Impacts of Effluents and Wastes of Shrimp Processing Industries on Soil and Water Environment in and around Khulna city

(Ph. D Thesis)

Submitted by

Reg. No. 127 (2010-11)
Re Reg. No. 61 (2015-16)

Department of Soil, Water and Environment
University of Dhaka
Dhaka, Bangladesh
June-2016

Impacts of Effluents and Wastes of Shrimp Processing Industries on Soil and Water Environment in and around Khulna city

(Ph. D Thesis)

Submitted by
Reg. No. 127 (2010-11)
Re Reg. No. (2015-16)

Department of Soil, Water and Environment
University of Dhaka
Dhaka, Bangladesh
June-2016

Dedication

The entire achievement of this Ph D research is dedicated to my beloved father **Late Shaikh Atiar Rahman** whose dream was to see two letters and a full stop (Dr.) with my name.

Acknowledgement:

I am cordially grateful to **Almighty Allah** because He has given me power, merits, intelligence and courage which helped me to complete the dissertation properly.

I take into my confidence; it is an undying fame to divulge my veneration, and cordial gratitude to my respectable Supervisor **Professor Dr. M. Mahbubur Rahman** and Co-Supervisor **Professor Dr. A.H.M. Julfiquar Ali,** Department of Soil, Water and Environment, University of Dhaka for their acuminous, sagacious, pain taking and preserving superintendence throughout the tenure of the research work and fruitful accomplishing of this dissertation. I express my deep sense of gratitude and indebtedness to all of my honorable teachers of the Department of Soil, Water and Environment, University of Dhaka for their kind help and encouragement.

I also profess my indebtedness and devote reverence to **Md. Muhsin Farazi,** Scientific Officer, SRDI, Farmgate, Dhaka and **Milton Haldar,** Scientific Officer, BCSIR, Chittagong, for providing necessary laboratory facilities to analyze heavy metals to carry out the research work. I am grateful to **Md. Mahmudul Islam,** PhD researcher, Soil Science Discipline, Khulna University for helping me in Microbiology laboratory.

I am grateful to **Kazi Azaduzzaman,** Manager (Research and Evaluation), Japan Association of Drainage and Environment (JADE), Khalishpur, Khulna. There is no way to show love and gratefulness to my MS students **Sheikh Yesin ali, Md. Tarek Bin Salam, Ipsita sarkar** who continuously helped me for collecting literature and composing thesis and **Professor Dr. Md. Mujibur Rahman,** Environmental Science Discipline, Khulna University for helping me using GIS for Map preparation.

Last but not the last, I express my heartfelt gratitude and regards to my beloved life parner **Fargin Hossain Tinna,** Lecturer, Department of Zoology, Bangladesh Navy College, Khulna for her affectionate encouragement and inspiration during the period of this research. At last I am showing my love and affection to my son **Ahmed Arabi** whose life starts with the initializing of my PhD research.

Author

List of Tables

List of Figures

Contents:

Abstract

Impacts of Effluents and Wastes of Shrimp Processing Industries on Soil and Water Environment in and around Khulna city

Shaikh Motasim Billah

Department of Soil, Water and Environment

Dumping of solid and liquid wastes without treatment is a common practice and of great concern in Bangladesh. Most of the industries in Bangladesh do not follow the environmental compliance for ETP in their plants and release untreated wastes in the environment. There are 130 shrimp processing industries at present in Bangladesh of which 48 are located in and around Khulna city. These industries are mainly involved in processing and packaging shrimps for exporting to the world market. Due to the nature of the industries, substantial quantity of solid wastes and effluents are generated during the process and disposed off in the nearby agricultural lands, channels, canals, rivers, low lying areas, along road side ditches and water bodies. Fish processing activities involve production of large quantities of biodegradable solid organic wastes and by-products from inedible fish parts as well as effluents containing salts, fat-oil-grease (FOG), proteins, carbohydrates, suspended and dissolved solids, high levels of phosphates and nitrates, heavy metals and pathogenic and other micro flora. These waste streams can have extremely high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) and if discharged without treatment into water bodies, the pollutants it contains can cause oxygen depletion in the environment and phytotoxicity. It is hypothesized that untreated wastes and effluents released in the environment from fish processing industries in and around Khulna city will have detrimental effects on receiving soils and water bodies. Crop production and crop quality is also expected to be affected. There are no systematic studies have yet been carried out in Khulna region to identify the nature of contaminants present in the wastes and effluents released and the impact on the environment. Systematic analysis of wastes and effluents for the identification of the pollutants and how these are affecting soil and water qualities and causing environmental quality degradation and crop damages deserve to be investigated.

The Environmental Impact Assessment (EIA) was conducted in some selected areas in and around Khulna city. Twelve shrimp processing industries were selected for survey and soil and effluent samples were collected from four large industries for this study. Analysis of effluents, representative soil and water samples were conducted for different physical and chemical parameters as required in the investigation. Seed germination test and pot experiments were conducted to observe the effect of effluents on seed germination and on plant growth and yield. On ground survey of the shrimp processing plants in the present investigation are observed to be constructed on the road side agricultural lands surrounded by, rivers, canals, ponds and small water bodies and the wastes (6800Kg/day/plant) and effluents (47500L/day/plant) generated are directly released in the environment. None of the industries are following the compliance of ETP as required by ECR-97. Effluent released from the investigated shrimp processing industries contains various degrees of chemical species or substances that can affect soil and water, notable of which are pH (8.06±1.12), EC (15.21±2 $mSCm^{-1}$), DO (1.7±0.12 mgL^{-1}), TDS (1777±553 mgL^{-1}), TSS (543±187 mgL^{-1}), BOD (377±15 mgL^{-1}), COD (593±10 mgL^{-1}), HCO_3^{-+} (28.8±5.95 mgL^{-1}), SO_4^{2-} (372±46 mgL^{-1}), Cl^- (0.9±0.06%), NH_4^+-N (50.17±32.06 mgL^{-1}), NO_3^--N (12±1.5 mgL^{-1}), Na^+ (70±4 $meqL^{-1}$), K^+ (3.39±0.17 $meqL^{-1}$), Ca^{2+} (9.3±0.42 $meqL^{-1}$), Mg^{2+} (9.3±0.42 $meqL^{-1}$), SAR (16.47±1.03), SSP (66.94±1.45%), Hardness (105.29±1.09 mgL^{-1}), Zn (94.48±21.02 mgL^{-1}), Mn (129±19 mgL^{-1}), Pb (2.75±3.25 mgL^{-1}), Cd (0.19±0.31 mgL^{-1}), Cr (16.6±0.03 mgL^{-1}), Ni (7.25±6.05 mgL^{-1}), TC ($2.9\times10^3\pm0.6\times10^3$ c.f.u/100 ml), FC (235±76c.f.u/100 ml). The effluents also found to contain different levels of NH_4^+ and NO_3^- Nitrogen (92.6±3.2 mgL^{-1}), PO_4^{3-} (26.5±2.6 mgL^{-1}), SO_4^{2-}-S (372±46 mgL^{-1}), K^+ (3.39±0.17 $meqL^{-1}$), Na^+ (70±4 $meqL^{-1}$), Mg^{2+} (9.3±0.42 $meqL^{-1}$), Ca^{2+} (9.3±0.42 $meqL^{-1}$), DOC (233.6±70 mgL^{-1}). Effluent characteristics significantly changed with distance travelled over a cross section of land. Concentrations measured at a distance of about 350m from the source point were- turbidity (305-665 NTU), temperature (24-27.5 ^{0}C), pH (7.48-8.18), EC (12.1-17.21 $mScm^{-1}$), Salt (0.77-1.1%), DOC (186-328.67 mgL^{-1}), DO (0.15-1.82 mgL^{-1}), TDS (1320-2350 mgL^{-1}), TSS (366-966 mgL^{-1}), BOD (367-436 mgL^{-1}), COD (572-980 mgL^{-1}), HCO_3^- (16.02-34.75 mgL^{-1}), SO_4^{2-} (306-485 mgL^{-1}), Cl^- (0.73-0.96%),

NH_4^+-N (7.57-92.87 mgL^{-1}), NO_3 -N (10.7-17.9 mgL^{-1}), Na^+ (42-71 $meqL^{-1}$), K^+ (2.7-3.91 $meqL^{-1}$), Ca^{2+} (23.72-27.22 $meqL^{-1}$), Mg^{2+} (6.75-9.72 $meqL^{-1}$), Hardness (87.16-106.38 mgL^{-1}), Zn (68.3-124.7 mgL^{-1}), Mn (99-165 mgL^{-1}), Pb (1-8 mgL^{-1}), Cd (0.05-0.59 mgL^{-1}), Cr (16.1-18.7 mgL^{-1}), Ni (3.3-13.3 mgL^{-1}), TC (2.3×10^3-4.75×10^3c.f.u/100 ml) and FC (110-411c.f.u/100 ml). The chemical properties of the soils receiving effluents were also changed, notable of which are pH (7.2-7.74), EC (4.27-6.69 $mScm^{-1}$), Percent Salt (0.27-0.43), CEC (12.2-29.7 $meq100g^{-1}$ soil), OC (2.04-2.98%), OM (3.51-5.13%), Total N (0.14-0.21%), Available N (38.2-137.75 $mgKg^{-1}$), C:N ratio (12.81-18.47), S (18.75-32.1 $mgKg^{-1}$), P (14.2-24.1 $mgKg^{-1}$), Na^+ (74.89-193.5 $meq100g^{-1}$ soil), K^+ (2.79-5.83 $meq100g^{-1}$ soil), Ca^{2+} (10.88-12.41 $meq100g^{-1}$ soil), Mg^{2+} (2.88-3.71 $meq100g^{-1}$ soil), Zn (88.4-200.6 $mgKg^{-1}$), Mn (350-928 $mgKg^{-1}$), Pb (1-10 $mgKg^{-1}$), Cd (0.2-0.8 $mgKg^{-1}$), Cr (32.4-49.3 $mgKg^{-1}$) and Ni (20.4-47 $mgKg^{-1}$). Seed germination tests carried out with the raw and diluted effluent showed comparable results with three different plant species namely Red amaranth (*Amaranthus curentus*), Stem amaranth *(Amaranthus lividus)* and Water spinach (*Ipomoea aquitica*). The application of raw effluent significantly reduced seed germination of different species up to a level of 24%, however Stem amaranth *(Amaranthus lividus)* was mostly affected and the order was SA>RA>WS. The recovery of the effect on seed germination was observed at a dilution of 75%. Pot experiments carried out to assess the effect of effluents with or without dilutions on growth and yield of Red amaranth (*Amaranthus curentus*), Stem amaranth *(Amaranthus lividus)* and Water spinach (*Ipomoea aquitica*) showed to have significant effects on the growth parameters and biomass production like the number of leaves/plant, Fresh weight/plant, dry weight/plant and percent moisture content compare to the control treatment (uncontaminated soil) and the order was SA>RA>WS. Soils treated with raw effluents reduced the number of leaves per plant (38.1%), fresh weight per plant (50.14%), dry weight per plant (42.57%) and percent moisture content (6%) in Red amaranth; reduced the number of leaves per plant (46.14%), fresh weight per plant (47.21%), dry weight per plant (47.49%) and percent moisture content (7.32%) in Stem amaranth and reduced the number of leaves per plant (48.51%), fresh weight per plant (27.79%), dry weight per plant (35.51%) and percent moisture content (8.42%) in Water spinach. The effects were recovered at a dilution level of 75%.

Uptake of N, P and S was reduced in raw effluent treated crops and the effects were recovered at a dilution level of 50%. Treatment with raw effluent reduced uptake of N to a level of 49.09% in RA, 36.81% in SA and 47.03% in WS; Phosphorous up to 47.89% in RA, 58.6% in SA and 59.86% in WS and S up to 53.8% in RA, 52.84% in SA and 37.93% in WS. Raw effluent treated plants accumulated reduced levels of Ni, Mn, Cr and Zn compared to the control treatment i.e. 54.88% reduction of Ni in RA, 81.36% in SA and 62.48% in WS; 50.17% Mn in RA, 50.44% in SA and 43.33% in WS; 60.69% Cr in RA, 74.43% in SA and 63.19% in WS and 33.09% Zn in RA, 46.6% in SA and 40.85% in WS. Environmental Impact Assessment (EIA) of the wastes and effluents released from the fish processing industries confirmed potential negative impacts on soil physical and chemical properties and water quality around the industries. It is evident from the results that untreated effluents released in the environment from different shrimp processing industries can have significant level of damaging effects on soil and water quality and crop production though some positive effects as well. The effluents analyzed for different physical, chemical and biological parameters showed presence of chemical species and substances that can have detrimental effects on soil biota and can change physical and chemical properties of soils. The effluents also showed to contain chemical species like N, P, S, OC, K^+, Na^+, Mg^{2+}, Ca^{2+}, Ni, Zn and Mn that can be a potential source of nutrients if applied as irrigation water after removal of unwanted toxic chemical species and reduction of salt contents. It is also noted that none of the industries of shrimp processing plants have ETP and they are not following the compliance of ECR-1997. The installation of ETP required to be enforced for all industries. Khulna is the most fish producing region in the country, and the surface water quality of this area is very important. If the surface water quality is affected, the production and quality of fish may also be affected and can have negative impacts on export and thus on our national revenue.

1. Introduction:

Dumping of solid and liquid wastes without treatment is a common practice and of great concern in Bangladesh. Most of the industries in Bangladesh do not follow the environmental compliance for ETP in their plants and release untreated wastes in the environment. There are 130 shrimp processing industries at present in Bangladesh of which 48 are located in and around Khulna city (Reza and Rahman, 2015). These industries are mainly involved in processing and packaging shrimps for exporting to the world market. Due to the nature of the industries, substantial quantity of solid wastes and effluents are generated during the process and disposed off in the nearby agricultural lands, rivers, canals, low lying areas, along road side ditches and water bodies. Ahsan *et al*. (2013) reported that about 1 ton of waste materials are produced by each of the industries per day and released in the environment without treatment causing foul odor, crop damages and soil and water quality deterioration in the surrounding areas. Fish processing activities involve production of large quantities of biodegradable solid organic wastes and by-products from inedible fish parts as well as effluents containing salts, fat-oil-grease (FOG), proteins, carbohydrates, suspended and dissolved solids, high levels of phosphates and nitrates, heavy metals and pathogenic and other micro flora (Vallini *et al*., 1989). These waste streams can have extremely high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) and if discharged without treatment into water bodies, the pollutants, it contains can cause oxygen depletion in the environment (Islam *et al*., 2004) and phytotoxicity (Reza and Rahman, 2015). Sulfides resulting from the fish processing have been proved to inhibit nitrification process (Bremner and Bundy, 1974). It is hypothesized that untreated wastes and effluents released in the environment from fish processing industries in and around Khulna city will have detrimental effects on receiving soils and water bodies. Crop production and crop quality is also expected to be affected. There are no systematic studies have yet been carried out in Khulna region to identify the nature of contaminants present in the wastes and effluents dumped and the impact on the environment. Systematic analysis of wastes and effluents for the identification of the pollutants and how these are affecting soil and water qualities and causing environmental quality degradation and crop damages deserve to be investigated.

General aims of the research work

- To generate information on fish processing activities, volume of waste and effluents generated and potential for polluting the environment and how these are affecting soil and water quality and thereby crop production
- To protect soils and crops from pollution damages, prevent economic loss and impacts on the livelihood of the people

Specific objectives of the research work

- To determine the nature and quantity of wastes generated from shrimp processing industries

- To identify type of pollutants including microbiological and metal pollutants in the wastes and effluents

- To determine the effects of soil and water quality levels on crop growth and yield and compare with unaffected soil of the same nature and to assess environmental impacts

2. Literature Review:

2.1. Shrimp Processing in Khulna region:

Shrimp is called the “White gold of Bangladesh”. Among the 11 shrimp species in Bangladesh four species are common and worth mentioning are *Macrobrachium rosenbergii* (the golda), *Metapenaeus monoceros* (the harina), *Penaeus indicus* (the chaka) and *Penaeus monodon* (the bagda) (Shafiqur Rahman *et al.,* 2010). Shrimp processing is almost exclusively concentrated in Khulna where as shrimp cultivation is mainly concentrated in four districts namely Satkhira, Khulna, Bagerhat and Cox’s Bazar (Nuruzzaman, 2006). Production area of Shrimps is shown in Fig. 2.1.

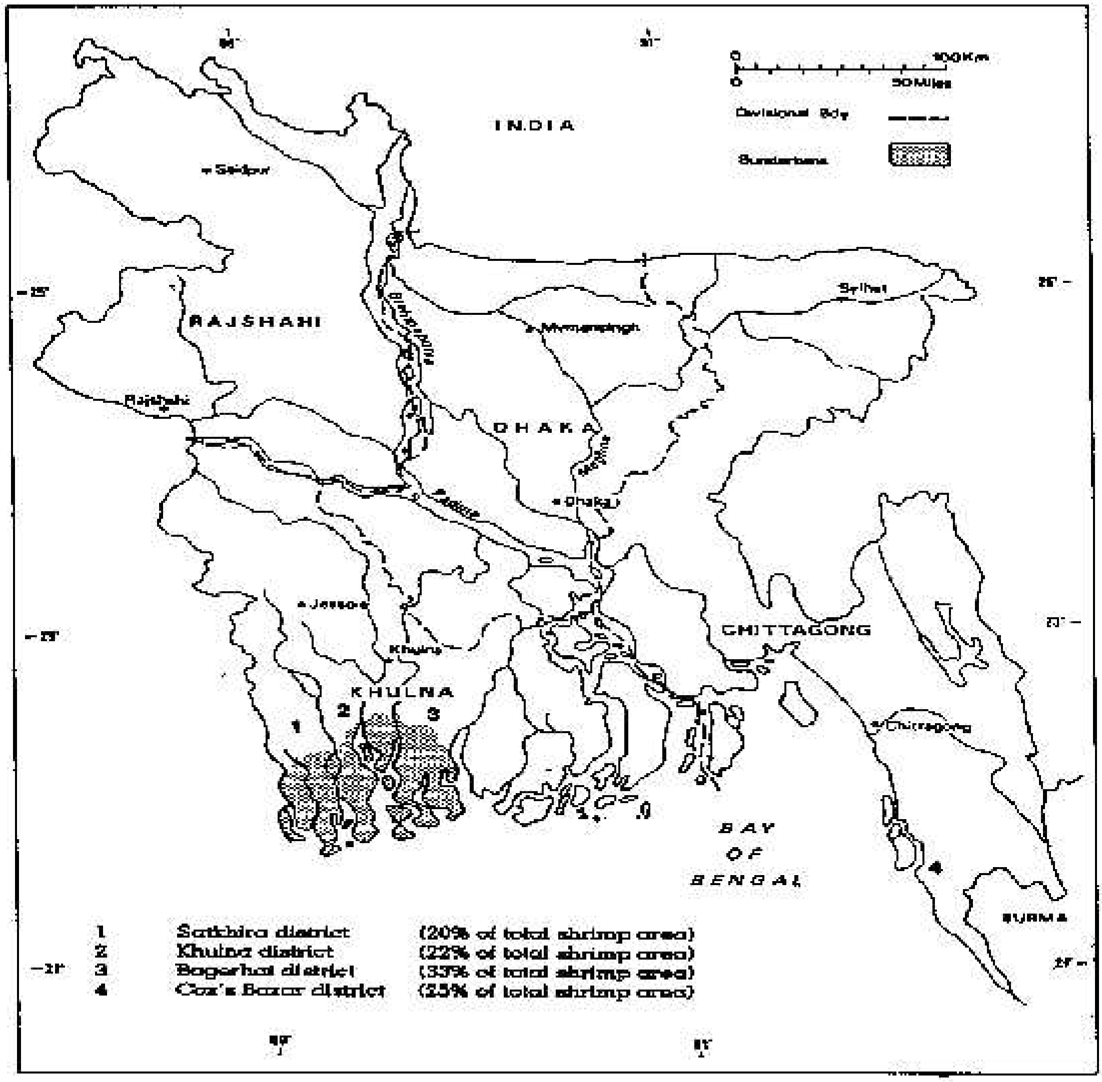


Fig. 2.1. Map of Bangladesh showing four major shrimp growing districts with their contribution of the total shrimp area.

Total production of shrimp in Bangladesh is 66,900 tones/ year (DOF, 2011) which is 2.5% of global production (Enamul Haque, 2011). 12% of export earnings come from Shrimp sector in Bangladesh (Hamid and Alauddin, 2013). Total production of shrimp in Khulna region is 41,400 tones/ year which is 62% of the total production of Bangladesh (DOF, 2011). 90% of the produced shrimp of khulna region is exported and rest 10% is consumed locally. Contribution of Fisheries of Bangladesh in GDP is 6% (BBS, 2010) and Contribution of Shrimp in GDP is 4.7% where as contribution of shrimp sector in Khulna in GDP is 2.91% (Aftabuzzaman, 2010). Seventy one percent solid waste and 68% effluent of the total shrimp waste and effluents are produced from Khulna region (Begum *et al.,* 2006b). Maximum Shrimp processing industries are discharging waste and effluent to the agricultural field, low lying area, canals, and road sides even in rivers (Salam and Billah, 2013). Information gathered so far confirm that Shrimp Processing Industries in Khulna are growing. There is also a potential for increasing shrimp production in Khulna region (up to 1200 Kg/ ha; Presently 250 Kg/ha) (Ahsan *et al.,* 2013). Fish processing involves transportation, processing, quality assurance and Packaging. This involves instrumental operations and use of a variety of chemicals (ASCC, 1995). We can't stop production and processing (for economic importance). It is also expected that generation of wastes and effluents will also increase to a similar extent with production and processing. As the literature reviewed so far, the wastes and effluents released from fish processing industries confirm presence of toxic metals, dye stuff, salts, FOG, DOC, soluble proteins, various types of pathogens and other materials that have significant negative impacts on the environment (Soil, water, crops etc.) (Vallini *et al*., 1989).

Table. 2.1. Expansion of Shrimp area in Bangladesh from 2003-2004 to 2009-10 (DOF, 2011) (NA= Not Available)

Year	Khulna Region (ha)	Chittagong Region (ha)	Total (ha)
2003-2004	104,624	29,792	137,996
2004-2005	110,000	30,000	140,000
2005-2006	NA	NA	NA
2006-2007	NA	NA	NA
2007-2008	107,962	29,792	14,353
2008-2009	136,655	30,118	166,377
2009-10	156,290	34,958	196,078
% new area	(+33%)	(+14%)	

The area used for shrimp cultivation, production of shrimp, earning from shrimp and % export earning from 1992-2011 are presented in fig 2.2, 2.3, 2.4, 2.5 (DOF, 2012).

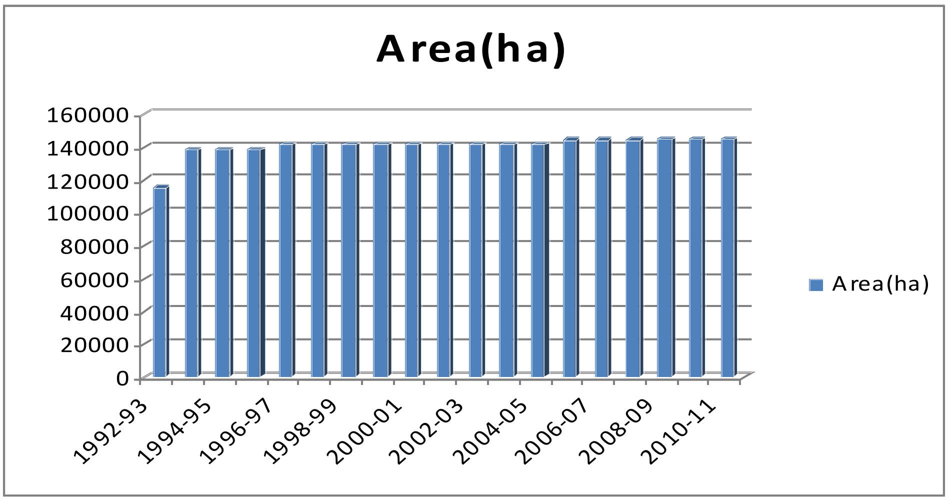


Fig. 2.2. Area used for shrimp culture.

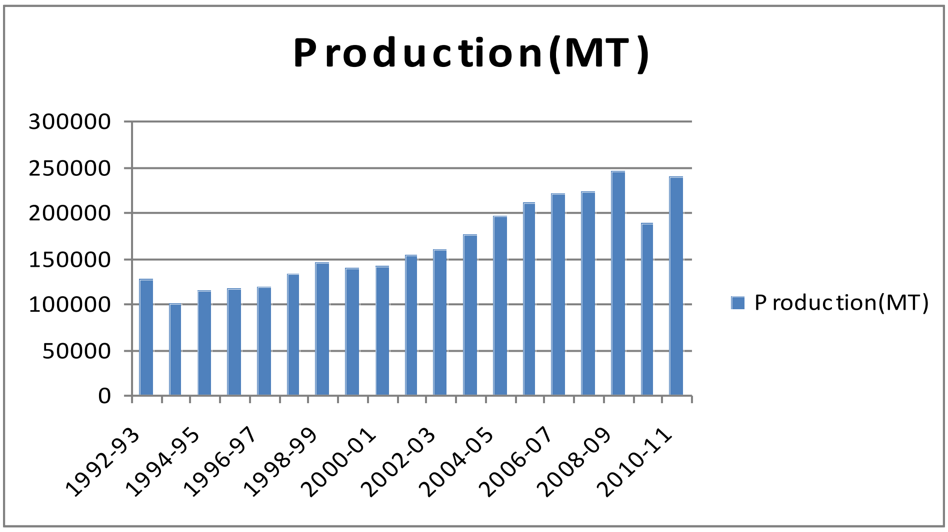


Fig 2.3. Total production of shrimps

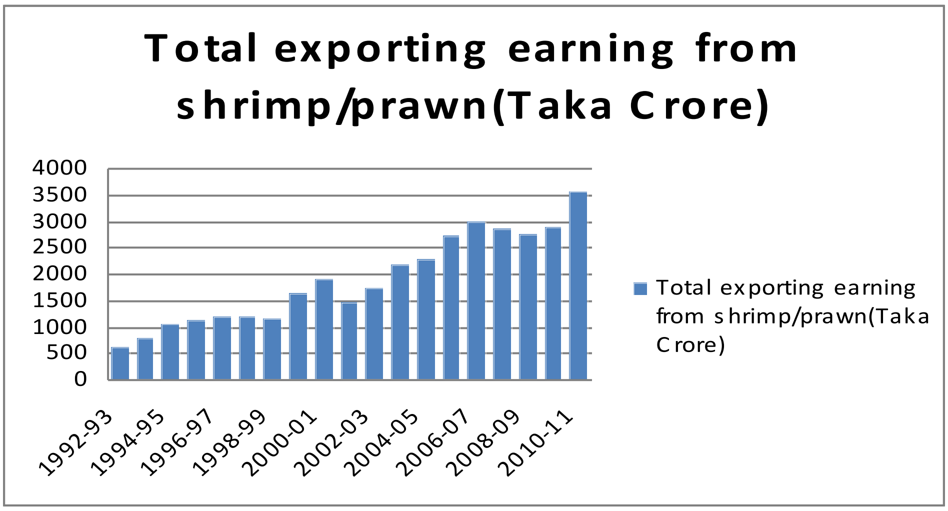


Fig. 2.4. Total export earnings from shrimp sector.

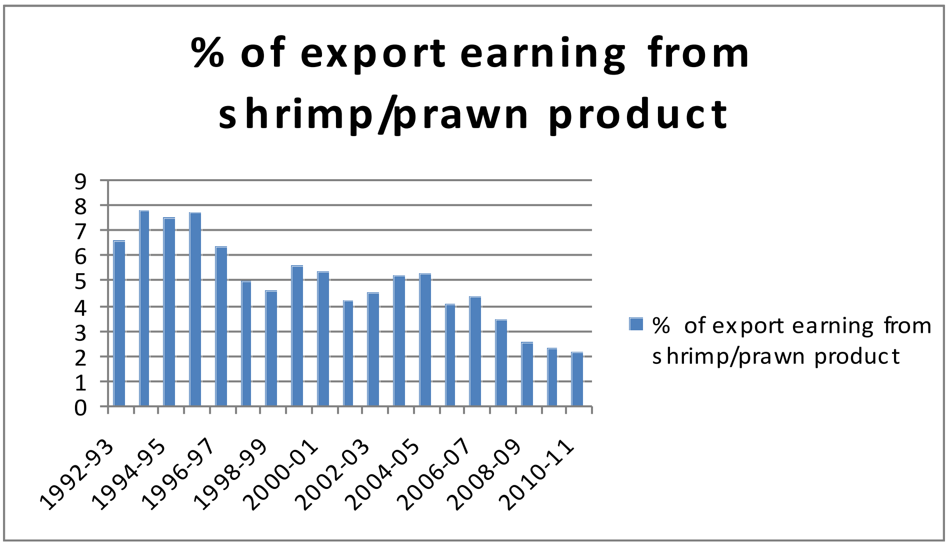


Fig. 2.5. % export from shrimp sector.

2.2. Climate and drainage system in Khulna region:

The mean monthly rainfall and temperature data of the study area from 2003-2012 (10 years) are presented in tables 2.2 and 2.3. The average rainfall in peak processing time is 296mm and in off-season is 48mm and temperature in peak processing time is 26.37°C and in off-season is 19.26°C respectively (Data obtained from Weather Observation Center, Gallamari, Khulna).

Table. 2.2. Monthly mean rainfall in mm during last 10 years in Khulna region (Weather observation center, Gallamari, Khulna)

Year	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
2012	66	18	1	52	63	255	391	254	374	89	80	2
2011	0	1	16	28	145	381	387	614	367	3	6	0
2010	0	2	14	21	146	287	180	205	157	332	0	13
2009	1	6	10	23	130	233	347	568	357	111	20	0
2008	66	36	48	36	151	190	301	202	379	187	0	0
2007	0	54	14	92	119	374	591	160	397	197	113	0
2006	0	0	5	19	230	262	522	364	579	79	1	0
2005	15	0	148	43	215	102	435	194	410	420	0	0
2004	0	0	7	85	180	383	253	266	621	183	0	0
2003	0	0	155	63	125	251	287	255	145	315	0	22
Average	15	12	42	46	151	272	370	308	379	192	22	04
Average	Off season 48mm				Peak period 296mm							

Table. 2.3. Monthly mean temperature in degree Celsius during last 10 years in Khulna region (Weather observation center, Gallamari, Khulna)

Year	**Month**											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
2012	14.32	15.57	21.99	24.34	26.4	27.71	26.67	26.66	26.51	23.62	19.06	13.71
2011	12	16.18	20.54	23.47	25.5	26.49	26.54	26.2	25.94	25.24	19.36	14.75
2010	11.89	16.57	23.38	26.87	25.93	26.61	26.97	27.03	26.45	24.96	21.05	14.31
2009	15.23	16.91	21.15	25.59	26	26.94	26.53	26.26	26.39	23.6	20.07	14.23
2008	13.84	15.26	22.4	24.5	25.34	26.21	26.3	26.61	26.21	23.8	19.65	16.39
2007	12.25	16.95	19.65	24.39	25.86	26.32	26.35	26.78	26.1	24.13	20.52	14.36
2006	12.82	18.81	21.09	24.93	25.67	26.87	26.39	26.01	26.02	24.89	20.09	15.04
2005	13.49	17.34	22.11	25.2	25.89	27.3	26.28	26.92	26.27	24.69	18.97	14.8
2004	13.19	15.66	21.85	24.94	26.15	26.19	26.43	26.49	26.25	23.7	18.61	15.76
2003	11.08	16.74	19.63	25.48	26	26.24	26.55	26.68	26.33	25.02	19.03	15.4
Average	13.02	16.60	21.34	24.97	25.87	26.69	26.50	26.56	26.24	24.37	19.64	14.88
Average	Off season 19.26°C				Peak period 26.37°C							

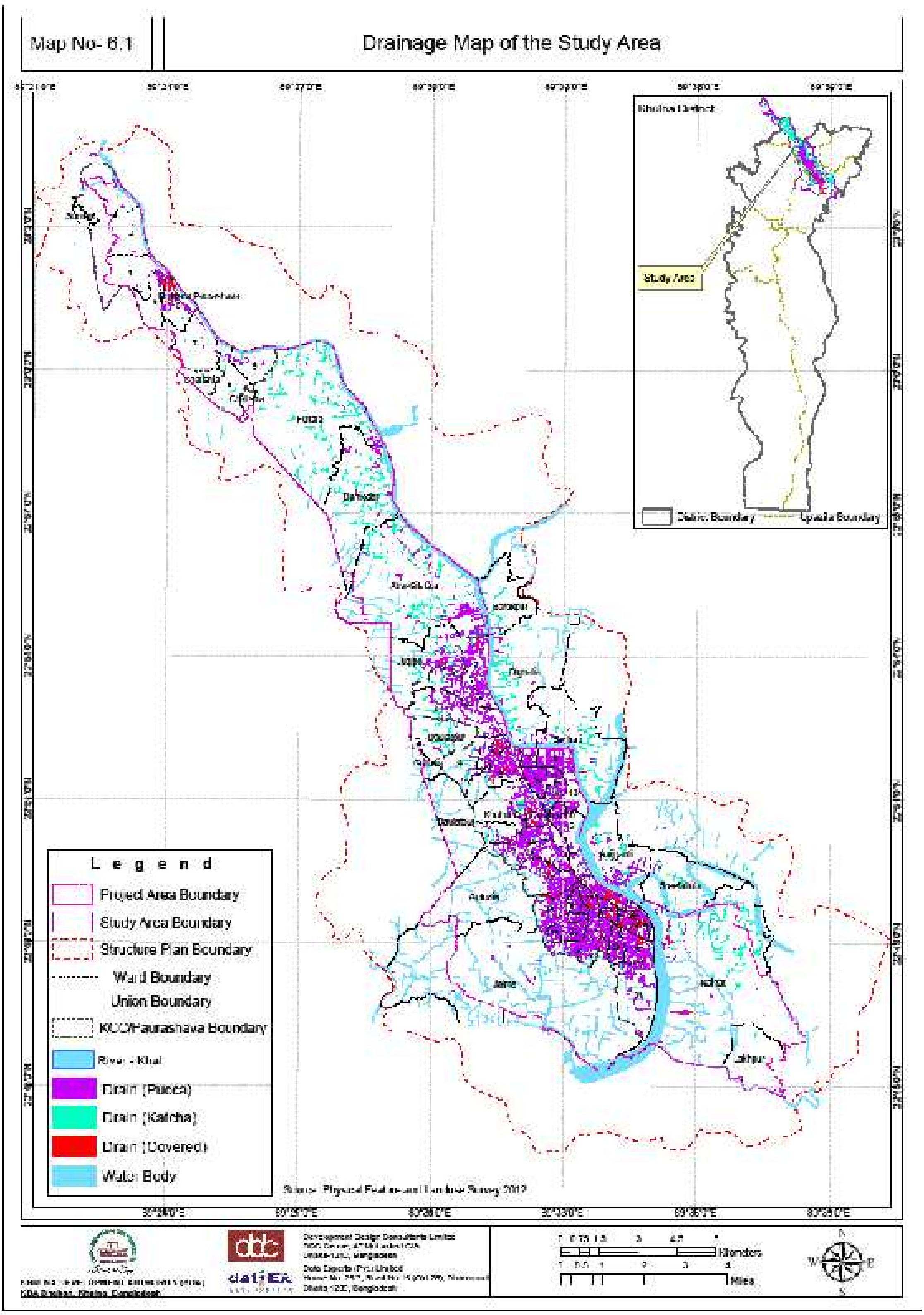


Fig. 2.6. Drainage system of Khulna region (KDA, 2012).

2.3. Prospects and problems of Shrimp sector in Khulna region:

Shrimps of Bangladesh are widely accepted for their freshness and pollution free production in maximum case (Shafiqur Rahman *et al.,* 2010). Bangladesh's coastal brackish water shrimp export sector has grown over the last thirty years in response to expanded global demand for high quality sea food and attempts by governments to diversify the economy (Pokrant *et al.,* 2002). Shrimp processing industry is one of the foreign currencies earning industry of the country which plays a vital role include women in economic sector. Bangladesh government declared shrimp farming as an industry under second five year plan (1985-90) and took necessary measures to develop shrimp production (Haque, 1994). On the contrary, now a days a great problem is observed in the exporting of shrimp in the foreign countries because in farias and depots some unethical trade practices like pushing foreign materials (shagu, juice of ladies finger, water etc.) in Khulna region (Daily Purbanchal, 2012). Temporary and unskilled labors are employed in shrimp industries (Funge-Smith and Stewart, 1994). Most of the workers undergo various physical, mental, social and professional insecurities which affects the production and processing of shrimps and ultimately on our economy (Rezaul Karim and Selina Ahmed, 2010).

2.4. Employment opportunities in shrimp sector in Khulna region:

Compared to other shrimp producing countries in the world for instance, Thailand, Vietnam, Srilanka, India etc. Bangladesh is far behind in its production, despite of the fact that the country has the potential for producing shrimp to similar extent with a further scope for employment and income generation and improved livelihood of the people in the region. Currently Bangladesh is producing 200-300kg shrimp per hector compare to 1200 kg per hector in the above mentioned countries. If the production of shrimp can be increased up to that level and the demand for shrimp in the world market goes up there will be a pressure in the fish processing industries and thereby an increasing production of solid and liquid wastes. If the untreated wastes and effluents released in the environment, as currently practiced will have significant negative impact, as no processing industries are following the compliance of ECR-1997 (Hamid and Alauddin, 2013). Twenty millions people are engaged in shrimp cultivation and shrimp processing and other backward linkages (DOF, 2011).

Shrimp farming supports a large number of associated industries, including input suppliers (hatchery operators, manufacturers and suppliers of feeds, equipment, chemicals, etc.) and families and businesses dealing with post harvest handling and processing, distribution, marketing and trade (Enamul Haque, 2011). The shrimp sector plays a dominant role in nutrition, employment and foreign exchange earnings. About 1.2 million people directly and 10 million people indirectly depend on fisheries for their livelihood. This figure is about 12% of the total population of the country (Choudhuri, 1993). The expanded shrimp plant operations ultimately require, at least 200 persons additional to the present complement, in the following categories: a) Processing plant workers-180 b) Technical Staff-10 and c) Security personnel-10 (BCAS, 2001). The training of personnel is done on the job in their respective areas/ roles. Technical staff associated with the processing plant will also be sent for training courses in country and overseas (Erdogdu *et al.,* 2001). The fisheries sector contributes over 5 per cent of gross domestic product (GDP) and about 5 per cent to foreign exchange earnings through export (BBS, 2004).

Table 2.4. Distribution of employment for different livelihood groups (Banks, 2002).

Livelihood groups	**Labour**	**% of total income**
Wild fry collectors	444,000	41
Wild fry faria	5176	49
Wild fry aratdar		62
Traders/faria selling wild fry to farms	1791	82
Hatcheries	1845	
Hatchery agents		
Traders/faria selling hatchery to farms		63
Shrimp farms/ producer	266,485	63
Shrimp traders/faria	5293	65
Small shrimp depots	4349	65
Large shrimp depots		90
Processing factories	**9780**	**80**
Commission agents	500	
Feed factories	230	
Transports		
Total	**741,449**	**66**

2.5. Processes/ steps employed in the shrimp processing industries in Khulna region.

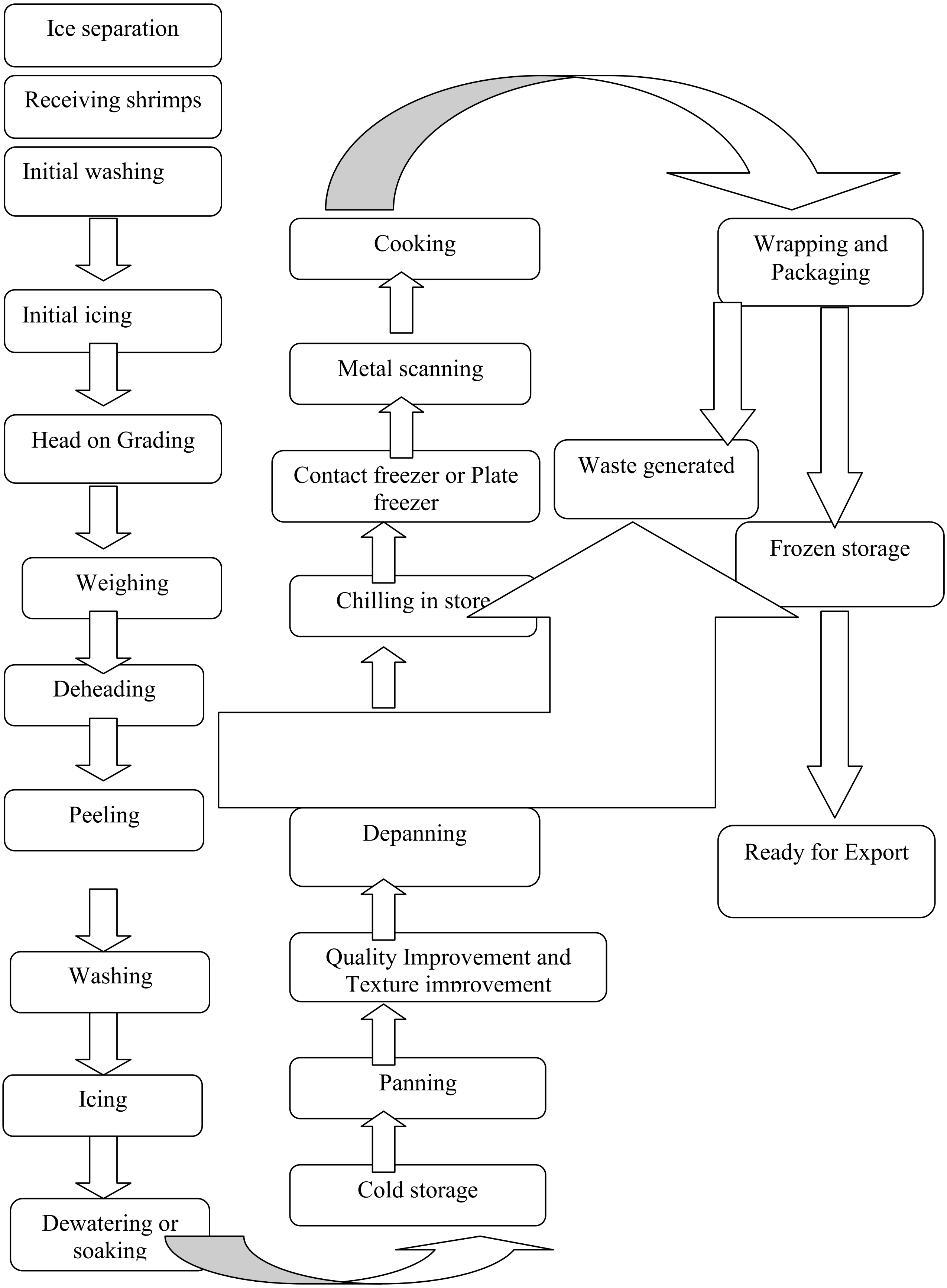


Fig 2.7. Flow chart of shrimp processing (Soeb Mahmud, 2007)

2.5.1. Transport and Processing:

Shrimps are transported to the industry through various channels and using road ways and navigation. Various types of vehicles like van, rickshaw, boat, engine driven boat, mini truck, truck, pick up etc. are normally used for shrimp transportation (Anisul Huq *et al.,* 2009).

Fig. 2.8. Transportation of shrimp to the processing industry through navigation

At the processing plant workers will de-vein, remove heads, wash and pack the shrimp in plastic lined boxes. The shrimp will be blast frozen (-40^0C), and stored under refrigeration (-20^0C) ready for loading and transport in refrigerated trucks for shipment. At full capacity, the new plant will process about 1,095 kg (2500 lbs) of shrimp per day or 400000kg (882,000 lbs) per year. The water used for washing the shrimp and scrubbing the tables will contain one tea spoon of household bleach to every five gallons of water. Plant operations will generate, on a daily basis, an undetermined volume of waste water, and about 360 kg waste heads (33% of total weight) and other solid waste. Waste wash-water will be collected in floor drains and discharged to a septic tank and absorption pit (Rabalais *et al.,* 1994). Processing includes de-heading and cleaning of the shrimps, freezing and packing, there are 130 processing factories in Bangladesh with a capacity for processing 825 tons per day. Of these, 35 are presently operational in Khulna (mostly located along the Rupsha River), 38 are operational in the Chittagong district and 57 plants have either closed down or are waiting approved for a quality inspection license. Khulna accounts for around 60-75% of the total production capacity (Enamul Huque, 2011). Only around 20% of the total factory capacity is utilized (PDO-ICZMP, 2002).

Fig. 2.9. Receiving and Grading of Shrimps

2.5.2. De-heading of shrimps:

De-heading is the part of cleaning process for exporting. After buying, de-heading is required for selling to commission agents or to final processing plants. Mainly local female labors are engaged in de-heading of shrimps and usually it is done at night. Usually 4-5 female labors work together for de-heading process. They clean and de-head 30-50 kg shrimp in a night. On an average, each of them earns taka 100-150 in one night as a labor wage at 3-4 Tk/Kg rate (Barmon *et al.,* 2011).

Fig. 2.10. De-heading of shrimps

2.5.3. Icing of shrimps:

Icing is a part of cleaning and preservation for selling to commission agents and final processors or exporters. Usually aratdar buy shrimps from farmers and faria with head. The shrimp keep in ice for 4-5 hours in plastic containers or big aluminium pots for easy and sophisticated de-heading. Aratdar finish buying process at the end of day, and keep the shrimps in to icing containers or pots at the evening time. The icing process occurs in every day in the peak time of shrimp harvesting. After icing, de-heading starts from 9-10pm and finish at the end of night (morning). In morning, aratdar send de-heading shrimps to commission agents for selling to final processors or exporters using light vehicles or van pullers (Barmon *et al.,* 2011).

Fig 2.11. Icing of Shrimps

Fig 2.12. Deicing of shrimps

Fig. 2.13. Dewatering of shrimps

Fig. 2.14. Chilling of Shrimps

2.5.4. Water Housing:

Ware housing is mainly used for shrimps packaging for exporting. Generally, two layer warehousing facilities are adopted in the factory. The first layer preserves semi or unprocessed shrimps in 5-10 kg packs and it keeps at -5^{0}C. The second layer is used for fully processed shrimp/prawn that is shipped to buyers after verification and this layer is kept at a temperature of between -12^{0}C to 20^{0}C (Barmon *et al.,* 2011).

Fig. 2.15. Water housing of shrimps

Fig. 2.16. Peeling of Shrimps

Fig. 2.17. Shrimps after Peeling

Fig. 2.18. Metal Detection of shrimps

Fig. 2.19. Cooking of shrimps (not mandatory for all industries, depends on buyer’s desire).

2.5.5. Packaging of shrimp:

Processors and exporters use manufactured carton, plastic packets and trays with customized labels for packaging. The quality and packaging style varies according to the requirements of the buyers and the price negotiated by the buyers. Exclusive and simple plastic packs or blocks are frequently used for shrimps packaging for exporting. Exclusive packaging is used for higher prices and simple plastic packs or blocks are used for lower international market prices of shrimps. Usually developed countries prefer simple packaging because disposal is expensive (Barmon *et al.,* 2011).

Fig. 2.20. Packaging of shrimps

2.5.6. Marketing channels of shrimps:

Once harvested, the flow of shrimps from gher to factory takes place within 24-36 hours. The post harvest trade flow goes from farmer to sub-depot to depot to agent to factory. All trade ultimately feeds through the agents who buy the entire product pre scale to the factory (PDO-ICZMP, 2002). Large depots may employ up to 25 farias (intermediaries) each purchasing directly from the farm gate. Farias generally trade with the smaller bagda farmers. Some larger scale farmers are able to by-pass the farias and supply direct to the 'depot' or even to the agent (10% of the total). There are no direct links between farmers and processing factories (less than 1 per cent) (PDO-ICZMP, 2002). Processors provide a commission to agents who compete for supplies at the depots. The agents subsequently use this finance as capital for lending (through the faria network to producers). One agent may deal with several factories. The market channel for shrimp's trade is presented in Fig. 2.21.

