1000E4	.00000	.00000	11000.0000	11000.0000	11000.00	11000.00
	National sea food ltd	3	1.0000E4	3805.55128	2.0816E3	1043.3141	18958.8959	6000.00	13000.00
	Organic shrimps export ltd	3	8.0000E3	600.00000	2.8887E2	8757.9311	9242.0688	7500.00	8500.00
	Total	24	1.2125E4	3345.83310	6.6292E2	10712.2630	13637.7370	6000.00	18000.00
TS	Cosmos sea food ltd	3	7.5000E3	284.57513	1.5275E2	6842.7589	8157.2411	7200.00	7700.00
	Fresh foods ltd	3	8.5000E3	284.57513	1.5275E2	7842.7589	8157.2411	8300.00	8800.00
	Jahanabad sea foods ltd	3	7.5000E3	300.00000	1.7320E2	6764.7667	8245.2413	7200.00	7800.00
	Jalabad frozen foods ltd	3	8.0000E3	200.00000	1.1547E2	7503.1725	8496.8275	7800.00	8200.00
	Khulna frozen food export ltd	3	7.0000E3	1000.00000	5.7735E2	4515.8623	9484.1377	6000.00	8000.00
	Modern sea food ltd	3	8.5000E3	132.28757	76.37626	8171.3785	8828.6205	8350.00	8600.00
	National sea food ltd	3	7.5000E3	1322.87586	7.6376E2	4213.7947	10786.2053	6000.00	9500.00
	Organic shrimps export ltd	3	7.2000E3	199.74984	1.1532E2	6703.7939	7886.2061	6970.00	7330.00
	Total	24	7.7125E3	747.19812	1.5252E2	7398.9855	9028.0145	6000.00	8800.00
TDS	Cosmos sea food ltd	3	8.6500E3	522.01533	3.0138E2	8553.2420	9248.7580	8500.00	7550.00
	Fresh foods ltd	3	7.8000E3	100.00000	57.73503	7551.5882	9048.4138	7700.00	7000.00
	Jahanabad sea foods ltd	3	6.7000E3	200.00000	1.1547E2	8203.1725	7195.8275	6500.00	8000.00
	Jalabad frozen foods ltd	3	7.1000E3	100.00000	57.73503	6851.5882	7348.4138	7000.00	7200.00
	Khulna frozen food export ltd	3	6.2000E3	100.00000	57.73503	5951.5882	6448.4138	6100.00	6300.00
	Modern sea food ltd	3	7.7000E3	200.00000	1.1547E2	7203.1725	8196.8275	7500.00	7900.00
	National sea food ltd	3	6.5000E3	264.57513	1.5275E2	5842.7589	7157.2411	6300.00	6800.00
	Organic shrimps export ltd	3	6.5000E3	200.00000	1.1547E2	6003.1725	6995.8275	6300.00	6700.00
	Total	24	6.9312E3	599.35453	1.2030E2	6892.3832	7180.1168	6100.00	7900.00
TSS	Cosmos sea food ltd	3	5.4333E2	15.27925	8.81917	505.3875	581.2792	530.00	580.00
	Fresh foods ltd	3	6.7000E2	26.45751	15.27526	604.2759	735.7241	640.00	690.00
	Jahanabad sea foods ltd	3	7.8000E2	8.68026	5.00000	758.4887	801.5133	770.00	785.00
	Jalabad frozen foods ltd	3	8.5000E2	10.00000	5.77350	825.1598	874.8414	840.00	860.00
	Khulna frozen food export ltd	3	7.5000E2	20.00000	11.54701	700.3172	799.6828	730.00	770.00
	Modern sea food ltd	3	8.0000E2	10.00000	5.77350	775.1598	824.8414	790.00	810.00
	National sea food ltd	3	8.5000E2	30.00000	17.32051	876.4769	1024.5241	820.00	890.00
	Organic shrimps export ltd	3	7.0000E2	18.02776	10.40833	655.2188	744.7834	680.00	715.00
	Total	24	7.5542E2	117.85280	24.07701	705.6098	805.2738	630.00	680.00
COD	Cosmos sea food ltd	3	1.6800E3	10.00000	5.77350	1655.1598	1704.8414	1670.00	1690.00
	Fresh foods ltd	3	1.8500E3	151.32746	87.38805	1474.0818	2225.8182	1680.00	1970.00
	Jahanabad sea foods ltd	3	1.8000E3	105.83005	81.10101	1537.1035	2062.8964	1690.00	1890.00
	Jalabad frozen foods ltd	3	1.9500E3	26.45751	15.27526	1884.2759	2015.7241	1930.00	1980.00
	Khulna frozen food export ltd	3	1.4000E3	20.00000	11.54701	1350.3172	1448.6828	1390.00	1420.00
	Modern sea food ltd	3	1.7000E3	26.45751	15.27526	1834.2759	1765.7241	1670.00	1720.00