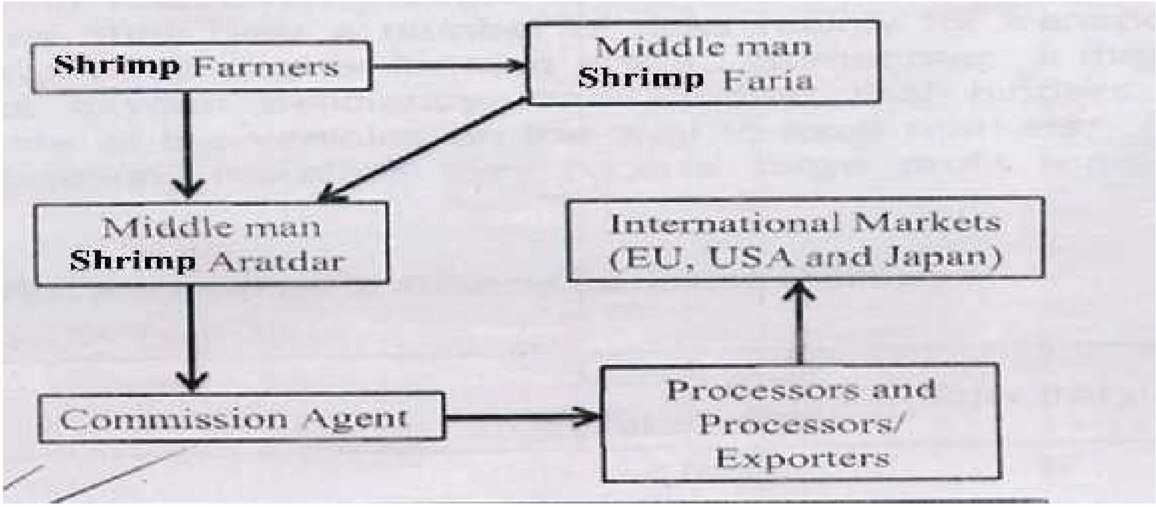


Fig 2.21. Marketing channel of shrimps from farmers to international markets

2.6. Chemicals commonly used in shrimp Processing industries in Khulna region and their necessities of use:

Table 2.5. The chemicals used in the shrimp processing industries (Martin *et al.,* 2002).

Steps	Chemicals used	Chemicals released
Use of brine solution and ice	Brine solution, NH3	Cl^{-}, Na^{+}, NH_3
Application of Caustic soda and lime for glazing	Caustic soda and lime	NaOH, Na, Ca, Mg, K, CO_3^{2-}
Washing and Chlorination	Bleaching powder, Chlorine	Ca, Cl
Cleaning of the tables and equipments	Soap, detergent, harpics, liquid soaps	Na, H-COOH
Deheading and Peeling		S, N, NO_3^{-}, SO_4^{2-}
Water housing/ Washing	Saline water, Chill water	$CaCO_3$, $CaCl_2$, $MgCO_3$, $MgCl_2$, NaCl, Na_2CO_3, $NaHCO_3$
Texture improving	STP, SMBP, STPP, SMBS, Sodium-di- phosphate	Na, P, S, Pb, Cd, Cr, Ni
Coloring the shrimp for good looking	Dye stuff (Neelikon Orange red dye) ($C_{16}H_{10}N_2Na_2O_7S_2$) and other dye	C, Na, S, Pb, Cd, Cr
Use of pesticides during shrimp preservation	Cholarmphenicol, Nitrofuran	Pb, Cd, Cr, Ni, Zn, Mn etc.
During Shrimp cum paddy culture	Residual Pesticides and Fertilizers	Pb, Zn, SO_4^{2-}, NH_3, N, Mn, PO_4^{2+}, K, Cl^{-}

2.6.1. Sodium tri-phosphate (STP) treatment:

Sodium tri-phosphate (STP) is important functional additives used in shrimp processing. STPs reduce shrimp losses and improve textural properties especially by increasing the water holding capacity of shrimp (Erdogdu *et al.* 2001). It is used to assure food safety is accompanied by changes in appearance, flavor, nutritive value and textural sensory attributes. The major changes occurring in shrimp during processing are shrinkage, toughening of tissues, releasing of shrimp flesh and color changes. Processing methods are even reported to affect these changes (Dreeling *et al.,* 2000). Water holding capacity decreases in shrimp during processing which is important economical considerations. Therefore, minimization of losses to a certain safety level would be desirable (Erdogdu *et al.,* 2001). Flesh losses, changes in textural properties are widely recognized as affecting consumer's satisfaction. Textural changes or texture is basically related to the physical characteristics that are experienced (Brady and Hunecke, 1985). Action mechanism of phosphates is based on the ionization of protein molecules, increasing the interaction between protein and water molecules due to increased pH and ionic strength, and reducing the interaction among the proteins (Cheftel *et al.,* 1985). STPs are usually most popular form of phosphates used in the shrimp industry (Steinhauer, 1983). Poly ionic character of STP enabling it to attach to positive sites on protein molecules to improve protein solubility and enhance water binding (Unal *et al.,* 2006).

2.6.2. Sodium tri poly phosphate (STPP):

Industrially, sodium tri polyphosphate (STPP) is prepared by heating and stoichiometric mixture of disodium phosphate (Na_2HPO_4) and monosodium phosphate (NaH_2PO_4) under carefully controlled conditions. $2Na_2HPO_4 + NaH_2PO_4 \rightarrow Na_5P_3O_{10} + 2H_2O$

STPP is mainly used in shrimp processing industries as preservative. Due to its physico-chemical properties, STP/STPP is not distributed or transported to the atmosphere, and thus is not expected to end up in soil via atmospheric deposition. Because it is very water soluble, it is not significantly transferred to sewage sludge, and therefore to soil by sludge spreading. As STPP is an inorganic substance, biodegradation studies are not applicable; However STPP can be hydrolyzed, finally to orthophosphate, which can be assimilated by algae and/ or by micro- organisms. STPP thus ends up being assimilated in to the natural phosphorus cycle.

Reliable published studies confirm biochemical understanding, showing that STPP is progressively hydrolyzed by biochemical activity in contract with waste waters and also in the natural aquatic environment (http://en.wikipedia.org/wiki/sodium_ triphosphate).

2.6.3. Sodium Meta bi Sulphate:

Sodium Meta bi Sulphate is widely used in shrimp processing industry to keep the shrimps freshness and as antiseptic. White or light yellow crystal powder, a strong smell of sulfur di oxide, relative density is 1.4, easy to dissolve in water and glycerin. It is used for antiseptic and germicide (for shrimp preservation, inhibitor and freshen agent for shrimps). Sodium Meta bi Sulfate creates acidity and solubility is increased with the increase of temperature and release as huge amount of sulfur and H_2S in soil and water body (Erdogdu *et al.* 2001).

2.7. Machineries Used in Shrimp Processing Industries:

Different machineries are used to process shrimp in the shrimp processing industries. The most common machineries are Compressor, Flake ice machine, Chill water machine, Generator, Plate Freezer, Blast Freezer, Boiler, Cold store, Ice store, Ice breaking Machine, Air Cooler, Reverse Osmosis Plant, Ozone generator to clear bacteria, UV treatment plant, Individual Quick Frozen Machine (IQF Machine), Metal Detector, Shrink wrapping machine, Soaking machine, Water pump and commercial Cook Machine etc. These machines are responsible for generation of heat, noise, foul odor which creates public nuisance and problematic for health (Barmon *et al.,* 2011).

Various machineries used in Shrimp Processing industries are shown below:

Fig 2.22. Receiver and Conveyor belt

Fig 2.23. Compressor

Fig 2.24. Flake ice machine

Fig 2.25. Chill water machine

Fig 2.26. Individual Quick Frozen Machine (IQF Machine)

Fig 2.27. Generator

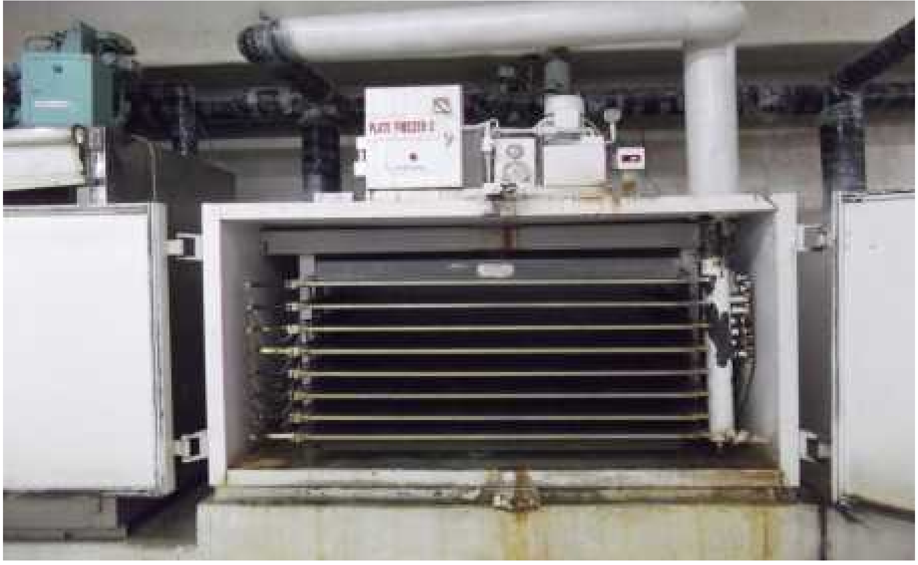


Fig 2.28. Plate Freezer

Fig 2.29. Blast Freezer

Fig 2.30. Boiler

Fig 2.31. Cold store

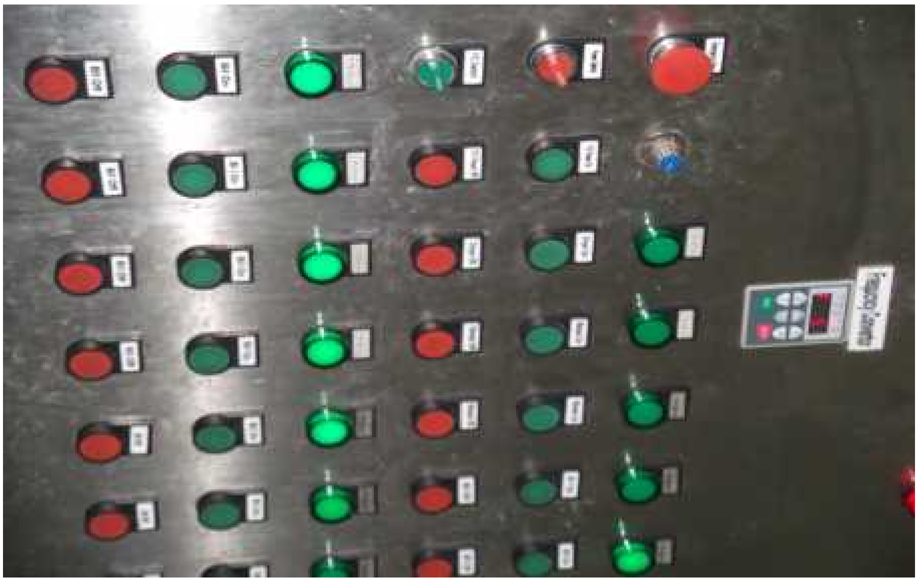


Fig 2.32. Frequency Counter

Fig 2.33. Ice store

- There are also some machines such as:

- Air Cooler
- Reverse Osmosis Plant
- Ozone generator to clear bacteria
- UV treatment plant
- Individual Quick Frozen Machine (IQF Machine)
- Metal Detector
- Shrink wrapping machine
- Soaking machine
- Water pump and;
- Commercial Cook Machine etc.

2.8. Shrimp processing waste load:

Shrimp processing processing plants generate heavy loads of wastes that are complex mixtures of many substances including fish and shrimp muscles, scales and shells, soluble proteins, fats and oils, partially decomposed organic matters, different chemical substances, pathogens, bacteria, viruses and other microflora, inorganic nutrients particularly nitrogen and phosphorus and many others. Total shrimp waste production in Khulna region is about 1, 14,000mt/year (Khan and Hossain, 1996). Most of the wastes generated are discharged into the nearby river through discharge channels and are potentially hazardous to the receiving environments. In most instances, the pollutants exceed the assimilative capacities of nearby coastal waters. Moreover, too many processing plants in one area will eventually overwhelm natural ecosystems nearby. Frequently unwanted fertilization causes eutrophication of coastal waters (Dzeizak, 1990). Some of the raw materials, such as dye, bleaching powder, STP, SMBP, STPP, SMBS, chlorine, ammonia, caustic soda, lime, brine solution, detergent, saline water, soluble protein and fat have to be removed during processing. Residual chemicals such as bleaching powder, STP, SMBP, STPP, SMBS, chlorine, ammonia, caustic soda, lime, brine solution, detergent, saline water etc. can contribute to the waste. Micro pollutants such as insecticides from raw shrimp are also of growing concern. Chemical analysis suggests that Shrimp Processing Industry wastes are characterized by color, high BOD, low pH and high dissolved salts (Ahsan *et al.,* 2013). The Shrimp Processing Industry in Bangladesh is expanding and creating environmental pollution. The quantity of liquid waste discharged from each Shrimp Processing Industry varies from 16700 L to 46500 L per day. Any shrimp processing industry in Rupsha Upazilla produce 5-7 metric tones waste and several thousand gallons of effluents per day (Ahsan *et al.,* 2013). During peeling process huge amount of shells are produced in shrimp processing industries because shrimp body is covered by a thick shell. Most of the shells contain the sulfur compounds. Shrimp industries have produced huge amount of shells every day as wastes. Sulfur compounds of these shells are bio-degradable and produce SO_2 and H_2S and acidity in soil and water micro environment (Cheftel *et al.,* 1985). The main inputs in a processing plant are whole fresh or iced shrimp, water, ice, Calcium hypo chloride and other chemicals. Packaging materials are a source of waste. Liquid soap and detergents used during cleaning. The outputs are the fresh chilled fillet exported or consumed, remaining fats, meat carcasses, and waste water specially from the filleting and trimming processes, small pieces of shrimp and protein heat from ice manufacture, chilling and the cold room.

The outputs of the processing industries usually contain a large bulk of waste products. Generally, the head, shell and tail portions of shrimp are removed during processing and these account for approximately 40% of the volume of raw materials (Stevens, 1981). Increasing production of inedible parts of shrimp such as heads, shells and tails is causing environmental problems as a result of uncontrolled dumping. The unloading, washing and separating ice, sorting, grading and receiving before shipping all constitute handling and sources of contamination from personnel (Steven, 1996). Waste from post harvest shrimp processing losses is defined as bio waste shrimps are normally sold headless and often peeled of the outer shell, thus the waste generated. About 30-45 per cent by weight, shrimp raw material is discarded as waste when processed shrimp is headless, shell on products. Peeling process involves removal of shell from shrimp/prawn, increase the total waste production up to 45 per cent (Subasshinghe, 1999). So, the fish parts head, shell, flesh, raw fish, damaged fish, tail, fat, shrimp fingers etc. and packaging materials like polythene, papers, plastics, cartons, polystyrenes, jute ropes, plastic ropes, scotch tape, labels, PP band and paper board are generated from shrimp processing industries.

Fig 2.34. Fats released from Shrimp Processing Industries

Over use of chemicals might be the cause of killing of many organisms and goes to the body of the shrimp and come out with the parts of shrimp which are thrown as waste from the shrimp processing industry (Anwer, S. M. 2003).

About 17,255 tones of shrimps were processed in different months in 1997 with a corresponding production of 6277 tones wastes through all seasons of a year. On average the waste bulk constituted 35 percent of the raw materials (Paez-Osuna *et al.,* 1998). The cleaning, separation and packaging of the shrimp processing industries have resulted in the generation of complex mix of solid organic materials and effluents which is presented in table 2.5. Jensen, 1965 estimated that 78-85 per cent of the shrimp is lost in the waste when mechanical peeling is used and shrimp processors dehead and discard a significant portion of the catch at ghers to minimize the degradation of product and to permit extension of fishing trips. Either saline or fresh water is used for processing, depending on the availability and quality of water at a plant location. Peelers are the biggest water users and waste generators in shrimp processing. About 60 per cent of plant effluent results from mechanical peeling (Costa, 1977). It is estimated that about 13,678mt year^{-1} of shrimp head is produced annually from the shrimp processing industries located in the Khulna region and a small portion of shrimp waste (*Macrobrachium rosenbergii*) is collected for sun drying by low-income consumers (Superno and Poernomo, 1992).

Table 2.6. Nutritional value of fresh shrimp/ fresh shrimp waste and dry shrimp/ dried shrimp wastes.

Nutritional items	fresh shrimp/ fresh shrimp waste	dry shrimp/ dried shrimp wastes
Moisture	77.4 gm/100gm	6gm/100gm
Mineral	1.7 gm/100gm	16.4gm/100gm
Fiber	Absent	Absent
Food energy	89 K Cal/100 gm	349 KCal/ 100gm
Protein	19.1 gm/100gm	68.1gm/100gm
Fat	1 gm/100gm	8.5 gm/100gm
Carbohydrate	0.8 gm/100gm	Absent
Calcium	323mg/100gm	4.38 gm/100gm
Ferrous	5.3mg/100gm	Absent
Vitamin-A	Absent	Absent
Vitamin-B_1	Absent	0.01mg /100gm
Vitamin-B_2	Absent	0.10 mg/100gm
Vitamin-C	Absent	Absent

(Source: Department of Nutrition and Food Science, Dhaka University, 1992)

Table 2.7. Effluent characteristics of shrimp processing industries (Michael *et al.,* 1980).

Parameter	(mgL^{-1})
Nitrogen (N)	77
Ammonium-N	1.4
Phosphorus	18
Chemical oxygen demand (COD)	790
Biochemical Oxygen Demand (BOD)	490
Suspended Solids (SS)	780
Total Organic Carbon (TOC)	220
Sulfur (S)	0.67
Chloride (Cl)	72
Fluoride (F)	0.35
Calcium (Ca)	105
Magnesium (Mg)	5.2
Sodium (Na)	65
Potassium (K)	9
Oil and grease	65
Copper (Cu)	0.056
Zinc (Zn)	0.080
Chromium (Cr)	0.017
Stontium (Sr)	0.24
Lead (Pb)	0.3
Cadmium (Cd)	0.026
pH	6.8
Conductivity µmhos/cm	590
SAR	1.7

2.9. Mode of dumping of shrimp processing wastes and effluents in Khulna region

The disposal routes of wastes and effluents of shrimp processing industries are presented in percent basis (Soeb Mahmud, 20007).

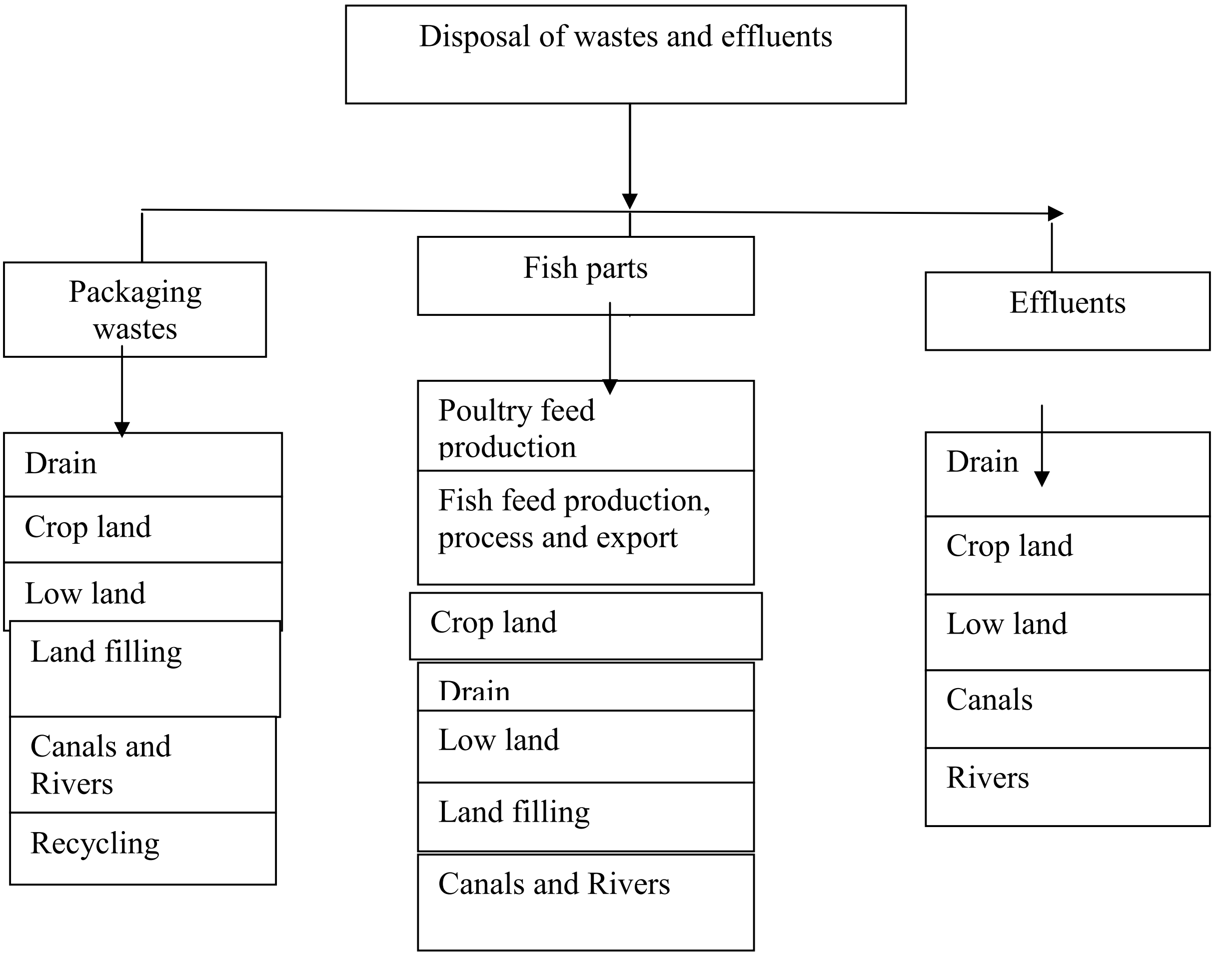


Fig. 2.35. Disposal routes of wastes and effluents of shrimp processing industries

Fig 2.36. Wastes are dumped on agricultural land

The heads are collected and sold for use as fish and poultry feed but a great portion is mixed with soil and water in the vicinity. The comprising waste water, organic particulars and toxic chemicals are discharged in open drains and ultimately find its way on to land surfaces and in natural waters in the vicinity without treatment. As a result, water, air, soil and food are getting continuously polluted (Ahsan *et al.,* 2013). A large amount of waste produced by this Shrimp Processing Industry is discharged in natural water bodies directly or indirectly through open drains, low lying areas, with a direct link to the Rupsha River, is polluted in such a degree that sometimes it has become unsuitable for public uses (Salam and Billah, 2013).

Types of solid wastes produced from shrimp processing industries are listed as:

A) Wastes from Packaging:

- Polythene
- Papers
- Plastics
- Cartons
- Polystyrenes
- Jute ropes
- Plastic ropes
- Scotch tape
- Labels
- PP band
- Paper board

B) Wastes from Fish body:

- Head
- Shell
- Flesh
- Raw fish
- Damaged fish
- Tail
- Fat
- Shrimp fingers etc.

Fig 2.37. Effluents are discharging to the river

The 70% of the depots dumped their waste materials to the nearest pond/ditch and remaining 30% depots dumped their waste to near drain (Anonymous, 2003). The 100% agents of Bagerhat district said that they didn’t treat their waste material before dumping and 40% agents dumped near ponds/ditches/canals where as 60% agents sold their waste materials (Shafiqur Rahman *et al.,* 2010). The owners of the shrimp processing plants said that they sold their 60% shrimp waste including shrimp head, shrimp shell while 40% waste materials were dumped near pond/ditches. Factory water contained chlorinated water, which disinfectants or destroys microbes, when it reaches into drain or canal it reduces microbes those microbes are responsible for spoiling the waste materials and 60 percent factory discharged their used water to near drain (Shafiqur Rahman *et al.,* 2010).

Fig 2.38. Effluents discharged to the land through pipeline

Fig 2.39. Wastes dumping site of Shrimp processing industries

2.10. Effluent Treatment Plant (ETP) facility in Khulna region:

The Shrimp Processing Industries are producing huge amount of wastes and effluents, we need to process the shrimps in controlled way, So, ETP is mandatory. According to ECA-1995 (Ammended-2010), under section 9, Where, due to incident, the discharge of any environmental pollutant occurs or activities or an accident is likely to occur in excess of the limit prescribed by the rules, the person responsible and the person of occupied of the place of occurrence or related organization shall take measures to control or mitigate the environmental pollution by installation of ETP. And under subsection 15A, where a person or a group of persons or the public suffers loss due to violation of a provision of this Act or the rules made there under or a direction issued under section7, the person, and group, public or on behalf of them the Director General may file a suit for compensation. According to the Environment Conservation Rules, 1997, the standard limits of the discharge of liquid waste and gaseous emission shall be determined in accordance with the standards specified in Schedules 9, 10 and 11, and the standards of the discharge or emission of wastes of various industrial units shall be determined in accordance with standards specified in Schedule -12. But from the survey it is clear that the shrimp processing industries of Khulna region are discharging huge amount of effluents without installation of ETP. Though some industries have water treatment plant but there was no ETP in any surveyed industries.

2.11. Physical and chemical properties of soil and water changed by waste generation and effluent discharge from Shrimp Processing Industries

2.11.1. Physical Properties:

2.11.1.1. Bulk density (Db):

Organic matter present in shrimp processing wastes lowers bulk density and there is a significant linear correlation between soil OM and bulk density. Increase of 1% to 6% OM, variation of bulk density from 1.5gcm^{-3} to 1.0 gcm^{-3} was found in sandy and loamy soil (Gupta *et al.,* 1977). Organic wastes added in soil enrich OM, porosity and soil volume and finally reduces bulk density because it is more porous in nature (Gupta, 1999).

2.11.1.2. Moisture Content:

Addition of wastes and organic residues to the soil increases soil moisture content and soil water retention at specific water potential. Increase in soil water retention in a sandy soil was attributed to the prevalent action of sludge organic matter (Gupta *et al.,* 1977) and the soil application of liquid sludge (30-60tons dry solids/ha) to a silt loam soil. Moisture content increases for using OM because it decreases evaporation rate and increase water absorption and porosity (Kelling *et al.,* 1977).

2.11.1.3. Color:

Dyes are used in processing industries to color shrimps and present it with appearance. One of the common used dyes is Neelikon orange red dye. Color of water is a good indicator about its quality. Pure water is colorless, odorless and transparent clear liquid. The presence of humic acids, fulvic acids, metallic ions, suspended matter, phytoplankton, weeds, dyes and industrial effluents may cause color in natural water (Gupta and Govindarajan, 2000). Water appears brownish to dark color due to the presence of OM. Humic acid impart yellow color (Chhabra, 1996). Presence of metal ions imparts the color of water and color should be removed to make for general and industrial use and to discharge it in to watercourses (Chopra and Kanwer, 1980).

2.11.1.4. Turbidity:

Suspended and colloidal matter such as clay, silt, fine organic and inorganic matter, plankton and microscopic organisms are responsible for turbidity (Lenore *et al.,* 1998). Turbidity restricts the light penetration in water and reduce primary production i.e. photosynthesis (Gupta and Govindarajan, 2000). The standard value of turbidity is 5NTU (WHO, 1993) and 10 NTU for Bangladesh (Ahmed and Rahman, 2000).

2.11.1.5. Temperature:

Temperature of water plays vital role in regulating the activities of cultured aquatic animals. The rate of chemical and biological reactions will be double for every 10^0 C increase in temperature. Aquatic organisms use twice dissolved oxygen and chemical reactions progress twice as fast at 30^0 C than 20^0 C but the optimum temperature is about 25-30^0 C (WHO, 1993). The optimum temperature for drinking and irrigation water ranges from 20 to 30^0C (DOE, 1991). The ideal water temperature for the culture of tropical fishes and shrimps is between 28 to 31 ^{0}C (NACA, 1995). The temperature of the soil and water contaminated by wastes and effluents of shrimp processing industries increases because of heavy machineries like compressor, flake ice, chill water machine, boiler, ice store, ice breaking machine, plate freezer, blast furnace, cold storage, generator, IQF plant etc. are used which produce heat and utilization of chemicals such as Sodium Meta bi Sulfate increase of temperature in soil and water body (Erdogdu *et al.* 2001) and also decrease for the use of ice and cheel water, as a result the temperature remain more or less than the optimum level. A rise in temperature accelerates chemical reactions, reduces solubility of gases, amplifies taste and odor, and even elevates metabolic activity of organisms (Gupta and Govindarajan, 2000). Temperature of the water quality parameters of the adjacent plant area to Rupsha river was measured as 23 to 27^0C (DOE, 2004) and adjacent to plant area to and about half km south of Rupsha river was found 28.57^0C (Begum *et al.,* 2006b).

2.11.1.6. Total Suspended Solids (TSS):

Constituents present in water sample in suspended form are called TSS. This consists of organic debris and humified matter. Most suspended solids can be removed from water by filtration. Water quality is deteriorated with the increase of TSS. TSS of shrimp processing effluents is 100-800mgL^{-1} (Carawan, 1991). TSS (780 mgL^{-1}) was found in the shrimp processing effluent in North Carolina (Michael *et al.,* 1980). The standard value of TSS in water for industrial use is 150mgL^{-1}, for irrigation use is 200mgL^{-1} and for drinking water is 5mgL^{-1} (ECR, 1997).

2.11.1.7. Total Dissolved Solids (TDS):

One of the most important parameters of water quality for drinking, industrial and irrigation use is Total Dissolved solids (TDS). TDS is the measure of the concentration of soluble salts in water samples. Organic and inorganic constituents present in water in dissolved form are called TDS. TDS is the sum of all the ions present in water and represents the total salt content of the water. Water containing TDS less than 1000mgL^{-1} could be considered as fresh water for irrigation uses and would not affect the osmotic pressure of soil solution (Todd, 2001). A sufficient quality of bicarbonate, sulfate and chloride of Ca^{2+}, Mg^{2+} and Na^{+}, caused high TDS values (Karanth, 1994). The quality of irrigation water on the basis of TDS is presented in table 2.8.

Table 2.8. Quality of irrigation water for TDS (Todd, 2001).

Water class	TDS (mgL^{-1})
Fresh water	0-1,000
Brackish water	1,000-10,000
Saline water	10,000-100,000
Brine	>100,000

2.11.2. Physico-chemical properties:

2.11.2.1. pH:

pH is a good indicator for quality soil, water and crop production and most plant grows well in neutral to slightly acid soil (6.5-7.5) and maximum plant nutrients become available and pH 7 at 25^{0} C representing absolute neutrality (Ramesh and Anbu, 1996). For soil acidity the concentration of H^{+} increases and replaces cations like Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} so soil becomes deficient of basic cations. In strong or very strong acidic soil Al, Fe, Mn and even heavy metals may exist in toxic quantities because of their excess solubility in acid. If available P is present in soil, the Al, Fe and Mn react with phosphorus to form insoluble phosphates and become unavailable for plants. Clay mineral formation and microbial activity can be affected by soil pH.

Table 2.9. Soil classification based on pH (Sodrul Amin, 1998)

Soil classes	Soil pH
Extremely acid	<4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.o
Very strongly alkaline	>9.0

Water supply and water treatment, e.g., acid base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control is pH dependent (Lenore *et al.,* 1998). The volume and characteristics of shrimp processing effluents often exhibit highly alkaline (pH-11) or highly acidic (pH-3.5) (Saeed *et al.,* 2003). The pH of the effluent from different steps of the shrimp processing ranged from 6.7 to 7.5 and therefore it is within acceptable limit (Michael *et al.,* 1980). Alkalinity of water, possible due to the presence of appreciable amount of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-} and HCO_3^{-} ions and irrigation water with a pH exceeded the normal range may cause nutritional imbalance or may contain toxic ions (Rao *et al.,* 1982).

Table 2.10: Guidelines for irrigation water quality on the basis of pH.

pH	Degree to Restriction on use
6.5-8.4	None
8.4-9.4	Slight to moderate
<5 and >9.5	Severe

Soils with a pH between 7 and 8.3 will promote microbial activity, but may limit P, Fe, Mn, Cu and Zn availability at toxic level and help to increase availability of these nutrients under alkaline conditions.

Soil pH determines the microbial community at rhyzosphere and vegetation above soil surface (Bennett, 1993). Decrease of soil pH is due to the production of organic acids during organic matter decomposition or by nitrification (Chen and Avenimelech, 1986). Increased soil pH occurred when waste materials are added to soil; other researchers noted a decrease in soil pH when waste materials are added to the soil (Silviera and Sommers, 1997). Sometimes pH is varied in the adjacent area of shrimp processing industries due to the application of lime in processing period (Boyd, 2008).

2.11.2.2. EC and Salinity:

The electrical conductivity (EC) of soil and water is an important indicator of salinity problem. The effluent of shrimp processing industries is basic in reaction and had high value for electrical conductivity (EC) (Saeed *et al.,* 2003). Soil degradation through salinization is exacerbated by the use of chemical fertilizers and pesticides in the shrimp ghers which comes to the shrimp processing wastes through water and fish parts (Zahurul Haque and Saifuzzaman, 1991). Shrimp processing industries are known to cause salinization, which can affect the productivity of surrounding croplands and it has a significant negative effect on paddy yield which can be minimized by rain water harvesting, application of appropriate chemicals and the maintenance and regulation of sluice gates during shrimp cultivation (Saeed *et al.,* 2003). EC less than 1 $dScm^{-1}$ indicates that soils are highly suitable for cultivation, whereas EC values between $3dScm^{-1}$ and $4dScm^{-1}$ indicates that soils will not produce an optimum yield. Soils with an EC value more than $4dScm^{-1}$ are designated as saline soils and need reclamation to restore them for cultivation (SANDEE, 2009). Salinity has a negative and statistically significant influence on paddy yield. It is found that a 1 per cent increase in EC produces a 0.063 per cent decrease in paddy yields because salinity is causing a decline in crop productivity (SANDEE, 2009). Higher salinity levels have reduced the land for grazing, consequently the scarcity of fodder has led to a reduction of livestock. Salinity problems affect agricultural productivity of the world because it restricts the nutrients uptake by the plants (Misra and Ahmed, 1987). Salinity in irrigation water reduces water availability to the crop so yield is affected (Ayers and Wescot, 1994). The high salinity in the surface soils of some profiles may be due to the upward movement of salt by capillary action (Hossain and Mc Conchie, 1994). On the basis of EC water class are given in the following table 2.13.

Table 2.11. Quality of irrigation water in respect of EC (Ayers and Wescot, 1994).

EC (dS/m)	Degree of Restriction of use
<0.7	None
0.7-3.0	Slight to moderate
>3.0	Severe

Ayers and Wescot (1994) also mentioned that the water having EC less than 0.2 dS/m is not considered as good quality for long term use because low EC causes adverse effect on the physical properties of soil.

2.11.2.3. Cation Exchange Capacity (CEC):

Soils contaminated by the effluents and wastes of shrimp processing industry contain high portion of OM which can significantly increase Cation Exchange Capacity (CEC) and finally improve soil because soil OM produce organic pools in soil which exchange exchangeable cations from soil solution by sorption mechanism (Dogbe, 2010). Increase in CEC results in additional cation binding sites which retain essential plant nutrients within the root zone. Possibly the CEC increase causes more complexing of heavy metals in an unavailable form for plant uptake (Kladivko and Nelson, 1979).

2.11.3. Chemical properties:

2.11.3.1. Organic Carbon and Organic matter:

The effluent from shrimp processing industries contains huge amount of OM, small particles of flesh, soluble proteins and carbohydrates (Mauldin and Szabo, 1974). Shrimp waste is the store house of OM so it could be used as agricultural purpose such as organic manure (Chandrkrachang *et al.,* 1991). Under humid and high temperature conditions decomposition of the shrimp waste occurs more rapidly because these contain protein, fat which are easily degraded, producing organic compounds (Superno and Poernomo, 1992). The excessive enrichment of organic carbon creates artificial Oxygen demand problem and release organic acids for lowering soil pH (Tan Kim, 1994).

Shrimp processing wastes contain huge amount of fats, flesh, carcasses, head, shell, tail, packaging material, ropes, labels, damaged fish, fingers, brain, muscles, scales, soluble proteins, oils, cartons, papers etc. which account 50% of the volume of raw materials and after decomposition produce the high load of OM in soil (Steven, 1996; Subasshighe, 1999). Michael (1980) analyzed the shrimp processing effluent and found 220 mgL^{-1} Organic carbon or 0.38% OM. Organic matter provides potential benefits including improving the fertility, structure, water holding capacity and reducing the amount of synthetic fertilizers needed for crop production (Blay *et al.,* 2002). It has positive effect on soil tilth, aeration, pH buffering, CEC and microbial activity (Bauer and Black, 1992). It is reported that irrigation, drainage, intensive cultivation and environmental settings decreased the soil OM (Umeda and Yamada, 1980).

2.11.3.2. Nitrogen (N):

The more important concern is that the untreated waste input high amount of nutrients, such as nitrogen which contribute to the eutrophication of coastal waters. This increase in primary productivity is one probable cause for persistent hypoxic zone during the summer months (Rabalais *et al,* 1994). Nutrients such as N may be present in quantities in excess of those necessary to promote suitable environmental conditions for biological treatment. NH_3-N was found in shrimp processing waste 802mg/l. Michael (1980) analyzed the shrimp processing effluent and found NO_3-N (7.7 mgL^{-1}) and NH_4^+-N (80.2 mgL^{-1}). So, shrimp processing effluent contains high portion of nitrogen. Land application of these wastes and effluents consider the soil assimilative capacity for the nitrogenous constituents (Carlile and Philips, 1976). Organic wastes dumping on soil mineralized and release Nitrogen. Nitrogenous fertilizers Urea, Ammonium sulfate etc. are used in shrimp cum paddy culture which is also a source of N in soil. Waste could provide significant N for crops but application at higher rates may be limited for salt content, or potential movement of NO_3-N in to ground water (Stomberg *et al.,* 1984). Lin and Nash (1996) estimated that 26% of the nitrogen applied as shrimp feed accumulated in the soils.

2.11.3.3. Phosphorous (P):

Like nitrogen, one of the important concerns is that the untreated waste and effluent input high amount of phosphorous which contributes to the eutrophication and crop loss. This increase in primary productivity is one probable cause for persistent hypoxic zone during the summer months (Rabalais *et al,* 1994). Waste and effluents of shrimp processing industries increase the phosphorous associated with the presence of high OM content and concentration of phosphorous is in hazardous condition in shrimp processing area (Bremner and Bundy, 1974). Michael *et al.,* 1980 found 18mgL^{-1} P in the shrimp processing waste water in North Carolina. Use of STP, SMBP, STPP, Sodium bi phosphate in the various steps of shrimp processing can enhance the availability of phosphorous in contaminated soil and water (Ahsan *et al.,* 2013). Use of fertilizer like TSP and pesticides like diazinon, parathion in the indigenous shrimp cum paddy culture land which come through the bioaccumulation of shrimp body or by using such water for washing release Phosphorus in the receiving soil and water. Discharge of wastewater may increase the phosphate level and stimulate the growth of photosynthetic aquatic micro- and macro organisms in nuisance quantities (Lenore *et al.,* 1998). Bhuiyan (1988) observed that the available phosphorus of different soil series of Bangladesh ranged from 2.2 to 14ppm. Organic matter increases the available P in soil as reported by Whalen *et al.,* 2000. Lin and Nash (1996) estimated 24% of the P applied as shrimp feed accumulated in soils.

2.11.3.4. Available Sulfur (S):

Solid waste and effluents of shrimp processing industries increase the Sulfur content in receiving soil and water which is associated with the presence of high OM content and for the use of SMBS**.** The concentration of sulfur is in hazardous condition in the contaminated soil and effluents of shrimp processing industries due to the use of H_2SO_4 and Sodium Meta bi Sulfate in the processing steps of shrimps (Ahsan *et al.,* 2013). A significant portion of sulfides contained in shrimp processing waste water might be converted to H_2S at pH below 8.5 to 9.0 and Sulfur compounds of the shells are biodegradable and produce SO_2 and H_2S (Cheftel *et al.,* 1985). The Sulfur contents of surface soil are higher than subsoil (Begum *et al.,* 2009). Bhuiyan (1988) stated that the mean value of available sulfur of different soils of Bangladesh is 16.8ppm.

Addition of organic matter improve sulfate from sulfur content depending on the composition and source of the organic matter (Cifuents and Lindemann, 1998). A high total Sulfur concentration in shrimp processing area contains iron pyrite, which oxidizes yielding excess acidity and soils with >0.75 ppm S are considered as acid sulfate soils (Boyd, 2008).

2.11.3.5. Sodium (Na):

The qualitative analysis of the effluent discharged from shrimp processing industries showed the presence of excess Sodium for the use of brines (Saeed *et al.,* 2003). If the sodium concentration is greater than 60% of the total cations then the water becomes unfit for irrigation. Recommended maximum concentration of Na^+ for long term irrigation is 40meqL^{-1} (Ayers and Wescot, 1994). Standard value Na^+ is 10meqL^{-1} for irrigation water and for drinking water is 40mgL^{-1} (WHO, 1993). High level of sodium to the soil might be due to the intensity of intrusion of tidal saline water periodically and permanently, and directly related with the time of inundation, and due to intensification of agriculture with saline water (Ahmed *et al.,* 1973). Michael *et al.,* 1980 found the sodium in the shrimp processing effluent was 65mgL^{-1} for the use of brine solution, saline water, STP, SMBP, STPP, SMBS, lime, caustic soda, liquid soap and detergents in the various steps of shrimp processing. As the proportion of exchangeable sodium increases, the soil tends to become more dispersed and puddle thereby causing poor aeration and water permeability becomes low. Most tree crops and other woody type perennial plants are particularly sensitive to low concentrations of sodium. Most annual crops are not so sensitive, but may be affected by higher concentrations. Sodium sensitive crops include deciduous fruits, nuts, citrus and beans. Excess of sodium causes deficiency of K^+ and scorching of leaf-tips in addition to determination in soil physical conditions (Chhabra, 1996).

2.11.3.6. Potassium (K):

Abdel and Hussain (2001) showed that significant effect of organic matter improving the exchangeable K in soil. Organic matter increases K availability in the soil because it contains higher CEC and reduces potassium losses in soil (Billah *et al.,* 2010). Potassium concentration in most drinking water is about 20 mgL^{-1} and brines contain more than 100 mgL^{-1} of potassium (Chhabra, 1996). Recommended maximum concentration of K^+ for long term irrigation use on all soils is 2meqL^{-1} (Ayers and Wescot, 1994).

K^+ values 0.271-0.36 meqL^{-1} indicates optimum and 0.181-0.27 meqL^{-1} indicate medium in water (Muslem *et al.,* 2005). According to WHO, 1993 the standard value of Potassium for drinking water is 12mgL^{-1}. Michael *et al.,* 1980 found the potassium in the shrimp processing waste water was 9mgL^{-1} for the use of brine solution and saline water in the various steps of shrimp processing. In plant, Potassium is an essential element for plants and associated with metabolism, protein synthesis by linking amino-acids but too high potassium content in soil induces iron chlorosis and magnesium deficiency (Boynton and Burrel, 1944).

2.11.3.7. Calcium (Ca):

Ahsan *et al.* (2013) analyzed contaminated soil samples of shrimp processing industries and found Ca^{2+} values ranged from 30.09-35.69 meq/100g of soil. Calcium concentration was found in the waste water discharged from shrimp processing industry was 105mgL^{-1} (Michael *et al.,* 1980). Excess Calcium comes to the shrimp processing waste water for the use of saline water, lime ($CaCO_3$), bleaching powder Ca(OCl)Cl, in the processing steps and use of TSP fertilizer in the Shrimp cum paddy culture. The permissible limit value of calcium for drinking water is 75mgL^{-1} (WHO, 1993). The contribution of Ca^{2+} content in water was largely dependent on the solubility of $CaCO_3$, $CaSO_4$ and rarely on $CaCl_2$ (Karanth, 1994). Irrigation water containing less than 20meqL^{-1} is suitable for irrigation crops (Ayers and Wescot, 1994). Salam and Billah (2013) analyzed some shrimp processing effluent samples and found Ca^{2+} values ranged from 3.6-5.6 meqL^{-1}. Organic substances improve available calcium content in soil. The solubility of calcium is increased through the effect of inorganic and organic acid produced as the result of the decomposing organic matter (Rosen and Bierman, 2005). Calcium is an important nutrient for plant growth and necessary for healthy fruits and flowers and Ca^{2+} regulates the enzyme activity for the absorption of other nutrients, proper cell formation, cell division, metabolic activity, and starch breakdown and nitrate uptake (Lenore *et al.,* 1998). The range >7.5meq/100g of soil Ca^{2++} indicated very high level of calcium (Muslem *et al.,* 2005). Excess calcium may cause deficiency in either magnesium or potassium in plants (Bennett and Linstedt, 1993).

2.11.3.8. Magnesium (Mg):

The solubility of Magnesium is increased through the effect of inorganic and organic acid produced as the result of the decomposing organic matter (Rosen *et al.,* 2005). The Mg^{2+} content of soils is variable, ranging from 0.1% in coarse sandy soils in humid regions to 4% in fine textured arid or semiarid soils formed from high Mg^{2+} containing parent material. The range >1.875 meq/100g of soil magnesium indicates very high level of magnesium (Muslem *et al.,* 2005). High concentration tolerated in plant; however, imbalance with calcium and potassium may reduce growth (Bennett and Linstedt, 1993). Ahsan *et al.*, (2013) analyzed some contaminated soil samples of shrimp processing industries and found Mg^{2+} values ranged from 3.69-5.83 meq/100g of soil. The qualitative analysis of waste water showed the presence of excess Magnesium was found in effluent discharged from shrimp processing plants (Saeed *et al.,* 2003). Magnesium concentration was found in the waste water discharged from shrimp processing industry was 5.2mgL^{-1} (Michael *et al.,* 1980). The common aqueous species is Mg^{2+}, important contributors to the hardness of water. Excess magnesium comes to the shrimp processing waste water due to the use of saline water, lime ($MgCO_3$) in the various steps of shrimp processing. The permissible limit value of magnesium for drinking water is 30mgL^{-1} (WHO, 1993). In high salinity waters magnesium ions are in much higher proportion than calcium ions. Owing to very high solubility, magnesium chloride is exceptionally toxic to plants (Gupta and Gupta, 1987). Irrigation water containing less than 5meqL^{-1} is suitable for irrigation crops (Ayers and Wescot, 1994). Salam and Billah (2013) analyzed some shrimp processing effluent samples and found Mg^{2+} values ranged from 0.8-2.0 meqL^{-1}.

2.11.3.9. Chloride (Cl^-):

Chloride (Cl^-) ion is one of the major inorganic anions in the effluents and wastes. The concentration of Cl^- is higher in the waste water discharged from Shrimp Processing Industries for its excess content of brine solution NaCl, KCl etc. Salts. The Chlorides of Ca, Mg, K and Na are very water soluble. The qualitative analysis of waste water showed the presence of excess chlorides (Saeed *et al.,* 2003). Chloride content in the Rupsha River located in the adjacent area to Shrimp Processing plants was found 432mgL^{-1} and 611mgL^{-1} during low and high tide respectively (Begum *et al.,* 2006b).

In the waste water discharged from shrimp processing plants in North Carolina contained 72mgL^{-1}of Cl$^-$ (Michael, R.1980). Most of the soil Cl$^-$ commonly exists as soluble salts such as NaCl, $CaCl_2$ and $MgCl_2$. Chloride acts as a catalyst in metabolic reactions such as photosynthesis, respiration and other enzymatic activities (Lenore *et al.,* 1998). Chloride sensitive plant may suffer when Cl$^-$ in the extract exceeds 5 to 10 meqL$^-$. Annual crops can however, absorb a relatively high concentration of Cl$^-$ before showing the specific toxicity symptoms (Salam and Billah, 2013) but fruit plants are particularly sensitive in the concentration of Cl$^-$ as low as 2 to 3 meqL$^-$, may cause leaf damage (Chhabra, 1996).

Table 2.12. Quality of irrigation water on the basis of Cl$^-$ concentration (Ayeres and Wescot, 1994).

Chloride (Cl$^-$) concentration (meqL$^-$)	Water quality class
4	Excellent water
4-7	Moderately good water
7-12	Slightly usable
12-20	Not suitable for irrigation
>20	Highly restricted for irrigation

2.11.3.10. Zinc (Zn):

Zinc (Zn) is used in a number of processes in shrimp processing industries for coloring of fishes by using dyes. Pesticides are used to preserve fishes and it is used in the shrimp cum paddy culture and fertilizer like ZnO and $ZnSO_4$ are also used which is a source of Zn in the shrimp processing wastes and effluents and ultimately in the soils and water of the adjacent area of Shrimp processing industries. Zn is an essential growth element for plants and animals but at elevated levels it is toxic to aquatic life and plants. According to FAO, standard level of Zn in irrigation water is 10mgL^{-1}. The U.S. EPA drinking water standard is 2mgL^{-1} (Lenore *et al.,* 1998). 2mgL^{-1} Zn in irrigation water for long term use and 10mgL^{-1} for short term use in toxic to many plants (Rowe and Faser, 1995). The availability of Zn decreases with increased soil pH. Zn forms stable complexes with soil OM components. High P availability can reduce Zn deficiency (Khan *et al.,* 1998). Zn concentration was found 0.08mgL^{-1} in the shrimp processing waste water (Michael *et al.,* 1980).

2.11.3.11. Manganese (Mn):

Manganese (Mn) is a common element and can be found everywhere. It is essential trace element but it is toxic when excess concentration is present in human body. After absorption in the human body Mn will be transported through blood to liver, the kidneys and damage them. It also affects our respiratory tract and brain, lung embolism and bronchitis may occur (WHO, 1993). The standard value of Mn concentration is 0.1mgL^{-1} for drinking water 0.2mgL^{-1} Mn for long term use and 10mgL^{-1} Mn for short term use in irrigation are toxic for a number of crops (ECR, 1997). From the use of pesticides in preservation of shrimps may increase the Mn concentration in the soil and water of the adjacent area of the shrimp processing industries.

2.11.3.12. Lead (Pb):

Pb concentration may increase in the soil and water of the contaminated sites of shrimp processing industries due to the use of pesticides for shrimp preservation, pesticides like Pb arsenate is used in the shrimp cum paddy culture and for the use of sea water in washing step of shrimp processing which contains Lead hydro carbonate $Pb_2(OH)_2CO_3$ and Tetra methyl lead $Pb(CH_3)_4$ (Jensen, 1965). It comes to the body by ingestion and toxic for us. The permissible limit value of Pb for soil is 100 ppm and for drinking water is 0.01 mgL^{-1} (WHO, 1993) and 0.05 mgL^{-1} for Bangladesh (Ahmed and Rahman, 2000). The adults are very much affected if more than 0.5 mgL$^{-1`}$ Pb enters in their body but the infants are affected by ingestion of only 0.25 mgL^{-1} Pb. Osteolysis, Hypertention, Spontaneous abortion, Anemia, Cancer, Kidney failure, Defected off spring, Brain damage, Pneumonia, Allergy, Asthma, Vomiting, Sperm damage and Memory loss are the results of consuming excess lead in body. Pb comes to human body 65% by food, 20% by water and 15% by air (FAO, 2002). Pb in irrigation water can inhibit plant cell growth at very high concentrations. Michael *et al.* (1980) found <0.3 mgL^{-1} of Pb in the shrimp processing effluents in North Carolina.

2.11.3.13. Cadmium (Cd):

Michael *et al.,* 1980 found 0.026mgL^{-1} Cd in the waste water discharged from the shrimp processing industries. Cadmium is not essential for plants and animals. It is extremely toxic and accumulates in the kidneys and liver and damages them.

FAO recommended maximum level of Cd for irrigation water is 0.05ppm. The U.S. EPA drinking water standard is 0.005 ppm (Lenore *et al.,* 1998). According to the ECR, 1997 the standard of Cd for drinking water is 0.005mgL^{-1}. Excess Cd can cause diarrhoea, stomach pains and severe vomiting, bone fracture, reproductive failure, brain damage, damage immune system, psychological disorders, DNA damage and cancer development (FAO, 2002).Long term use of Cd 0.01 mgL^{-1} and short term use of Cd 0.05 mgL^{-1} is toxic to beans, beets, turnips etc. (Rowe and Fraser, 1995).

2.11.3.14. Chromium (Cr):

Chromium compounds frequently are added to cooling water control in shrimp processing industries. Chromium is not essential for plants but essential trace element for animals. Chromium is carcinogenic and corrosive to tissue (FAO, 2002). Mortality and reproduction failure of earthworms Pheretima posthuma in common for exposed to Cr^{6+} (Soni and Abbasi, 1981). According to Rowe and Fraser (1995) long term use of Cr 0.1mgL^{-1} and short term use of Cr 1.0mgL^{-1} as irrigation water is toxic to plants. Drinking water standard of Cr is 0.1mgL^{-1} (Lenore *et al.,* 1998).

2.11.3.15. Nickel (Ni):

Industrial waste and effluents contain excess amount of nickel. The permissible limit value of nickel for drinking water is 0.1 mgL^{-1} and 0.02 mgL^{-1} long term uses and 2mgL^{-1} short term nickel use in irrigation water is toxic to a number of plants which toxicity is reduced at neutral or alkaline pH (Rowe and Fraser, 1995). Human gains Ni by breathing, drinking water or through food and it is dangerous for human health as a result lung cancer, nose cancer, prostate cancer, sickness, dizziness, lung embolism, respiratory failure, birth defects, asthma, allergy, skin rashes, heart disorder and bronchitis are prevalent in human being (FAO, 2002).

2.11.3.16. Biological Oxygen Demand (BOD):

Biological Oxygen Demand (BOD) is defined as the amount of Oxygen required for the microorganisms to stabilize biologically decomposable organic matter under aerobic condition. If more OM is present in water, more the biological oxygen demand (BOD) (Trivedi and Gurdeep, 1992). Michael *et al.,* 1980 characterized the effluent of shrimp processing industry and observed BOD 490mgL^{-1}, Steven (1996) found the BOD value 500-1550mgL^{-1} for shrimp processing effluents and Carawan (1991) reported a BOD of 1081mgL^{-1}. Saha (2001) analyzed the water samples of Rupsha River during high tide and low tide, which river is affected by shrimp processing wastes and effluents and found BOD 123mgL^{-1} during low tide and 165mgL^{-1} during high tide. The permissible limit value of BOD for drinking water is 0.2mgL^{-1}, 5mgL^{-1} for fisheries and irrigation and 100mgL^{-1} for industrial use (ECR, 1997).

2.11.3.17. Chemical oxygen demand (COD):

Chemical oxygen demand is the amount of O_2 required to decompose chemicals. COD of shrimp processing effluents is 1300-3250mgL^{-1} (Steven, 1981). Carawan (1991) reported COD of 2216mgL^{-1} in shrimp processing effluent. Michael *et al.* (1980) found 790mgL^{-1} COD in shrimp processing effluent. Rupsha River adjacent to shrimp processing area exhibits COD 232mgL^{-1} (Saha, 2001). Standards for drinking water for COD are 4mgL^{-1} (Ahmed and Rahman, 2000). Standard value for industrial use is 200-400mgL^{-1} (WHO, 2003).

2.11.3.18. Dissolved Oxygen (DO):

Waldon (1991) reported that untreated effluents from shrimp processing industries cause low Dissolved Oxygen (DO) concentration that violate the water quality standard for DO criterion. The DO values were recorded in the adjacent to shrimp processing plant area to Rupsha river were 4.34 (1988), 3.64 (1999), 3.50 (2000), 3.60 (2001), 3.8 (2002), 3.2 (2003) and 3.68 mgL^{-1} (2004) (DOE, 2004). The analysis for DO is a key test in water pollution and waste treatment process control (Lenore *et al.,* 1998). The acceptable limit of DO in water body is 4-6 mgL^{-1} (NACA, 1995). Furthermore, in ponds where DO concentration is very low, shrimp may die from lack of oxygen (Billah *et al.,* 2008).

2.11.3.19. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-):

Saeed *et al.* (2003) found very small amount of Carbonate (CO_3^{2-}) but relatively high amount of bicarbonate (HCO_3^-) in the shrimp processing effluent and the amount of bicarbonates was less than that of Calcium and Magnesium. Carbonate (CO_3^{2-}) as well as bicarbonates (HCO_3^-) is often present in sodic (alkali) water. Both Carbonate and bicarbonate are of importance because of their tendency to combine with and precipitate the divalent cations Ca^{2+} and Mg^{2+}. Carbonate containing water is strongly alkaline, but bicarbonate containing water is mild in nature. If the pH of water is less than 9, there should be essentially no carbonate reported. Whereas, the standard solution of sodium bicarbonate has pH of 8.4, those of sodium carbonate have pH as high as 12.0. Due to low solubility, appreciable amounts of carbonates and bicarbonates are found only in low salinity waters (EC <3 dSm^{-1}), although proportion of carbonate ions are much less than bicarbonate ions. When the concentration of carbonate ions increases to 5-10 $meqL^{-1}$, calcium ions are virtually eliminated. It is believed that absolute amounts of carbonate ions from 5-10 $meqL^{-1}$ may cause toxic effect to the plant growth (Gupta and Gupta, 1987).

Table 2.13. Quality of irrigation water in respect of HCO_3^- is given in the following table 2.22 (Ayers and Wescot, 1994).

HCO_3^- ($meqL^{-1}$)	Degree of restriction to use
<1.5	None
1.5-8.5	Slight to Moderate
>8.5	Severe

2.11.3.20. Sulfate (SO_4^{2-}):

There is excess Sulfate (SO_4^{2-}) in the effluent discharged from shrimp processing plants due to the decomposition of shells, tails and damaged body of the shrimp, use of chemicals like H_2SO_4 and Sodium Meta bi sulfate. Not only this, in the paddy cum shrimp culture fertilizer like $ZnSO_4$ and Pesticides like parathion, diazinon are used, which is a source of SO_4^{2-} via the shrimp body or by the direct use of that water in shrimp processing. Sulfate (SO_4^{2-}) concentrations are associated with the presence of high OM content and remain in hazardous level in shrimp processing effluent for rice (Islam, 1977).

A significant portion of the Sulfate (SO_4^{2-}) which remains in shrimp processing effluent might be converted to H_2S at pH below 8.5-9.0. Higher concentration of Sulfate can be lethal (EPA, 1974). According to the (WHO, 2003) guidelines the acceptable limit value of Sulfate (SO_4^{2-}) is 520mgL^{-1} for drinking purpose.

2.11.4. Biological properties of effluents:

Microbial contamination: Huge amount of water is used in shrimp processing plants to wash shrimp and for other processing purposes, which is a good source of microbial contamination (Anisul Huq *et al.,* 2009).

2.11.4.1. Total Coliform (TC):

Total coliforms are the measure of drinking water quality. The total coliforms are the group of bacteria that multiply at 37^{0}C. The thermo tolerant bacteria can grow at 44.2^{0}C temperature like *Escherichia coli.* Total coliforms belong to the genera *Escherichia, Citrobactor, Enterobactor and Klebsiella* (Fujioka *et al.,* 1999). The permissible limit value of total coliform is absent/ 100 ml in drinking water, 200 c.f.u for recreational activity, 5000 c.f.u for industrial use and 1000 c.f.u for irrigation use (ECR, 1997). Waterborne organisms are responsible for diarrhea and respiratory distress to heart disease (WHO, 1993).

2.11.4.2. Fecal Coliforms (FC):

Fecal coliform may originate from organically enriched water such as industrial effluents especially from shrimp processing industries. Of the thermo tolerant organisms only *E. Coli* is considered to be specially of faecal origin, being always present in the faeces of human, mammals, birds (Fujioka *et al.,* 1999). Overloaded and poorly functioning waste disposal with low flow of water can introduce huge fecal coliforms. Organic wastes discharged from shrimp processing industries to the surrounding area are full of these fecal coliforms. Low flow of water during dry period and dry area accelerates fecal coliforms population so fecal coliform is low in wet season due to dilution effect and small drop of human faeces contains millions of fecal coliforms bacteria (Fujioka *et al.,* 1999). The permissible limit value of fecal coliform is absent/ 100 ml in drinking water and 1000 c.f.u for irrigation use (ECR, 1997).

2.12. Potential Impacts of Shrimp Processing:

The world today is facing with three main problems: ever increasing human population, food shortage and environmental pollution. The last one is a serious problem in the developed countries while developing countries too have their share of it, through their increased rate of industrialization and uncontrolled discharge of pollutants in to the water and air etc. Shrimp processing industrial wastes and effluents contain various poisonous salts, alkalis, acids, odor, gases, heavy metals, insecticides and pesticides. These effluents and wastes are thrown in to the canals, streams or rivers where they deteriorate the water quality and unfit for use in irrigation and drinking purposes (Chadderton, 1988). Effluents which are thrown out relentlessly in to the environment causing eco disasters of varying types and magnitude. Therefore, it is imperative to assess the quality of various effluents and their effects on soils and vegetation (Ansari *et al.,* 2001).

Fig. 2.40. Solid wastes of Shrimp Processing Industries dumped on river side

The waste and effluents loads of shrimp processing industries have not been receiving enough attention, since long characterization of the shrimp processing effluent is particularly important not only for the protection of ecosystem but also the sustainability of the shrimp culture itself. Wastes are primarily organic in nature and therefore subject to bacterial decay which increases BOD and reduces DO and creates starvation of O2 for aquatic life (Boyd and Jasan clay, 1998). The countries 130 shrimp processing industries, mostly located in and around Khulna city, are releasing a large quantity of wastes and effluents during processing, causing a severe environmental pollution.

The pollution is seriously affecting the livelihood of some 10 million people in and around the Khulna city, which is on the brink of an environmental disaster. Disposal of these wastes into water course or on to land, with or without prior sedimentation, creates a great problem in the environment in the vicinity. So, it has become essential to treat the waste to a certain degree prior to its disposal. Experts say that despite the zero-pollution philosophy, advocated by some developed countries, a developing country like Bangladesh must depends on rapid industrialization in an endeavor to upgrade the standards of living. The Shrimp Processing Industry in Bangladesh is expanding and creating environmental pollution. The quantity of liquid waste discharged from each Shrimp Processing Industry varies from 16700 L to 46500 L per day (Ahsan *et al.,* 2013). The effluent, organic particulates and toxic chemicals are discharged in open drains and ultimately find its way on to land surfaces and in natural waters in the vicinity without treatment. As a result, water, air, soil, shelter and food are getting continuously polluted (Ahsan *et al.*, 2013). A large amount of waste produced by this shrimp processing industries are discharged in natural water bodies directly or indirectly through open drains, low lying areas, with a direct link to the Rupsha river, is polluted in such a degree that sometimes it has become unsuitable for public uses. In summer when the rate of decomposition is higher, serious air pollution is caused in the whole of Rupsha area, including a part of not too far high-class residential area, by producing intolerable obnoxious odors (Salam and Billah, 2013).

Table 2.14. Composition of the water of Rupsha river adjacent to the study area (DOE, 2004).

Parameter	Concentration
BOD	165ppm
DO	3.68ppm
COD	232ppm
Cl^-	611ppm
pH	7.7
Temperature	23 ◦C
%Salt	0.28%

Nutrients resulting from decaying organic matter enhance plant growth and excessive plant growth results in eutrophication. Partially decomposed processing effluents entering in water contains variety of harmful substances and pathogens. Yet, as nutrient levels increase so does the chance of algal bloom development, toxin production and corresponding decrease in dissolved oxygen and creates fish mortality (Bonsdorff *et al.,* 1997). Eutrophication has been shown to cause major changes in species composition, trophic structure and food web of benthic and fish community and function of aquatic animals over large areas (Riegman, 1995). Mass release of wastes and effluents loss of amenities affecting the recreational use of water (Rashid *et al.,* 2000). While processing plants where hampering the environment and aquatic ecosystem dumping the used water and shrimp waste materials directly to nature without treatment (Shafiqur Rahman *et al.,* 2010). For the increase of salinity and discharged effluent and use of chemicals affect ecosystems, and loss of biodiversity, declining production/ yield of rice and other crops and greater income polarization. It affects the sustainability of livelihoods and on the sustainability of rural communities (Alauddin and Tisdell, 1998).

Fig. 2.41. Soil seriously contaminated by the discharged effluents of Shrimp Processing Industries.

2.12.1. Effects on Agriculture:

Shrimp processing has other negative environmental impacts including deforestation, salinization of soil and water, depletion of wild shrimp and fish larvae stocks, water pollution and loss of agricultural lands (Common, 1988). The agricultural land has been degraded since the introduction of shrimp production and processing in Bangladesh. The excess salt of the effluent can exhibit many problems such as loss in crop production, fresh water crisis and related gastro-intestinal diseases, loss of green vegetables, fodder and reduce yield of rice (Chowdhury *et al.,* 2006). Yield of barley is also decreased (Watson *et al.,* 1958). Livelihood change experience focusing on the history of farmer's dislocations; loss of land, damage to crops and farmsteads, changes in livelihood and living standard, and accessibility to social capital resources, especially organizational, as alternative survival strategy (Zahurul Haque and Saifuzzaman, 1991).

Fig .2.42. Soil contaminated by wastes and effluents

The irony is that even when the water has been released, salt has spilled out in the surface land and vast areas have become unfit for any type of cultivation. This process hampers the microbiological system and decreases the soil fertility significantly (Anwer, S.M. 2003).

Fig .2.43. Agricultural land damaged by solid wastes of Shrimp Processing industry

2.12.2. Effects on Ecosystem:

Ecological effects of shrimp processing (eg. Loss of crops, nutrient enrichment and eutrophication, longevity of chemicals and toxicity to non-target species, development of antibiotic resistance, and introduction of exotic species are discussed in depth by Macintosh and Phillips, 1992. Environment can be degraded and the environmental problems associated with shrimp processing have been widely reported through out the period of 1990s. For the increased intrusion of salinity, agricultural land, especially rice fields are affected and degraded (Bhattacharya *et al.,* 1999). The untreated wastes generated from shrimp processing has impact on biodiversity, soil and marine species (Deb, 1997). In localities near shrimp processing industries, the run off, waste products, excessive amounts of salt, or drug and chemical by-products, threatens rivers, streams, soil and other fresh water sources (Primavera, 1993). Ecological effect of salt and acid destroys food resources, displaces biota, releases toxic levels of aluminium, precipitates iron and alters physical and chemical properties of water (Williams and Khan, 2002). The recent expansion of the shrimp processing industries is contributing to the degradation of ecosystems and how this affects rural communities in northwestern Mexico (Escutia, 1997). Stonich (1995) showed that the natural environment was affected and the livelihood of the population of rural Honduras was also affected. Drainage from the shrimp processing industries having a detrimental impact on organisms in lagoons and water bodies (Ramirez, 1999).

Feed and fertilizer, such as lime, cow dung, urea, TSP, oil cake and fish meal are used for shrimp cultivation. Some portion is absorbed by the body of the shrimp release with fish parts as waste and increase nutrients to the adjacent soil and water body (Riegman, 1995; PDO-ICZPM, 2002).

2.12.3. Occupational health hazards in Shrimp Processing Industries.

Various types of health risks including cold and fever, skin diseases, diarrhea, respiratory and reproductive tract infection are getting prevalent for workers of shrimp processing industries. Not only this, the health and insecurity of women has increased through the occurrences of kidnapping, rape, wage discrimination and other forms of female harassments (Rezaul Karim and Selina Ahmed, 2010). Sometimes the infected shrimps are brought in the processing plant and viruses, parasites etc. are discharged with effluents and make further problems for aquatic lives, plants and shrimp itself and it is also a major source of health hazards for human. Diseases causing micro organisms like bacteria, such as *E. coli 0157:H7*; protozoa, such as *Cryptospo radium* and *Giardia;* and viruses, such as *hepatitis A* are common (Briggs and Funge-Smith, 1994). Water borne organisms may cause diarrhea, respiratory distress, heart disease etc. Pathogens can cause chronic diseases, such as degenerative heart disease and stomach cancer. To combat diseases, shrimp traders use antibiotics drugs and chemicals in the processing plants and on the way of processing plants. Thirteen chemicals are used and they are dangerous to ingest and many are illegal for use. Antibiotics like *cholarmphenicol* and *nitrofuran* are banned because these are carcinogenic Excessive use of antibiotics breeds antibiotic-resistant bacteria like *Vibrio* bacteria which are responsible for food poisoning, cholera etc. Pesticides are used to kill off parasites and other organisms in shrimp processing industries. The chemicals come out with effluent which is potentially harmful for human consumption.

2.12.4. Effect of effluents of shrimp processing industries on plants:

The effluent contains toxic amounts of sodium and chloride (Saeed *et al.,* 2003). The possibility of toxic effects, which might determine the choice of crop, should be attributed to the presence of greater amount of chlorides in waste water. Higher contents of chlorides are dangerous for plant growth (Hayward *et al.,* 1946).

To investigate the effects of effluents of shrimp processing industries and its dilutions on seed germination and seedling growth and the result indicated that it was unfit for agriculture but reduced harms for dilution effect (Hayward and Wedleigh, 1949). Some concerning factors like source of pure water, irregular icing, improper handling and transportation were identified harmful effects on crop production (Shafiqur Rahman *et al.,* 2010). Excess salt content of the shrimp processing effluents reduces the uptake of essential plant nutrients by plants and affect its growth and yield especially yield of rice. As shrimp processing wastes and effluents contain essential nutrients, so, by minimizing salt concentration and heavy metals this can be used as fertilizer for better crop growth (Stevens, 1996).

2.13. Experiences of the local people of Khulna region on environmental quality degradation from Shrimp Processing Industries:

- A survey was conducted by asking a simple question like-Do you see any environmental problem around a fish processing industry in your locality?

The answers are summarized below

- Agricultural land, canal, river, farmer's land, low lying area, water bodies are polluting and soil and water quality are deteriorating
- Color of the soils and water is changing
- Various non biodegradable materials such as polythene, Scotch tape, plastic rope, cartons, Polystyrene, papers along with biodegradable solid wastes are dumped and causing aesthetic problems and public nuisance on the surrounding soil/ environment
- Producing foul odor from shrimp processing industries and air pollution
- The yield of rice and other crops are decreasing in surrounding areas
- Increase in weed propagation in crop fields
- Availability of fish and number of species are reducing in receiving water bodies
- Loss of biodiversity
- Irrigation water quality is deteriorating
- Receiving soils and water bodies are being affected by the chilled water released from the industries
- Workers are suffering from cold, fever, skin diseases, diarrhea, respiratory problems etc.
- Ammonia gas leakage
- Sound/ noise pollution

2.14. Management of the wastes of shrimp industries in Khulna region:

Waste management is beneficial to the environment but there are economic opportunities in modern waste management. These materials sorting facilities and composting operations to the development and production of value added products from diverted materials (Derm Flynn *et al.,* 2001). A range of business and employment opportunities in a country will be increased as a result of their waste management strategy. Many new jobs can be created in a country those directly associated with collection, hauling and sorting of waste materials (Rhoades and Bernstein, 1971).

Various waste management options adopted in Khulna region are discussed below:

2.14.1. In Feed-processing plant, for poultry industry and use in Fisheries:

Flesh, fats, shells, heads and legs which are the main elements of waste generated from shrimp processing industries are used as main raw materials along with other raw materials for poultry feeds usually; farmers gather the shells and legs of shrimp inside the roads and river/canal sides in Khulna region. At the end of the day they collect it and sell to the poultry feed factories, where these are processed and poultry feed is produced. Thus the problem of waste is converted to wealth and helps our economy from both side, one is - by reducing waste load and another is to develop our poultry farms to supply protein to the living being. If the heavy metals and toxic substances are in permissible limit, the waste can be used for fishery especially in further shrimp production by proper treatment (Barmon *et. al.,* 2011). When all pathogens, heavy metals and toxic substances are completely removed from fish body then these fishes can be used for eat and sell in the market to earn money which can contribute in economy (Billah, 2010). The wastes generated from shrimp processing industries of Khulna region are reused to produce feed for shrimp production. A number of agro-based industries have been established for making an artificial feeds for shrimp/prawn production. For example, shells, heads and legs of shrimp/ prawn are used as main raw materials for feed meals of shrimp/ prawn production (Barmon *et. al.,* 2011).

2.14.2. Land Filling:

Wastes of Shrimp processing industries are successfully use in land fills in Khulna region. Removing organic materials from land fills through composting would reduce the potential for leachate production, gas formation, gulls and other pests. Land fills may be less expensive than incinerators to build and operate (Michael *et al.,* 1980). Wastes can be used to fill up the low land but where it is exercised the surround air becomes polluted and foul smell prevails there. Chemicals, pathogens and toxic substances including heavy metals present in waste pollute the soil and water in vicinity and pollute the ground water by leaching, so, by minimizing these it can be used for land filling (Billah, 2010).

Fig: Landfill

Fig. 2.44. Waste management by land filling

2.14.3. Screening:

The pollutants of Shrimp Processing Industries wastes are of organic, inorganic and toxic and require elaborate treatment before disposal to prevent physical, chemical and biological pollution of the receiving body of water. The Shrimp Processing Industrial waste with high concentration of dissolved solids, suspended solids, chlorides, dyes, ammonia etc. are being discharged every day in the receiving water and soil. A clean technology can overcome environmental pollution physical, chemical and biological cleaning methods.

Physical treatments include mainly screening and primary sedimentation, the only treatment which is provided in most of the Shrimp Processing Industries in Bangladesh. Screens are required to remove fleshing, fats, tails, legs and floating substances. A continuous flow sedimentation tank designed on maximum of suspended solids. However, in most of the Shrimp Processing Industries, the fill and draw sedimentation tanks are not used in Bangladesh. No appreciable reduction of Dissolved Solids, BOD, COD, Colour, Chlorides can be achieved in the physical treatment process (Salam and Billah, 2013). Screening reduced the BOD load from processing operations by 38% (Carawan, 1991).

2.15. Management options practices in different countries may be introduced in Khulna region:

2.15.1. Awareness and Training:

It is to provide training to the people related to the shrimp processing which make them aware of the risk of shrimp processing industries, create meaningful liaison with the processing plants and reduce inefficiencies in production, so, it is suggested that a dialogue may be initiated and also include developing a common policy prescription for the industry to make it environmentally sustainable (Enamul Hoque, 2011).

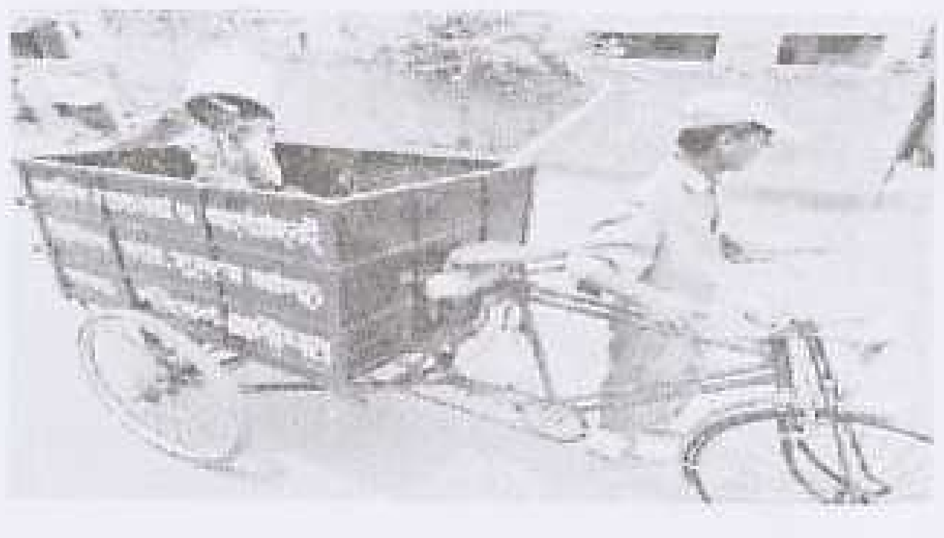


Figure 4.6.3.3 Van collection system

Fig. 2.45. Van collection system of wastes

2.15.2. Source separation and waste diversion:

The industries should separate various wastes from the source and used for various purposes. Waste diversion removes materials from the waste stream. Typically, waste diversion includes waste reduction, re-use and recycling, composting and waste exchanges. At first step in waste diversion is taken by separating recyclables at source (Derm Flynn *et al.,* 2001).

The waste producers should separate their wastes such as fats, head and tail, cartoons, Polystyrenes, papers etc. and separate bins are transported to the related factories to produce new things by recycling for further use and biodegradable wastes will be used for compost production, ultimately the total volume of wastes will be reduced and the problem of waste will be converted to wealth (Widarto, 1989).

2.15.3. Recycling:

Shrimp waste could be processed in drying for recycle use such as shrimp meal, fishmeal, poultry meal; shrimp meal etc (Ariyani, 1989). Shrimp meal is valuable in tropical fish, poultry and bird diets where properties or pigment enhancement are of greater importance (Meyers, 1986). A number of materials that could be recycled including polystyrenes, papers, polythene, plastics etc. Polystyrenes are used to carry shrimps to the processing industries. After receiving shrimps polystyrenes, are dumped as waste which can be separated, transported to the Polystyrenes industry to recycle and huge amount of paper is used for packaging which comes out as waste can be separated and transported to the paper industry for further use (Widarto, 1989). Polythene and plastics can be recycled in plastic industry to reduce volume of waste and for further use (Derm Flynn *et al.,* 2001). Wastes can be processed for prepare fish meal for producing fish and shrimp and poultry feed for poultry industry and fat portion can be used for making soap and detergents (Derm Flynn *et al.,* 2001). The vegetative part of the waste can be recycled for produce compost (Billah, 2010).

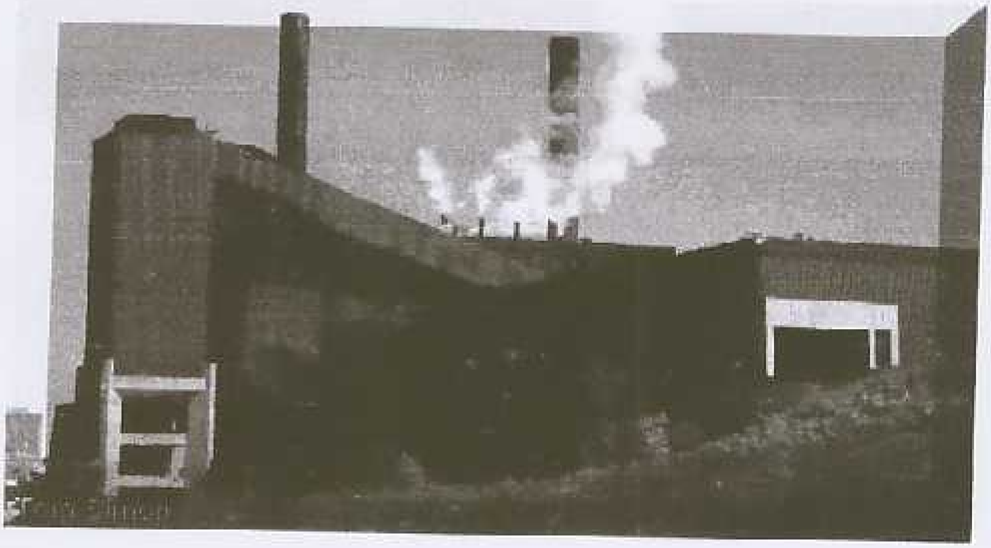


Fig: Recycling of solid wastes

Fig. 2.46. Recycling of solid wastes

2.15.4. Composting and use in Agriculture:

Composting at the shrimp processing industries at greater scale was suggested frequently during waste management, as a strategy for both removing a large volume of waste from disposal and turning waste into a useful product. Organic material makes up approximately 65 per cent of shrimp processing waste (Begum *et al.,* 2006a). Corporate or government subsidized programs for composting is suggested with the large scale commercial composting only possible in major population centers. There are markets for selling and using compost through gardeners, agricultural farms, shrimp cultivation ponds, municipalities and nursery (EJF, 2003). This can reduce volume of waste and as a source of income and it can be used for increasing agricultural products and yield. Organic matter, organic manure, compost, humus etc. are produced from waste which can be applied in the agriculture to meet the nutrient demand of plants because this waste contains a plenty of organic matter, phosphorous, nitrogen, calcium, magnesium, sulfur etc (Derm Flynn *et al.,* 2001). As this waste contains a very limited amount of heavy metal and huge amount of salts, pathogenic bacteria and fungus so this must be avoided to apply in the agricultural field where raw vegetables like lettuce, kherai, chili, cucumber etc. are produced because the people who will take these as food may be affected by heavy metals and pathogenic bacteria. This type of waste can be used in agriculture when it doesn't exceed the permissible limit value of heavy metals, toxic substances and pathogens.

After separating heavy metals it can be used in agriculture in those fields where long duration crops like rice, maize, wheat etc are produced because the toxic substances and pathogens will be removed in this long duration till harvesting of the crops. Not only this, it can be used in forest without treatment because it supplies nitrogen and act as organic manure for the woody plants of the forest (Stevens, 1996). The plants of the forests are mainly used for wood, not for food so the heavy metals, toxic substances and pathogens can't be come to our food chain. Normally wood plants grow in 20 or 30 years so for the passing of this long period the toxic substances, heavy metals and pathogens will be removed and can't do any harm for the timber plants of the forests (Islam *et al.,* 2004).

Figure: Barrel Type Composting System;

Fig. 2.47. Composting of wastes in a barrel

2.15.5. Incineration:

After recycling and composting have been maximized incineration can be considered. Modern incinerators are extremely costly to build and operate, and there is an ongoing cost of meeting the ever increasing regulations. However, there was also the suggestion that we should have open minds about new technology (Derm Flynn *et al.,* 2001). Incineration is such type of waste management system where the wastes are burnt in scientific way where a long and high device is made of bricks or steel.

Wastes are thrown over the holler by the help of crane and during falling waste pass a long distance and moisture is vaporized because fire avails with high temperature in the bottom. As the device is very long so the harmful gases produced from shrimp waste burning goes to the upper atmosphere and responsible for air pollution but not create so harm to the people of the vicinity of the incinerator so it is suggested to set up an incinerator in an uninhabited land. Very small amount of ash is produced from the incinerator and this is collected and disposed in the sea or in land filling (Derm Flynn *et al.,* 2001).

2.15.6. Sun drier:

The collected shrimp parts are dried through traditional sun drying in open place under humid and high temperature, decomposition occurs more rapidly because these contain protein, fat which are easily degraded, producing organic compound (Superno and Poernomo, 1992).

Fig. 2.48. A solar dryer

2.15.6.1. Technique of solar drying:

The dryer base made of steel plate is about 5 feet length and 2.5 feet wide with a height of 2.5 feet. These sheets is placed and tied with bamboo pole and height of the drier from ground is about 3.5 feet (Fig. 2.50). In solar drying method, polythene is used as dryer roof acts as insulator and the dryer base is black colored which retain and increase the internal temperature. Solar drier can increase the temperature almost double and very efficient to dry.

In addition it can be a very appreciable technique to dry shrimp waste regarding the weather constraint shrimp waste is degradable in high temperature and humidity (Begum *et al.,* 2006a). The traditional open sun method does not change the temperature and depends upon the air temperature, the trial begin (at 7:00am) with 28^0 C and reached the highest 32^0 C after 8 hour. In night the temperature gradually decreased to 29^0 C and again increases up to next 32 h about 31^0 C. While internal temperature of solar drier show increase steadily from 28^0 C to 44^0 C during the first 8 h then follow by a decrease rate up to 24 h and increase in the next 32 h and temperature change followed almost nearly of first 24 h (Begum *et al.,* 2006a) (Fig 2.51).

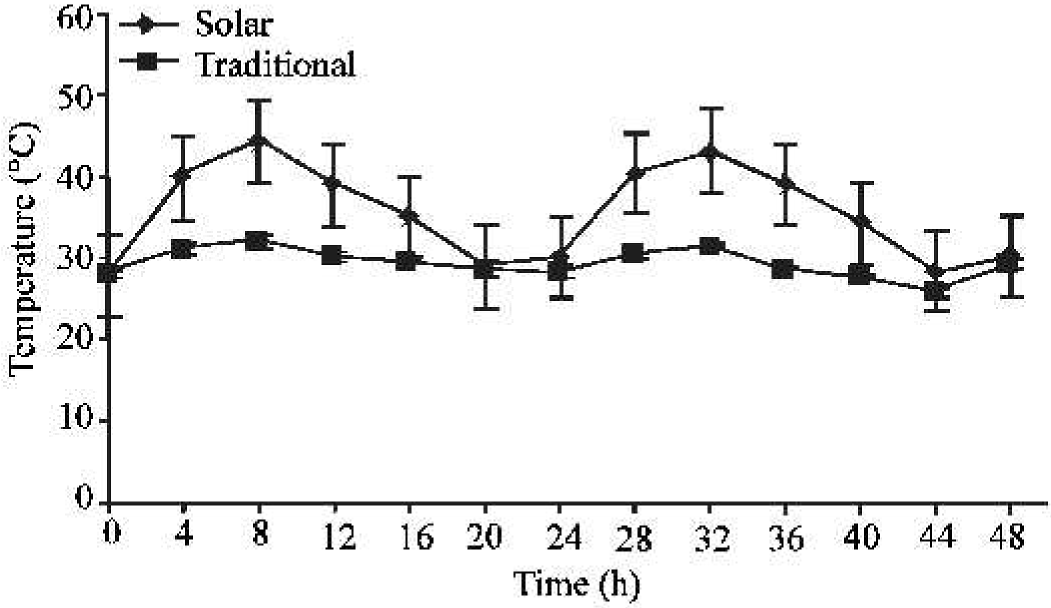


Fig. 2.49. Change the temperature of traditional drying and solar drier method within 48 h (vertical lines indicate±standard deviation)

Moisture and ash content in solar drier product is significantly lower than that of traditional dried product. Solar drier take 7 days to dry enough while in the traditional open sun drying took 25 days (Begum *et al*., 2006a).

2.15.7. Treatment Options:

The basic options for minimization of shrimp processing wastes are to ‘reduce’, ‘reuse’ and ‘recycle’ of the wastes. Reuse and recycling of waste materials are particularly difficult to apply in food industries and, therefore, reduction of wastes is considered the best option in dealing with the processing wastes. Reduction in waste production can be achieved through a number of ways such as conservation of water, improved housekeeping, control of raw material quality, adoption of technological modification and improved general management practices. Conserving water use, although an integral part of waste management, can be hard in industries where hygiene must be the overriding priority (McDonald *et al.,* 1999). Good housekeeping practices that cover prevention of accidental spillages (chemicals, fuel, fish materials) and good management of raw materials and products to avoid contamination. Raw material control is also key to reducing waste production and profit maximization (Howard, 1997). Installing trays along the edges of filleting and trimming benches will catch the fish pieces as they accumulate. In addition to catching trays, wastewater can be screened to remove fish solids and make the wastewater more easily treatable (Howard, 1997). Restricting the use of detergents and soaps would make separation and recovery of fats from the wastewater stream easier (Wheatley, 1991). Szabo *et al.* (1979) reported in a shrimp canning plant that an effective water and wastewater management program could result in a 60.1% reduction in BOD. As regulations become more restrictive and analysis techniques more sensitive, a number of wastewaters such as those with highly alkaline or acidic wastes, copper, zinc, chrome and sanitizing solutions containing chlorine, will adversely affect the food processing industry-including aquatic products processors (Dillon, 1993).

2.16. Recommendations for management of waste generated from shrimp processing industries. (Source: Draft protocol for sustainable shrimp production, 2003, Environmental justice foundation).

1. Government should initiate public awareness and education program on waste management generated from shrimp processing industries and encourage communities to develop and implement regional waste management systems in districts and unincorporated areas and especial emphasis should be given for diversion, e,g. assisting with transportation of recyclables.
2. Government should consider means of encouraging entrepreneurs and innovators to investigate value added products as well as the viability of a central diverted waste marketing agency/ waste exchange.
3. Composting should be encouraged through information and demonstration projects for collection and composting techniques at the household, community and commercial scales.
4. Government should initiate a study to determine the sources, volume and types of packaging coming into the area and the associated waste management policies and practices of sending and receiving parties and individuals, communities, business and industry and government share the responsibility for waste management and strict illegal dumping.
5. The possibility of funds/ grants for small-scale industry to carry out EIA should be explored. Establish procedures for EIA and monitoring to minimize the adverse ecological changes and related social and economic consequences resulting from discharge of effluents, use of chemicals and other activities.
6. Saline water use in shrimp processing may be restricted only where high salinity water is used to wash shrimps. The use of fresh water in shrimp processing operations must be regulated and training facilities for the concerned officials and workers for provision of mulching and post drainage management facilities in the vicinity of shrimp processing industries. Mulching improves the physical and microbiological properties of salt affected soils and promotes leaching of soluble salts and by drainage, waste water to be drained (Anwer, S.M. 2003).

7. Government must provide frame works for adequate planning; ensure use of environmentally friendly designs; ensure use of appropriate technologies (Production and waste management); limit use of chemicals, provide mechanisms for periodic environmental audits of activity; and restoration mitigation and compensation. Government should approve lists of chemicals and methods of application for shrimp processing. Manufacturers should provide labels with the composition of chemicals, disposal procedure and environmental and human safety precautions.
8. The rights of local communities, particularly those involved in shrimp processing must be protected and the use of trade related instruments and mechanisms (such as fines for pollution, pollutant taxes, commodity taxes, and performance bonds) should be explored to ensure that the polluter pays principle is applied.
9. Controlled use of inputs; treatment and careful discharge of effluents; and conservation of water resources. The site location and method of management of shrimp processing operations must not adversely affect the surrounding ecosystems, agricultural lands, natural vegetation, other shrimp farms or wild populations and processing systems should be designed and managed to promote good health of the workers and those living in the locality.
10. Water quality (such as temperature, pH, salinity, Oxygen, Ammonium and nitrate concentration, turbidity etc.) should conform to the natural requirements of the shrimp processing and should be monitored and recorded regularly. Processing plant will be established where quality water is available with other facilities and proper waste management and WHO class IA, IB pesticides, class II chemicals, toxic and bio accumulative compounds should be prohibited in shrimp processing.
11. All processing wastes should be disposed of in responsible and environmentally sound methods. Waste water from processing plants and deheading must be subjected to appropriate purification process and the cleaning of operating rooms as well as the implements and machines must ensure good hygiene along with highest possible environmental awareness. Mechanical and physical processes are preferred to chemical processes and shrimp heads and other processing residues/ trimmings should be reused, though direct feeding to same species must not be allowed.
12. STPP, STP, Sodium Meta bi sulfide (to stop the discoloration of shell post harvest) should not be used and discharge of waste and effluent in an active way in connection with the industrial restructuring and to increase investment in pollution prevention (Islam *et al.,* 2004).

2.17. The Bangladesh Environment Conservation Act, 1995

Government of the People's Republic of Bangladesh

Ministry of Environment and Forest

An Act to provide for conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution.

1. **Short title and commencement** (1) This Act may be called the Bangladesh Environment Conservation Act, 1995.

6A. **Restrictions on manufacture, sale etc. of articles injurious to environment**: If, on the advice of the Director General or otherwise, the Government is satisfied that all kinds or any kind of polythene shopping bag, or any other article made of polyethylene or polypropylene, or any other article is injurious to the environment, the Government may, by notification in the official Gazette, issue a direction imposing absolute ban on the manufacture, import, marketing, sale, demonstration for sale, stock, distribution, commercial carriage or commercial use, or allow the operation or management of such activities under conditions specified in the notification, and every person shall be bound to comply with such direction.

7. **Remedial measures for injury to ecosystem.-** (1) If it appears to the Director General that any act or omission of a person is causing or has caused, directly or indirectly, injury to the ecosystem or to a person or group of persons, the Director General may determine the compensation and direct the firstly mentioned person to pay it and in an appropriate case also direct him to take corrective measures, or may direct the person to take both the measures; and that person shall be bound to comply with the direction.

8. **Information to the Director General regarding environmental degradation or pollution. -** (1) Any person affected or likely to be affected as a result of pollution or degradation of the environment may, in the manner prescribed by rules, apply to the Director General for remedy of the damage or apprehended damage.

(2) The Director General may hold a public hearing and take other measures for disposing of an application made under this section.

9. **Discharge of excessive environmental pollutant etc.-** (1) Where, due to an accident or other unforeseen incident, the discharge of any environmental pollutant occurs or is likely to occur in excess of the limit prescribed by the rules, the person responsible and the person in charge of the place of occurrence shall take measures to control or mitigate the environmental pollution.

11. Power to collect samples etc.

(1) A person authorized in this behalf by the Director General may, in the manner prescribed by rules, collect from any factory, premises or other place any sample of air, water, soil or other substance for analysis.

(2) Subject to the provisions of sub-section (3) or (4), as the case may be, the report of a sample collector or the report of a laboratory or both the reports shall, in relation to a sample collected under this section, be admissible as evidence in the concerned proceedings.

(3) Subject to the provisions of sub-section (4), the person collecting the sample under sub-section (1) shall --

(a) serve, in the manner prescribed by rules, a notice to the occupier of the place or his agent specifying his intention to collect any sample;

(b) collect samples in presence of that occupier or his agent;

(c) place the sample in a container and seal the container after recording signatures of himself and of the occupier or his agent on the container;

(d) prepare a report on the collection of the sample and record signatures of himself and of the occupier or his agent;

(e) Without delay send the container to the laboratory specified by the Director General.

12. **Environmental Clearance Certificate.-** No industrial unit or project shall be established or undertaken without obtaining, in the manner prescribed by rules, an Environmental Clearance Certificate from the Director General.

13. **Formulation of environmental guidelines.-** The Government may, by notification in the official Gazette from time to time, formulate and publish environmental guidelines relating to the control and mitigation of environmental pollution, conservation and improvement of the environment.

15A. **Confiscation of materials and equipments involved in offence.-** Where a person is found guilty and sentenced under section 15, all equipments or parts thereof, transport, substance or any other thing used in the commission of the offence may be confiscated under order of the court.

15A. **Claim for compensation.-** Where a person or a group of persons or the public suffers loss due to violation of a provision of this Act or the rules made there under or a direction issued under section 7, the Director General may file a suit for compensation on behalf of that person, group or the public.

2.18. The Bangladesh Environment Conservation (Amendment) Act, 2010

An Act to provide for further Amendment of The Bangladesh Environment Conservation Act,1995 (Act No.1of 1995).

1. Short title and commencement.- (1) This Act may be called the Bangladesh Environment Conservation Act,(Amendment) 2010.

2. **Amendment of section 2 under Act No. 1 of 1995**.- The Bangladesh environment conservation Act, 1995 (Act No. 1 of 1995), noted it as act, it's section 2 are as follows-

" Hazardous waste" means any kinds of waste, due to its physical or chemical properties or contraction with other waste or substances create toxicity, infection, oxidation, exploration, radioactivity, decay or other harmful effect to environment;";

6C.**Restriction on production, import, storage, loading, transportation etc of hazardous waste.-** to protect the environmental damage, govt with respect to provision of other law can control by means of provision production, processing, contain, storage, loading, supply, transportation, import, export, disposal, dumping etc of hazardous waste.

5. **Amendment of section 9 under Act No. 1 of 1995.** – Section 9 of this act

"(1) Where, due to incident, the discharge of any environmental pollutant occurs or activities or an accident is likely to occur in excess of the limit prescribed by the rules, the person responsible and the person of occupied of the place of occurrence or related organization shall take measures to control or mitigate the environmental pollution.

(b) After subsection (4) following subsection (5) shall be included, such as: -

"(5) Due to the activities of under subsection (1) emitted waste or pollutant excessed the prescribed limit is proved by the Director General or a person authorized by him in immediate test, then that test report shall be accepted as evidence in court.".

"15A. **Claim for compensation.-** Where a person or a group of persons or the public suffers loss due to violation of a provision of this Act or the rules made thereunder or a direction issued under section7, the person, group, public or on behalf of them the Director General may file a suit for compensation.

2.19. The Environment Conservation Rules, 1997

Short Title: These Rules may be called the Environment Conservation Rules, 1997.

5. **Application relating to pollution or degradation of environment**:

(1) Any person affected or likely to be affected as mentioned in sub-section (1) of section 8 may apply to the Director General in Form-1 for remedy of the damage or apprehended damage.

(2) The Director General shall, within three months of receiving an application under sub-rule (1), dispose it of in accordance with sub-section (2) of section 8.

6. **Notice for collection of Sample:** An officer intending to collect a sample under sub-section (3) of section 11 shall send to the occupier of the concerned place or his agent a notice in accordance with Form-2 about his intention.