	National sea food ltd	3	1.8800E3	10.00000	5.77350	1855.1598	1904.8414	1670.00	1890.00
	Organic shrimps export ltd	3	1.2000E3	100.00000	67.73503	951.5882	1448.4138	1100.00	1300.00
	Total	24	1.6825E3	294.37477	51.92403	1575.0870	1789.9130	1100.00	1990.00
BOD	Cosmos sea food ltd	3	4.4000E2	21.78448	12.58308	385.8585	494.1405	425.00	455.00
	Fresh foods ltd	3	6.6000E2	50.00000	28.86751	525.7931	774.2069	600.00	700.00
	Jahanabad sea foods ltd	3	8.5000E2	51.98152	30.00000	720.9204	979.0798	780.00	880.00
	Jalabad frozen foods ltd	3	4.5000E2	30.00000	17.32051	375.4769	524.5241	420.00	480.00
	Khulna frozen food export ltd	3	6.7000E2	10.00000	5.77350	645.1598	894.8414	660.00	890.00
	Modern sea food ltd	3	8.8000E2	10.00000	5.77350	855.1598	704.8414	670.00	890.00
	National sea food ltd	3	5.0000E2	80.00000	48.18802	301.2880	698.7310	420.00	580.00
	Organic shrimps export ltd	3	7.5000E2	10.00000	5.77350	725.1598	774.8414	740.00	760.00
	Total	24	6.2375E2	145.02061	29.60221	582.5132	884.9868	420.00	890.00
Nitrate	Cosmos sea food ltd	3	1.5200E2	4.00000	2.30940	142.0634	161.9366	148.00	156.00
	Fresh foods ltd	3	1.3500E2	10.00000	6.77350	110.1588	159.8414	125.00	145.00
	Jahanabad sea foods ltd	3	1.4500E2	5.00000	2.88675	132.5793	157.4207	140.00	150.00
	Jalabad frozen foods ltd	3	1.3000E2	4.35880	2.51681	119.1719	140.8281	127.00	135.00
	Khulna frozen food export ltd	3	1.6800E2	4.00000	2.30940	158.0834	175.9366	162.00	170.00
	Modern sea food ltd	3	1.3187E2	5.77350	3.33333	117.3245	146.0088	125.00	135.00
	National sea food ltd	3	1.5700E2	6.08278	3.51188	141.8898	172.1104	150.00	181.00
	Organic shrimps export ltd	3	1.4500E2	14.10674	8.14453	109.9569	190.0431	132.00	190.00
	Total	24	1.4521E2	13.87314	2.79102	139.4347	160.9820	125.00	170.00
Microbe	Cosmos sea food ltd	3	54.0000	6.00000	3.48410	39.0952	68.9048	48.00	60.00
	Fresh foods ltd	3	78.0000	5.29150	3.05505	64.8552	91.1448	74.00	84.00
	Jahanabad sea foods ltd	3	47.0000	9.53939	5.50757	23.3028	70.6972	38.00	57.00
	Jalabad frozen foods ltd	3	38.0000	2.84575	1.52753	31.4276	44.5724	35.00	40.00
	Khulna frozen food export ltd	3	57.0000	6.00000	3.48410	42.0952	71.9048	51.00	63.00
	Modern sea food ltd	3	65.0000	2.00000	1.15470	60.0317	69.9683	63.00	67.00
	National sea food ltd	3	68.0000	3.60555	2.08167	69.0433	76.9567	64.00	71.00
	Organic shrimps export ltd	3	71.0000	5.29150	3.05505	67.8552	84.1448	67.00	77.00
	Total	24	59.7500	13.48187	2.75198	64.0571	85.4429	35.00	84.00
Plankton	Cosmos sea food ltd	3	73.0000	3.00000	1.73205	65.5476	80.4524	70.00	78.00
	Fresh foods ltd	3	67.0000	17.00000	9.81495	14.7897	89.2303	40.00	74.00
	Jahanabad sea foods ltd	3	84.0000	1.00000	.57735	81.5159	88.4841	63.00	85.00
	Jalabad frozen foods ltd	3	53.0000	2.00000	1.15470	48.0317	57.9683	51.00	55.00
	Khulna frozen food export ltd	3	74.0000	2.00000	1.15470	69.0317	78.9683	72.00	78.00
	Modern sea food ltd	3	65.0000	.00000	.00000	65.0000	65.0000	55.00	65.00
	National sea food ltd	3	40.0000	1.73205	1.00000	43.6973	52.3027	47.00	50.00
	Organic shrimps export ltd	3	42.0000	1.00000	.57735	39.5159	44.4841	41.00	43.00
	Total	24	58.2500	12.05873	2.48148	52.1590	63.3420	40.00	75.00

Table 6: Intra-zone data analysis, zone 3.