7. **Procedure for issuing Environmental Clearance Certificate**: (1) For the purpose of issuance of Environmental Clearance Certificate, the industrial units and projects shall, in consideration of their site and impact on the environment, be classified into the following four categories:

(a) Green;

(b) Orange – A;

(c) Orange – B; and

(d) Red.

(2) Industries and projects included in the various categories as specified in sub-rule (1) have been described in Schedule – 1.

(3) Environmental Clearance Certificate shall be issued to all existing industrial units and projects and to all proposed industrial units and projects falling in the Green Category.

(4) For industrial units and projects falling in the Orange – A, Orange – B and Red categories, firstly a Location Clearance Certificate and thereafter an Environmental Clearance Certificate shall be issued:

(9) Upon receiving Location Clearance Certificate under Sub-rule (8), the entrepreneur–

(i) May install machinery including ETP (applicable for industrial units or projects of Orange-A and Orange-B Category only);

1 Where an application is received under clause (d) of sub-rule (9) in relation to an industrial unit or project of Red Category, the EIA report along with the time schedule and ETP design shall, within sixty working days, be approved or the application shall be rejected mentioning appropriate reasons;

2 After EIA is approved under sub-rule (11), the entrepreneur –

(i) may open L/C for importing machineries which shall include machineries relating to ETP; and

(ii) shall, after installation of ETP, apply for Environmental Clearance Certificate without which he shall not have gas line connection and shall not start trial production in case of an industrial unit, and in other cases shall not start operation of the project.

8. **Validity period of Environmental Clearance Certificate.** – (1) The period of validity of an Environmental Clearance Certificate shall be, in case of Green Category, three years from the date of its issuance and in other cases one year.

(2) Each Environmental Clearance Certificate shall have to be renewed at least thirty days before expiry of its validity period.

11. **Determination of environmental standards.**– For carrying out the purposes of clause (a) of sub-section (2) of section 20, the standards for air, water, sound, odor and other components of the environment shall be determined in accordance with the standards specified in Schedules - 2, 3, 4, 5, 6,7 and 8.

13. **Determination of the standards for discharge and emission of waste:**

For carrying out the purposes of clause (e) of sub-section (2) of section 20, the standard limits of the discharge of liquid waste and gaseous emission shall be determined in accordance with the standards specified in Schedules 9, 10 & 11, and the standards of the discharge or emission of wastes of various industrial units shall be determined in accordance with standards specified in Schedule -12.

18. **Various services and their fees:** (1) Upon application of any person or organization, the Department shall supply analysis report of the samples of water, liquid waste, air and sound and also the information or data derived from such analysis.

(2) For services under sub-rule (1), appropriate fees are payable.

17. **Information of special incident:** If, at any place, discharge or emission of environment pollutants occur in excess of the prescribed standards or if any place is under threat of facing such discharge or emission as a result of any accident or unforeseen incident, then the person or persons in charge of that place shall immediately inform the Director General of the occurrence or the threat.

SCHEDULE – 1

Classification of industrial units or projects based on its location and impact on environment.

1 GREEN Category

1 Assembling and manufacturing of TV, Radio, etc.

2 Assembling and manufacturing of clocks and watches.

3 Assembling of telephones.

4 Assembling and manufacturing of toys (plastic made items excluded).

5 Book-binding etc.

(B) ORANGE-A Category

1. Dairy Farm, 10 (ten) cattle heads or below in urban areas and 25 cattle heads or below in rural areas.
2. Poultry (up to 250 in urban areas and up to 1000 in rural areas)
3. Grinding/husking of wheat, rice, turmeric, pepper, pulses (up to 20 Horse Power)
4. Production of shoes and leather goods (capital up to 5 hundred thousand Taka)
5. Furniture of wood/iron, aluminum, etc. (capital up to 5 hundred thousand Taka) etc.

(C) ORANGE-B Category

1. PVC items.
2. Hotel, multi-storied commercial & apartment building.
3. Glue (excluding animal glue).
4. **Processing fish, meat and food.**
5. **Processing of prawns & shrimps etc.**

(D) RED Category

1. Tannery.
2. Chemical dyes, polish, varnish, enamel.
3. Pesticides, fungicides and herbicides.
4. Industry (excluding nitrogen, oxygen and carbon dioxide).
5. Waste incinerator etc.

Table. 2.15. Standards for drinking and irrigation water (ECR, 1997).

Sl. No.	Parameter	Unit	Standard for Drinking water	Standard for Irrigation water
1	Ammonia (NH_4-N)	mg/L	5	15
2	BOD_5 20°C	mg/L	0.2	100
3	Cadmium	mg/L	0.005	0.05
4	Calcium	meqL-1	1.875	20
5	Chloride	mg/L	150	600
6	Chromium (hexavalent)	mg/L	0.05	1
7	Chromium (total)	mg/L	0.05	1
8	COD	mg/L	4	400
9	Coliform (fecal)	n/100 ml	0	1000
10	Coliform (total)	n/100 ml	0	1000
11	Color	Hazen unit	15	15
12	EC	dSm^{-1}	0.3	1.2
13	HCO_3^-	mg/L	5	8.5
14	DO	mg/L	6	4.5-8
15	Hardness (as $CaCO_3$)	mg/L	200	500
16	Kjeldhl Nitrogen (total)	mg/L	1	1
17	Lead	mg/L	0.05	0.1
18	Magnesium	meqL-1	1.25	5
19	Manganese	mg/L	0.1	5
20	Nickel	mg/L	0.1	1
21	Nitrate	mg/L	10	10
22	Odor	mg/L	Odorless	Odorless
23	pH	mg/L	6.5-8.5	6-9
24	Phosphate	mg/L	6	15
25	Phosphorus	mg/L	0	15
26	Potassium	meqL-1	0.31	2
27	Sodium	meqL-1	0.87	40
28	Suspended Solids	mg/L	10	200
29	Sulfate	mg/L	250	400
30	Total dissolved solids	mg/L	1000	2100
31	Temperature	°C	20-30	40-45
32	Turbidity	JTU	10	200
33	Zinc	mg/L	5	10

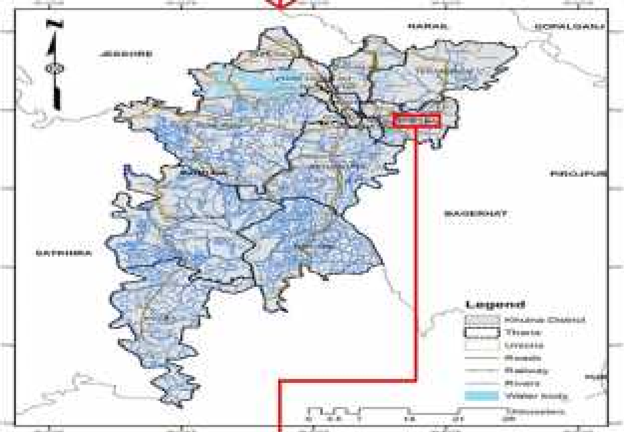
3. Materials and Methods:

3.1. Description of the study area:

Khulna is the southwestern coastal city of Bangladesh and its area is 4334.46 Km^2, stands on the bank of the river Rupsha. Geographically, Khulna lies between 22^{0}49' North latitude and 89^{0}34' East longitude. The major portion of this region is low lying land, barely one meter above mean sea level, and below high tide level. As such, all the low lands are inundated during high tide and salinity is caused by tidal incursion. Khulna District has the great potential of shrimp culture, processing and thus waste delivered. Among total registered shrimp processing industries in Bangladesh, about 70% running industries are situated in this region. A total of 48 shrimp processing plants have been established in Khulna district (Hamid and Alauddin, 2013). Four major shrimp processing industries Atlas Sea Food Ltd. Cosmos Sea Foods, Fresh Foods Ltd. and Rosemco Foods Ltd. situated in Khulna and Rupsha Upazilla are considered as the representative study area of pollution source for the analysis of soil and water. These industries can be representative of all the industries involved in fish processing in the Khulna region because above mentioned four industries are large in size and process 42.3% of the total received shrimps of surveyed 12 industries and generate maximum wastes as well as effluents. The industries have another similar character that those industries are discharging their wastes and effluents to the agricultural land.

3.2. Geology and land form of the study area: The land type of the study area is medium low land. The physiography is Ganges tidal floodplain (SRDI, 1989).

BANGLADESH MAP



KHULNA DISTRICT MAP

RUPSHA UPAZILA MAP

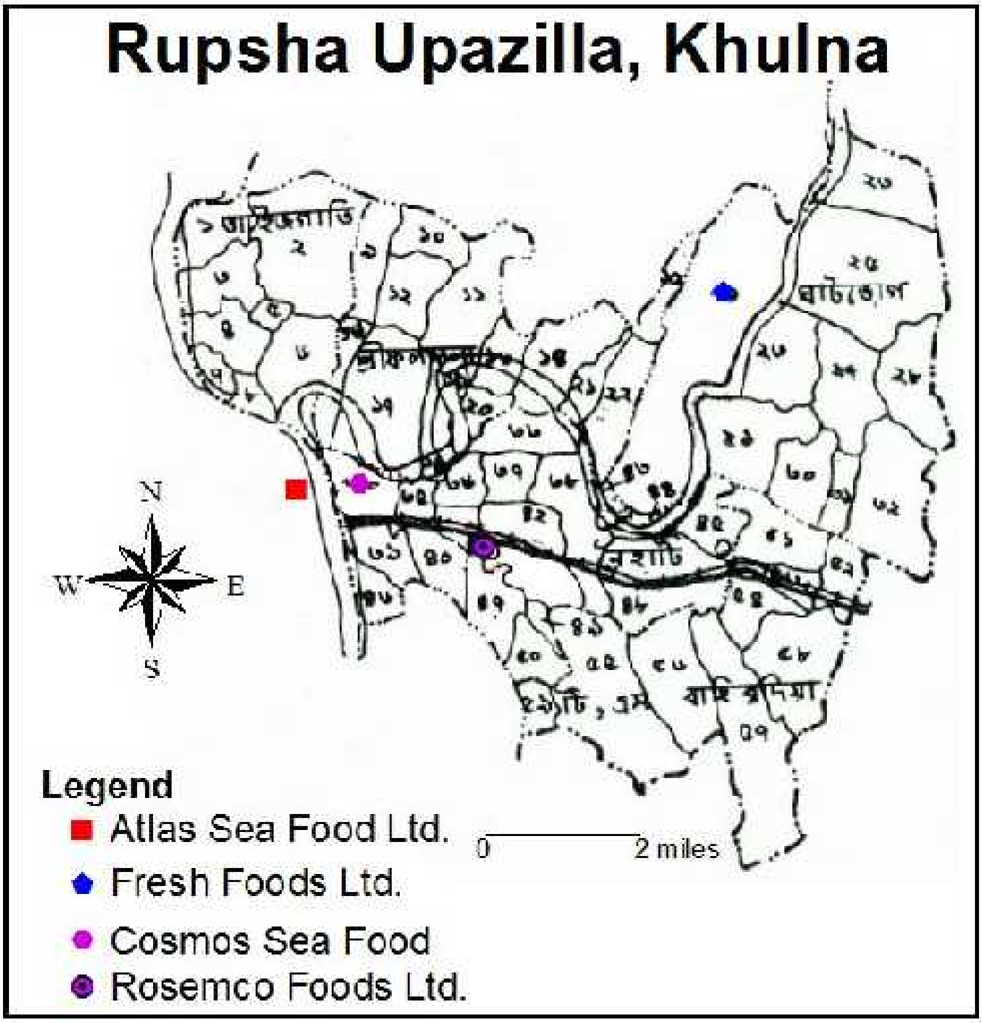


Fig. 3.1. Map of the study area

3.3. Experimental Methods and experimental Design

The Environmental Impact Assessment (EIA) was conducted in some selected areas of Shrimp Processing Industries in and around Khulna city. The selected four industries are involved in processing large amount of fish and generate solid wastes and effluents that can have significant environmental impact if released in the environment without treatment. Therefore, the studies involved an exploratory survey of the physical environment of the area around the industries and identify any visible effect on the surrounding environment through identification of common indicators. Information was collected regarding fish processing, chemicals used in the process, machineries and/or techniques used, and probable sources/routes of adding contaminants to the environment through a structured questionnaire (Appendix 22). Analysis of contaminated soils and effluents was carried out for environmental quality parameters and analysis of representative soil and effluents samples was carried out for different physical, chemical and biological parameters as required in the investigation.

3.4. Survey in the study area:

A survey was conducted in twelve shrimp processing industries located in Ruphsha Thana and Khulna city in the year 2011. The area covers from 2 to 8 Acres and 5 to 25 Officers and 131 to 500 Workers work in the surveyed industries. Structured questionnaires were prepared and interview of the persons related with the administration and management of the shrimp processing industries was taken. They responded the interview and answered gently. Twelve industries were selected because those industries can be representative of all the industries involved in fish processing in Khulna region because those are comparatively large in size and generate huge wastes as well as effluents because of maximum shrimp processing.

Questionnaires for the survey are as follows:

Name of the industry:
Location of the industry:
Year of establishment:
Name and designation of the person interviewed:
Number of officers and workers:

1. How much shrimp is received and processed daily?
    a) In Season----------------- b) Off- Season ----------------
2. How much solid wastes are generated daily from the industry?
    a) In Season----------------- b) Off- Season ----------------
3. How much effluents are discharged daily from the industry?
    a) In Season----------------- b) Off- Season ----------------
4. What is your waste management plan?
    a) Do you have ETP? i) yes ii) no
    b) How do you dispose up solid waste?
    c) How do you dispose up effluent?
5. What type of solid wastes is generated from the industry?
6. Which routes do you use for disposal of wastes and effluents?
7. Have you noticed any changes in the surrounding environment?
8. What are the processing steps in your industry?
9. What type of chemicals is used for processing shrimps in the industry?
10. What type of machineries is used for processing shrimps in the industry?
11. Have you had any report of occupational health hazard?
19. What is the market of your product?

3.5. Analytical methods: Effluents, plant and soil samples were analyzed for the physical, chemical and biological parameters as follows.

Effluents: Temperature, Turbidity, pH, EC, Hardness, DOC, DO, TDS, TSS, BOD_5, COD, CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-, NO_3^--N, NH_4^+-N, Na^+, K^+, Ca^{2+}, Mg^{2+}, Mn, Zn, Pb, Cd, Cr, Ni, TC and FC.

Plant: N, P, S, Zn, Mn, Pb, Cd, Cr and Ni.

Soil: Physical: Moisture content, Particle size analysis, Textural class and Bulk density.
Chemical: pH, EC, CEC, Organic carbon, Total N, Available N, P, Na, K, Ca, Mg, S, Zn, Mn, Pb, Cd, Cr and Ni.

3.6. Collection of effluent and water samples:

Replicate effluent samples were collected from three points of four industries in the peak processing time. One replicate water sample was collected from reserve water tanks of each industry used for processing to prepare composite samples and considered as reference water (RW) for comparing. Three composite water samples from each of pond water, canal water, river water and shallow tube well water were collected from the study area to observe the extent of the effect of the effluents on those surrounding water resources. Effluent samples were randomly collected in sterilized plastic bottles (500ml) to cover most of the investigated area during 25th July, 2011. Samples were collected according to the sampling techniques as outlined by Hunt and Wilson (1986). The bottles were completely filled with effluents in a way so that no air remains above the surface. Each bottle was cleaned thoroughly by rinsing with dilute HNO_3 followed by washing with distilled water. One was preserved with toluene for regular water analysis and other was preserves with acid for the heavy metal analysis. Another 500 ml air-tight water samples for each sampling points were also collected in sterilized bottle for microbial analysis and kept in icebox to maintain 4°C (inhibit microbial multiplication). All the samples were preserved into the Laboratory of the Department of Soil, Water and Environment, University of Dhaka. Effluent samples were filtered with filter paper (Whatman No. 1) to remove undesirable solids and suspended materials before chemical analysis. The chemical analyses of effluents were performed as quickly as possible on arrival at laboratory.

3.7. Analysis of the Physical properties of effluents:

Effluents color: The effluents color was determined by eye observation in the source points.

Temperature: The temperature of the effluents was determined by Thermometer in the source points.

Turbidity: The turbidity of the effluents samples was determined by using Turbidity meter (Model: Mettler - Toledo Ag, CH-8603).

Total Dissolved Solids (TDS): Total dissolved solid (TDS) was determined by simply evaporating effluent samples.

Total Suspended Solids (TSS): Total Suspended Solids (TSS) was determined by the suspended constituents were separated by filtration and after drying, the weight of the suspended materials was determined.

3.8. Analysis of the Chemical properties of effluents:

Dissolved Oxygen (DO): The Dissolved Oxygen (DO) of the effluent samples was determined in the source points by DO meter (Model: Mettler - Toledo Ag, CH-8603).

Biological Oxygen Demand (BOD): Biological Oxygen Demand (BOD) of the effluent samples was determined by DO meter (Model: Mettler - Toledo Ag, CH-8603).

Chemical Oxygen Demand (COD): Chemical Oxygen Demand (COD) of the effluent samples was determined by the titrimetric method described by Jackson, 1973.

pH: pH of effluent samples was determined electrochemically with the help of glass electrode pH meter as suggested by Jackson (1973).

EC: The Electrical conductivity (EC) of effluents was measured by EC meter (Jenway EC meter).

Carbonate (CO_3^{2-}): Carbonate (CO_3^{2-}) contents of the effluents samples were determined by Titrimetric method as described by Jackson, 1973.

Bi-Carbonates (HCO_3^-): Bi-carbonate (HCO_3^-) content of the effluent samples was determined by Titrimetric method as described by Jackson, 1973.

Chloride (Cl^-): Chloride (Cl^-) contents of the effluent samples were determined by Titrimetric method as described by Jackson, 1973.

Sulphate (SO_4^{2-}): Sulphate (SO_4^{2-}) content of effluent samples was determined by turbidimetric method (Hunt, 1986). The intensity of the color was taken in a Spectrophotometer (Model: Jenway 6100) at 420 nm of wavelength.

Dissolved Organic Carbon (DOC): Dissolved Organic Carbon of effluent samples was determined by Walkley Black's Wet Oxidation method as outlined by Jackson (1962).

Nitrate (NO_3^--N): Nitrate (NO_3^--N) content of effluent samples was determined by turbidimetric method (Hunt, 1986). The intensity of the color was taken in a Spectrophotometer (Model: Jenway 6100) at 410 nm of wavelength.

Ammoniacal Nitrogen (NH_4^+-N): Ammoniacal Nitrogen (NH_4^+-N) of effluent samples was determined by alkali distillation method without adding Devarda's alloy (Imam and Didar, 2005).

Sodium (Na^+): Sodium (Na^+) content in effluent samples was determined separately by Flame emission spectrophotometer (Model: Jenway, PEP-7) using Sodium filter, as outlined by Jackson, 1973.

Available Potassium (K^+): The available Potassium (K^+) was measured by Flame emission spectrophotometer (Model: Jenway, PEP-7) at 769 nm wave length using Potassium filter, as outlined by Jackson, 1973.

Available Calcium (Ca^{2+}): The Available Calcium (Ca^{2+}) content was determined by EDTA Complexometric titration method (Jackson, 1973).

Available Calcium (Ca^{2+}) and Magnesium (Mg^{2+}): The Available Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) was determined from NH_4OAc (pH-7) extract as described by Jackson 1967. The content of Ca^{2+} and Mg^{2+} was determined by EDTA Complexometric titration method (Jackson, 1973).

Available Magnesium (Mg^{2+}): Available Magnesium (Mg^{2+}) was determined by deducting the content of (Ca^{2+}) from the content of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}).

Heavy metals (Pb, Cd, Cr, Mn, Ni, Zn): Heavy metals were determined from effluents by HNO_3 digestion method followed by Atomic Absorption Spectrophotometer as suggested by Portman and Riley (1964).

Hardness:

Todd (1980) expressed H_T (Hardness) as:

$$H_T = 2.5 \times Ca^{++} + 4.1 \times Mg^{++}$$

Whereas, all ionic concentrations were expressed as meL^{-1} but for hardness was expressed as mgL^{-1}.

3.9. Analysis of the Microbiological properties of effluents:

Total Coliforms (TC): Total Coliforms (TC) was determined by Membrane Filter Technique as described by Harley and Prescott, 2002.

Faecal Coliforms (FC): Faecal Coliforms (FC) was determined by KONFIRM Test as described by Harley and Prescott, 2002.

3.10. Test crops used in the experiment

The effluents released in the environment and its impact on the growth and yield of some selected leafy vegetables were investigated following seed germination test and net house experiment/ pot experiment with different dilutions. Lal Shak/ Red amaranth (*Amaranthus curentus*), Danta/ Stem amaranths *(Amaranthus lividus*) and Kalmi Shak/ Water spinach *(Ipomoea aquatica)* were used as the test crops for the experiment. These particular varieties have gained popularity among the farmers of the study area for their high yielding potential and can be grown throughout the year and harvested in a short time (One month). A brief description of the seeds of the test crops is presented in Table 3.1.

Table 3.1. Description of the Test Crops:

Name	Red amaranth	Stem amaranth	Water Spinach
Local name	Lal Sak	Danta	Kalmi Shak
Scientific Name	*Amaranthus curentus*	*Amaranthus lividus*	*Ipomoea aquatica*
Seed Source	BADC, Jessore	Sobuz Beez Bhandar, Siddique Bazar, Dhaka	Sobuz Beez Bhandar, Siddique Bazar, Dhaka
Purity	95%	98%	95%
Germination rate	60-70%	80%	80%
Seed rate	5 kg ha^{-1} (BARI, 2005)	5 kg ha^{-1} (BARI, 2005)	5 kg ha^{-1} (BARI, 2005)
Net. Weight	50 gm per packet	50 gm per packet	50 gm per packet

3.11. Layout of the Pot Experiment:

The experiment was laid out in Complete Randomized Design (CRD) with three replications. 3 Kg soil was used in each pot (15.5cm X 9.5cm). Layout of the experiment has been shown in the Fig. 3.2.

T_0R_1	T_2R_1	T_1R_1
T_0R_2	T_1R_2	T_2R_2
T_2R_3	T_0R_3	T_1R_3
T_3R_1	T_5R_1	T_4R_1
T_4R_2	T_3R_2	T_5R_2
T_3R_3	T_5R_3	T_4R_3

Fig. 3.2. Layout of the Pot Experiment

3.12. Treatments of the investigation

Six treatments were conducted in the experiment for each crop. Three replications were conducted for each treatment and for individual species of crops to avoid experimental error. The treatments are as follows:

T0 = Control/ Uncontaminated soil and water

T1 = Uncontaminated soil and 100% undiluted effluent

T2 = Uncontaminated soil and 75% effluent

T3 = Uncontaminated soil and 50% effluent

T4 = Uncontaminated soil and 25% effluent

T5 = Uncontaminated soil and 10% effluent

3.13. Preparation of soil samples for pot experiment:

The soil was stored for about two weeks before sieving by 2mm sieve and mixed it extensively with a shovel in 18 pots. Pots were filled up to top (3kg) and soil moisture was maintained at field capacity (0.33g water g soil^{-1}) by weighing individual pots and adding lost water as required and room temperature was maintained in the pots.

Table. 3.2. Composition of uncontaminated soil, uncontaminated water and effluent used in the pot experiment.

Source	pH	EC	Av. N	PO_4^{2-}	SO_4^{2-}	Ca	Mg	K	Na	Cd	Cr	Zn	Ni	Pb	Mn
		mS/Cm	mgL^{-1}/Kg			meqL^{-1}/100g soil				mgL^{-1} /Kg					
Uncont. soil	7.1	1.9	19.02	7.27	11.5	3.4	1.76	0.63	16	ND	14.05	66.47	12.5	ND	97
Uncont. water	7.6	2.9	25.53	14.3	65	3.82	2.4	1.7	21	ND	12.2	48.8	1.9	ND	22
Effluent	8.0	15	92.6	26.5	437	29	9	4	75	ND	18.0	122	14	6	148

* ND=Not detected (Below 0.02ppm)

3.14. Seed Germination:

A seed germination test was carried out by applying effluent of different dilution to see any effect on germination. Seed germination test was carried out by the seeds of three locally grown leafy vegetable species namely Red amaranth (*Amaranthus curentus*), Stem amaranths *(Amaranthus lividus*) and Water spinach *(Ipomoea aquatica).* The test was carried out in pertidishes at room temperature (28 ^{0}C), following the method of Manmathan and Lipitan (2013) and Seed germination percentage was calculated by the following formula:

%Germination = (Seeds germinated/Total seeds) ×100%.

3.15. Sowing of seeds:

The seeds were sown on 26th June, 2012. The seeds were sown thoroughly as it was possible to keep uniformity and then the seeds were covered by soils. 0.01g seeds of each of the species @5Kg ha^{-1} as recommended by BARI, 2005 were sown in each pot. After germination on the sixth day five plants/pot were maintained for the experiment until harvest.

3.16. Application of effluent:

2 L effluent was collected from each of four industries and thoroughly mixed to prepare composite effluent and different diluted effluents were prepared to use in various treatments (0%, 100%, 75%, 50%, 25%, 10% effluent) in pot experiments. Raw and diluted effluents were supplied every day to each pot to ensure sufficient moisture maintaining field capacity level of the same strength following the equation,

Water for application = (Field Capacity/ 100 - %MC/100) × Soil (Kg) × 10 × Height of pot for normal crop growth (Rattan Lal and Monoj K. Shukla, 2002).

Water application in the pot experiment of Stem amaranth is shown on the following fig. 3.3.

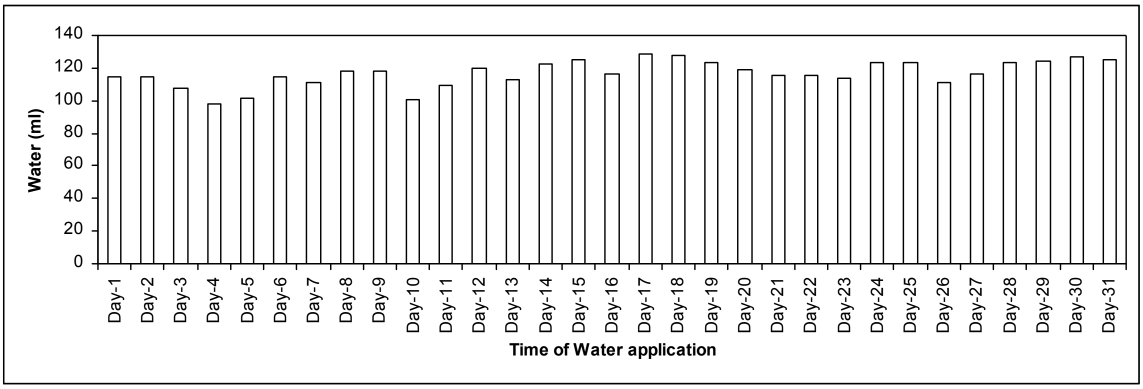


Fig. 3.3. Water application in the pot experiment of Stem amaranth

Water application in the pot experiment of Red amaranth is shown on the following fig. 3.4.

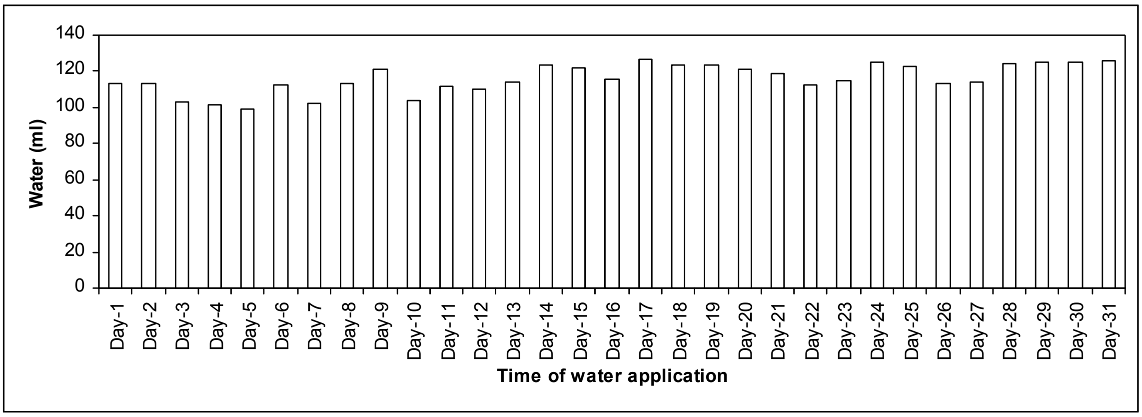


Fig. 3.4. Water application in the pot experiment of Red amaranth

Water application in the pot experiment of Water spinach is shown on the following fig. 3.5.

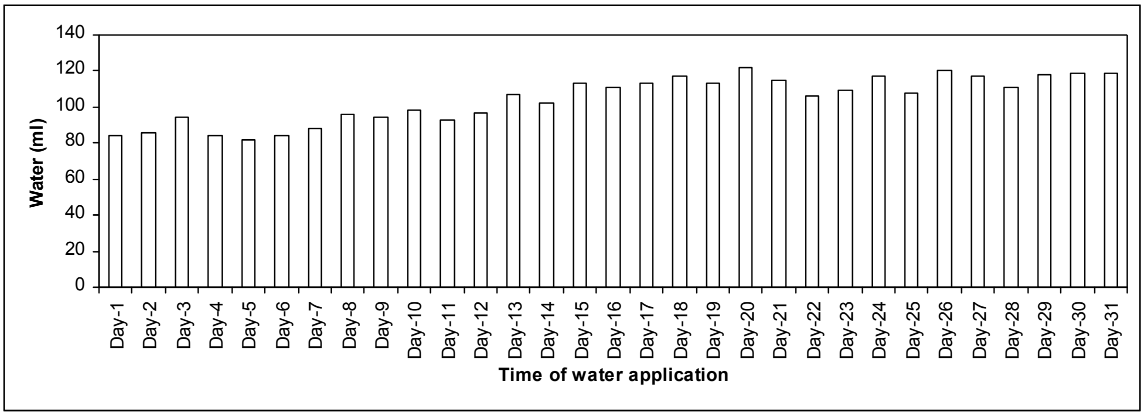


Fig. 3.5. Water application in the pot experiment of Water spinach

3.17. General observations:

The pots under experiment were frequently observed to note any change in the crop growth and other characteristics. The crop growth was very luxuriant in some treatments and lower in some treatments.

Harvesting:

The experimental crops were harvested after 31days of germination on 1st August, 2012. The harvested plants were tagged separately, weighed, oven dried at 65°C temperature for 48 hours until moisture content reached to a minimum level. Dry weight of plants per pot from each treatment was recorded.

Data collection of different attributes of the crops:

The following parameters were recorded and their mean values were calculated from the sample plants during experiment.

3.18. Factors related to growth and yield of plants:

Leaves per plant (nos):

The number of leaves of five plants of each pot was counted and average value was considered.

Fresh weight per plant (g/plant):

At harvest of five plants from each pot, fresh weight of whole plant was taken by an electrical balance and their mean value was calculated as fresh weight expressed in gm/plant.

Dry weight per plant (gplant):

Five plants of each pot were collected and oven dried at 65°C for 48 hours, weighed in gm/plant by an electrical balance and average value was recorded.

Moisture content (%):

Percent moisture was calculated by using the formula:

$$\textbf{Moisture content (\%)} = \frac{Wf - Wo}{Wf} \times 100$$

Where, Wf = Fresh weight of the plant sample

Wo = Oven dry weight of the plant sample

3.19. Collection of plant samples:

The plants were uprooted after 31 days of germination and the whole plants were washed with distilled water. The parts of the plants were separated by using a scissor to cut larger parts of the plant in to smaller size. The samples were kept in paper bags and date, location of the sampling, treatment number was written on the paper bags. Plants of the same treatment of three replicated pots were kept in separate packets. Plant samples were processed for laboratory analysis as per standard methods.

3.20. Preparation of plant samples:

The Paper bags were put in an oven at 65 ^{0}C for 48 hours until a constant dry weight was obtained. After completion of the drying the dry weight was measured. The samples were cut in to smaller pieces and powdered in a grinding mill and passed through 0.5 mm sieve. The powder was mixed thoroughly. The powdered samples were preserved in plastic pots and tagged properly for chemical analysis.

3.21. Analysis of N, P, S and heavy metals of the plant samples

N, P, S and heavy metals (Zn, Ni, Cd, Cr, Pb, Cd) were analyzed from plant samples by the methods mentioned in 3.8.

Determination of protein content: Protein content in plants was determined by multiplying % nitrogen values with 6.25 as suggested by Blake, 1965.

Determination of Heavy metals (Pb, Cd, Cr, Mn, Ni, and Zn): Heavy metals were determined from plant samples by HNO_3 digestion method followed by Atomic Absorption Spectrophotometer as suggested by Portman and Riley (1964).

3.22. Collection of soil samples:

Replicate soil samples along with core samples were collected from three points of each of four industries. Point–A is the main effluent discharging and waste disposal point, Point-B is the highly polluted effluent accumulated point and point-C is the contaminated agricultural land. Samples were collected in the peak processing period. Seasonal variation was not considered because for a certain period processing is carried out that is rainy season (May to September) and average rainfall is 296mm/month so, flashing is not affected. Three soil samples from the adjacent area of each industry of the four was collected and mixed thoroughly to prepare a composite sample which was considered as reference soil (RS) (USDA, 1951).

The sampling locations of the study area:

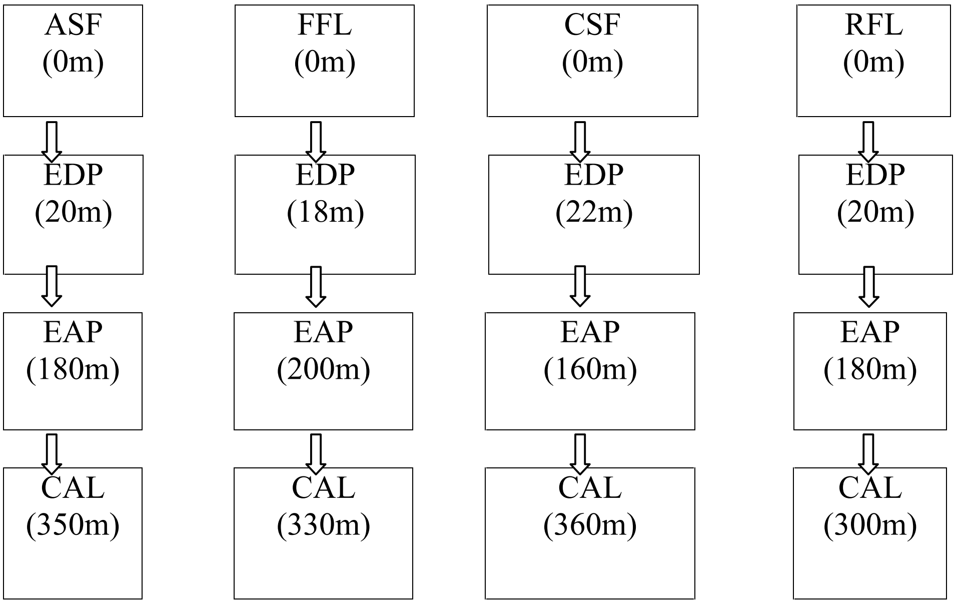


Fig. 3.6. Sampling locations of the study area

Note: ASF= Atlas Sea Food Ltd. FFL= Fresh Foods Ltd. CSF= Cosmos Sea Foods, and RFL= Rosemco Foods Ltd. EDP= Effluent Dumping Point, EAP= Effluent Accumulation Point, CAL= Contaminated Agricultural Land.

3.23. Preparation of Soil Samples:

Polluted and non polluted soil samples for the use of analytical work were air dried by spreading on separate sheets of papers after it was transported to the laboratory of Soil Science Discipline, Khulna University. After drying, the larger aggregates were broken gently by crushing it by a wooden hammer. Crushed soils were passed through a 2 mm sieve and sieved soils were preserved in plastic bags and labeled properly. These were later used for various physical, physico-chemical, chemical and chemical analysis in the laboratory of the Department of Soil, Water and Environment, University of Dhaka, Soil Science Discipline, Khulna University and SRDI, Dhaka.

3.24. Analysis of soil Physical properties:

Moisture Content: Soil moisture content was determined by Gravimetric method (Oven-drying) as described by Blake, 1965.

Particle size Analysis: Particle size distribution of the soil samples were determined by Hydrometer method (Bouyoucos, 1962).

Texural Class: Texural Classes were determined by using Marshall's Triangular Coordinate System (Brady and Weil, 2002).

Bulk Density (Db): Core method was used to determine bulk density (Db) of soils (Blake and Hartge, 1986; Ruhlmann *et al.,* 2006).

3.25. Analysis of soil Physico-Chemical properties:

***pH**:* Soil pH was determined electrochemically with the help of glass electrode pH meter as suggested by Jackson (1973). The ratio of soil to water was 1: 2.5 as suggested by Jackson (1962).

***EC**:* Electrical conductivity (EC) of the soil was measured by the help of EC meter (Jenway EC meter). The soil and water ratio was 1: 2.5 as described by USDA, 2004.

CEC: CEC of the soil samples were determined by extracting the soil with 1N KCl (pH, 7.0) followed by the replacing the Potassium in the exchange complex by 1N NH_4OAC (Ruhlmann *et al.,* 2006). The displaced Potassium was determined by Flame Analyzer at 589nm (Jackson, 1967).

3.26. Analysis of soil Chemical properties:

OC and OM: Organic Carbon of soil samples was determined by Walkley Black's Wet Oxidation method as outlined by Jackson (1962). Organic matter was calculated by multiplying the percent value of organic carbon with the conventional Van- Bemmelene's factor of 1.724 (Piper, 1950).

Total Nitrogen: The total Nitrogen of the soil was determined by Micro- Kjeldahl's method following H_2SO_4 acid digestion as suggested by Jackson, 1962.

Available Nitrogen: Available Nitrogen of the soil was determined by Semi-micro Kjeldahl's method following H_2SO_4 acid digestion as suggested by Jackson, 1973.

Available Phosphorus (P): Available Phosphorus was determined by Vanadomolybdophosphoric yellow color method in nitric acid system as suggested by Jackson, 1967. It was measured by Spectrophotometer at 420 nm wavelength.

Sodium (Na^+): Sodium (Na^+) content in soil samples was determined separately by Flame emission spectrophotometer (Model: Jenway, PEP-7) using Sodium filter, as outlined by Jackson, 1973.

Exchangeable Potassium (K^+): The Exchangeable Potassium (K^+) was extracted from the soil samples by 1N NH_4OAc (pH-7) solution followed by measurement of extractable K^+ by Flame emission spectrophotometer (Model: Jenway, PEP-7) at 769 nm wave length using Potassium filter, as outlined by Jackson, 1973.

Available Calcium (Ca^{2+}): The Available Calcium (Ca^{2+}) was determined from NH_4OAc (pH-7) extract as described by Jackson 1967. The content of Ca^{2+} was determined by EDTA Complexometric titration method (Jackson, 1973).

Available Calcium (Ca^{2+}) and Magnesium (Mg^{2+}): The Available Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) was determined from NH_4OAc (pH-7) extract as described by Jackson, 1967. The content of Ca^{2+} and Mg^{2+} was determined by EDTA Complexometric titration method (Jackson, 1973).

Available Magnesium (Mg^{2+}): Available Magnesium (Mg^{2+}) was determined by deducting the content of (Ca^{2+}) from the content of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}).

Available Sulfur (S): The Available Sulfur content of soil samples was determined by turbidimetric method as described by Jackson, 1973. It was measured by Spectrophotometer (Model: Jenway 6100) at 420 nm wavelength.

Heavy metals (Pb, Cd, Cr, Mn, Ni, Zn): Heavy metals were determined from soil samples by Aqua regia (HNO_3: HCl=1:3) followed by Atomic Absorption Spectrophotometer as suggested by Portman and Riley (1964).

3.27. Statistical Analysis

The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. Standard deviation, Standard error, LSD and DMRT were carried out by using computer programs and IBM.SPSS.Statistics.V20.32bit.CoMrADO.

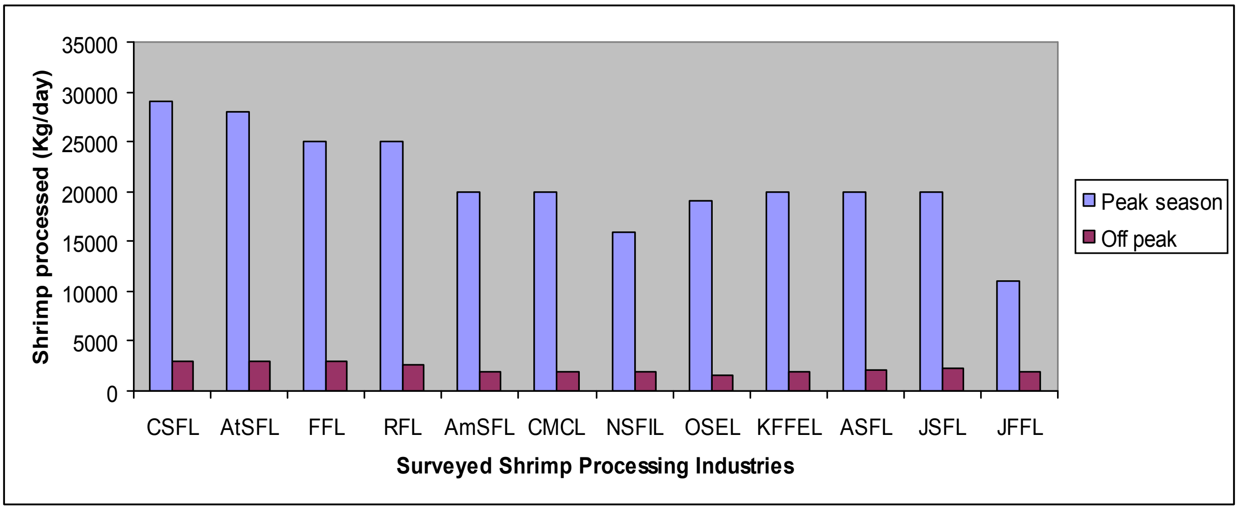
Results and Discussion:

4.1. Survey report:

A survey was conducted during the year 2011 considering both the peak season and off-peak. The results are presented below:

4.1.1. Shrimp received and processed in surveyed Shrimp Processing Industries:

Average 21000 and 2250 Kg/day/plant shrimp was processed in peak season (May–September) and off- peak (October – April) respectively.



(CSFL=Cosmos Sea Foods Ltd. AtSFL= Atlas Sea Foods Ltd., FFL= Fresh Foods Ltd. RFL=Rosemco Foods Ltd. AmSFL=Amam Sea Foods Ltd. CMCL= Chalna Marine and Co. NSFIL=National Sea Food Industries Ltd. OSEL=Organic Shrimps Export Ltd. KFFEL= Khulna Frozen Foods Export Ltd. ASFL=Apello Sea Foods Ltd. JSFL=Jahanabad Sea Foods Ltd. and JFFL=Jalalabad Frozen Foods Ltd.).

Fig 4.1. Shrimp processed in surveyed Shrimp Processing Industries (Kg/ day)

4.1.2. Solid waste generated from Shrimp processing industries:

Average 6800 and 775 Kg/day/plant solid waste was produced in peak season and off-peak.

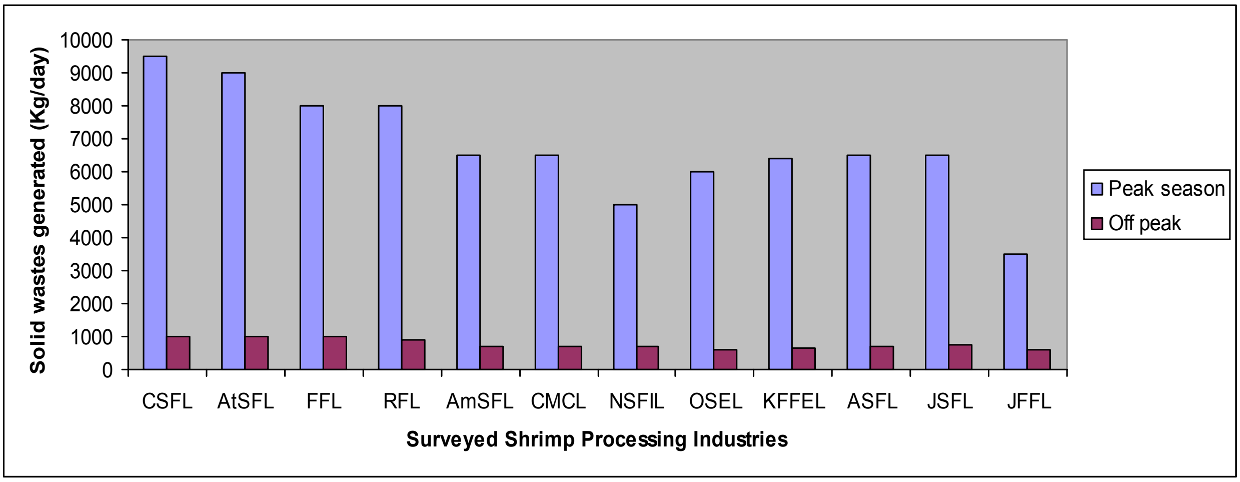


Fig 4.2 (a) Solid waste generated from surveyed Shrimp Processing Industries (Kg/day)

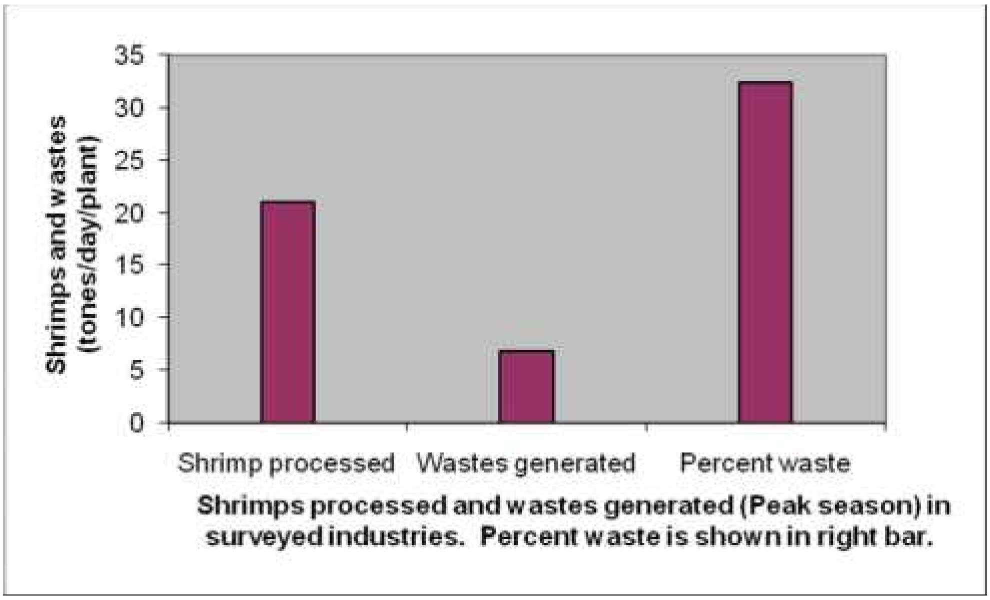


Fig 4.2 (b) Shrimps processed, wastes generated and percent waste in peak season (tones/ day/plant)

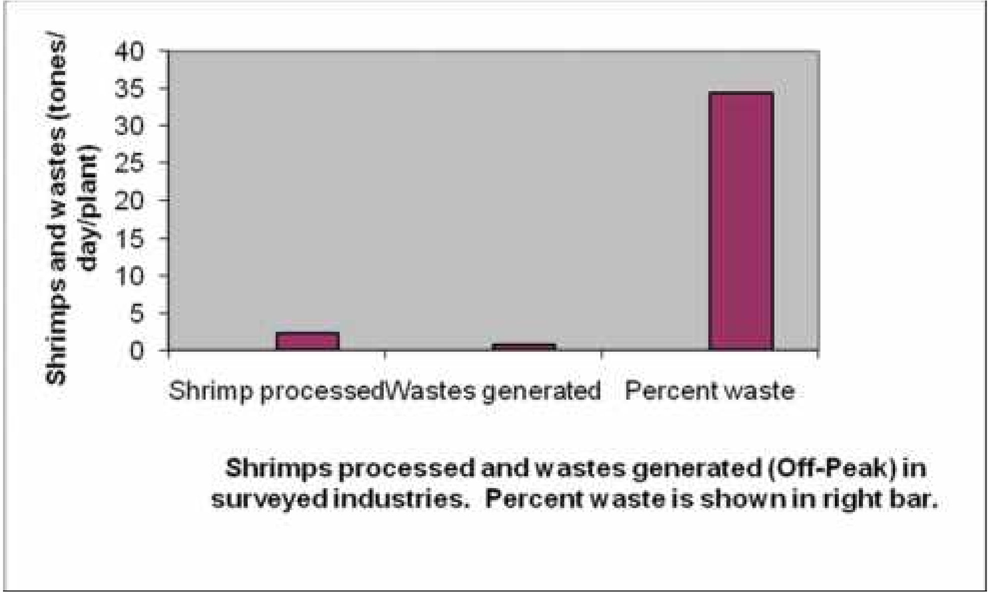


Fig 4.2 (c) Shrimps processed, wastes generated and percent waste in off-peak (tones/ day/plant)

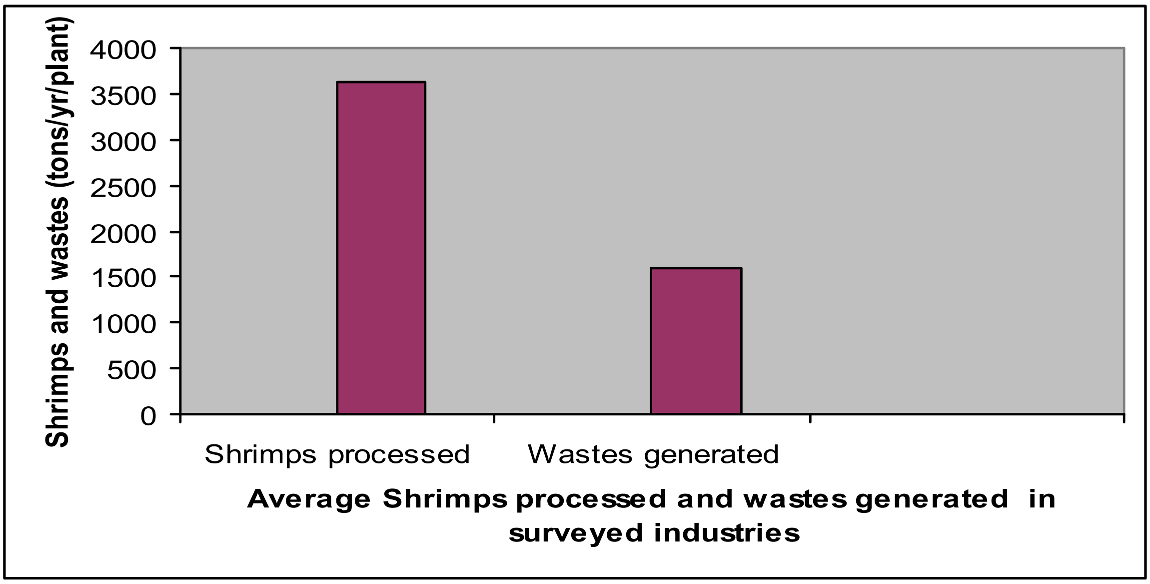


Fig 4.2 (d) Annual shrimps processed and wastes generated (tones/Yr/plant)

4.1.3. Effluents discharged from shrimp processing industries:

Average 47500 and 5591 L/day/plant effluent was discharged in peak season and off-peak respectively. The Ratio of shrimp: waste: effluent is 3:1:7 in peak season and 2.9:1:7.2 in off-peak.

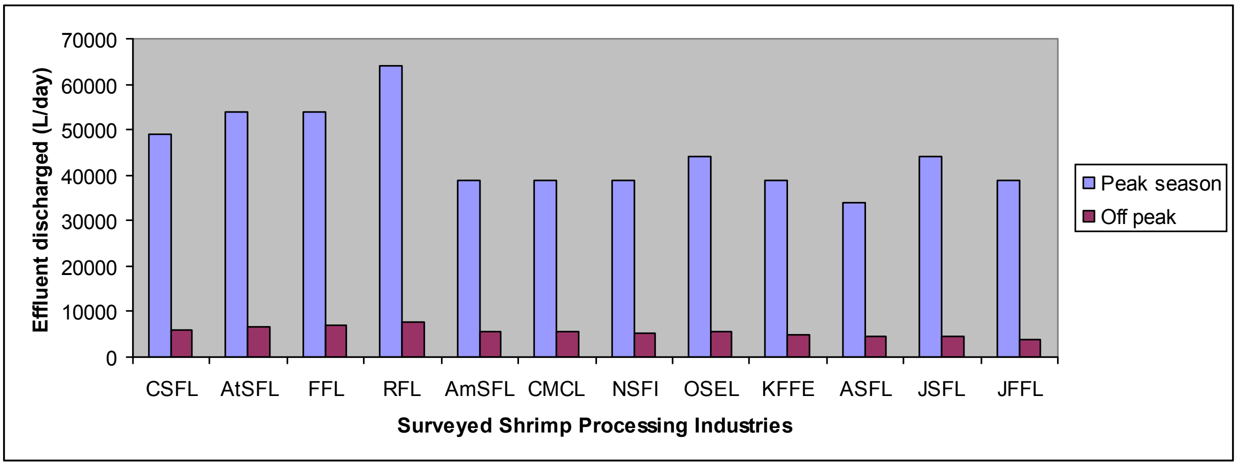


Fig 4.3 (a). Effluent discharged from surveyed Shrimp Processing Industries (L/day)

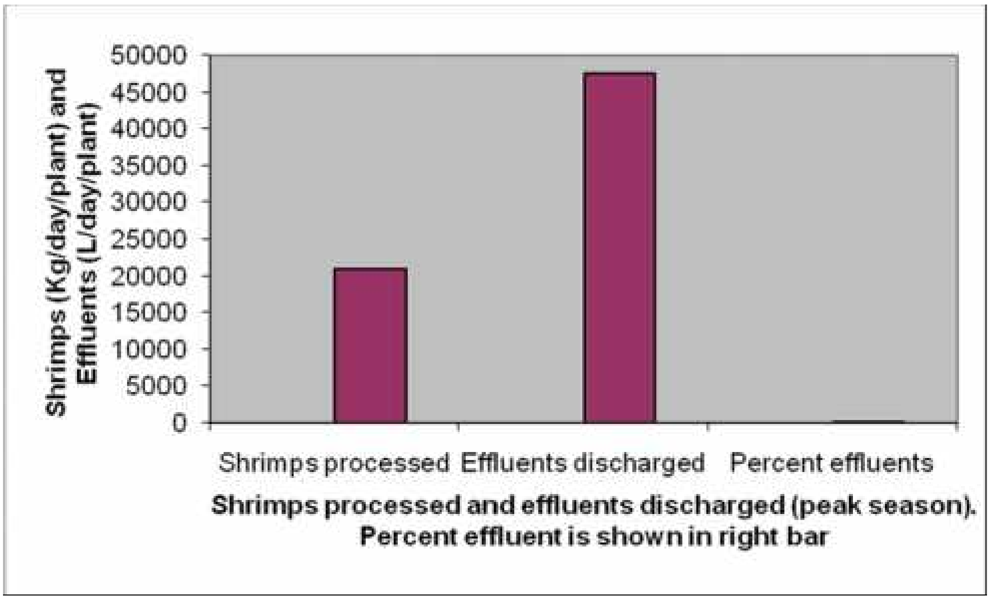


Fig 4.3 (b) Shrimps processed, effluents discharged and percent effluent in peak season (L/ day/plant)

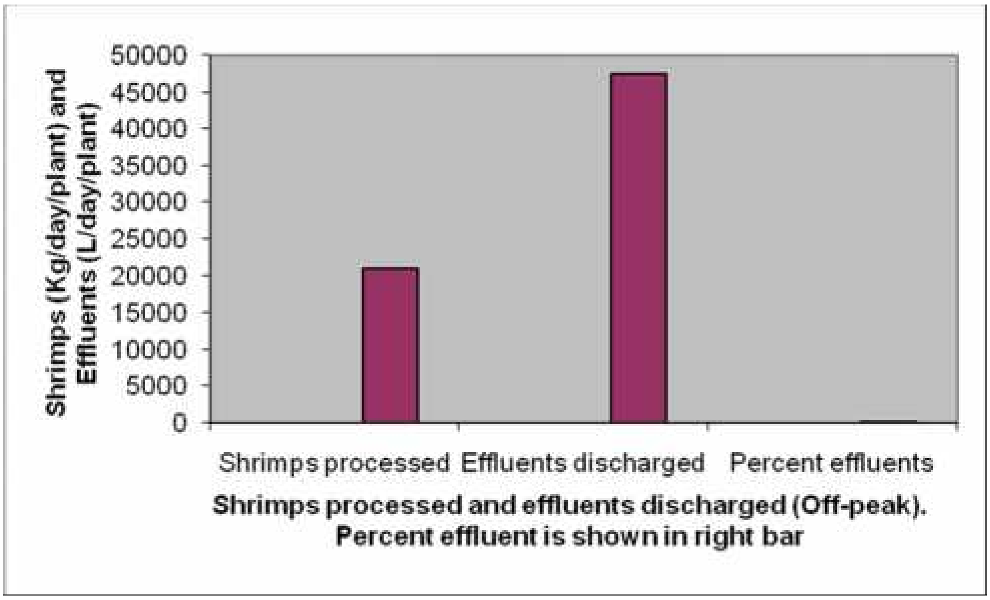


Fig 4.3 (c) Shrimps processed, effluents discharged and percent effluent in off-peak (L/ day/plant)

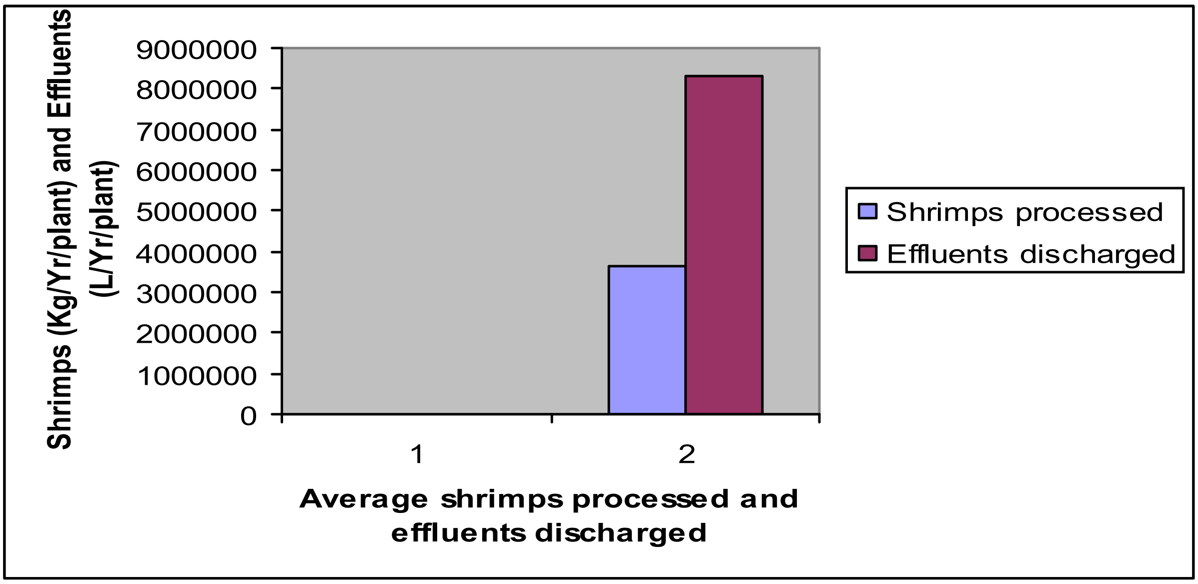


Fig 4.3 (d). Annual shrimps processed (Kg/Yr/plant) and Effluents discharged (L/Yr/plant)

Table 4.1. Shrimp processed, solid wastes and effluents discharged/ plant/day in 12 surveyed industries

	Peak season (May – Sept) (Mean)	Off-peak (October – April) (Mean)
Shrimp Processed Kg/day/plant	21,000	2,250
Solid waste Produced Kg/day/plant	6,800	775
Effluent Discharged L/day/plant	47,500	5,591
Ratio of shrimp processed: solid waste: effluent	3:1:7	2.9:1:7.2

4.1.4. Waste management in the surveyed industries:

For the waste management in industrial plants, establishment of ETP is mandatory according to the compliance of ECA-1995 (Ammended-2010), under section 9, Where, due to incident, the discharge of any environmental pollutant occurs or activities or an accident is likely to occur in excess of the limit prescribed by the rules, the person responsible and the person of occupied of the place of occurrence or related organization shall take measures to control or mitigate the environmental pollution by installation of ETP.

Under subsection 15A, where a person or a group of persons or the public suffers loss due to violation of a provision of this Act or the rules made there under or a direction issued under section 7, the person, and group, public or on behalf of them the Director General may file a suit for compensation. No ETP in any of the twelve surveyed industries was noted (Fig. 4.4).

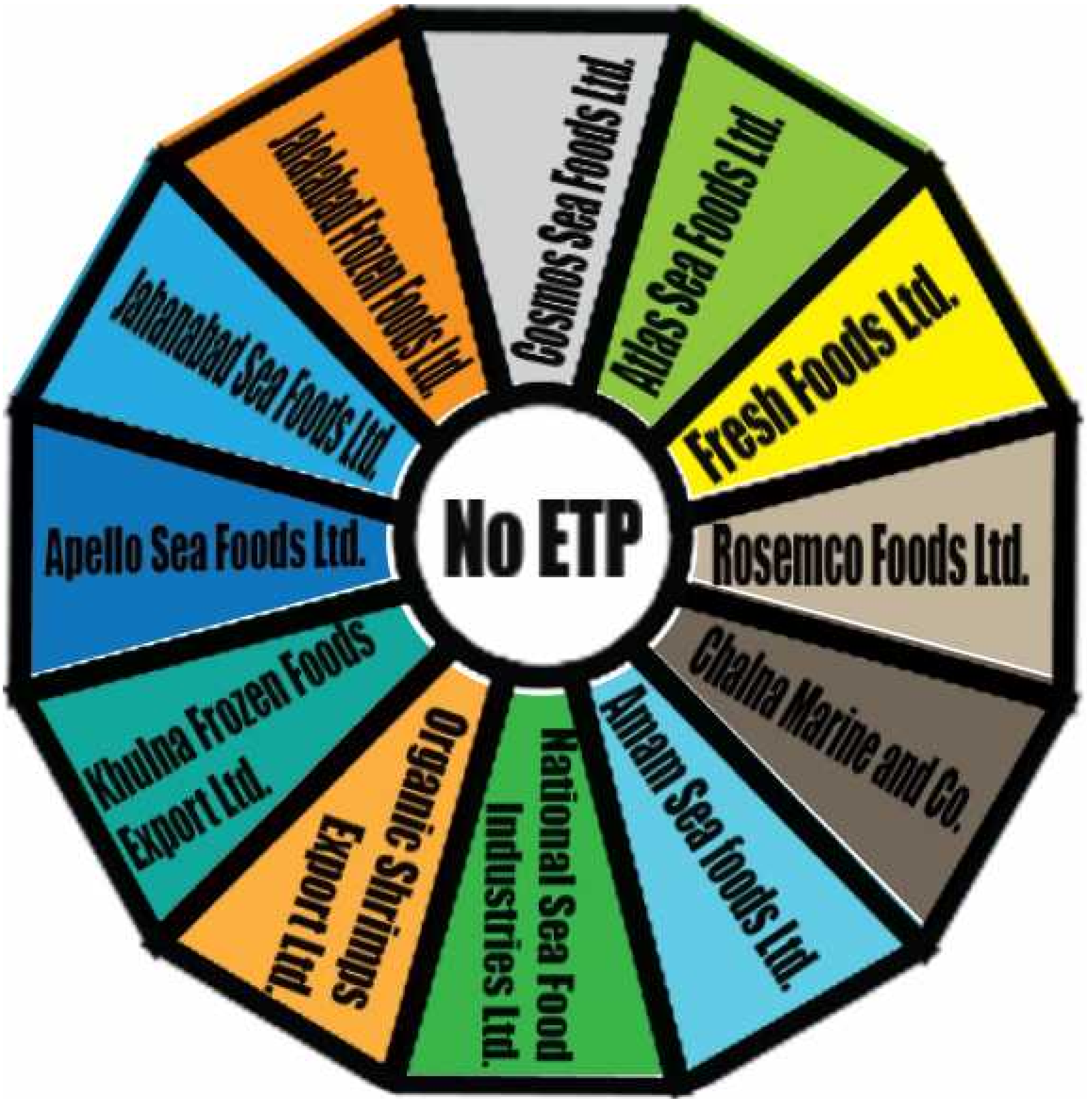


Fig. 4.4. ETP facilities in surveyed shrimp processing industries

4.1.5. Type of wastes generated and disposal:

According to ECA-1995 (Ammended-2010), under section 2, "Hazardous waste" means any kinds of waste, due to its physical or chemical properties or contraction with other waste or substances create toxicity, infection, oxidation, exploration, radioactivity, decay or other harmful effect to environment". According to ECA-1995, under section 6A, If, on the advice of the Director General that any kind of polythene shopping bag, or any other article made of polyethylene or polypropylene, or any other article is injurious to the environment, the Government may, by notification in the official Gazette, issue a direction imposing absolute ban on the manufacture, import, marketing, sale, demonstration for sale, stock, distribution, commercial carriage or commercial use, or allow the operation or management of such activities under conditions specified in the notification, and every person shall be bound to comply with such direction. According to ECA-1995 (Ammended-2010), under section, 6C**,** to protect the environmental damage, government with respect to provision of other law can control by means of provision production, processing, contain, storage, loading, supply, transportation, import, export, disposal, dumping etc. of hazardous waste. But from the survey it is clear that the shrimp processing industries of Khulna region are generating huge amount of solid wastes which are listed below.

4.1.5.1. Type of solid wastes produced from shrimp processing industries are listed as:

A) Wastes from Packaging:

- Polythene
- Papers
- Plastics
- Cartons
- Polystyrenes
- Jute ropes
- Plastic ropes
- Scotch tape
- Labels
- PP band
- Paper board

B) Wastes from Fish:

- Head
- Shell
- Flesh
- Raw fish
- Damaged fish
- Tail
- Fat
- Shrimp fingers etc.

4.1.5.2. Disposal of wastes:

The disposal routes of wastes and effluents of shrimp processing industries are presented in percent basis:

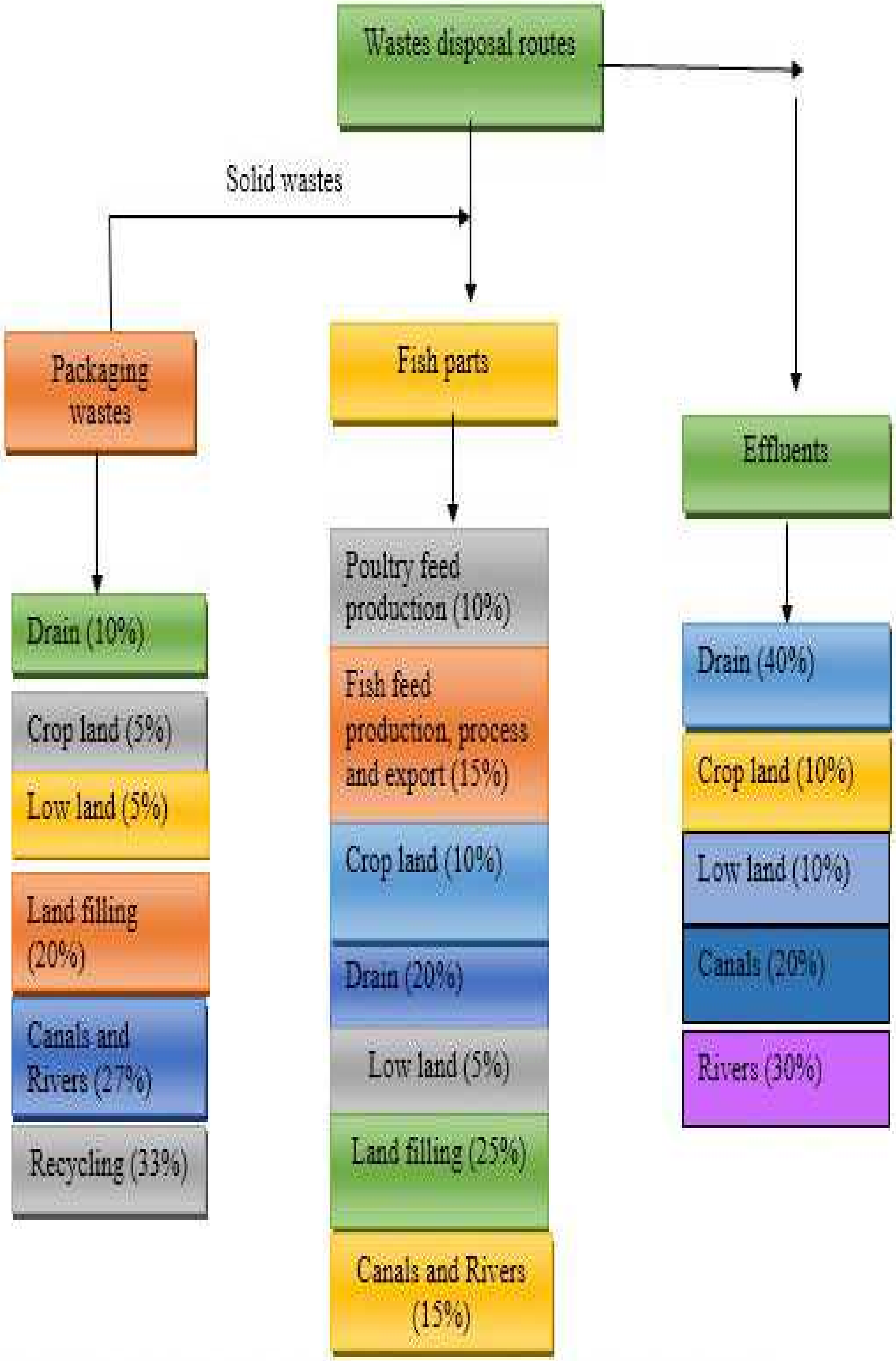


Fig. 4.5. The disposal routes of wastes and effluents of shrimp processing industries

4.1.6. Experiences and concern of the local people of Khulna region on environmental quality degradation from Shrimp Processing Industries:

The environmental problems gathered from local people around surveyed shrimp processing industries are summarized below:

- Agricultural land, canal, river, farmer’s land, low lying area, water bodies are polluting and soil and water quality are deteriorating
- Color of the soils and water is changing
- Various non biodegradable materials such as polythene, Scotch tape, plastic rope, cartons, Polystyrene, papers along with biodegradable solid wastes are dumped and causing aesthetic problems and public nuisance
- Producing foul odor and causing air pollution
- The yield of rice and other crops are decreasing in surrounding areas
- Increase in weed propagation in crop fields
- Number of fish and species diversity is changing
- Deterioration of Surface water quality
- Deterioration of soil quality
- Causing occupational and public health hazard such as cold, fever, skin diseases, diarrhea, respiratory problems, allergy, asthma, dysentery, water storage in lung etc.
- Ammonia gas leakage
- Sound/ noise pollution

4.1.7. Processes/ steps involved in the shrimp processing industries in Khulna region.

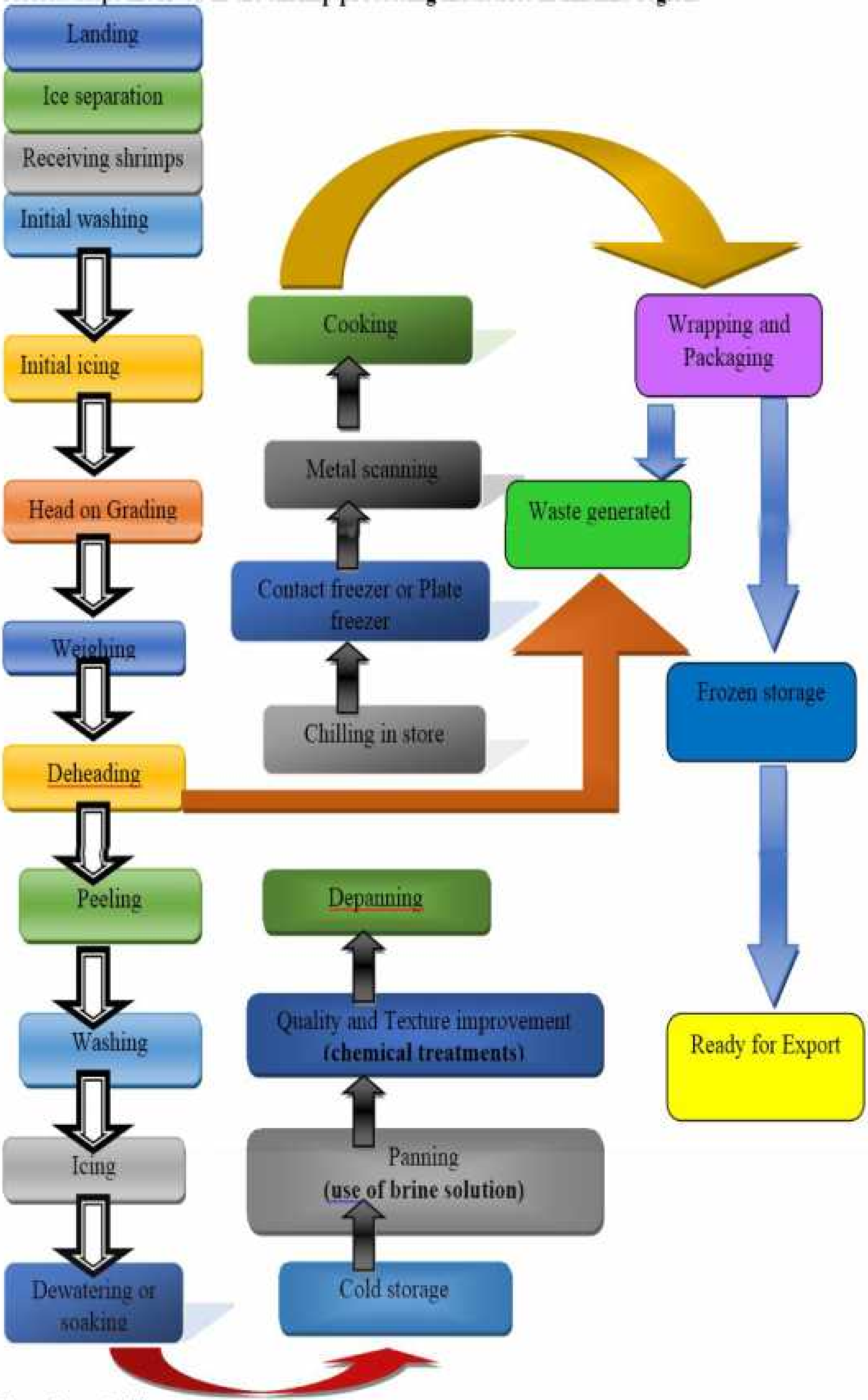
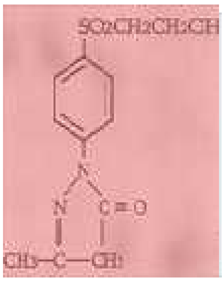
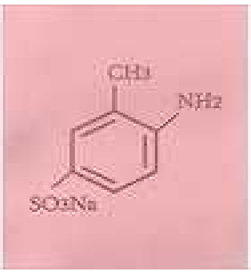


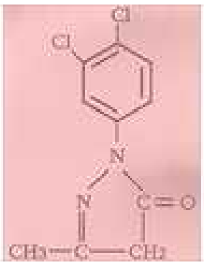
Fig 4.6. Flow chart of shrimp processing

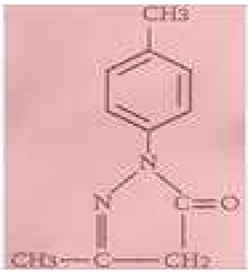
4.1.8. Chemicals Used in the shrimp processing industries:

Chemicals used in surveyed shrimp processing industries are listed as Brine solution, Caustic soda, Lime, Bleaching powder, Soap, Detergent, Salt, Chill water, Sodium Tri Phosphate (STP), Sodium Meta–bi-Phosphate (SMBP), Sodium Tri Poly Phosphate (STPP), Sodium Meta-bi-Sulfate (SMBS), Sodium-di-Phosphate, Chlorine (Cl), Pesticides during shrimp preservation, Ammonia (NH_3) and Dye stuff (Neelikon Orange Red). The formula of Neelikon dyes are:









Picture of Neelikon dyes:

Fig. 4.7. Neelikon dyes used in shrimp processing industries

4.1.9. Machineries Used in shrimp processing industries:

Machineries used in surveyed twelve shrimp processing industries are listed as Receiver/ Conveyor Belt, Compressor, Flake ice machine, Generator, Plate Freezer, Blast Freezer, Boiler, Cold store, Frequency Counter, Ice store and Ice Breaking Machine, Air Cooler, Reverse Osmosis Plant, Ozone generator to clear bacteria, UV treatment plant, Individual Quick Frozen Machine (IQF Machine), Metal Detector, Shrink wrapping machine, Soaking machine, Water pump and commercial Cook Machine.

4.1.10. Occupational health hazards among the workers:

Reported health problems among the workers are skin diseases, cold fever, allergy, asthma, dysentery, water storage in lung etc.

4.2. Raw effluents characteristics:

Raw effluents of the main disposal points of four shrimp processing industries were analyzed for physical, chemical and biological properties and the results are presented in table 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7.

4.2.1. Physical characteristics of the effluents:

The physical properties such as color, temperature and turbidity were measured and results are presented in table 4.2.

Table 4.2. Color, Temperature and Turbidity of effluents discharged from Shrimp Processing Industries

Water Samples		Turbidirty (NTU)	Temperature (^{0}C)
RW	Colorless	28	29
AFP1	Colored	368	24.0
AFP2	Colored	665	24.0
AFP3	Colored	517	25.0
CFP1	Colored	362	26.0
CFP2	Colored	560	24.5
CFP3	Colored	422	25.0
FFP1	Colored	340	26.0
FFP2	Colored	566	25.0
FFP3	Colored	419	26.5
RFP1	Colored	305	26.5
RFP2	Colored	499	25.0
RFP3	Colored	428	27.5

(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

The effluents collected from discharge points (P_1) was observed straw color most probably because shrimp processing industries use various types of dye stuff and chemicals as quality enhancer. The temperature of the effluents of outlet was 25.6±09 ^{0}C and turbidity was measured 344±14 NTU.

4.2.2. Chemical characteristics of the effluents:

Chemical characteristics of the effluents of the main disposal points were analyzed for pH, EC, %Salt, DOC, DO, TDS, TSS, BOD, COD, CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-, NH_4^+-N, NO_3^-- N, Na^+, K^+, Ca^{2+}, Mg^{2+}, Hardness, Zn, Mn, Ni, Cd, Cr, Pb, TC and FC. The results are presented in table 4.3, 4.4 and 4.5.

Table 4.3. pH, EC, %Salt and Dissolved Organic Carbon in effluents

Samples	pH	EC (mScm^{-1})	Salt (%)	DOC mgL^{-1}
RW	7.60fg	2.90f	0.19%f	82.33h
AFP1	8.10ab	17.21a	1.10%a	303.67ab
AFP2	7.80cdef	13.74c	0.88%c	328.67a
AFP3	7.65efg	12.48de	0.80%de	273cd
CFP1	7.88bcd	15.53b	0.99%b	200.33g
CFP2	7.82cde	13.90c	0.89%c	251.33de
CFP3	7.68defg	12.49de	0.80%de	238.33ef
FFP1	8.18a	15.54b	0.99%b	244.33e
FFP2	7.95bc	14.99b	0.96%b	284bc
FFP3	7.90bc	13.10d	0.84%d	276.67bcd
RFP1	8.08ab	12.57de	0.80%de	186g
RFP2	7.48g	12.11e	0.77%e	228.33ef
RFP3	8.09ab	12.10e	0.77%e	212fg

(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.4. DO, TDS, TSS, BOD_5, COD, CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-, NH_4^+-N and NO_3^--N in effluents

Samples	DO	TDS	TSS	BOD	COD	CO_3^{2-}	HCO_3^-	SO_4^{2-}	Cl^-	NH_4^+	NO_3^-
	mgL^{-1}								(%)	mgL^{-1}	
RW	3.71a	980e	84j	84g	108e	NIL	4.50g	65g	0.13d	3.17h	2.36h
AFP1	1.82b	1670c	440f	371f	572d	NIL	31.20bc	306f	0.92a	7.57h	11.4g
AFP2	0.25f	1667c	566g	403cd	966a	NIL	29.18d	401cde	0.78bc	75cd	14.8c
AFP3	0.45e	1682c	518i	411bcd	897b	NIL	27.12e	436bc	0.81bc	14.8g	13.8d
CFP1	1.79b	1320d	366g	378ef	598d	NIL	16.80f	418bcde	0.93a	42.57f	13.5de
CFP2	0.19f	1340d	490h	398d	956a	NIL	17.20f	445b	0.73c	89.97e	17.2a
CFP3	0.94d	1329d	410e	402cd	911b	NIL	16.02f	447b	0.76bc	54.3e	12.9ef
FFP1	1.64c	2330a	636a	392de	603d	NIL	32.45b	378e	0.81bc	68.3d	12.4f
FFP2	0.15f	2350a	966a	408cd	980a	NIL	32.0b	400cde	0.78bc	81.1bc	16.4b
FFP3	0.49e	2310a	922b	419abc	902b	NIL	31.61b	412bcde	0.77bc	75cd	14.7c
RFP1	1.55c	1790b	730d	367f	599d	NIL	34.75a	385de	0.96a	82.23bc	10.7g
RFP2	0.21f	1770c	839c	430ab	891bc	NIL	31.72b	423bcd	0.79bc	92.87a	17.9a
RFP3	0.56e	1774b	899b	436a	860c	NIL	29.52cd	485a	0.83b	87.74ab	13.4de

(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.5. Na^+, K^+, Ca^{2+}, Mg^{2+} and Hardness in effluents

Samples	Na^+	K^+	Ca^{2+}	Mg^{2+}	Hardness
	$meqL^{-1}$				mgL^{-1}
RW	21g	1.70h	3.82f	2.47h	15.70f
AFP1	69ab	3.41d	26.41ab	9.72a	105.88a
AFP2	54.de	3.87ab	25.68abcd	8.50c	99.05b
AFP3	46ef	2.77fg	23.79e	6.75g	87.16e
CFP1	71ab	3.10e	27.14a	9.23b	105.69a
CFP2	63bc	3.91a	25.19bcde	8.19cd	96.56bc
CFP3	53de	3.0ef	23.72e	7.28ef	89.15de
FFP1	66abc	3.56cd	26.69ab	9.67a	106.38a
FFP2	64bc	3.63bcd	25.98abc	7.53e	95.82bc
FFP3	42f	2.70g	24.23de	6.92fg	88.95de
RFP1	74a	3.47d	27.22a	8.57c	103.19a
RFP2	59cd	3.75abc	26.17abc	7.96d	98.07b
RFP3	47ef	2.87efg	24.72cde	7.50e	92.55cd

(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.6. Zn, Mn, Pb, Cd, Cr and Ni in effluents

Samples	Zn	Mn	Pb	Cd	Cr	Ni
	mgL^{-1}					
RW	48.8j	22j	Nil e	Nilf	12.2f	1.9h
AFP1	81.6f	112g	1de	0.50b	16.8de	13.3a
AFP2	75.2gh	128ef	2cde	0.52ab	17.1cd	12.9a
AFP3	78.0fg	102hi	4bc	0.59a	18.4ab	13.1a
CFP1	115.5bc	132de	6ab	0.08def	16.6de	7.7b
CFP2	122.1ab	108gh	8a	0.09def	17.4cd	4.3def
CFP3	116.6bc	99i	4bc	0.17cd	18.7a	4.4de
FFP1	68.3i	148bc	2cde	0.05ef	16.1e	4.6d
FFP2	71.5hi	136d	2cde	0.06ef	17.8bc	8.2b
FFP3	98.6d	145c	3cd	0.18c	17.4cd	6.3c
RFP1	112.5c	122f	2cde	0.14cde	16.9de	3.4fg
RFP2	124.7a	153b	1de	0.08def	17.3cd	3.6efg
RFP3	88.0e	165a	2cde	0.19c	18.3ab	3.3g

(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

The results show that the pH of the raw effluents of the outlet or source points was 8.06±0.12, EC was 15.21±2 $mSCm^{-1}$, Salt was 0.97±0.13%, DOC was 233.58 mgL^{-1}, DO was 1.7±0.12 mgL^{-1}, TDS was 1778±522 mgL^{-1}, TSS was 468±262 mgL^{-1}, BOD was 377±15 mgL^{-1}, COD was 593±10 mgL^{-1}, CO_3^{2-} was Nil, HCO_3^- was 28.8±6 mgL^{-1}, SO_4^{2-} was 372±46 mgL^{-1}, Cl^- was 0.91±0.05 mgL^{-1}, NH_4^+-N was 50.17±32 mgL^{-1}, NO_3^--N was 12±1.5 mgL^{-1}, Na^+ was 70±4 $meqL^{-1}$, K^+ was 3.39±0.17 $meqL^{-1}$, Ca^{2+} was 26.87±0.35 $meqL^{-1}$, Mg^{2+} was 9.3±0.37 $meqL^{-1}$, Hardness was 105.29±1.09 mgL^{-1}, Zn was 94.48±21.02 mgL^{-1}, Mn was 128.5±19.5 mgL^{-1}, Pb was 2.75±1.75 mgL^{-1}, Cd was 0.19±0.14 mgL^{-1}, Cr was 16.6±0.3 mgL^{-1} and Ni was 7.25±6.05 mgL^{-1}.

4.2.3. Biological properties of the effluents:

The results of the biological properties at effluent and up to 350m away are presented in table 4.7.

Table 4.7. Number of TC and FC in effluents

Samples	Total Coliforms	Faecal Coliforms
	(c.f.u/100ml)	
RW	1.9×10^2	12
AFP1	2.6×10^3	122
AFP2	4.1×10^3	178
AFP3	3.85×10^3	110
CFP1	2.3×10^3	201
CFP2	4.75×10^3	219
CFP3	3.45×10^3	176
FFP1	3.5×10^3	303
FFP2	4.5×10^3	207
FFP3	4.25×10^3	200
RFP1	3.2×10^3	311
RFP2	4.2×10^3	411
RFP3	4.55×10^3	275
CV =	35.52%	48.28%

(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

The results show that the TC of the raw effluents of the source points was $2.9\times10^3\pm0.6\times10^3$ and FC of the effluents was 235±76. The probable sources of contamination are reference water, ice, workers hands, fish it self etc.

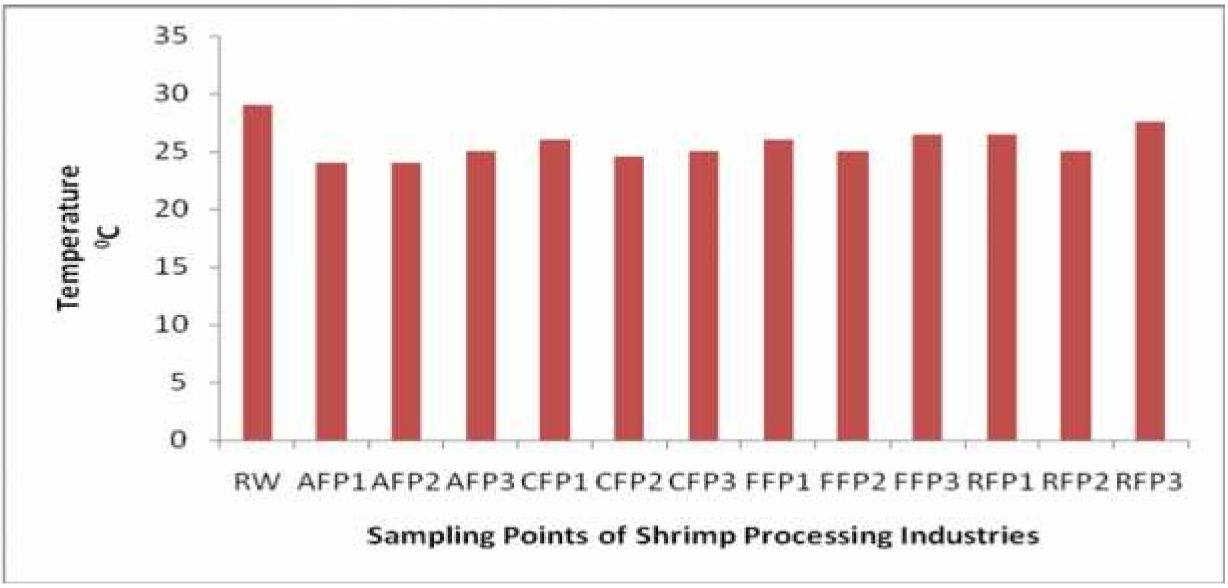
4.2.4. Changes in effluent characteristics with distance:

4.2.4.1. Color:

Effluents discharged from different shrimp processing industries were analyzed. Color varied in effluents in different locations. The effluent samples collected from discharge point (P1) was straw in color, most decomposed points (P_2) indicated dark in color and agricultural land contaminated with effluents (P_3) was brownish to dark in color but the reference water samples exhibited colorless, odorless and transparent clear liquid. Presence of humic acids, fulvic acids, metallic ions, suspended matter, phytoplankton, weeds, and dyes in industrial effluents may cause color in natural water (Gupta and Govindarajan, 2000). Dye stuffs used in shrimp processing industries is responsible for straw color in fresh effluents, dark color in P_2 is for the presence of reduced organic compounds (Chhabra, 1996) and brownish to dark color in P_3 due to the presence of OM. Colorful water is polluted water and it has restriction for use for drinking, irrigation and industrial uses.

4.2.4.2. Temperature:

Temperature of effluents was measured and the results show that the mean temperature of P_1 was $25.63\pm0.9\ ^0C$, $24.62\pm0.38\ ^0C$ for P_2 and $26\pm1.5\ ^0C$ for P_3 and $29\ ^0C$ for reference water samples (Table 4.2). So, the temperature of the effluents was less than that of reference water (Fig 4.8). The maximum temperature was recorded in I_4 $(26.3\pm1.2)\ ^0C$ and minimum in I_1 $(24.3\pm0.7)\ ^0C$. This variation of temperature is probably because of different activities including processing, freezing, storage etc. The water is not so hot or cold that can affect environmental quality including soil and water.

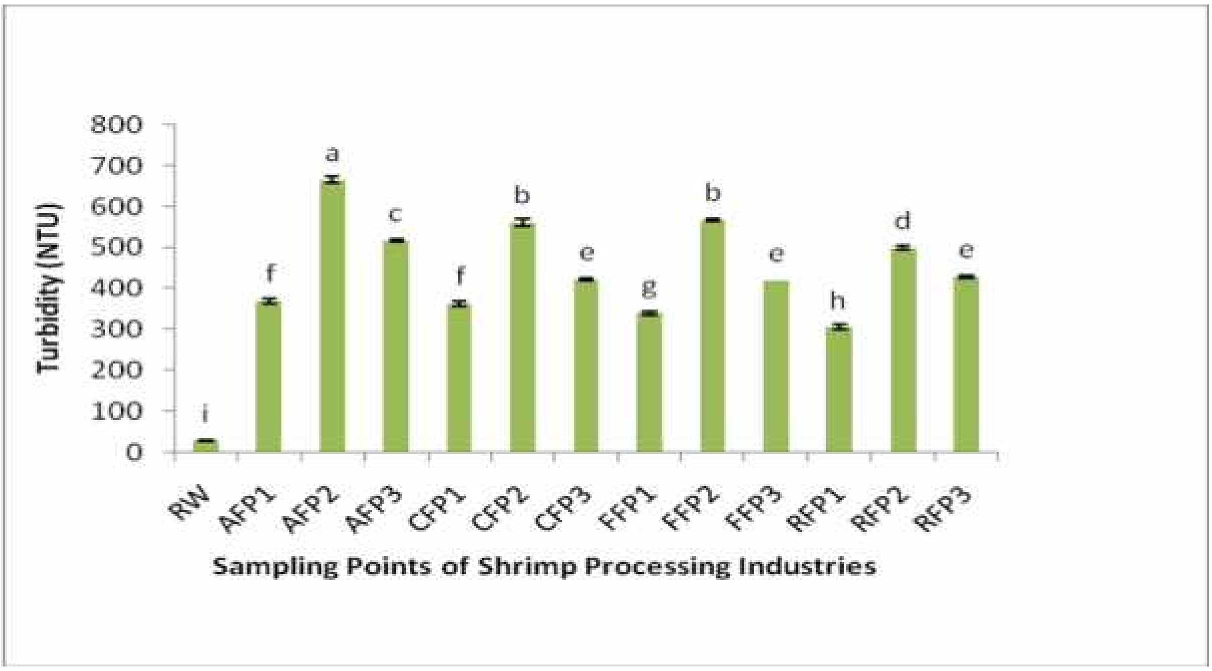


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.8. Temperature of the effluents from Shrimp Processing Industries

4.2.4.3. Turbidity:

Turbidity measured for effluents at discharge point were 344±14 NTU (Table 4.2) and increased with distance and traveling through cross section of land. The results show that the turbidity was measured and varied from 305 to 368 NTU at P_1, 499 to 665 NTU at P_2, 419 to 517 NTU at P_3 and 28 NTU was measured for RW (Table 4.2). The turbidity was highest (665 NTU) at P_2 which is the highly decomposed effluent accumulated point of maximum organic substances, followed by P_3, and P_1 (Fig 4.9). All values exceeded the values of the turbidity of RW. The results show that turbidity in all effluents was statistically significant at 5% level against RW (F=890.71) (Fig 4.9). However the differences in turbidity among the samples of different points and among the industries are statistically significant (Fig. 4.9). Increasing trend of turbidity may be caused by suspended and colloidal matter such as clay, silt, fine organic and inorganic matter, plankton and microscopic organisms by the addition of wastes and effluents released from the shrimp processing industries (Lenore *et al.,* 1998). Turbidity restricts the light penetration in water and reduce primary production *i.e.* photosynthesis (Gupta, 1999).



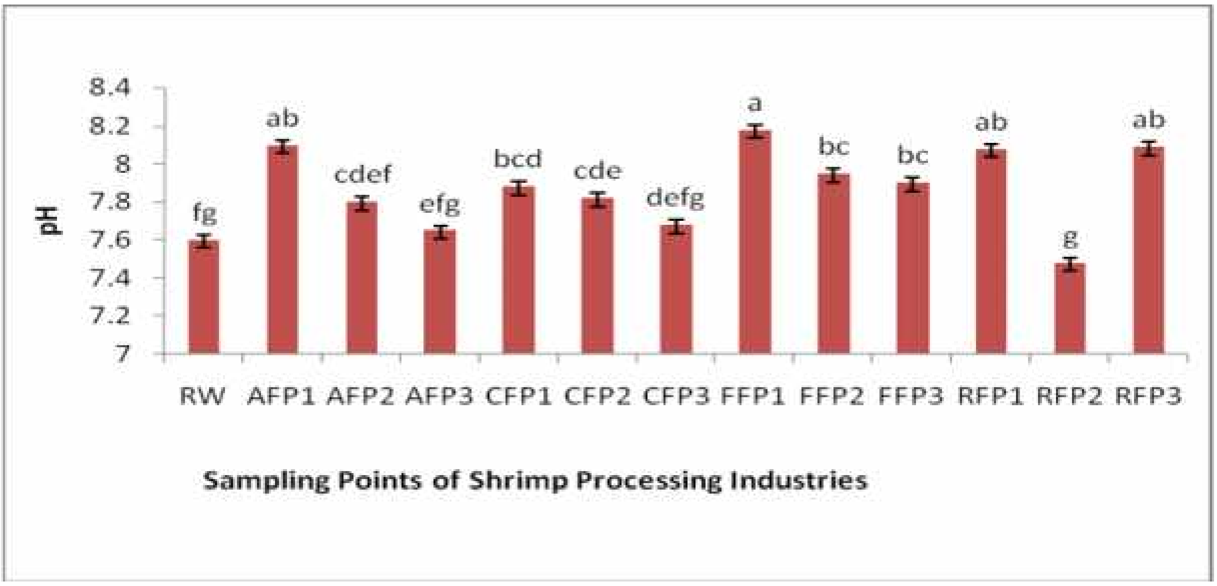
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.9. Turbidity of the effluents from Shrimp Processing Industries

4.2.4.4. pH

pH measured for effluents at discharge point were 8.06±0.12 (Table 4.3) and increased with distance and traveling through cross section of land. The pH was measured and varied from 7.88 to 8.18 at $P_{1,}$ 7.80 to 7.95 at P_2, 7.65 to 8.09 at P_3 and 7.60 was measured for corresponding reference water. The fish processing effluents at different points confirmed very high pH and magnitude of the difference is at the order of P1>P3>P_2 (Table 4.3). The highest pH (8.18) was observed at I_3P_1 and the lowest (7.48) at I_4P_2 (Fig. 4.10). The effluents of all industries and points contain significantly high pH than that of RW (Table 4.3). The results show that pH in all effluents is statistically significant at 5% level against RW (F=10.01) (Table 8.1). However the differences in pH among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.10). Containing high amount of organic matter, dyes and brine solution are mainly responsible for wide range pH variation. Main discharge point (P_1) contains highest pH for containing more salts and gradually reduced to P_3 and P_2. Extreme pH value or rapid change in pH can exert stress condition or destroy aquatic lives; even moderate changes from acceptable criteria limits of pH are deleterious to some species (EPA, 1974).