Treatment	Bagerhat sea foods ind. Ltd.	Harbor sea foods ltd.	Lockpur fish processing co. Ltd.	Rupsha fish and Allied ind. Ltd.
Temperature	31±0.00 ^c	30±0.57 ^c	31±0.00 ^c	30±0.00 ^c
pH	7.2±0.05 ^b	7.1±0.02 ^{bc}	6.9±0.05 ^c	7.2±0.05 ^b
Chloride	14000±1527.50 ^c	13000±1026.30 ^c	12500±288.67 ^c	11000±577.35 ^c
TS	8200±351.18 ^b	7000±115.47 ^c	6500±200.00 ^c	6800±251.66 ^c
TDS	7420±100.66 ^b	6350±28.86 ^c	5600±378.59 ^c	6000±57.73 ^c
TSS	781.67±3.33 ^b	650±11.54 ^c	860±5.77 ^a	750±18.92 ^b
COD	1450±30.00 ^c	1400±11.54 ^c	1700±17.32 ^b	1900±5.77 ^a
BOD	680±5.77 ^a	450±23.09 ^c	580±7.63 ^b	650±28.86 ^{ab}
Nitrate	150.33±2.60 ^{bc}	135±5.77 ^c	147.67±5.36 ^{bc}	166.67±2.40 ^b
Bacteria	43.33±3.33 ^c	74±2.00 ^b	86±1.15 ^b	37±6.11 ^c
Plankton	85±1.00 ^a	75±0.57 ^b	46±0.57 ^d	54±0.57 ^c

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
temp	Bagerhat sea foods ind. Ltd.	3	31.0000	.00000	.00000	31.0000	31.0000	31.00	31.00
	Harbor sea foods ltd.	3	30.0000	1.00000	.57735	27.5159	32.4841	29.00	31.00
	Lockpur fish processing co. Ltd.	3	31.0000	.00000	.00000	31.0000	31.0000	31.00	31.00
	Rupsha fish and Allied ind. Ltd.	3	30.0000	.00000	.00000	30.0000	30.0000	30.00	30.00
	Total	12	30.5000	.67420	.19462	30.0716	30.9284	29.00	31.00
pH	Bagerhat sea foods ind. Ltd.	3	7.2000	.10000	.05774	6.9516	7.4484	7.10	7.30
	Harbor sea foods ltd.	3	7.1000	.05000	.02887	6.9758	7.2242	7.05	7.15
	Lockpur fish processing co. Ltd.	3	6.9000	.10000	.05774	6.6516	7.1484	6.80	7.00
	Rupsha fish and Allied ind. Ltd.	3	7.2000	.10000	.05774	6.9516	7.4484	7.10	7.30
	Total	12	7.1000	.14924	.04308	7.0052	7.1948	6.80	7.30
chloride	Bagerhat sea foods ind. Ltd.	3	1.4000E4	2645.75131	1.5275E3	7427.5894	20572.4106	12000.00	17000.00
	Harbor sea foods ltd.	3	1.3000E4	1777.63988	1.0263E3	8584.1002	17415.8998	11600.00	15000.00
	Lockpur fish processing co. Ltd.	3	1.2500E4	500.00000	2.8867E2	11257.9311	13742.0689	12000.00	13000.00
	Rupsha fish and Allied ind. Ltd.	3	1.1000E4	1000.00000	5.7735E2	8515.8623	13484.1377	10000.00	12000.00
	Total	12	1.2625E4	1831.10746	5.2859E2	11461.5698	13789.4302	10000.00	17000.00
TS	Bagerhat sea foods ind. Ltd.	3	8.2000E3	608.27825	3.5118E2	6688.9580	9711.0420	7500.00	8600.00
	Harbor sea foods ltd.	3	7.0000E3	200.00000	1.1547E2	6503.1725	7496.8275	6800.00	7200.00
	Lockpur fish processing co. Ltd.	3	6.5000E3	346.41016	2.0000E2	5639.4685	7360.5305	6100.00	6700.00
	Rupsha fish and Allied ind. Ltd.	3	6.8000E3	435.88989	2.5168E2	5717.1895	7892.8105	6300.00	7100.00
	Total	12	7.1250E3	785.28852	2.2092E2	6638.7525	7611.2475	6100.00	8600.00
TDS	Bagerhat sea foods ind. Ltd.	3	7.4200E3	174.35596	1.0066E2	6986.8758	7853.1242	7220.00	7540.00
	Harbor sea foods ltd.	3	6.3500E3	50.00000	28.86751	6225.7931	6474.2069	6300.00	6400.00
	Lockpur fish processing co. Ltd.	3	5.6000E3	655.74385	3.7859E2	3971.0420	7228.9580	5000.00	6300.00