For high organic residues and humified materials in water body, the organic acid is high so, pH values might be less than the expected value but for excess salinity and positive ions (Na^+, K^+, Ca^{2+}, Mg^{2+}) the pH doesn't so less and ranged from 7.48 to 8.18. High concentrations of basic cations counter balances acidity (Fitz Patrick, 1986).



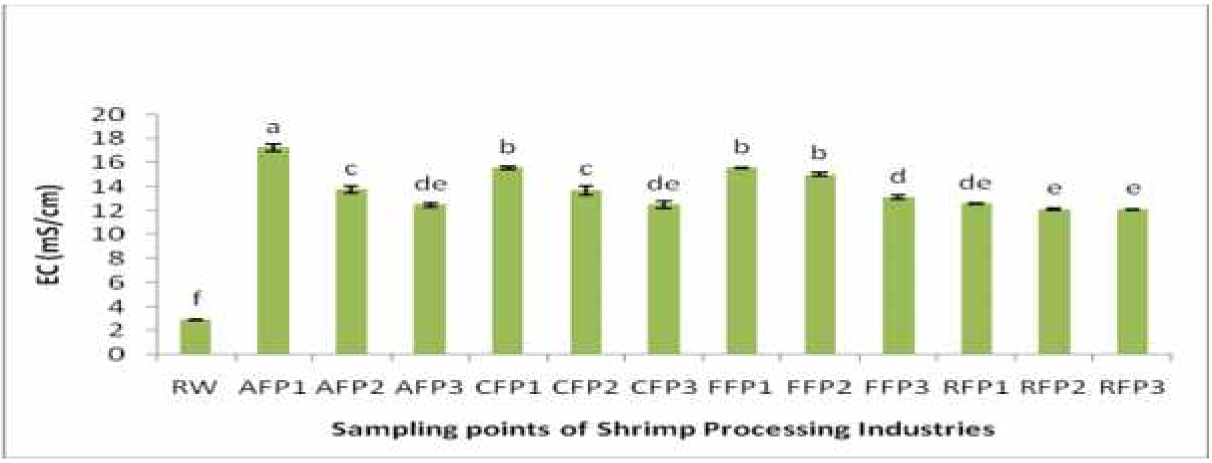
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.10. pH of the effluents from Shrimp Processing Industries

4.2.4.5. EC and Salinity:

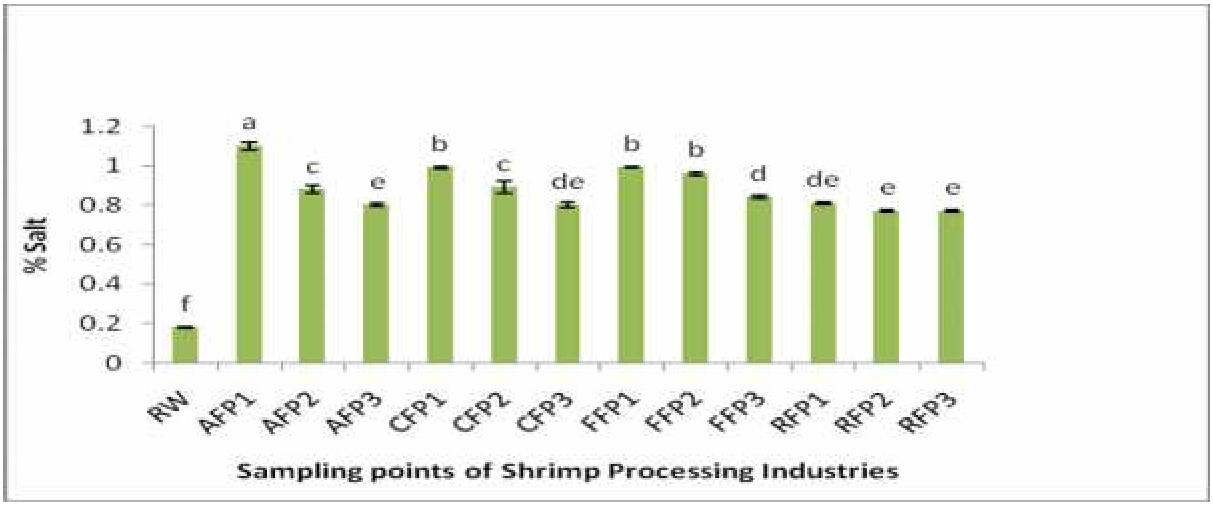
EC measured for effluents at discharge point (P_1) varied from 12.57 to 17.21 mS/Cm, 12.11 to 14.99 mS/Cm at P_2, 12.1 to 13.1 mS/Cm at P_3 and 2.9 mS/Cm was measured for RW (Table 4.3). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high EC and magnitude of the difference is at the order of P1>P2>P_3 (Table 4.3). The highest EC and salt (1.10% salt and EC 17.21 $mScm^{-1}$) was measured at I_1P_1 and lowest (0.77% salt and EC 12.10 $mScm^{-1}$) at I_4P_3 (Fig. 4.11 and 4.12). The effluents of all industries and points contained significantly high EC and salt than that of RW (Table 4.3). The results show that EC in all effluents was statistically significant at 5% level against RW (F=250.62) (Table 8.1). However the differences in EC among the samples of different points are statistically insignificant in most of the cases but among the industries significant differences were in Atlas and Cosmos Sea Foods Ltd. and insignificant for Fresh and Rosemco Sea Food industries (Fig. 4.11).

The highest EC and salinity was measured in P_1 of all industries because main disposal sites receives saline water and brine solution just after processing and washing of shrimps and the amount of EC or salt reduced with distance because positive ions such as K^+, Ca^{2+}, Mg^{2+}, Na^+ are counter balanced by H^+ produced from decomposition of the organic residues (Bremmer, 1971). In the present investigation the amount of DOC load is recorded also very high 200.33-328.67 mgL^{-1} (Table 4.3). The EC value or salt content was lowest in P_3 probably because of leaching loss, reduction of effluent flow to the last point and absorbed by plants. Continuous release of salt content can affect water, plants, crops and soil quality. Difference of percent salt measured for different shrimp processing industries can be explained by the differences in saline and brine water treatment during processing.



(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.11. EC of the effluents from Shrimp Processing Industries

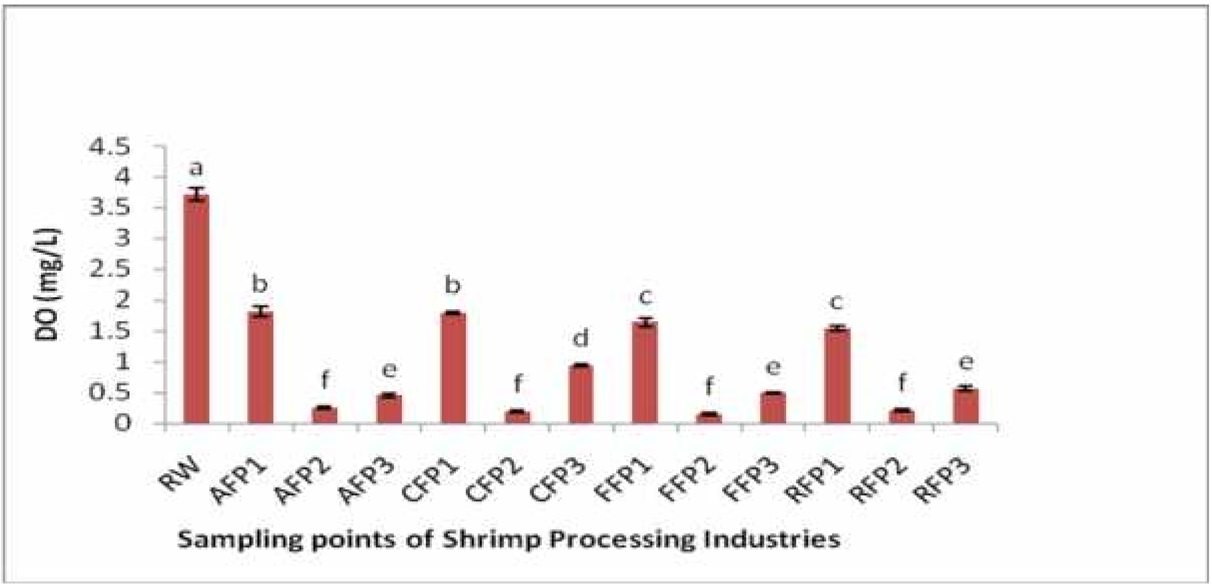


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.12. Percent salt of the effluents from Shrimp Processing Industries

4.2.4.6. Dissolved Oxygen (DO):

Dissolved Oxygen (DO) measured for effluents at discharge point (P_1) varied from 1.55 mgL^{-1} to 1.82 mgL^{-1}, 0.15 mgL^{-1} to 0.25 mgL^{-1} at P_2, 0.45 mgL^{-1} to 0.94 mgL^{-1} at P_3 and 3.71 mgL^{-1} was measured for RW (Table 4.4). The values decreased with distance and traveling through a cross section of land. The shrimp processing effluents at different points confirmed very low level of dissolved oxygen and magnitude of the difference is at the order of P1>P3>P_2 (Table 4.4). The highest DO (1.82 mgL^{-1}) was measured at I_1P_1 and lowest (0.15 mgL^{-1}) at I_3P_2 (Fig 4.13). The effluents of all industries and points contained significantly lower value of DO than that of RW (Table 4.4). The results show that DO in all effluent samples was statistically significant at 5% level against RW (F=477.46) (Table 8.1). However the differences in DO among the samples of different points and among the industries are statistically significant (Fig. 4.13). DO decrease in the most polluted sites for the decomposition of organic wastes, which is the food source of micro organisms. The micro organisms need dissolved O_2 which would be utilized within a short time, So, DO is very low.

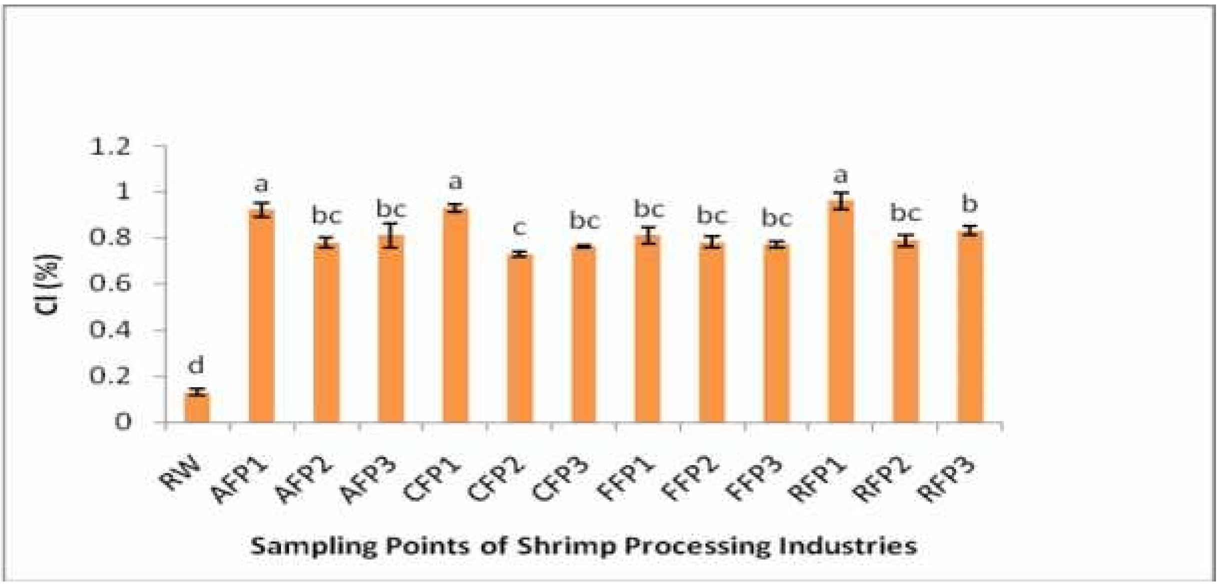


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.13. Dissolve Oxygen (DO) of the effluents from Shrimp Processing Industries

4.2.4.7. Chloride (Cl^-):

Chloride (Cl^-) measured for effluents at discharge point (P_1) varied from 0.81% to 0.96%, 0.73% to 0.79% at P_2, 0.76% to 0.83% at P_3 and 0.13% was measured for RW (Table 4.4). The values increased with distance and traveling through a cross section of land. The shrimp processing effluents at different points confirmed very high level of Chloride and magnitude of the difference is at the order of $P1>P3>P_2$ (Table 4.4). The highest Chloride (0.96%) was measured at I_4P_1 and lowest (0.73%) at I_2P_2 (Fig 4.14). The effluents of all industries and points contained significantly high chloride than that of RW (Table 4.4). The results show that Chlorides in all effluents was statistically significant at 5% level against RW (F=56.36) (Table 8.1). However the differences in chlorides among the samples of different points and among the industries are statistically insignificant in most of the cases (Fig. 4.14). Chloride content is highest in main disposal point P_1 due to the use of NaCl and brine solution for washing of shrimps in the various steps, lowest in P_2 for more dilution and leaching loss and intermediate in P_3 due to the evaporation for topographically high land and the decrease of the depth of water. Chloride is high in effluents indicates alarming for the water environment and might exceed Na^+ due to the base exchange phenomena (Karanth, 1994). Cl^- works on the photosynthesis reactions in plants, algae and other flora (Bennett, 1993).

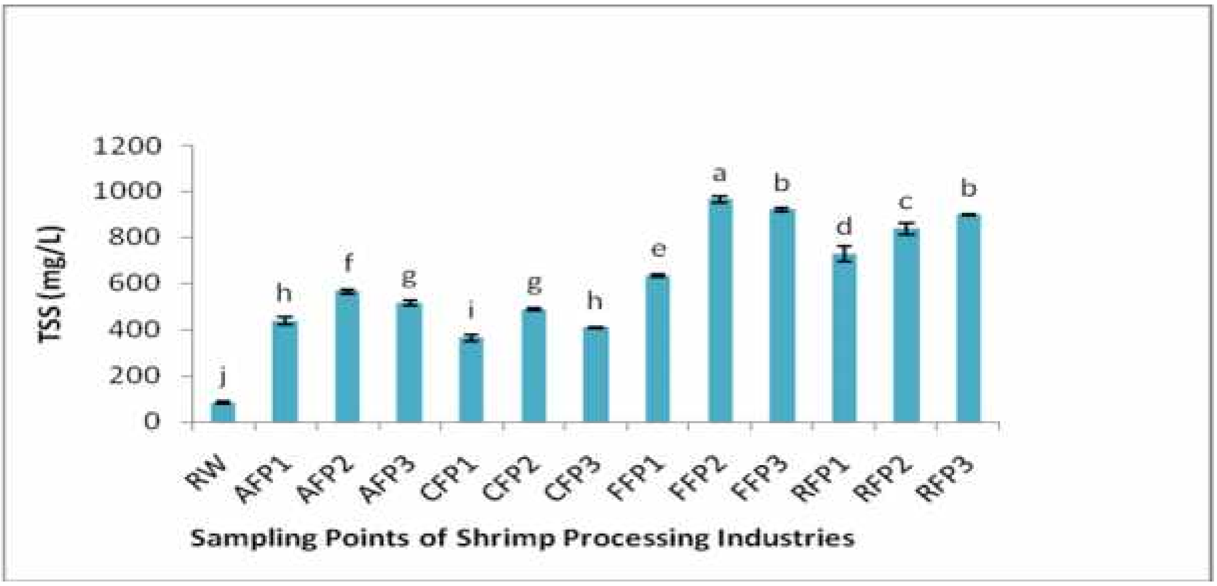


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.14. Chloride (Cl^-) of the effluents from Shrimp Processing Industries

4.2.4.8. Total Suspended Solids (TSS):

Total Suspended Solids (TSS) measured for effluents at discharge point (P_1) varied from 366 mgL^{-1} to 730mgL^{-1}, 490 mgL^{-1} to 966 mgL^{-1} at P_2, 410 mgL^{-1} to 922 mgL^{-1} at P_3 and 84 mgL^{-1} was measured for RW (Table 4.4). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of TSS and magnitude of the difference is at the order of P2>P3>P_1 (Table 4.4). The highest TSS (966 mgL^{-1}) was measured at I_3P_2 and lowest (366 mgL^{-1}) at I_2P_1 (Fig 4.15). The effluents of all industries and points contained significantly high TSS than that of RW (Table 4.4). The results show that TSS in all effluents was statistically significant at 5% level against RW (F=329.88) (Table 8.1). However, the differences in TSS among the samples of different points and among the industries are statistically significant in most of the cases (Fig. 4.15). Highest TSS values were in P_2 for better decomposition and slightly less in P_3 for topographic high position and lower flow of effluent. The findings of the study is more or less similar to the experiment of Carawan, 1991 and Michael *et al.,* 1980, who recorded 100 to 800 mgL^{-1} and 780 mgL^{-1} TSS respectively for the effluents discharged from the shrimp processing industries.

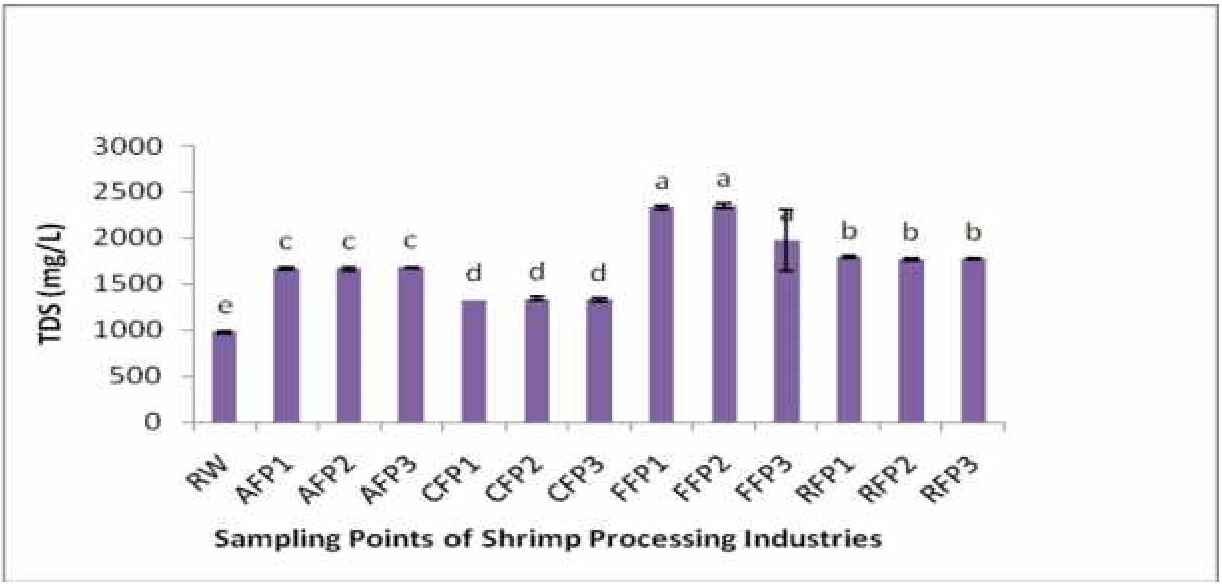


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.15. Total Suspended Solids (TSS) of the effluents from Shrimp Processing Industries

4.2.4.9. Total Dissolved Solids (TDS):

Total Dissolved Solids (TDS) measured for effluents at discharge point (P_1) varied from 1320 mgL^{-1} to 2330mgL^{-1}, 1340 mgL^{-1} to 2350 mgL^{-1} at P_2, 1329 mgL^{-1} to 2310 mgL^{-1} at P_3 and 980 mgL^{-1} was measured for RW (Table 4.4). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of TDS and magnitude of the difference is at the order of P2>P3>P_1 (Table 4.4). The highest TSS (2350 mgL^{-1}) was measured at I_3P_2 and lowest (1320 mgL^{-1}) at I_2P_1 (Fig 4.16). The effluents of all industries and points contained significantly high TDS than that of RW (Table 4.4). The results show that TDS in all effluents was statistically significant at 5% level against RW (F=654.80) (Table 8.1). However, the differences in TDS among the samples of different points and among the industries are statistically insignificant (Fig. 4.16). Carawan (1991) reported that TDS of shrimp processing effluents was 1000-8000 mgL^{-1} and Salam and Billah, 2013 measured 1165-1254 mgL^{-1}.



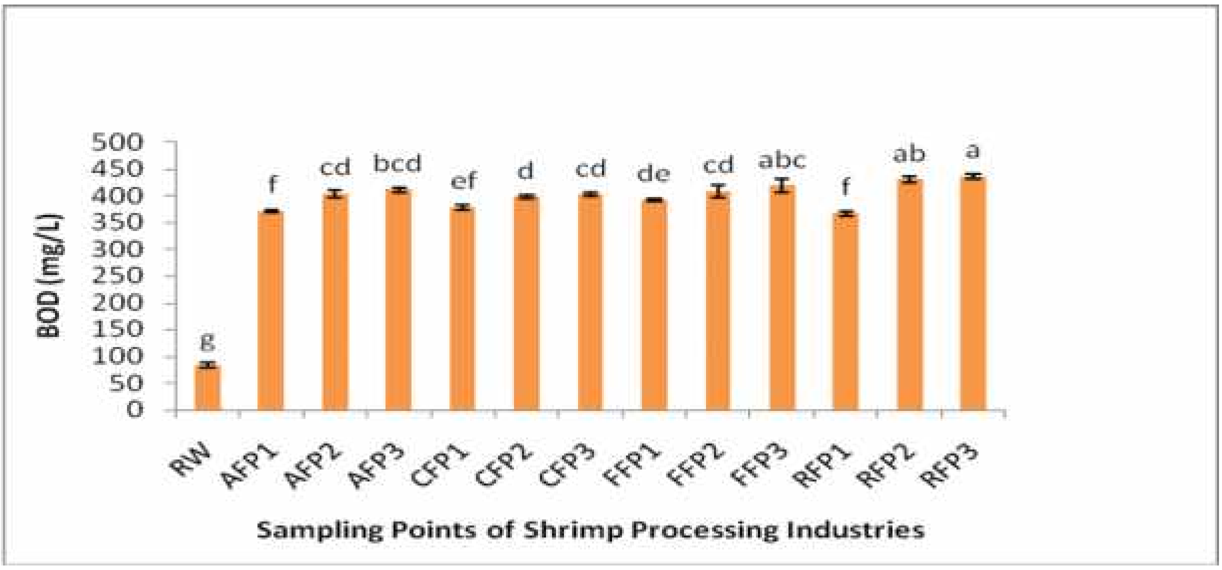
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.16. Total Dissolved Solids (TDS) of the effluents from Shrimp Processing Industries

4.2.4.10. Biological Oxygen Demand (BOD_5):

Biological Oxygen Demand (BOD_5) measured for effluents at discharge point (P_1) varied from 367 mgL^{-1} to 392 mgL^{-1}, 398 mgL^{-1} to 430 mgL^{-1} at P_2, 402 mgL^{-1} to 436 mgL^{-1} at P_3 and 84 mgL^{-1} was measured for RW (Table 4.4). The values increased with distance and traveling through cross section of land.

The shrimp processing effluents at different points confirmed very high level of BOD and magnitude of the difference is at the order of P3>P2>P_1 (Table 4.4). The highest BOD (436 mgL^{-1}) was measured at I_3P_3 and lowest (367 mgL^{-1}) at I_4P_1 (Fig 4.17). The effluents of all industries and points contained significantly high BOD than that of RW (Table 4.4). The results show that BOD in all effluent samples was statistically significant at 5% level against RW (F=202.74) (Table 8.1). However, the differences in BOD among the samples of different points and among the industries are statistically insignificant in most of the cases (Fig. 4.17). Fresh effluents of P_1 contains less microbial population so, the BOD is comparatively lower than other points. BOD is slightly increased in P_2 due to dilution effect and comparatively less microbial population for excess salinity and highest in P_3 for topographic high position, comparatively dry condition and highest microbial population with low flow of effluents. Michael *et al.,* 1980 who found BOD_5 values 490 mgL^{-1}, Steven (1996) found (500-1550 mgL^{-1}) and Carawan (1991) reported 1081mgL^{-1} in shrimp processing effluents.



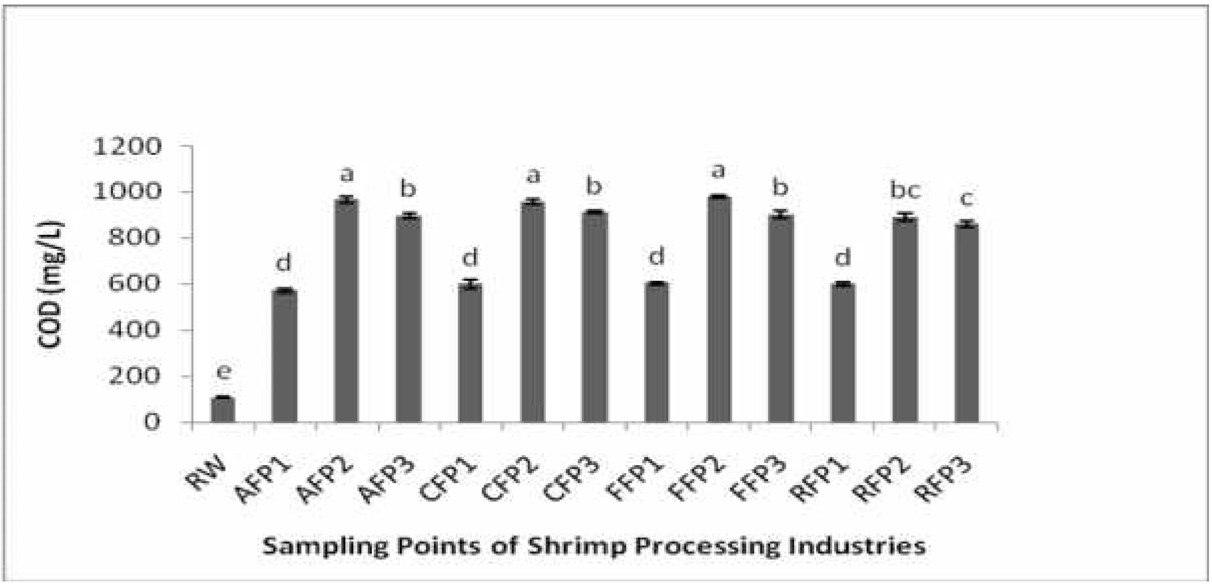
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.17. Biological Oxygen Demand (BOD_5) of the effluents from Shrimp Processing Industries

4.2.4.11. Chemical oxygen demand (COD):

Chemical oxygen demand (COD) measured for effluents at discharge point (P_1) varied from 572 mgL^{-1} to 603 mgL^{-1}, 891 mgL^{-1} to 987 mgL^{-1} at P_2, 860 mgL^{-1} to 911 mgL^{-1} at P_3 and 108 mgL^{-1} was measured for RW (Table 4.4). The values increased with distance and traveling through cross section of land.

The shrimp processing effluents at different points confirmed very high level of COD and magnitude of the difference is at the order of P2>P3>P_1 (Table 4.4). The highest COD (980 mgL^{-1}) was measured at I_3P_2 and lowest (572 mgL^{-1}) at I_1P_1 (Fig 4.18). The effluents of all industries and points contained significantly high COD than that of RW (Table 4.4). The results show that COD in all effluent samples was statistically significant at 5% level against RW (F=484.55) (Table 8.1). However the differences in COD among the samples of different industries as well as points are statistically significant in most of the cases (Fig. 4.18). Highest COD was in P_2 for high suspended and dissolved organic matters and medium was in P_3 for topographic high position and low OM in dry condition. Lowest COD was in P_1 because initially effluents are discharged here. COD of near by Rupsha river water was 232 mgL^{-1} (Begum *et al.,* 2006a). Michael *et al.,* 1980 who found 790 mgL^{-1} COD in effluents of shrimp industry, Steven (1996) and Carawan (1991) found 1300-3250 mgL^{-1} and 2216 mgL^{-1} respectively.

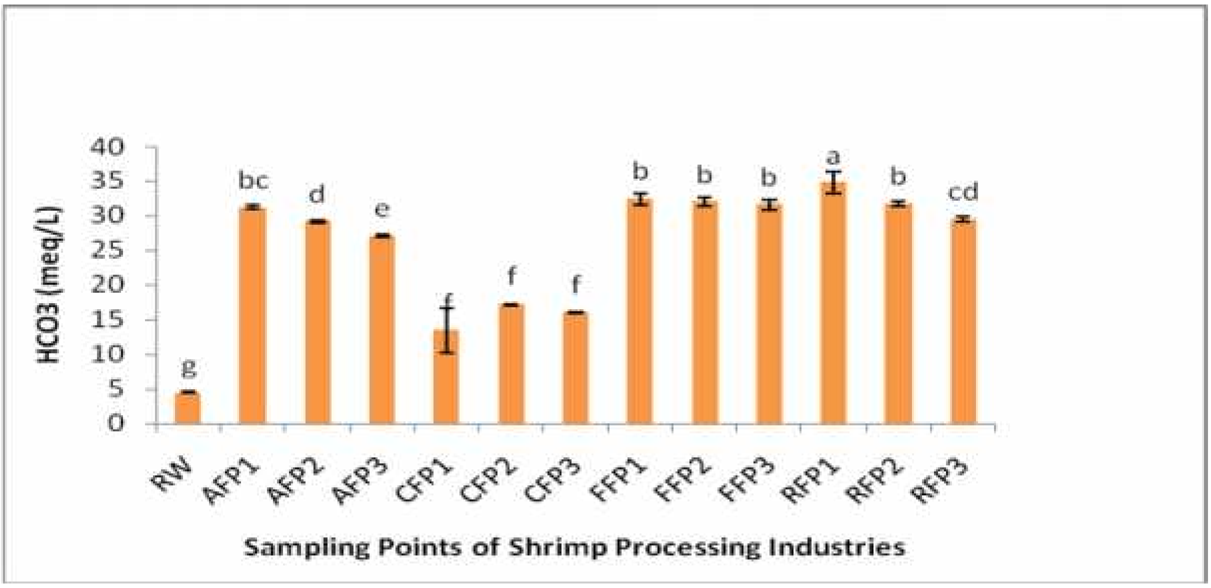


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.18. Chemical Oxygen demand (COD) of the effluents from Shrimp Processing Industries

4.2.4.12. Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-):

Bicarbonate (HCO_3^-) measured for effluents at discharge point (P_1) varied from 16.80 to 34.75 meqL^{-1}, 17.20 to 32.0 meqL^{-1} at P_2, 16.02 to 31.61 meqL^{-1} at P_3 and 4.5 meqL^{-1} was measured for RW but Carbonate (CO_3^{2-}) was nil for all points (Table 4.4). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of HCO_3^- and magnitude of the difference is at the order of P1>P2>P_3 (Table 4.4). The highest HCO_3^- (34.75 meqL^{-1}) was measured at I_4P_1 and lowest (16.02 meqL^{-1}) at I_2P_3 (Fig 4.19). The effluents of all industries and points contained significantly high HCO_3^- than that of RW (Table 4.4). The results show that HCO_3^- in all effluent samples was statistically significant at 5% level against RW (F=228.07) (Table 8.1). However the differences in HCO_3^- among the samples of different industries as well as points are statistically significant in most of the cases (Fig. 4.19). It was observed that the content of CO_3^{2-} was zero for all effluents samples because the pH of all effluents samples was less than 8.3. So, all Carbon remains in water as bicarbonate. The HCO_3^- was increased with distance for the presence of salts in effluents. Saeed *et al.,* (2003) found very small amount of Carbonate (CO_3^{2-}) but relatively high amount of bicarbonate (HCO_3^-) in the shrimp processing effluent and the amount of bicarbonates was less than that of Calcium and Magnesium.

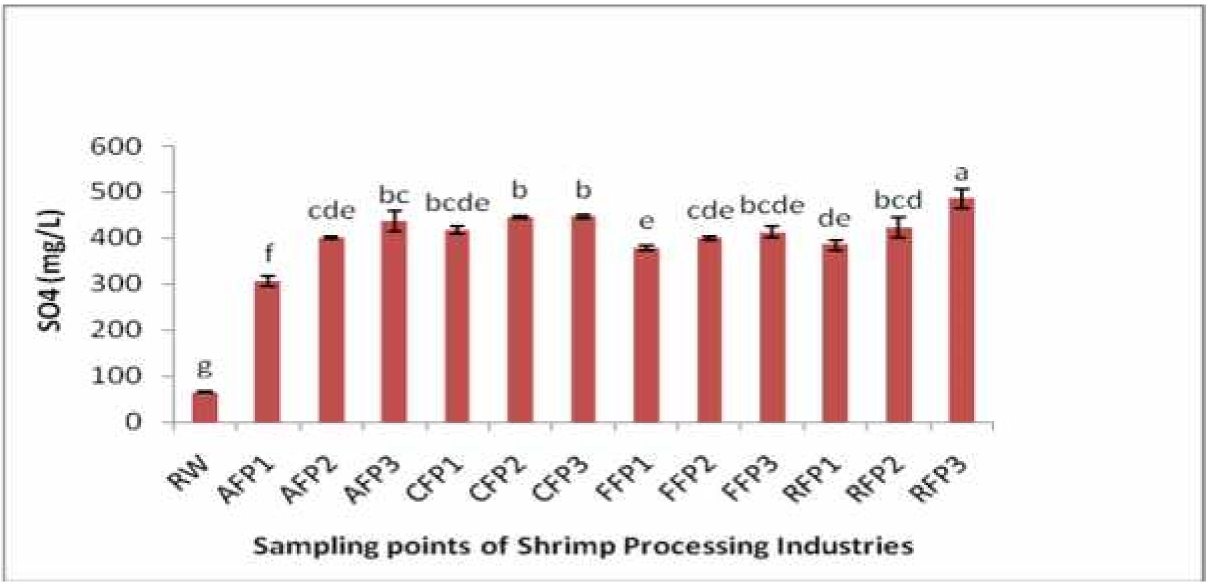


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.19. Bicarbonate (HCO_3^-) of the effluents from Shrimp Processing Industries

4.2.4.13. Sulfate (SO_4^{2-}):

Sulfate (SO_4^{2-}) measured for effluents at discharge point (P_1) varied from 306 to 418 mgL^{-1}, 401 to 445 mgL^{-1} at P_2, 412 to 485 mgL^{-1} at P_3 and 65 mgL^{-1} was measured for RW (Table 4.4). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Sulfate (SO_4^{2-}) and magnitude of the difference is at the order of P3>P2>P_1 (Table 4.4). The highest Sulfate (SO_4^{2-}) (485 mgL^{-1}) was measured at I_4P_3 and lowest (401 mgL^{-1}) at I_1P_2 (Fig 4.20). The effluents of all industries and points contained significantly high Sulfates (SO_4^{2-}) than that of RW (Table 4.4). The results show that SO_4^{2-} in all effluent samples was statistically significant at 5% level against RW (F=72.44) (Table 8.1). However the differences in SO_4^{2-} among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.20). Sulfate (SO_4^{2-}) was high in effluents due to the decomposition of shells, tails and damaged body of the shrimp, use of chemicals like H_2SO_4 and Sodium Meta bi sulfate. Highest SO_4^{2-} was in P_3, probably for topographic high position, dry condition which enhanced sulfate concentrations and medium was in P_2 for decomposition of the shells, tails and body of shrimp and lowest in P_1 which is the initial effluent discharge point.

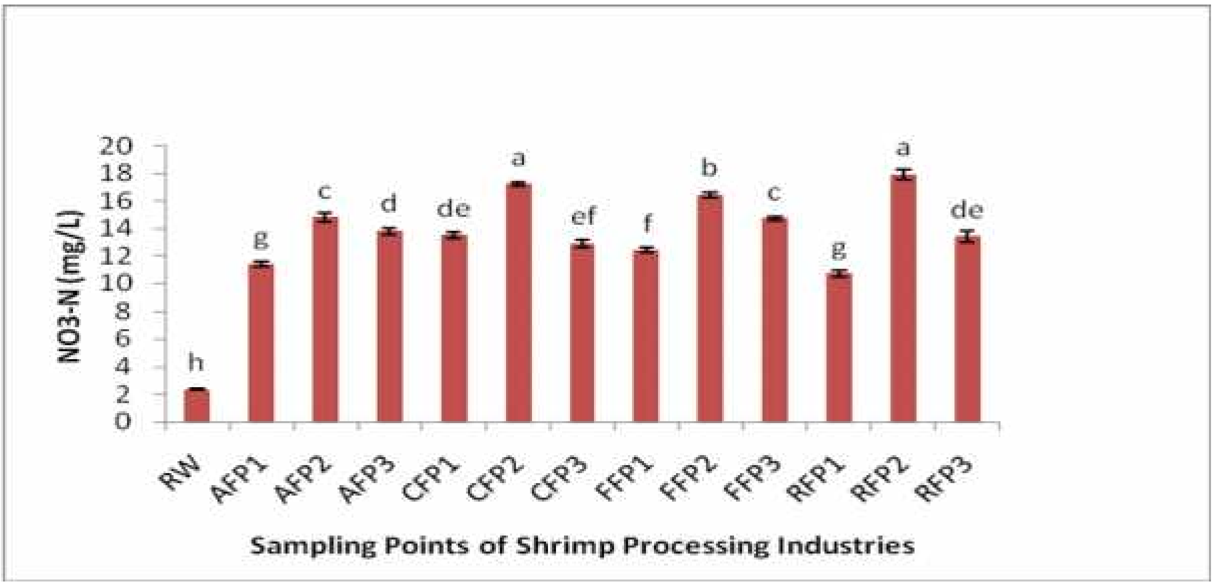


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.20. Sulfate (SO_4^{2-}) of the effluents from Shrimp Processing Industries

4.2.4.14. Nitrate (NO_3-N):

Nitrate (NO_3-N) measured for effluents at discharge point (P_1) varied for 10.7 to 13.5 mgL^{-1}, 14.8 to 17.9 mgL^{-1} at P_2, 12.9 to 14.7 mgL^{-1} at P_3 and 2.36 mgL^{-1} was measured for RW (Table 4.4). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Nitrate and magnitude of the difference is at the order of P2>P3>P_1 (Table 4.4). The highest Nitrate (17.9 mgL^{-1}) was measured at I_4P_2 and lowest (17.9 mgL^{-1}) at I_4P_1 (Fig 4.21). The effluents of all industries and points contained significantly high Nitrate than that of RW (Table 4.4). The results show that NO_3-N in all effluent samples was statistically significant at 5% level against RW (F=253.39) (Table 8.1). However the differences in NO_3-N among the samples of different industries as well as points are statistically significant in most of the cases (Fig. 4.21).



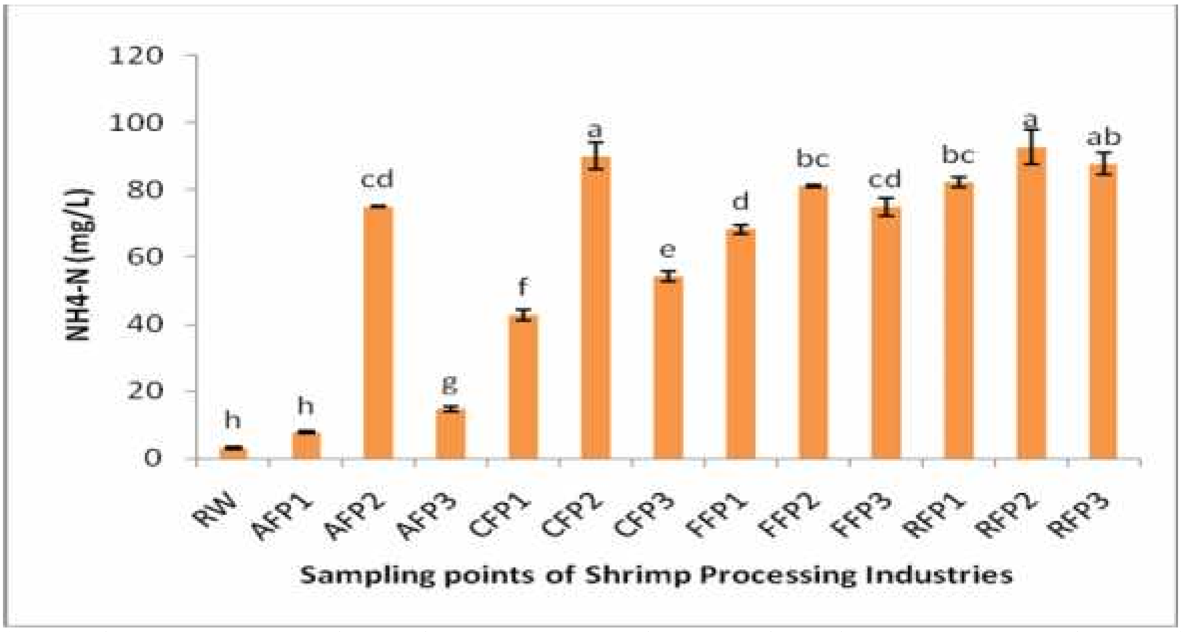
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.21. Nitrate (NO_3-N) of the effluents from Shrimp Processing Industries

4.2.4.15. Ammoniacal Nitrogen (NH_4^+-N):

Ammoniacal Nitrogen (NH_4^+-N) measured for effluents at discharge point (P_1) varied from 7.57 to 82.23 mgL^{-1}, 75 to 92.87 mgL^{-1} at P_2, 14.8 to 87.74 mgL^{-1} at P_3 and 3.17 mgL^{-1} was measured for RW (Table 4.4).

The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of NH_4^+-N and magnitude of the difference is at the order of P2>P3>P_1 (Table 4.4). The highest NH_4^+-N (92.87 mgL^{-1}) was measured at I_4P_2 and lowest (7.57 mgL^{-1}) at I_1P_1 (Fig 4.22). The effluents of all industries and points contained significantly high NH_4^+-N than that of RW (Table 4.4). The results show that the NH_4^+-N of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=192.75) (table 8.1). However, the differences in NH_4^+-N among the samples of different points are mostly significant and significant differences were observed in Atlas and Cosmos plants but insignificant was for Fresh and Rosemco plants (Fig. 4.22).



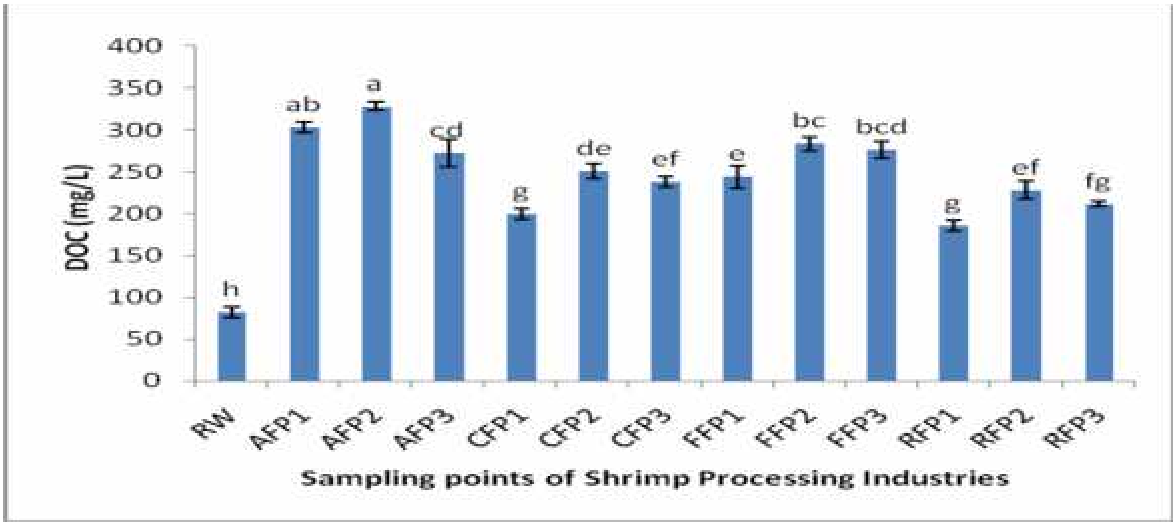
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.22. Ammoniacal Nitrogen (NH_4^+-N) of the effluents from Shrimp Processing Industries

4.2.4.16. Dissolved Organic Carbon (DOC):

Dissolved Organic Carbon (DOC) measured for effluents at discharge point (P_1) varied from 186 to 303.67 mgL^{-1}, 228.33 to 328.67 mgL^{-1} at P_2, 212 to 276.67 mgL^{-1} at P_3 and 82.33 mgL^{-1} was measured for RW (Table 4.3). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of DOC and magnitude of the difference is at the order of P2>P3>P_1 (Table 4.3). The highest DOC (328.67 mgL^{-1}) was measured at I_1P_2 and lowest (186 mgL^{-1}) at I_4P_1 (Fig 4.23).

The effluents of all industries and points contained significantly high DOC than that of RW (Table 4.3). The results show that the DOC of the effluent samples of Shrimp Processing Industries was statistically highly significant at 5% level against RW (F=47.75) (Table 8.1). However the differences in DOC among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.23). Michael *et al.* (1980) analyzed shrimp processing effluents and found 220 mgL^{-1} DOC. DOC depends on waste load and amount of shrimp processed.



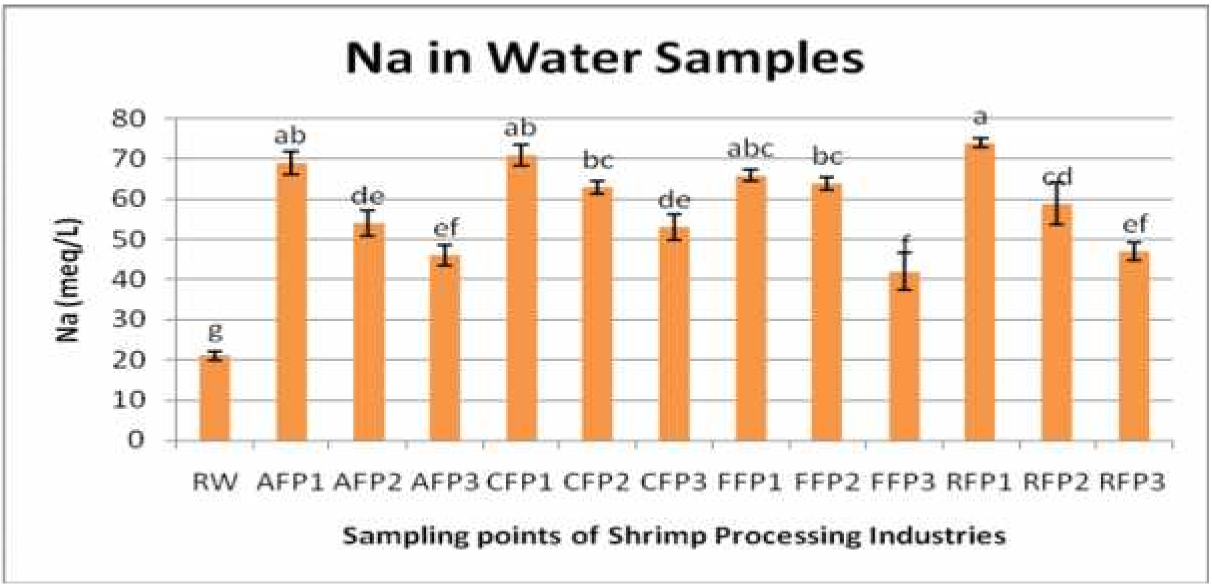
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.23. Dissolved Organic Carbon (DOC) of the effluents from Shrimp Processing Industries

4.2.4.17. Sodium (Na^+) in effluents:

Sodium (Na^+) measured for the effluents at discharge point (P_1) varied from 66 to 74 meqL^{-1}, 54 to 64 meqL^{-1} at P_2, 42 to 53 meqL^{-1} at P_3 and 21 meqL^{-1} was measured for RW (Table 4.5). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Sodium (Na^+) and magnitude of the difference is at the order of P1>P2>P_3 (Table 4.5). The highest Sodium (Na^+) (74 meqL^{-1}) was measured at I_4P_1 and lowest (42meqL^{-1}) at I_3P_3 (Fig 4.24). The effluents of all industries and points contained significantly high Sodium (Na^+) than that of RW (Table 4.5). The results show that the Na^+ values of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=25.79) (Table 8.1). However, the differences in Na^+ among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.24).