	Rupsha fish and Allied ind. Ltd.	3	6.0000E3	100.00000	57.73503	5751.5862	6248.4138	5900.00	6100.00
	Total	12	6.3425E3	784.84253	2.2079E2	5856.5422	6926.4578	5000.00	7540.00
TSS	Bagerhat sea foods ind. Ltd.	3	7.0187E2	5.77350	3.33333	767.3245	796.0088	775.00	785.00
	Harbor sea foods ltd.	3	6.5000E2	20.00000	11.54701	600.3172	699.6828	630.00	670.00
	Lockpur fish processing co. Ltd.	3	6.6000E2	10.00000	5.77350	835.1586	884.8414	850.00	870.00
	Rupsha fish and Allied ind. Ltd.	3	7.5000E2	32.79719	18.92959	668.5521	831.4479	715.00	780.00
	Total	12	7.6042E2	80.46821	23.22659	708.2909	811.5425	630.00	870.00
COD	Bagerhat sea foods ind. Ltd.	3	1.4500E3	51.96152	30.00000	1320.9204	1579.0796	1390.00	1480.00
	Harbor sea foods ltd.	3	1.4000E3	20.00000	11.54701	1350.3172	1440.6828	1380.00	1420.00
	Lockpur fish processing co. Ltd.	3	1.7000E3	30.00000	17.32051	1625.4759	1774.5241	1670.00	1730.00
	Rupsha fish and Allied ind. Ltd.	3	1.9000E3	10.00000	5.77350	1875.1586	1924.8414	1890.00	1910.00
	Total	12	1.6125E3	211.88011	61.18452	1477.8778	1747.1222	1380.00	1910.00
BOD	Bagerhat sea foods ind. Ltd.	3	6.8000E2	10.00000	5.77350	655.1586	704.8414	670.00	690.00
	Harbor sea foods ltd.	3	4.5000E2	40.00000	23.09401	350.6345	549.3655	410.00	490.00
	Lockpur fish processing co. Ltd.	3	5.9000E2	13.22876	7.63763	547.1378	612.8621	570.00	595.00
	Rupsha fish and Allied ind. Ltd.	3	5.5000E2	50.00000	28.86751	525.7931	574.2069	500.00	700.00
	Total	12	5.9000E2	96.74239	27.92712	528.5328	651.4672	410.00	700.00
Nitrate	Bagerhat sea foods ind. Ltd.	3	1.5033E2	4.50925	2.60342	139.1317	161.5349	146.00	155.00
	Harbor sea foods ltd.	3	1.3500E2	10.00000	5.77350	110.1586	159.8414	125.00	145.00
	Lockpur fish processing co. Ltd.	3	1.4767E2	9.29157	5.38448	124.5851	170.7482	140.00	158.00
	Rupsha fish and Allied ind. Ltd.	3	1.6667E2	4.16333	2.40370	156.3244	177.0090	162.00	170.00
	Total	12	1.4992E2	13.39238	3.86605	141.4076	158.4258	125.00	170.00
Microbs	Bagerhat sea foods ind. Ltd.	3	43.3333	5.77350	3.33333	28.9912	57.6755	40.00	50.00
	Harbor sea foods ltd.	3	74.0000	3.46410	2.00000	65.3947	82.6053	70.00	78.00
	Lockpur fish processing co. Ltd.	3	86.0000	2.00000	1.15470	81.0317	90.9683	84.00	88.00
	Rupsha fish and Allied ind. Ltd.	3	37.0000	10.58301	6.11010	10.7104	63.2896	25.00	45.00
	Total	12	60.0833	22.07202	6.37164	46.0594	74.1072	25.00	88.00
Plankton	Bagerhat sea foods ind. Ltd.	3	95.0000	1.73205	1.00000	80.6973	89.3027	83.00	96.00
	Harbor sea foods ltd.	3	75.0000	1.00000	.57735	72.5159	77.4841	74.00	76.00
	Lockpur fish processing co. Ltd.	3	46.0000	1.00000	.57735	43.5159	48.4841	45.00	47.00
	Rupsha fish and Allied ind. Ltd.	3	54.0000	1.00000	.57735	51.5159	56.4841	53.00	55.00
	Total	12	65.0000	16.39845	4.73382	54.5809	75.4191	45.00	96.00