Highest Na^+ was measured for P_1 most probably because of the main effluent discharge point and Na^+ is increased for using saline water, brine solution for washing, use of STP, SMBP, STPP, SMBS, lime, caustic soda, liquid soap, detergent and dyes in the various steps of shrimp processing industries. P_2 was intermediate because of excess decomposition of organic substances, organic acid produces here and replace Na^+ by H^+ as leaching loss and for dilution effect but lowest Na^+ was in P_3, Probably for leaching loss, plant uptake and low velocity of effluents. Michael *et al.* (1980) reported 65 $meqL^{-1}$ Na^+ in the waste water discharged from shrimp processing industries in North Carolina.



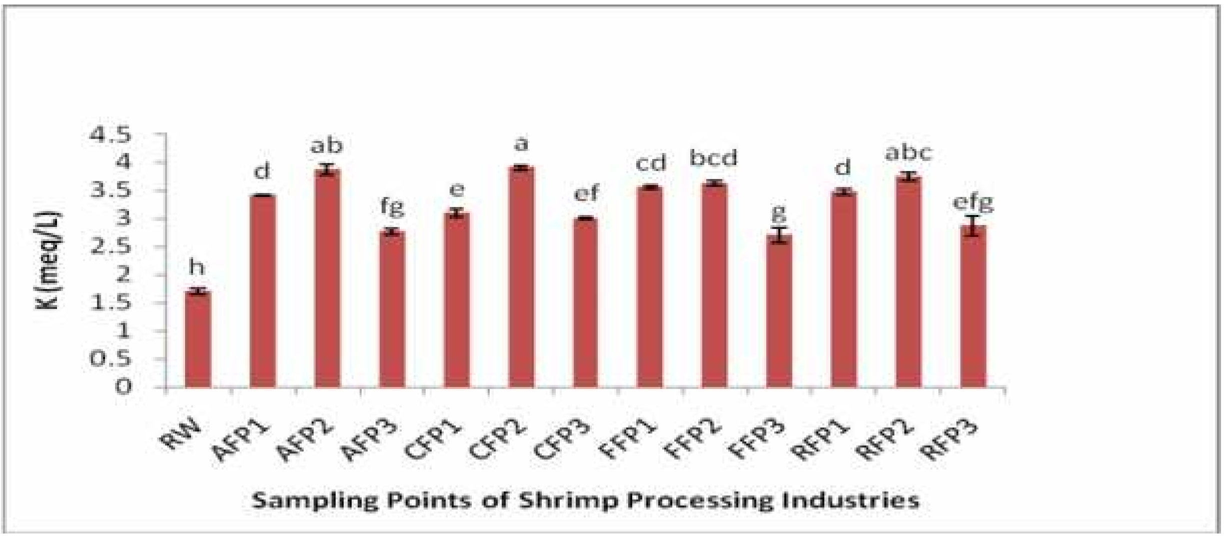
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.24. Sodium (Na^+) of the effluents from Shrimp Processing Industries

4.2.4.18. Potassium (K^+) in effluents:

Potassium (K^+) measured for the effluents at discharge point (P_1) varied from 3.10 to 3.56 $meqL^{-1}$, 3.63 to 3.91 $meqL^{-1}$ at P_2, 2.70 to 3.0 $meqL^{-1}$ at P_3 and 1.7 $meqL^{-1}$ was measured for RW (Table 4.5). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Potassium (K^+) and magnitude of the difference is at the order of P2>P1>P3 (Table 4.5). The highest Potassium (K^+) (3.91 $meqL^{-1}$) was measured at I_2P_2 and lowest (2.70 $meqL^{-1}$) at I_3P_3 (Fig 4.25). The effluents of all industries and points contained significantly high Potassium (K^+) than that RW (Table 4.5). The results show that the K^+ values of the effluent samples of Shrimp Processing Industries are statistically significant at 5% level against RW (F=58.37) (Table 8.1).

However, the differences in K^+ among the samples of different industries as well as points are statistically insignificant but exception was observed in point-3 and in Atlas and Rosemco plants (Fig. 4.25). The concentration of K^+ is higher in the effluents for the use of brine solution and saline in washing steps of shrimp processing. Highest K^+ was in P_2 for high OM which contains higher CEC and reduces K^+ losses, so, increase of K^+, intermediate was in P_1 and lowest was in P_3 for plant uptake, low effluent flow to the agricultural land and leach the K^+ ions by H^+ released from decomposition of OM.



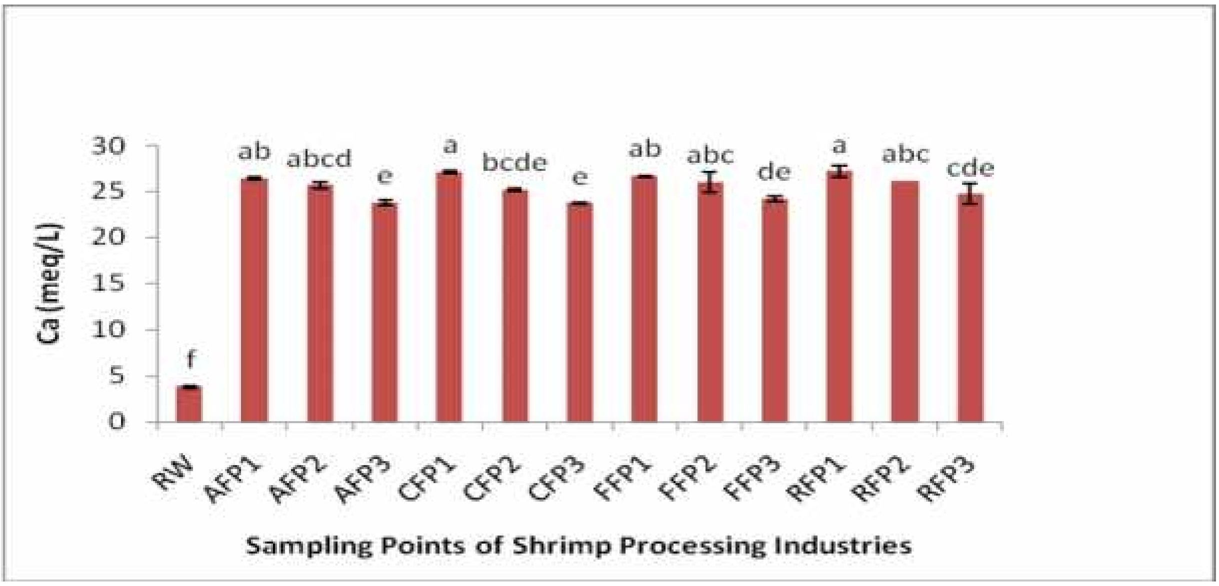
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.25. Potassium (K^+) of the effluents from Shrimp Processing Industries

4.2.4.19. Calcium (Ca^{2+}) in effluents:

Calcium (Ca^{2+}) measured for the effluents at discharge point (P_1) varied from 26.41 to 27.22 $meqL^{-1}$, 25.19 to 26.17$meqL^{-1}$ at P_2, 23.72 to 24.72 $meqL^{-1}$ at P_3 and 3.82 $meqL^{-1}$ was measured for RW (Table 4.5). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Calcium (Ca^{2+}) and magnitude of the difference is at the order of P1>P2>P3 (Table 4.5). The highest Calcium (Ca^{2+}) (27.22 $meqL^{-1}$) was measured at $I_4 P_1$ and lowest (23.72 $meqL^{-1}$) at I_2P_3 (Fig 4.26). The effluents of all industries and points contained significantly high Calcium (Ca^{2+}) than that of RW (Table 4.5). The results show that the Ca^{2+} values of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=147.82) (Table 8.1).

However the differences in Ca^{2+} among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.26). Organic substances increase the available Ca^{2+} content in effluents, solubility of calcium increased by inorganic and organic acid, as a result of decomposition of OM (Rosen *et al.,* 2005). Highest Ca^{2+} was in P_1 which is the initial stage of effluents and contains bleaching powder, P_2 was in intermediate for more organic substances, which released organic acid and increase the solubility of Calcium but for excess water and high solubility a portion of the Ca^{2+} may be leached by H^+ produced from OM decomposition. So, the total available Ca^{2+} values are less than that of P_1 and lowest was in P_3 for low effluent flow, distance, plant uptake, flashing effect and for leaching loss.



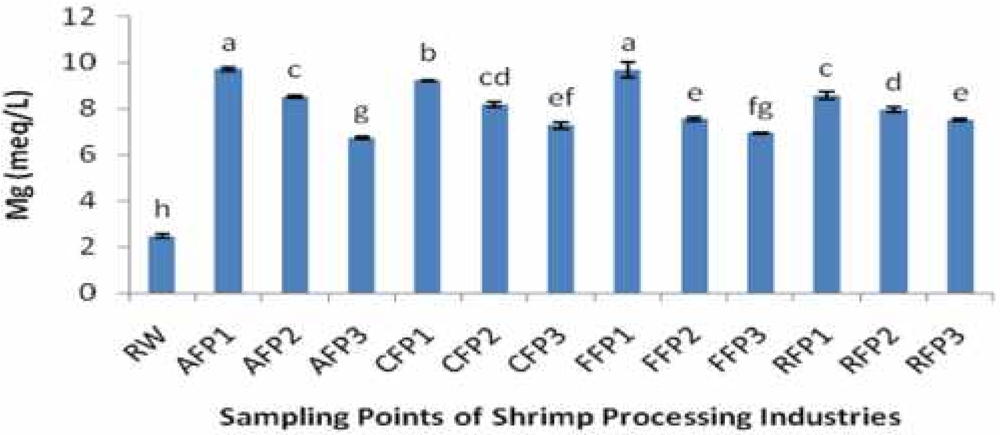
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.26. Calcium (Ca^{2+}) of the effluents from Shrimp Processing Industries

4.2.4.20. Magnesium (Mg^{2+}) in effluents:

Magnesium (Mg^{2+}) measured for effluents at discharge point (P_1) varied from 8.57 to 9.72 $meqL^{-1}$, 7.53 to 8.50 $meqL^{-1}$ at P_2, 6.75 to 7.50 $meqL^{-1}$ at P_3 and 2.47 $meqL^{-1}$ was measured for RW (Table 4.5). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Magnesium (Mg^{2+}) and magnitude of the difference is at the order of P1>P2>P3 (Table 4.5). The highest Magnesium (Mg^{2+}) (9.72 $meqL^{-1}$) was measured at I_1P_1 and lowest (6.75 $meqL^{-1}$) at I_1P_3 (Fig 4.27). The effluents of all industries and points contained significantly high Magnesium (Mg^{2+}) than that of RW (Table 4.5).

The results show that the Mg^{2+} values of the effluent samples of Shrimp Processing Industries was statistically highly significant at 5% level against RW (F=216.6) (Table 8.1). However the differences in Mg^{2+} among the samples of different industries as well as points are statistically significant in most of the cases (Fig. 4.27). Organic substances increase the available Mg^{2+} content in water, solubility of Mg^{2+} increased by inorganic and organic acid, as a result of decomposition of OM (Rosen *et al.,* 2005), Highest Mg^{2+} was in P_1 which is the initial stage of waste water release. P_2 was in intermediate for more organic substances, which increase the available calcium content because solubility of Mg^{2+} increased by organic acid, as a result of OM decomposition (Rosen *et al.,* 2005) but for excess water and high solubility a portion of the Mg^{2+} may be leached by H^+ produced from OM decomposition. So, the total available Mg^{2+} values are less than that of P_1 and lowest was found in P_3 for low effluent flow, distance, plant uptake and for leaching loss. Owing to very high solubility, $MgCl_2$ is exceptionally toxic to plants (Gupta and Gupta, 1987). Salam and Billah (2013) found 8-20meqL^{-1} and Michael *et al.* (1980) found 5.22 meqL^{-1} in shrimp processing effluents.



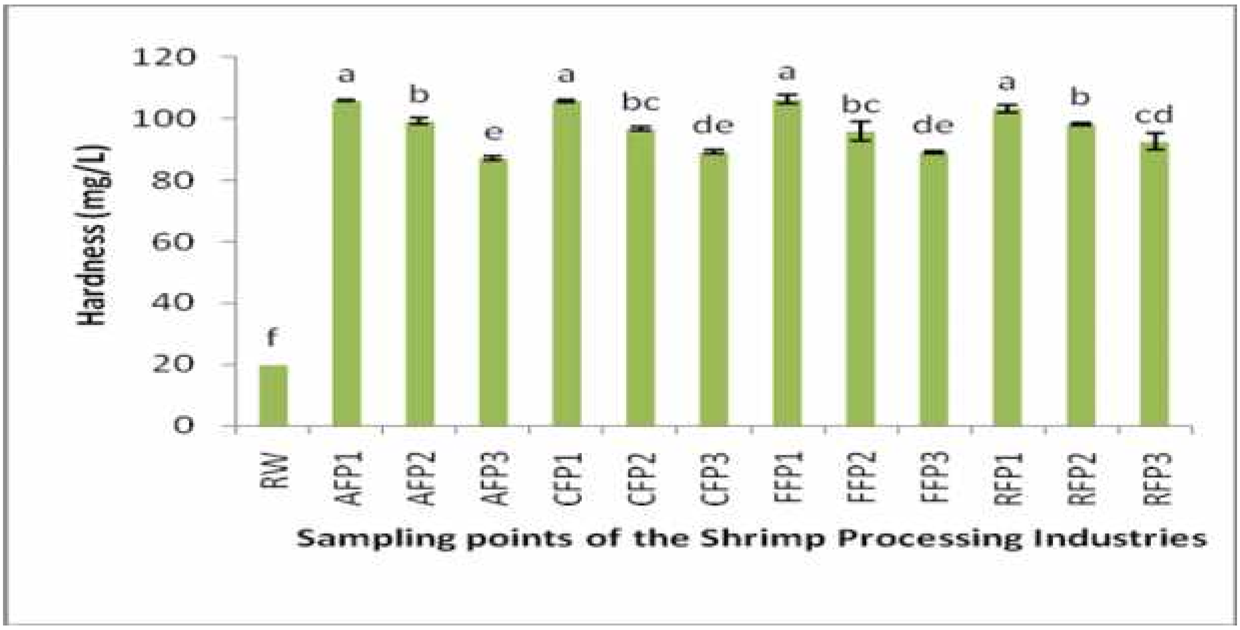
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.27. Magnesium (Mg^{2+}) of the effluents from Shrimp Processing Industries

4.2.4.21. Hardness (H_T):

Hardness (H_T) measured for effluents at discharge point (P_1) varied from 103.19 to 106.38 mgL^{-1}, 95.82 to 98.07 mgL^{-1} at P_2, 87.16 to 92.55 mgL^{-1} at P_3 and 15.7 mgL^{-1} was measured for RW (Table 4.5).

The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Hardness and magnitude of the difference is at the order of P1>P2>P3 (Table 4.5). The highest Hardness (106.38 mgL^{-1}) was measured at I_3P_1 and lowest (106.38 mgL^{-1}) at I_4P_1 (Fig 4.28). The effluents of all industries and points contained significantly high Hardness than that of RW (Table 4.5). The results show that the hardness (H_T) values of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=272.69) (Table 8.1). However, the differences in H_T among the samples of different industries as well as points are statistically significant in most of the cases (Fig. 4.28).



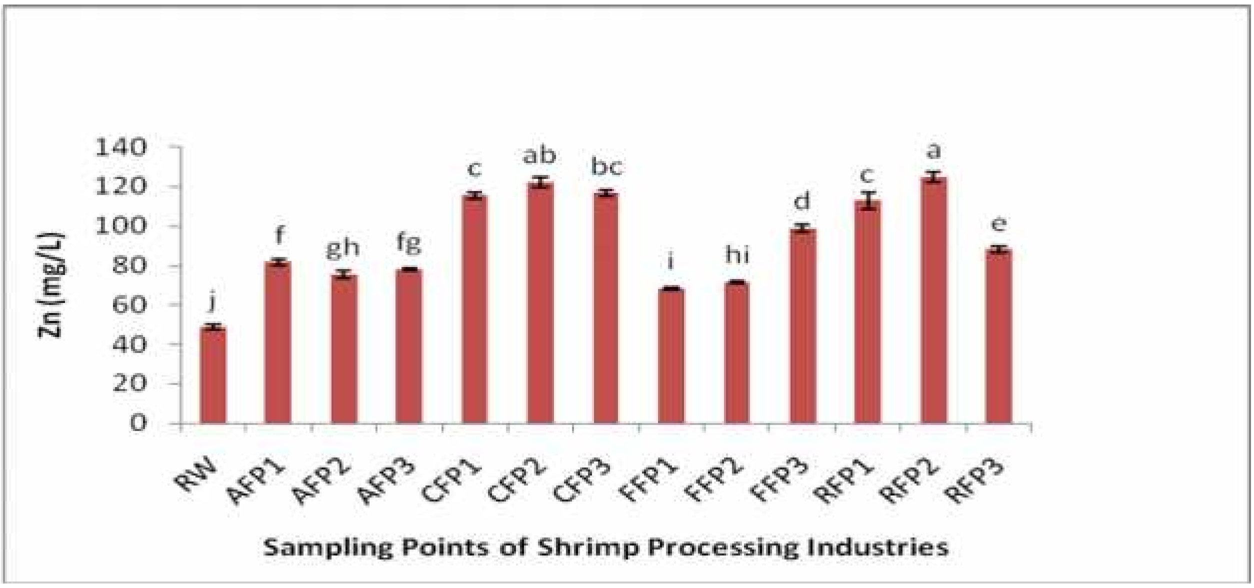
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.28. Hardness (H_T) of the effluents from Shrimp Processing Industries

4.2.4.22. Zinc (Zn):

Zn content measured for effluents at discharge point (P_1) varied from 68.3 to 115.5 mgL^{-1}, 71.5 to 122.1 mgL^{-1} at P_2, 78.0 to 124.7 mgL^{-1} at P_3 and 48.8 mgL^{-1} was measured for RW (Table 4.6). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Zn content and magnitude of the difference is at the order of P3>P2>P_1 (Table 4.6). The highest Zn (124.7 mgL^{-1}) was measured at I_4P_2 and lowest (68.3 mgL^{-1}) at I_3P_1 (Fig 4.29). The effluents of all industries and points contained significantly high Zn content than that of RW (Table 4.6).

The results show that the Zn content of the effluent samples of Shrimp Processing Industries was statistically highly significant at 5% level against RW (F=144.61) (Table 8.1). However, the differences in Zn content among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.29). Similar results were reported by Michael *et al.,* 1980. This significantly increased Zn concentration in effluents probably because of Zn content was found 0.08 mgL^{-1} in the shrimp processing effluents (Michael *et al.,* 1980). The Zn content is increased in the effluents measured for different points are probably because of the soils fertilized with ZnO, $ZnSO_4$ and pesticides.



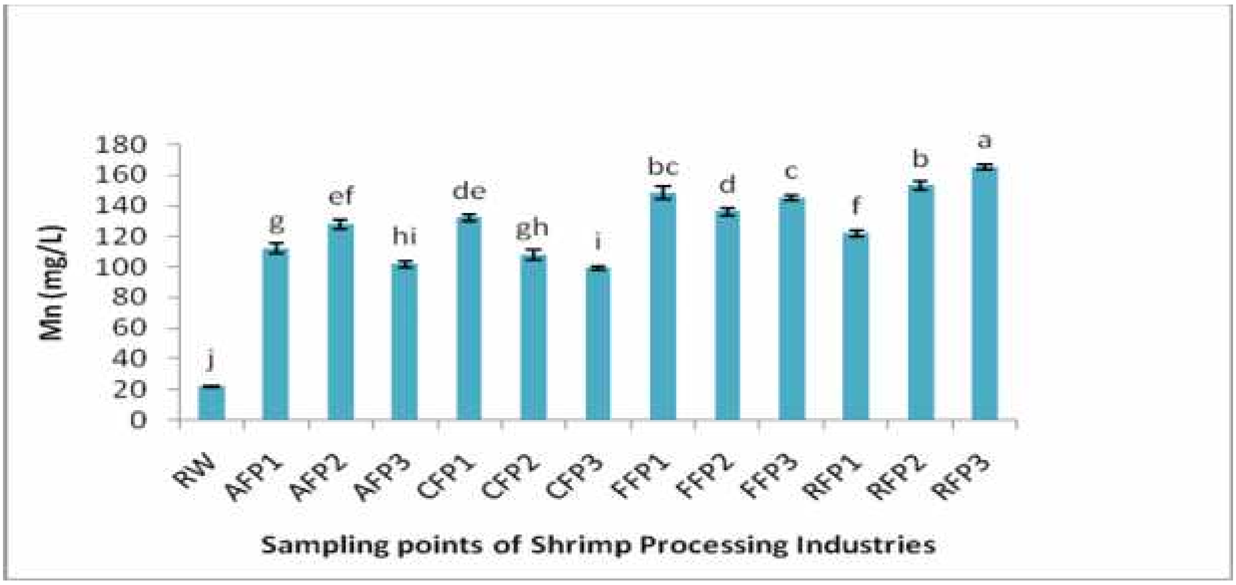
(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.29. Zinc (Zn) of the effluents from Shrimp Processing Industries

4.2.4.23. Manganese (Mn):

Mn content measured for effluents at discharge point (P_1) varied from 112 to 148 mgL^{-1}, 108 to 153 mgL^{-1} at P_2, 99 to 165 mgL^{-1} at P_3 and 22 mgL^{-1} was measured for RW (Table 4.6). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Mn content and magnitude of the difference is at the order of P3>P1>P_2 (Table 4.6). The highest Mn (165 mgL^{-1}) was measured at I_4P_3 and lowest (99 mgL^{-1}) at I_2P_3 (Fig 4.30). The effluents of all industries and points contained significantly high Mn content than that of RW (Table 4.6). The results show that the Mn content of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=192.98) (Table 8.1).

However, the difference in Mn content among the samples of different industries are significant but insignificant for different points except P_3 (Fig. 4.30). The content of Mn increased in the effluents of the contaminated sites due to the use of pesticides during preservation of shrimps and use of dyes during coloring of shrimps.

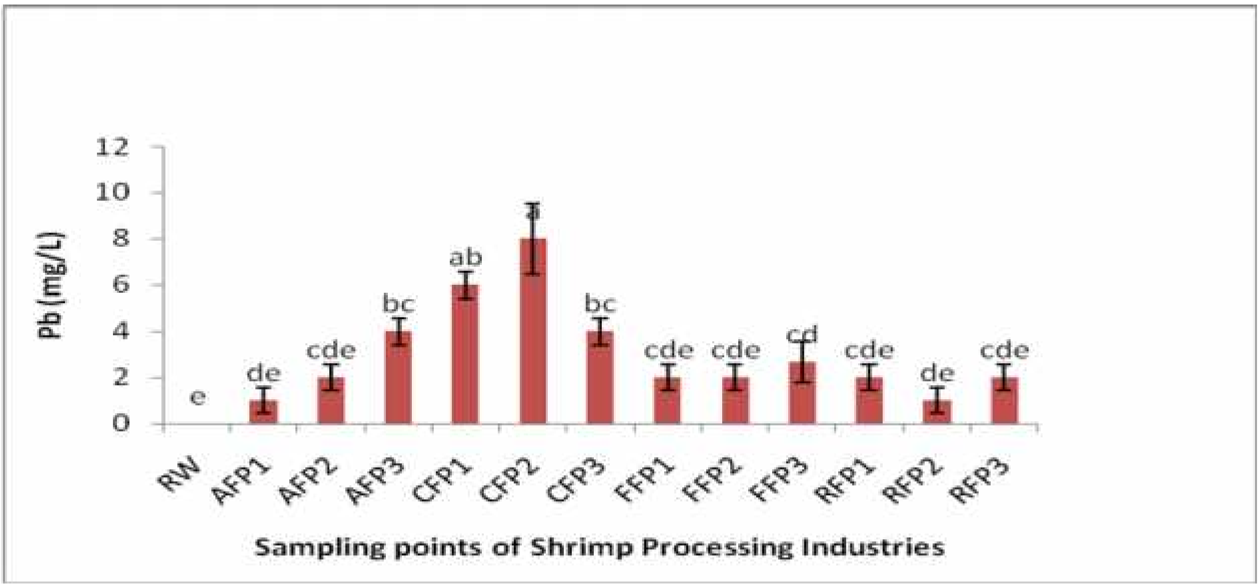


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.30. Manganese (Mn) of the effluents from Shrimp Processing Industries

4.2.4.24. Lead (Pb):

Pb content measured for effluents at discharge point (P_1) varied from 1 to 6 mgL^{-1} at P_1, 1 to 8 mgL^{-1} at P_2, 2 to 4 mgL^{-1} at P_3 and 0 mgL^{-1} was measured for RW (Table 4.6). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Pb content and magnitude of the difference is at the order of $P2>P1>P_3$ (Table 4.6). The highest Pb (8 mgL^{-1}) was measured at I_2P_2 and lowest (1 mgL^{-1}) at I_1P_1 and I_4P_2 (Fig 4.31). The effluents of all industries and points contained significantly high Pb content than that of RW (Table 4.6). The results show that the Pb content of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=9.7) (Table 8.1). However, the differences in Pb content among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.31). The Pb content increased in effluents due to use of pesticides for shrimp preservation, pesticides like Pb arsenate is used in the shrimp cum paddy culture and for the use of sea water in washing step of shrimp processing which contains Lead hydro carbonate $Pb_2(OH)_2CO_3$ and Tetra methyl lead $Pb(CH_3)_4$.

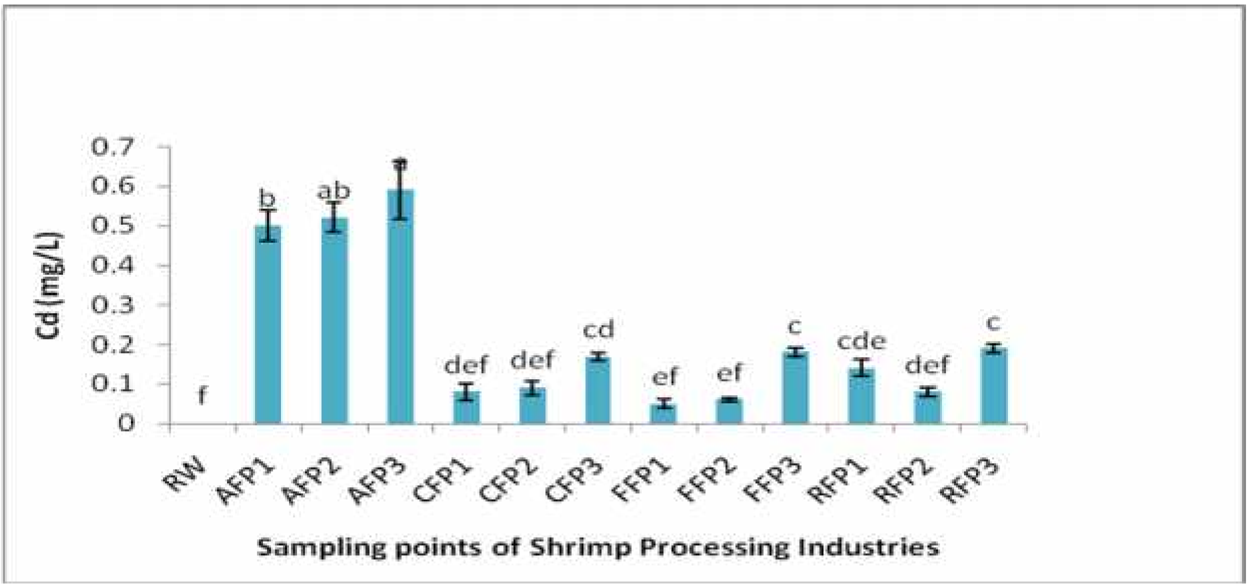


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.31. Lead (Pb) of the effluents from Shrimp Processing Industries

4.2.4.25. Cadmium (Cd):

Cd content measured for effluents at discharge point (P_1) varied from 0.05 to 0.50 mgL^{-1}, 0.06 to 0.52 mgL^{-1} at P_2, 0.17 to 0.59 mgL^{-1} at P_3 and 0 mgL^{-1} was measured for RW (Table 4.6). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Cd content and magnitude of the difference is at the order of $P3>P2>P_1$ (Table 4.6). The highest Cd (0.59 mgL^{-1}) was measured at I_1P_3 and lowest (0.05 mgL^{-1}) at I_3P_1 (Fig 4.32). The effluents of all industries and points contained significantly high Cd content than that of RW (Table 4.6). The results show that the Cd content of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=49.68) (Table 8.1). However, the differences in Cd content among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.32). Michael *et al.,* 1980 found 26 mgL^{-1} Cd in the waste water released from the shrimp processing industries.

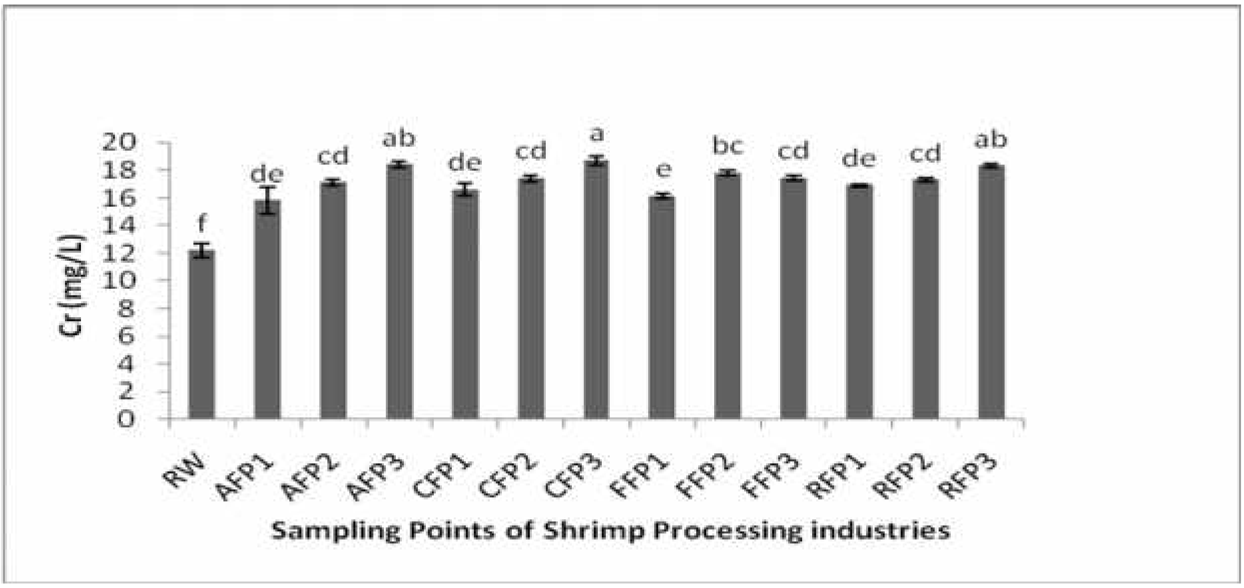


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.32. Cadmium (Cd) of the effluents from Shrimp Processing Industries

4.2.4.26. Chromium (Cr):

Cr content measured for effluents at discharge point (P_1) varied from 16.1 to 19.6 mgL^{-1}, 17.1 to 17.8 mgL^{-1} at P_2, 17.4 to 18.7 mgL^{-1} at P_3 and 12.2 mgL^{-1} was measured for RW (Table 4.6). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Cr content and magnitude of the difference is at the order of P1>P3>P_2 (Table 4.6). The highest Cr (18.7 mgL^{-1}) was measured at I_2P_3 and lowest (16.1 mgL^{-1}) at I_3P_1 (Fig 4.33). The effluents of all industries and points contained significantly high Cr content than that of RW (Table 4.6). The results show that the Cr content of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=39.12) (Table 8.1). However, the differences in Cr content among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig. 4.33). The Cr content is slightly increased in effluents due to the use of chromium salts in the cooling water for corrosion control in shrimp processing industries.

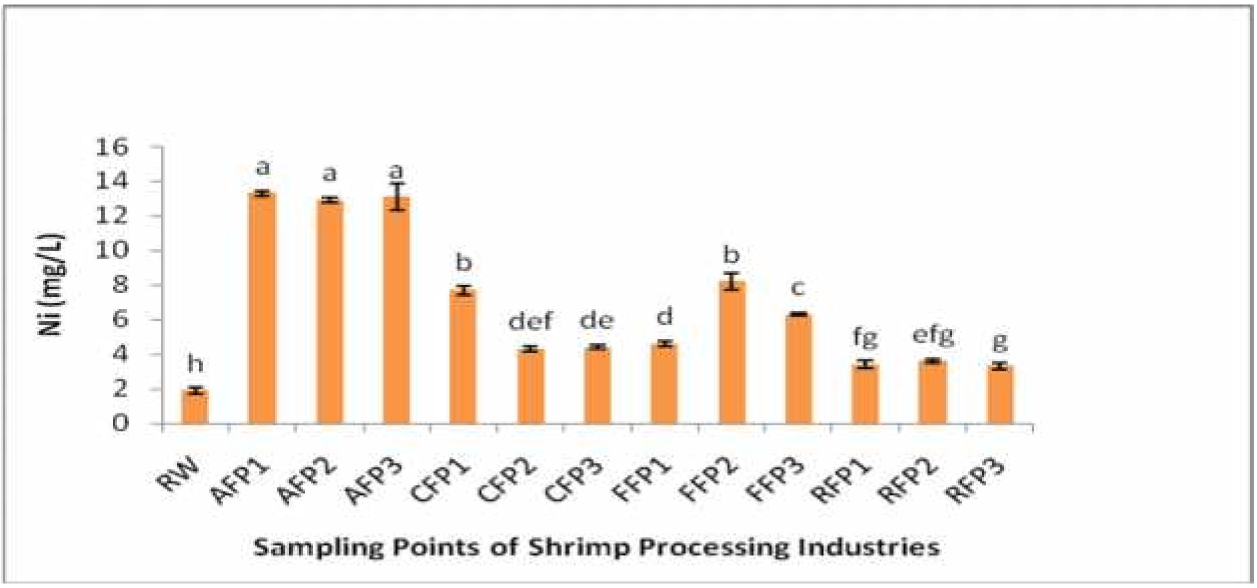


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.33. Chromium (Cr) of the effluents from Shrimp Processing Industries

4.2.4.27. Nickel (Ni):

Ni content measured for effluents at discharge point (P_1) varied from 3.4 to 13.3 mgL^{-1}, 3.6 to 12.9 mgL^{-1} at P_2, 3.3 to 13.1 mgL^{-1} at P_3 and 1.9 mgL^{-1} was measured for RW (Table 4.6). The values increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of Ni content and magnitude of the difference is at the order of P1>P3>P_2 (Table 4.6). The highest Ni (13.3 mgL^{-1}) was measured at I_1P_2 and lowest (3.3 mgL^{-1}) at I_4P_3 (Fig 4.34). The effluents of all industries and points contained significantly high Ni content than that of RW (Table 4.6). The results show that the Ni content of the effluent samples of Shrimp Processing Industries was statistically significant at 5% level against RW (F=176.31) (Table 8.1). However, the differences in Ni content among the samples of different points and different industries are statistically insignificant except Fresh Foods Ltd. (Fig. 4.34). All the effluents contained slightly higher Nickel content possibly due to the use of pesticides (Nicolite) in the shrimp cum paddy culture and for the use of heavy machineries in the various steps of shrimp processing industries.

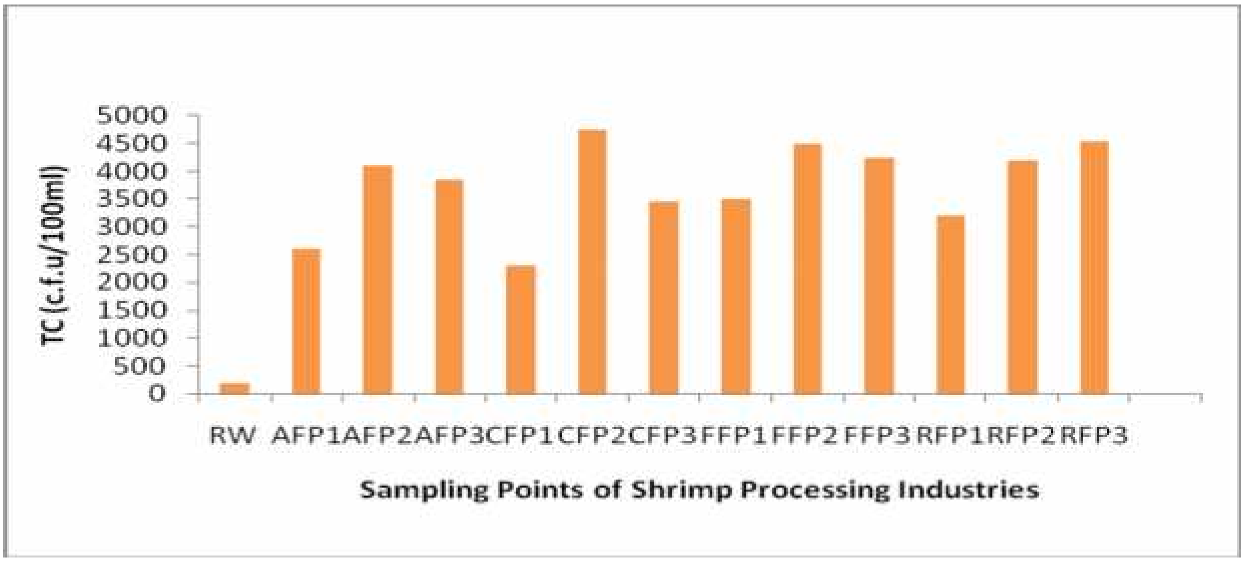


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.34. Nickel (Ni) of the effluents from Shrimp Processing Industries

4.2.4.28. Total Coliforms (TC) in effluents:

Total Coliforms (TC) measured for effluents at discharge point (P_1) varied from 2.3×10^3 to 3.5×10^3 c.f.u per 100 ml, 4.1×10^3 to 4.75×10^3 c.f.u per 100 ml at P_2, 3.45×10^3 to 4.55×10^3 c.f.u per 100 ml at P_3 and 1.9×10^2 c.f.u per 100 ml was counted for RW (Table 4.7). The TC was increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of TC and magnitude of the difference is at the order of $P2>P3>P_1$ (Table 4.7). The highest TC (4.75×10^3 c.f.u / 100 ml water) was isolated at I_2P_2 and lowest (2.3×10^3 c.f.u / 100 ml water) at I_2P_1 (Fig 4.35). The effluents of all industries and points contained significantly high TC than that of RW (Table 4.7). The Total coliforms (TC) of the effluents samples collected from different points of Shrimp Processing Industries varied at higher level (CV= 35.52%) (Table 4.7). The highest TC was in P_2 due to the presence of nutrient rich organic wastes which enhanced coliform population. The TC of P_3 is more than P_1 because of low flow of effluent. The lowest TC was measured for the effluents at P_1 for excess water and for dilution effect and for salt effect.

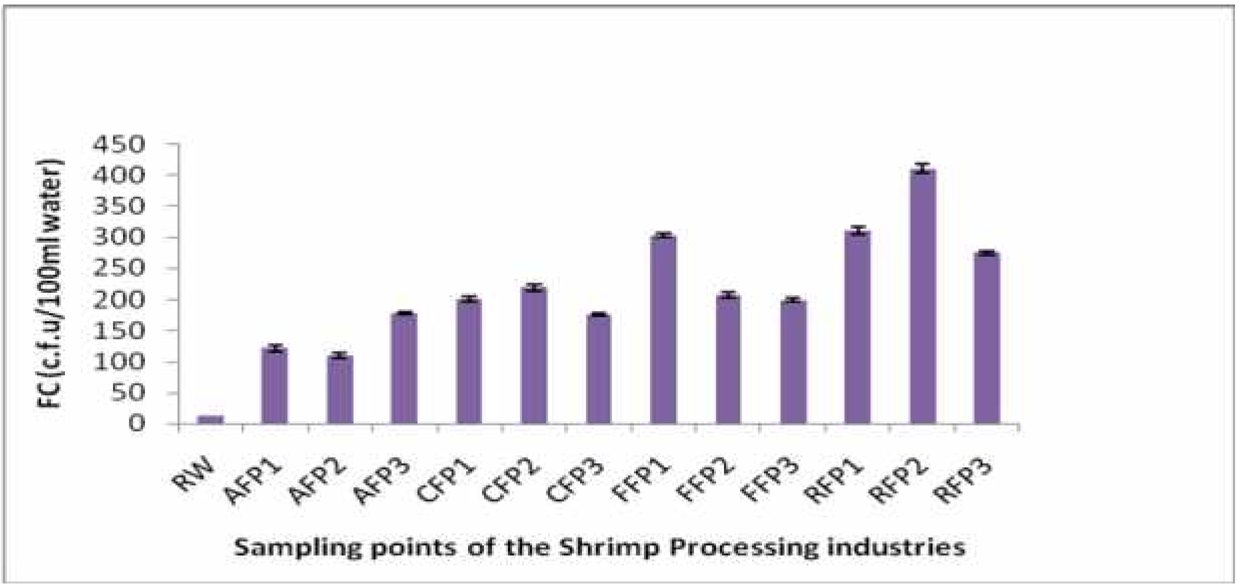


(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.35. Total coliforms (TC) of the effluents from Shrimp Processing Industries

4.2.4.29. Faecal Coliforms (FC) in effluents:

Faecal Coliforms (FC) measured for effluents at discharge point (P_1) varied from 122 to 311 c.f.u per 100 ml, 178 to 411 c.f.u per 100 ml at P_2, 110 to 275 c.f.u per 100 ml at P_3 and 12 c.f.u per 100 ml was counted for RW (Table 4.7). The FC was increased with distance and traveling through cross section of land. The shrimp processing effluents at different points confirmed very high level of FC and magnitude of the difference is at the order of P2>P1>P_3 (Table 4.7). The highest FC (411 c.f.u/ 100 ml) was isolated at I_4P_2 and lowest (110 c.f.u/100 ml) at I_1P_3 (Fig 4.36). The effluents of all industries and points contained significantly high FC than that of RW (Table 4.7). The Faecal coliforms (FC) of the effluent samples collected from different points of Shrimp Processing Industries varied at higher level (CV = 48.28%, SE = 28.07) (Table 4.7). The highest FC was in P_2 due to nutrient rich organic wastes which enhanced fecal coliform population. A small drop of human faeces can contain millions of faecal coliforms. Faecal coliforms are responsible for different health hazards. On the contrary faecal coliform is less than assumption because of excess salt.



(RW=Reference water, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.36. Fecal coliforms (FC) of the effluents from Shrimp Processing Industries

4.2.5. Germination Experiment

An experiment on seed germination was carried out with seed of Red amaranth (*Amaranthus curentus*), Stem amaranth *(Amaranthus lividus)* and Water spinach (*Ipomoea aquitica*) (Fig. 4.37).

Fig. 4.37. Picture of the Seed germination of Water spinach, Red amaranths and Stem amaranths

Results show that germination percentage of Water spinach at room temperature (28 ^{0}C), ranged from 68-88% for WS, 66-84% for RA and 62-76% for SA and the maximum percent seed germination was obtained for the seeds treated with fresh water for all test crops (92% for WS, 86% for RA and 80% for SA) (Table 4.8). However lowest percent seed germination was observed in raw effluent treated seeds (68% for WS, 66% for SA and 62% for WS) (Table 4.8). So, 24% germination percentage was hindered for WS, 20% for RA and 18% for SA and increased germination percentage for dilution effect (Fig. 4.38, 4.39 and 4.40). The results reveal that untreated effluent which is dumped in the environment can have significant damaging effect on seed germination. In the germination experiment the maximum reduction of seed germination was observed in Stem amaranths (18%) and dilution of raw effluent recovers the damaging effects (Table 4.8).

Table 4.8. % Seed germination and % germination reduced for the application of uncontaminated water, raw effluent and different diluted effluent

Water spinach	Total seeds	Germinated seeds	% Seed Germination	%Germination reduced
T_0	25	23	92%	
T_1	25	17	68%	24%
T_2	25	20	80%	12%
T_3	25	20	80%	12%
T_4	25	21	84%	8%
T_5	25	22	88%	4%
Red amaranths	Total seeds	Germinated seeds	% Seed Germination	Germination reduced
T_0	50	43	86%	
T_1	50	33	66%	20%
T_2	50	37	74%	12%
T_3	50	39	78%	8%
T_4	50	39	78%	8%
T_5	50	42	84%	2%
Stem amaranths	Total seeds	Germinated seeds	% Seed Germination	Germination reduced
T_0	50	40	80%	
T_1	50	31	62%	18%
T_2	50	35	70%	10%
T_3	50	37	74%	6%
T_4	50	36	72%	8%
T_5	50	38	76%	4%

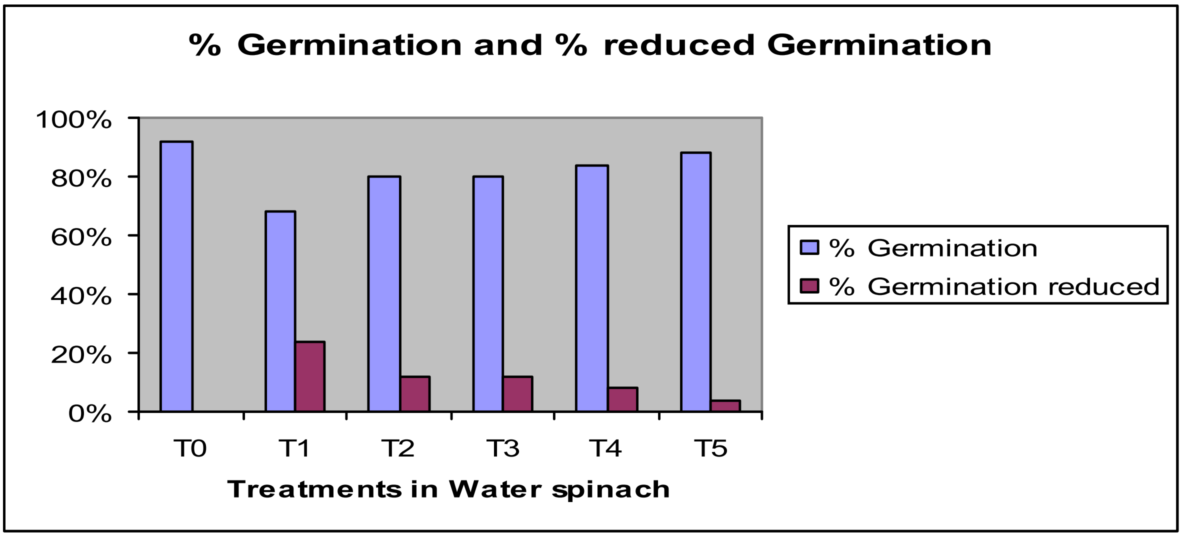


Fig. 4.38. Percent Germination and Reduced Percent Germination for the application of fresh water, raw effluent and different diluted effluent in Water spinach (*Ipomoea aquitica*)

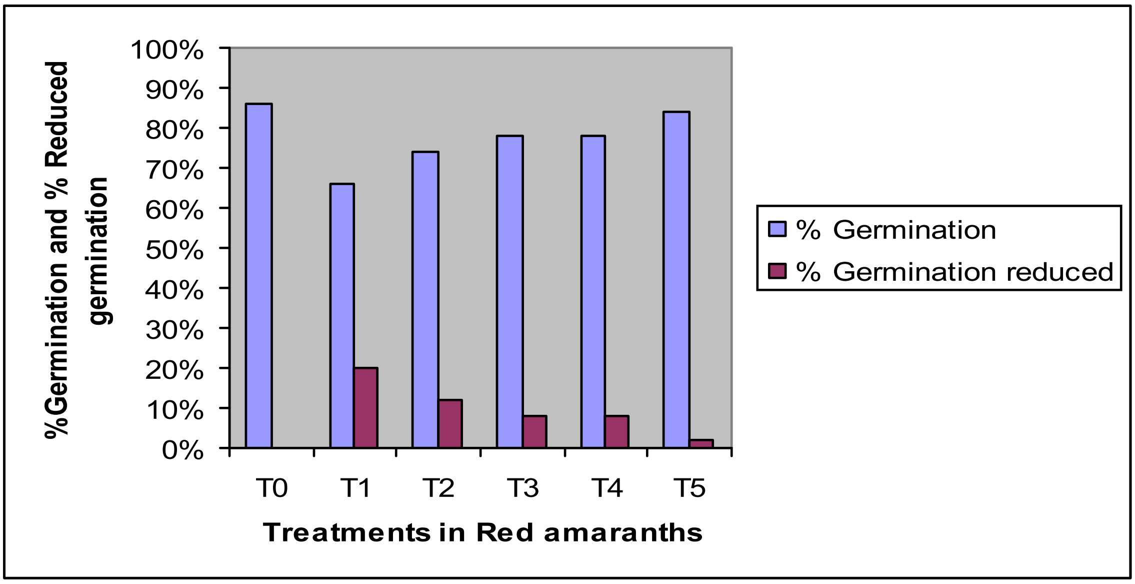


Fig. 4.39. Percent Germination and Reduced Percent Germination for the application of fresh water, raw effluent and different diluted effluent in Red amaranth (*Amaranthus curentus*)

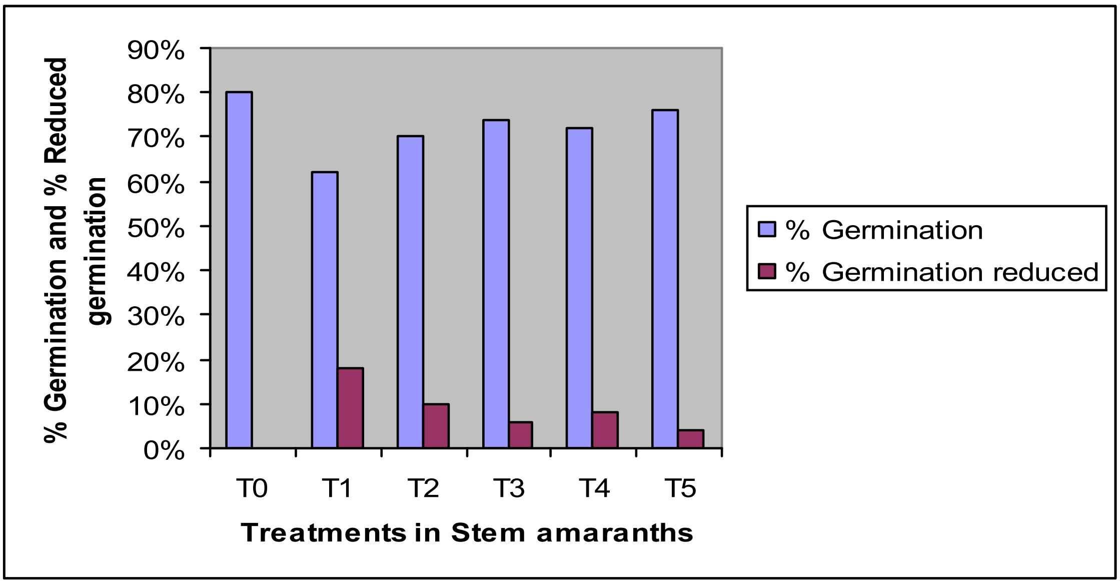


Fig. 4.40. Percent Germination and Reduced Percent Germination for the application of fresh water, raw effluent and different diluted effluent in Stem amaranth *(Amaranthus lividus)*

4.2.6. Effect of Shrimp Processing effluents on growth of Water Spinach (*Ipomoea aquatica*); Stem Amaranth (*Amaranthus lividus*) and Red Amaranth (*Amaranthus curentus*):

The effect of shrimp processing effluents on growth of three crops was studied following a pot experiment. The number of leaves per plant, fresh weight per plant, dry weight per plant and percent moisture contents were measured for the plants treated with undiluted effluents and effluent with different dilutions were compared with plants grown with uncontaminated water. The results are presented in table 4.9, 4.10 and 4.11.

Table 4.9. Growth of Water Spinach *(Ipomoea aquatica)* due to the application of raw and diluted effluents discharged from Shrimp Processing Industries

Treatments	No. of Leaves Per Plant	Fresh Wt./Plant (Root + Shoot) (g)	Dry Wt./Plant (Root +Shoot) (g)	Moisture Content (%)
T0	10.43a	3.49a	1.38a	65.94a
T1	5.37d	2.52e	0.89c	60.39b
T2	8.33c	2.76d	0.94c	62.34ab
T3	9.57b	2.97cd	1.10b	62.60ab
T4	9.9ab	3.10bc	1.16b	62.89ab
T5	10.07ab	3.26b	1.19b	64.71a
EMS	0.14	0.0165	0.1054	4.93
LSD	0.68	0.23	0.59	4.04

Table 4.10. Growth of Stem Amaranth *(Amaranthus lividus)* due to the application of raw and diluted effluents discharged from Shrimp Processing Industries

Treatments	No. of Leaves/ Plant	Fresh Wt./Plant (Root + Shoot) (g)	Dry Wt./Plant (Root+Shoot) (g)	Moisture Content (%)
T0	11.27a	7.16a	2.59a	65.71a
T1	6.07d	3.78d	1.36d	60.9b
T2	7.93c	4.03d	1.51cd	61.32b
T3	9.0b	4.95c	1.91bc	62.95ab
T4	9.67b	5.66bc	2.21ab	63.7ab
T5	11a	6.31ab	2.29ab	64.74a
EMS	0.12	0.2258	0.03	7.43
LSD	0.63	0.86	0.31	4.96
Significant/ Insignificant at 5% level	Signifiant	Signifiant	Signifiant	Insignifiant

Table 4.11. Growth of Red amaranth *(Amaranthus curentus)* due to the application of raw and diluted effluents discharged from Shrimp Processing Industries

Treatments	No. of Leaves/ Plant	Fresh Wt./Plant (Root +Shoot) (g)	Dry Wt./Plant (Root+Shoot) (g)	Moisture Content (%)
T0	8.4a	7.12a	2.02a	71.65a
T1	5.2e	3.55d	1.16d	67.35b
T2	5.8de	4.36c	1.20d	67.39b
T3	6.13cd	4.85c	1.56c	67.88ab
T4	6.47bc	5.83b	1.71bc	70.66ab
T5	6.93b	6.71a	1.92ab	71.33a
EMS	0.0188	0.0524	0.0046	8.22
LSD	0.25	0.49	0.1	5.22
Significant/ Insignificant at 5% level	Signifiant	Signifiant	Signifiant	Insignifiant

4.2.6.1. Number of leaves per plant:

The number of leaves per plant ranged between 6.37 to 10.43 in WS, 6.07 to 11.27 in SA and 5.2 to 8.4 in RA and the maximum number of leaves were counted in T_0 (uncontaminated water treated plants) and the lowest number of leaves were counted in T_1 (undiluted raw effluent treated plants) (Table 4.9, 4.10 and 4.11). The results show that the indiscriminate dumping of effluents and wastes have significant level of damaging effects on the receiving plants and confirmed detrimental effect on the number of leaves per plant up to 50% dilution for WS, up to 75% dilution for SA and up to 90% dilution for RA and the magnitude of the difference is at the order of $T_0 > T_5 > T_4 > T_3 > T_2 > T_1$ for all test crops (Table 4.9, 4.10 and 4.11). Results show that the number of leaves/ plant was statistically significant at 5% level against uncontaminated treated plants (F=76.93 for WS, 102.5 for SA and 210.43 for RA) and (LSD=0.68 for WS, 0.63 for SA and 0.25 for RA) (Table 8.3, 8.4 and 8.5). However the difference of number of leaves/ plant among treatments was statistically significant in T_0, T_1 and T_2 for WS, T_0, T_1, T_2 and T_3 for SA and T_0, T_1, T_2, T_4, T_5 for RA but insignificant in T_3, T_4 and T_5 for WS, T_0, T_5; T_3, T_4 for SA and T_2, T_3; T_3, T_4; T_4, T_5 for RA (Fig. 4.41, 4.42 and 4.43). On the basis of number of leaves /plant Red amaranth is most affected among three species followed by Water spinach and Stem amaranth. It is evident from the results obtained RA is very sensitive to SA and WS and effects could not be recovered even at 90% dilution for RA, 75% for SA and 50% for WS.

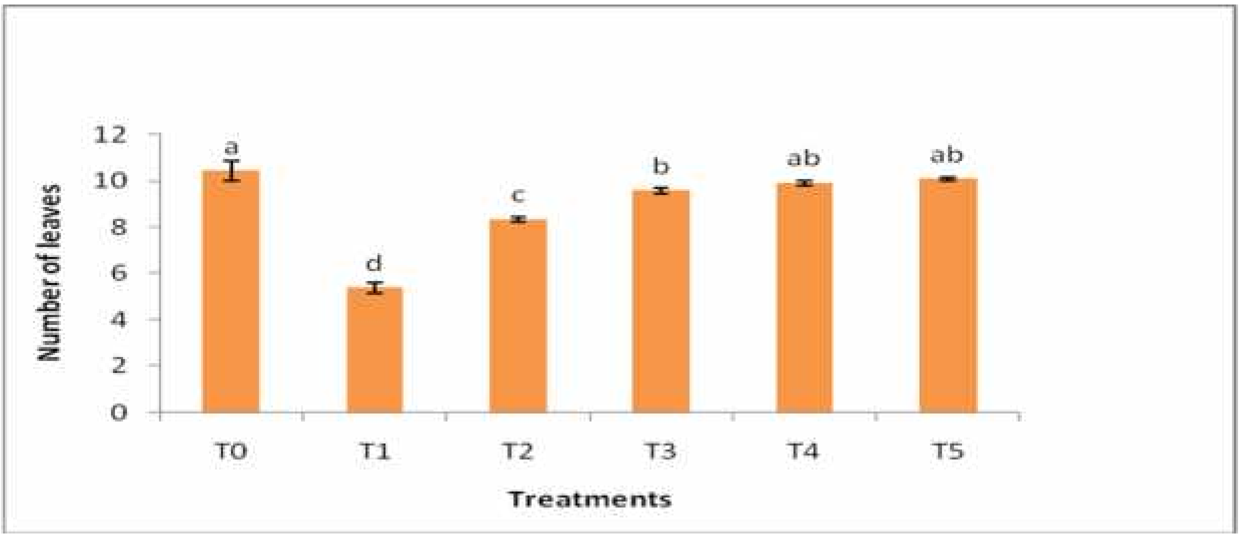


Fig. 4.41. Effect of raw and diluted effluents on the number of leaves of water spinach (*Ipomoea aquatica*)

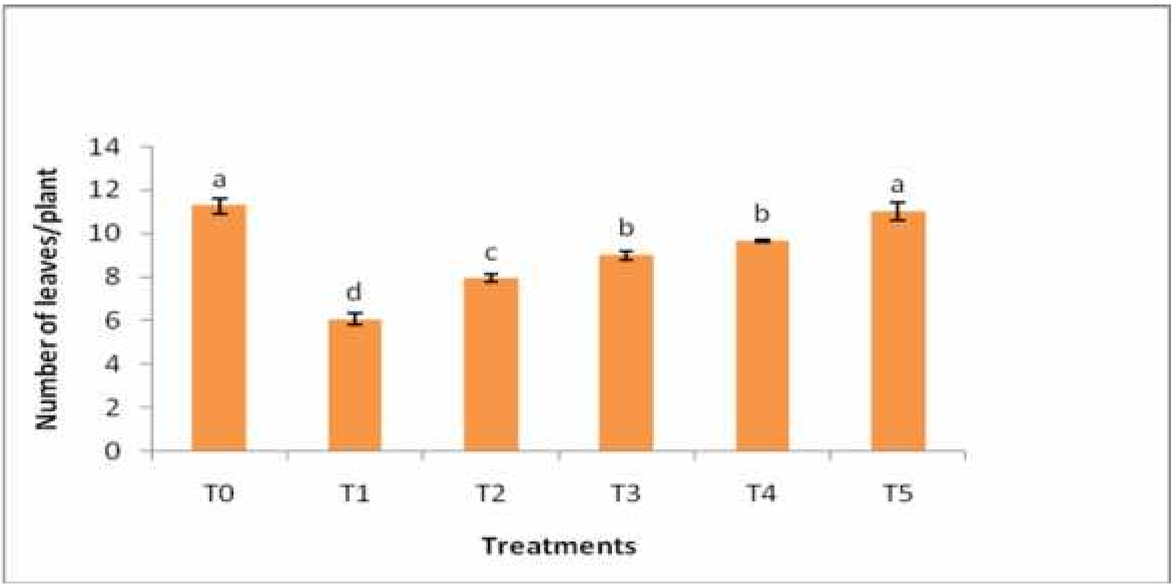


Fig. 4.42. Effect of raw and diluted effluents on the number of leaves of Stem Amaranth (*Amaranthus lividus*)

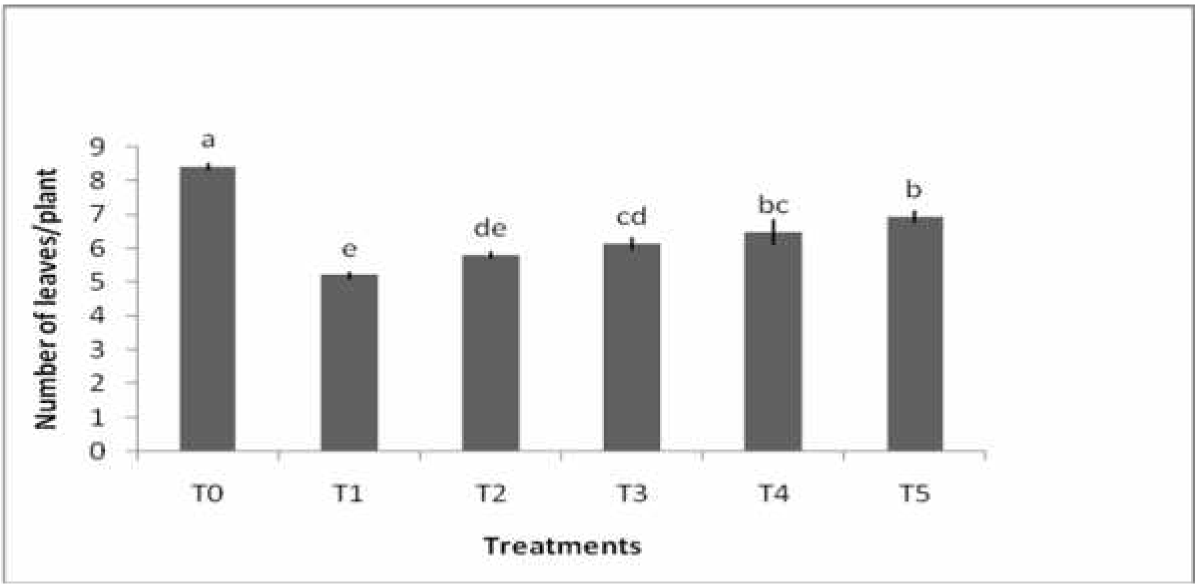


Fig. 4.43. Effect of raw and diluted effluents on the number of leaves of Red Amaranth (*Amaranthus curentus*)

4.2.6.2. Fresh weight per plant (gm):

The results show that the fresh weight/ plant ranged between 2.52 to 3.49 g in WS, 3.78 to 7.16 g in SA and 3.55 to 7.12 g in RA respectively. The maximum fresh weight 3.49 g was obtained for WS, 7.16 g (SA) and 7.12 g (RA) per plant was measured in fresh water treated plants (T_0) and the lowest was measured 2.52 g (WS) 3.78 g (SA) and 3.55g (RA) in raw effluent treated plants (T_1) (Presented in Table 4.9, 4.10 and 4.11).

The results reveal that the water has a significant impact on the fresh weight of the plants. It is possible that less uptake of water by the plants could have reducing effect of the plants. The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on the fresh weight/ plant up to 90% dilution for WS, up to 75% dilution for SA and up to 75% dilution for RA and magnitude of the difference is at the order of $T_0>T_5>T_4>T_3>T_2>T_1$ for all test crops (Table 4.9, 4.10 and 4.11). Results show that fresh weight/ plant was statistically highly significant at 5% level against fresh water treated plants 3.49 g (WS), 7.16 g (SA) and 7.12g (RA) and (LSD=0.23 for WS, 0.86 for SA and 0.49 for RA) (Table 8.6, 8.7 and 8.8). However the difference of fresh weight/ plant among treatments was statistically significant in T_0, T_1, T_2 and T_4 for WS, T_0, T_1, T_5 for SA and T_0, T_1, T_2, T_4 for RA but insignificant in T_2, T_3; T_3, T_4; and T_4, T_5 for WS, T_0, T_5; T_2, T_3 for RA and T_0, T_5; T_1, T_2; T_3, T_4; T_4, T_5 for SA (Fig. 4.44, 4.45 and 4.46). On the basis of fresh weight /plant Water spinach is most affected among three species followed by Red amaranth and Stem amaranth. Direct use of raw effluent should be avoided where as more dilution can decrease the harmful effects of effluents on the growth factor like fresh weight/ plant.

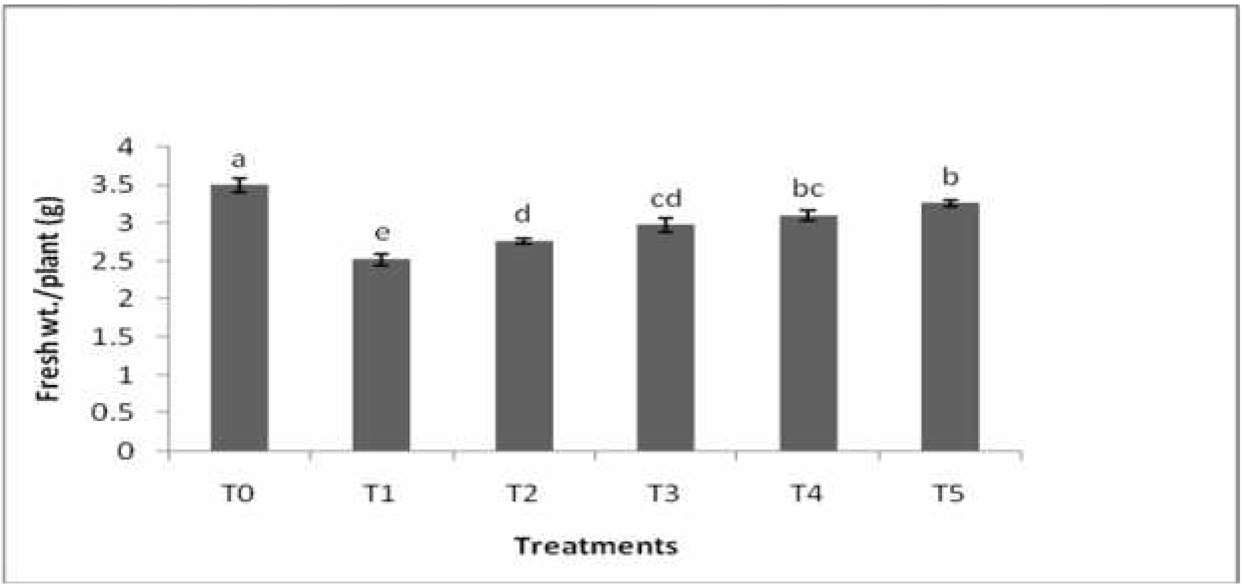


Fig. 4.44. Effect of raw and diluted effluents on fresh weight per plant of water spinach (*Ipomoea aquatica*)

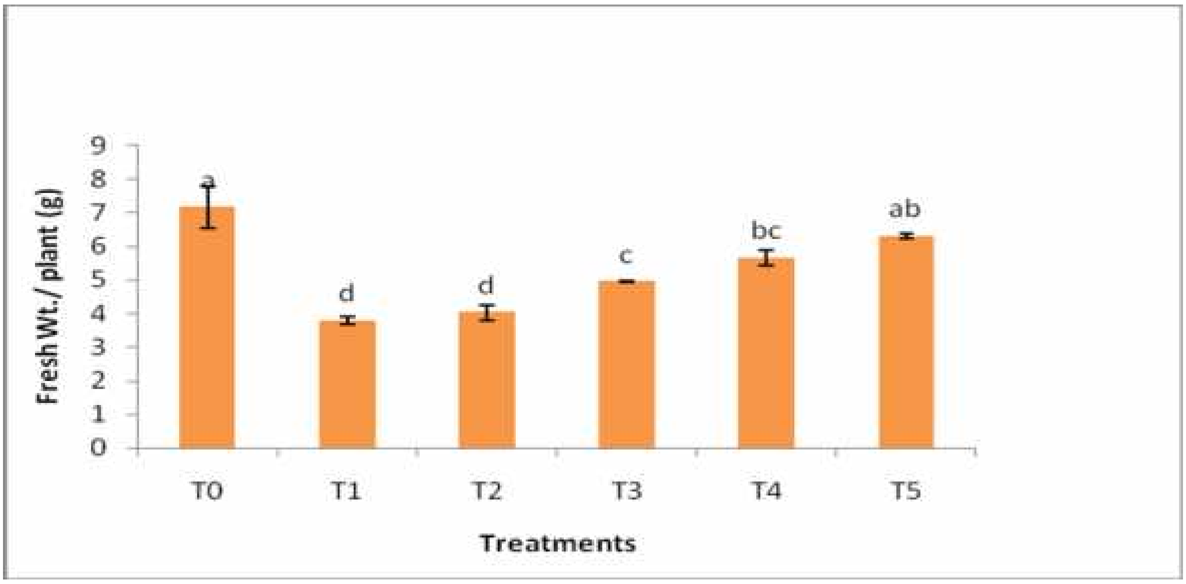


Fig. 4.45. Effect of raw and diluted effluents on fresh weight per plant of Stem Amaranth (*Amaranthus lividus*)

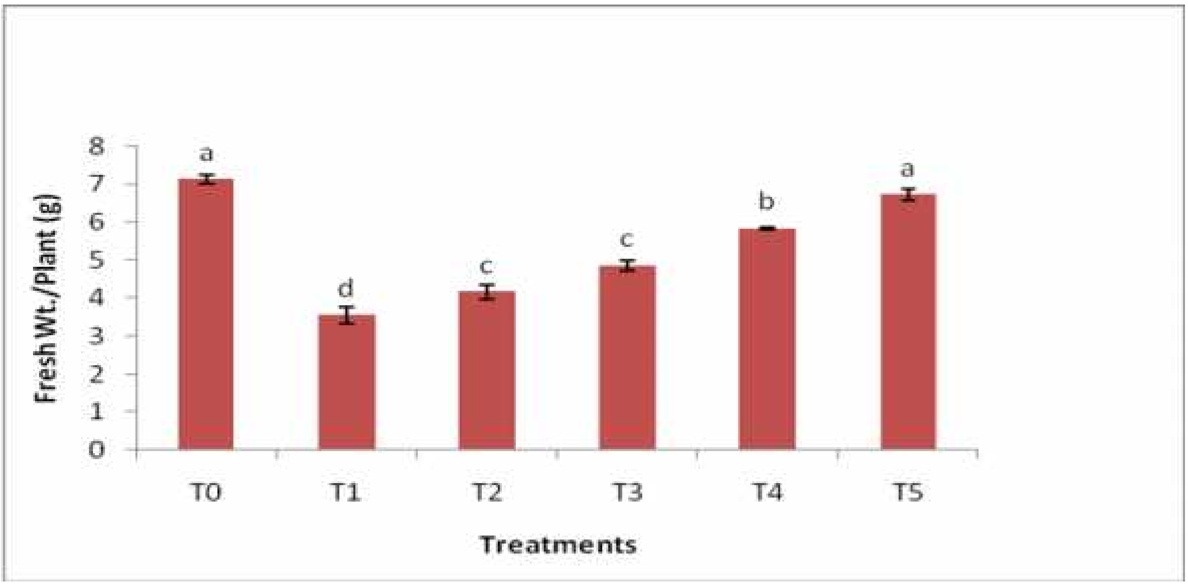


Fig. 4.46. Effect of raw and diluted effluents on fresh weight per plant of Red Amaranth (*Amaranthus curentus*)

4.2.6.3. Dry weight per plant (gm):

The results show that the dry weight/ plant ranged between 0.89 to 1.38 g for WS, 1.36 to 2.59 g for SA and 1.16 to 2.02 g for RA and maximum dry weight 1.38 g (WS), 2.59 g (SA) and 2.02 g (RA) per plant was measured in fresh water treated plants (T_0) and the lowest was measured 0.89 g (WS), 1.36 g (SA) and 1.16 g (RA) in raw effluent treated plants (T_1) (Table 4.9, 4.10 and 4.11).

The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on the dry weight/ plant up to 90% dilution for WS, up to 50% dilution for SA and up to 75% dilution for RA and magnitude of the difference is at the order of $T_0>T_5>T_4>T_3>T_2>T_1$ for all test crops (Table 4.9, 4.10 and 4.11). Results show that dry weight/ plant was statistically highly significant at 5% level against fresh water treated plants for RA and SA but insignificant for WS (F=0.91 for WS, 23 for SA and 82.6 for RA) and (LSD=0.59 for WS, 0.31 for SA and 0.10 for RA) (Table 8.9, 8.10 and 8.11). However the difference of dry weight/ plant among treatments was statistically significant in T_0, T_1, T_3 for WS, T_0, T_1 for SA and T_0, T_1, T_3 for RA but insignificant in T_1, T_2; T_3, T_4, T_5 for WS, T_0, T_4, T_5; T_1, T_2; T_2, T_3; T_3, T_4, T_5 for SA and T_0, T_5; T_1, T_2; T_3, T_4; T_4, T_5 for RA (Fig. 4.47, 4.48 and 4.49). On the basis of dry weight /plant Water spinach is most affected among three species followed by Stem amaranth and Red amaranth. Direct use of raw effluent should be avoided where as more dilution can decrease the harmful effects of effluents on the growth factor like dry weight/ plant.

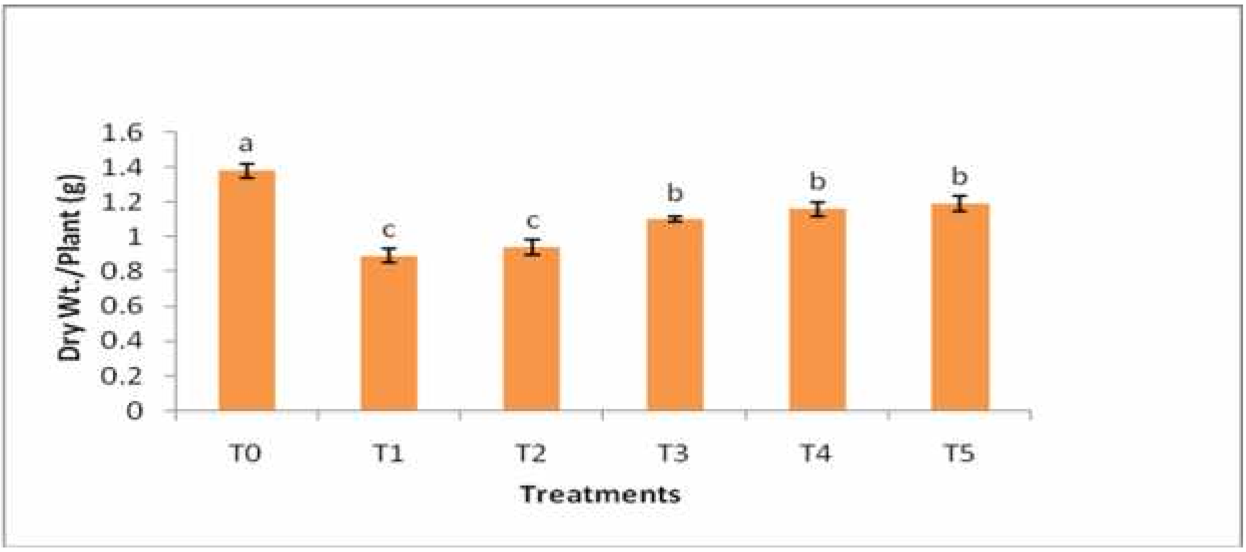


Fig 4.47. Effect of raw and diluted effluents on dry weight per plant of water spinach (*Ipomoea aquatica*)

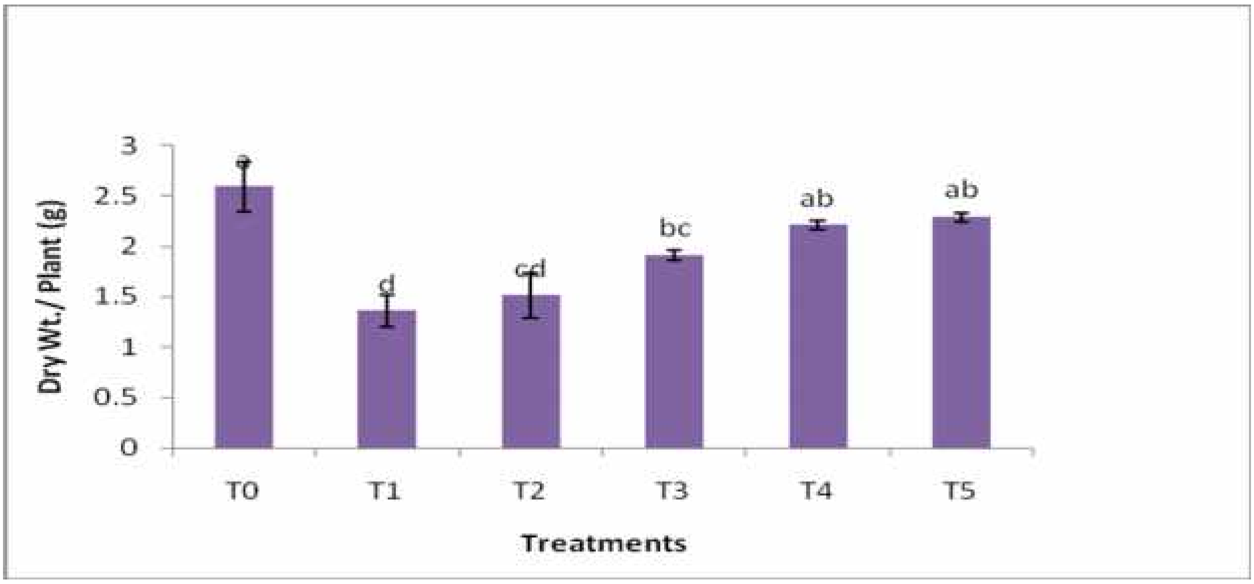


Fig 4.48. Effect of raw and diluted effluents on dry weight per plant of Stem Amaranth (*Amaranthus lividus*)

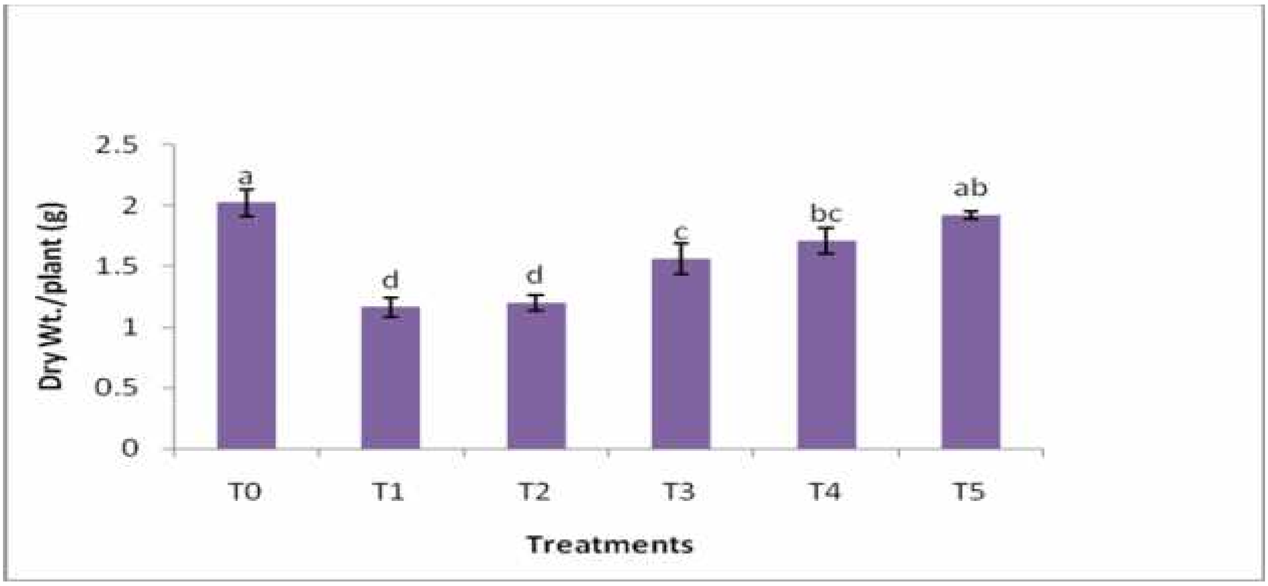


Fig 4.49. Effect of raw and diluted effluents on dry weight per plant of Red Amaranth (*Amaranthus curentus*)

4.2.6.4. Moisture content (%MC):

The results show that percent moisture content (%MC) ranged between 60.39 to 65.94% for WS, 60.9 to 65.71% for SA and 67.35 to 71.65% for RA and maximum %MC was 65.94% (WS), 65.71% (SA) and 71.65% (RA) in fresh water treated plants (T_0) and the lowest was measured 60.39% (WS), 60.9% (SA) and 67.35% (RA) in raw effluent treated plants (T_1) (Table 4.9, 4.10 and 4.11).

The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on %MC up to 25% dilution and magnitude of the difference is at the order of $T_0>T_5>T_4>T_3>T_2>T_1$ for all test crops (Table 4.9, 4.10 and 4.11). Results show that %MC was statistically insignificant at 5% level against fresh water treated plants for all test crops (F=2.39 for WS, 1.44 for SA and 0.83 for RA) and (LSD=4.04 for WS, 4.96 for SA and 5.22 for RA) (Table 8.9, 8.10 and 8.11). However the difference of %MC among treatments was statistically significant in T_0, T_1 for all species but insignificant in T_0, T_3, T_4, T_5; T_1, T_2, T_3, T_4 for all species (Fig. 4.50, 4.51 and 4.52). Percent moisture content of plants was decreased for the use of effluent might be due to the presence of salts which can reduce water content in plants by osmoregulation process. On the basis of % moisture content Water spinach is most affected among three species because it is a water loving plant affected by excess salts followed by Stem amaranth and Red amaranth

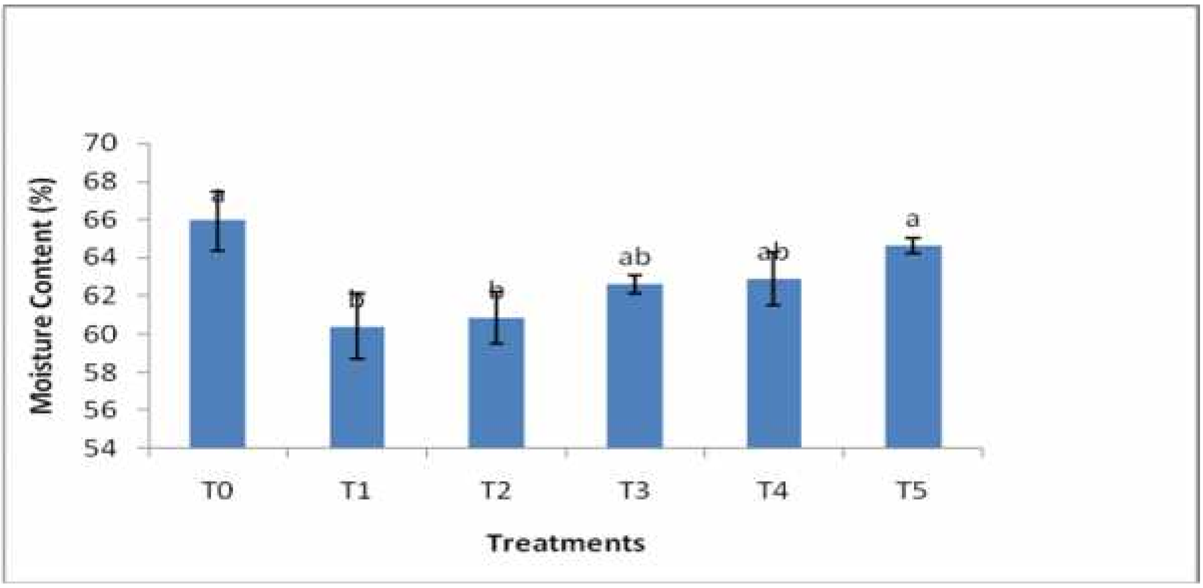


Fig 4.50. Effect of raw and diluted effluents on %moisture content of water spinach (*Ipomoea aquatica*)

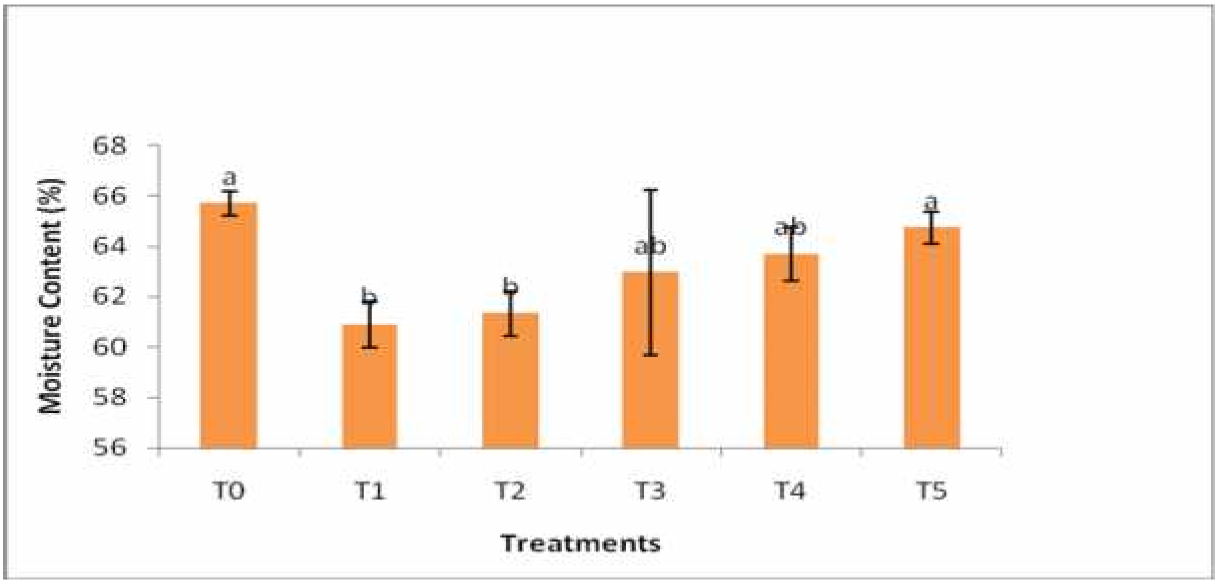


Fig 4.51. Effect of raw and diluted effluents on %moisture content of Stem Amaranth (*Amaranthus lividus*)

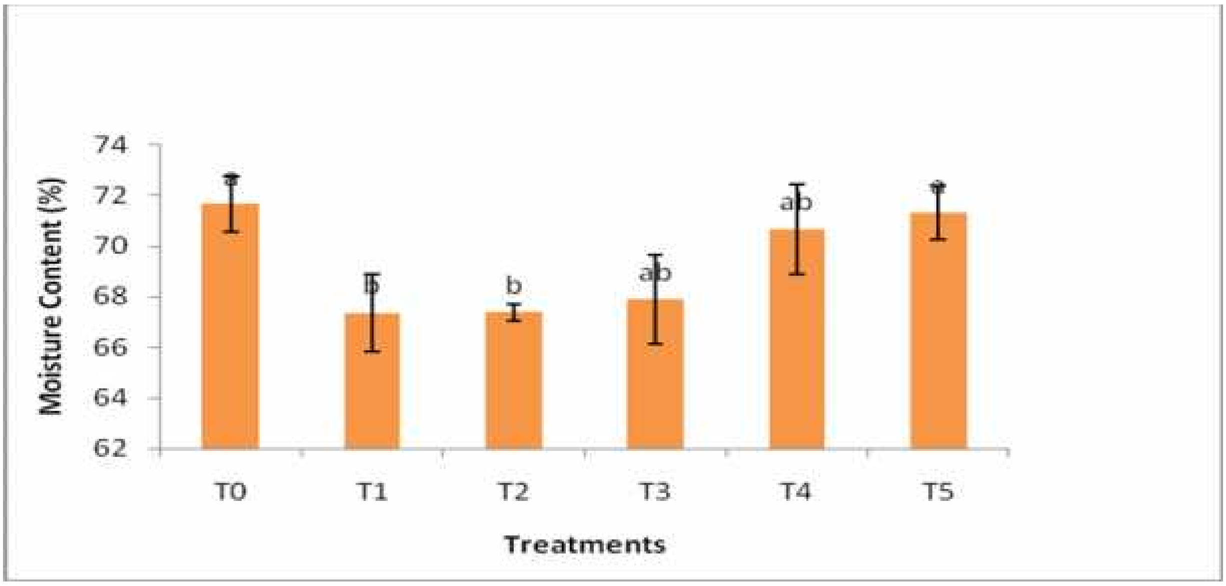


Fig 4.52. Effect of raw and diluted effluents on %Moisture content of Red Amaranth (*Amaranthus curentus*)

4.2.7. N, P, S and heavy metals in different varieties of crops grown on raw and diluted effluents treated soil.

The uptake of N, P, S and heavy metals by Red Amaranths (*Amaranthus curentus),* Stem Amaranths (*Amaranthus lividus*) and Water Spinach (*Ipomoea Aquatica*) grown in fresh and diluted effluent treated soils were analyzed and result is presented in (table 4.12, 4.13 and 4.14). Raw and diluted effluents were applied in six treatments on the test crops "Stem amaranth *(Amaranthus lividus),* Red amaranths (*Amaranthus curentus*) and Water spinach (*Ipomoea aquitica*)" to observe their nutrients and heavy metals uptake. In the present study, plants grown on effluent treated plants are compared with fresh water treated plants.

Table 4.12. Nutrients and heavy metals in Red amaranth *(Amaranthus curentus)* grown on raw and diluted effluents.

Treatments	Total N	P	S	Ni	Pb	Mn	Zn	Cr	Cd
	(%)	(mgKg^{-1})							
T0	2.2a	284a	158a	8.4a	BDL	28.7a	27.8a	4.07a	BDL
T1	1.12e	136d	85e	3.79c	BDL	14.3d	18.6b	1.6d	BDL
T2	1.32d	153cd	102d	5.77b	BDL	18cd	20.1b	2.13cd	BDL
T3	1.53c	171c	124c	6.09b	BDL	19.7bc	20.7b	2.43bc	BDL
T4	1.63c	207b	133bc	7.67a	BDL	21bc	22.7b	2.87b	BDL
T5	1.94b	234b	146ab	8.23a	BDL	23b	23.2b	4.03a	BDL
EMS	0.1134	303.56	53.5	0.384	-	5.99	6.48	0.126	-
LSD	0.6	31.69	13.3	1.14	-	4.45	4.63	0.65	-
Sig/ Insig. at 5% level	Significant	Significant	Significant	Significant	-	Significant	Significant	Significant	-

BDL=Below Detection Limit (<0.02ppm)

Table 4.13. Nutrients and heavy metals in Stem amaranth *(Amaranthus lividus)* grown on raw and diluted effluents.

Treatments	Total N	P	S	Ni	Pb	Mn	Zn	Cr	Cd
	(%)	(mg Kg^{-1})							
T0	1.63a	285a	176a	7.51a	BDL	34.3a	30.9a	3.48a	BDL
T1	1.03c	118d	93e	1.4e	BDL	17f	16.5d	0.89c	BDL
T2	1.12c	175c	106d	2.43d	BDL	20.7e	21.8c	1.88b	BDL
T3	1.18bc	240b	112d	3.1c	BDL	24.7d	24.6bc	2.09b	BDL
T4	1.34b	256ab	136c	3.2bc	BDL	27c	28.9ab	2.18b	BDL
T5	1.52a	261ab	153b	3.62b	BDL	30.7b	29.2a	3.37a	BDL
EMS	0.011	260.19	53.02	0.049	-	1.53	4.56	0.0231	-
LSD	0.19	30.99	21.06	0.4	-	79.6	3.88	0.28	-
Sig/ Insig. at 5% level	Significant	Significant	Significant	Significant	-	Significant	Significant	Significant	-

BDL=Below Detection Limit (<0.02ppm)

Table 4.14. Nutrients and heavy metals in Water spinach *(Ipomoea aquitica)* grown on raw and diluted effluents.

Treatments	Total N	P	S	Ni	Pb	Mn	Zn	Cr	Cd
	(%)	(mg Kg^{-1})							
T0	2.19a	289a	174a	11.7a	BDL	27a	30.6a	1.63a	BDL
T1	1.16e	116e	108e	4.39c	BDL	15.3d	18.1e	0.6c	BDL
T2	1.25e	175d	128d	6.87bc	BDL	18c	19de	0.9bc	BDL
T3	1.48d	206c	140c	8b	BDL	19.7c	21d	1.13b	BDL
T4	1.74c	244b	154b	9ab	BDL	22b	23.7c	1.17b	BDL
T5	1.96b	275a	169a	11a	BDL	25.7a	27.1b	1.67a	BDL
EMS	0.008	206.39	36.28	2.66	-	1.12	1.75	0.0469	-
LSD	0.16	26.1	10.96	2.97	-	2.01	2.32	0.39	-
Sig/ Insig. at 5% level	Significant	Significant	Significant	Significant	-	Significant	Significant	Significant	-

BDL=Below Detection Limit (<0.02ppm)

Table 4.15. Protein content in Red amaranth *(Amaranthus curentus)*, stem amaranth *(Amaranthus lividus)* and water spinach *(Ipomoea aquitica)*.

Treatments	Red amaranth (% protein)	Stem amaranth (% protein)	Water spinach (% protein)
T_0	13.75	10.19	13.69
T_1	7.0	6.44	7.25
T_2	8.25	.7.0	7.81
T_3	9.56	7.38	9.25
T_4	10.19	8.38	10.88
T_5	12.13	9.5	12.25

4.2.7.1. Total Nitrogen (N):

Total nitrogen ranged between 1.12-2.2% for RA, 1.03-1.63% for SA and 1.16-2.19% for WS. The highest N was in fresh water treated plants (T_0) for all test crops (2.2% for RA, 1.63% for SA and 2.19% for WS). However lowest N was in fresh effluent treated plants T_1 (1.12% for RA, 1.03% for SA and 1.16% for WS) (Table 4.12, 4.13 and 4.14). Results show that total nitrogen was in test crops was statistically highly significant at 5% level against N in fresh water treated plants (F=4.18 for RA, 26.19 for SA and 62.5 for WS) and (LSD= 0.6 for RA, 0.19 for SA and 0.16 for WS) (Table 8.15, 8.16 and 8.17). However the difference of total N among treatments was statistically significant in T_0, $T_{1,}$ T_4 for SA, T_0, $T_{1,}$ T_2, T_3, T_5 for RA and T_0, $T_{1,}$ T_3, T_4, T_5 for WS but insignificant in T_0, T_5; T_1, T_2; T_5; T_3, T_4 for SA, T_3, T_4 for RA and $T_{1,}$ T_2 for WS (Fig. 4.53, 4.54 and 4.55). The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on Total N up to 75% dilution for SA and RA and 90% dilution for WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Protein content is related with N accumulation and decreases with the decrease of nitrogen accumulation.

Protein content in fresh water treated plants ranged from 10.19-13.75% for different test crops and reduced in effluent treated plants ranged from 6.44-7.25% and ultimately reduces the food values of crops but dilution of effluent can minimize the effect on protein content (Table 4.15). Different plant species showing different level of responses in case of nitrogen accumulation and protein content due to the salt dilution effect in different treatment.

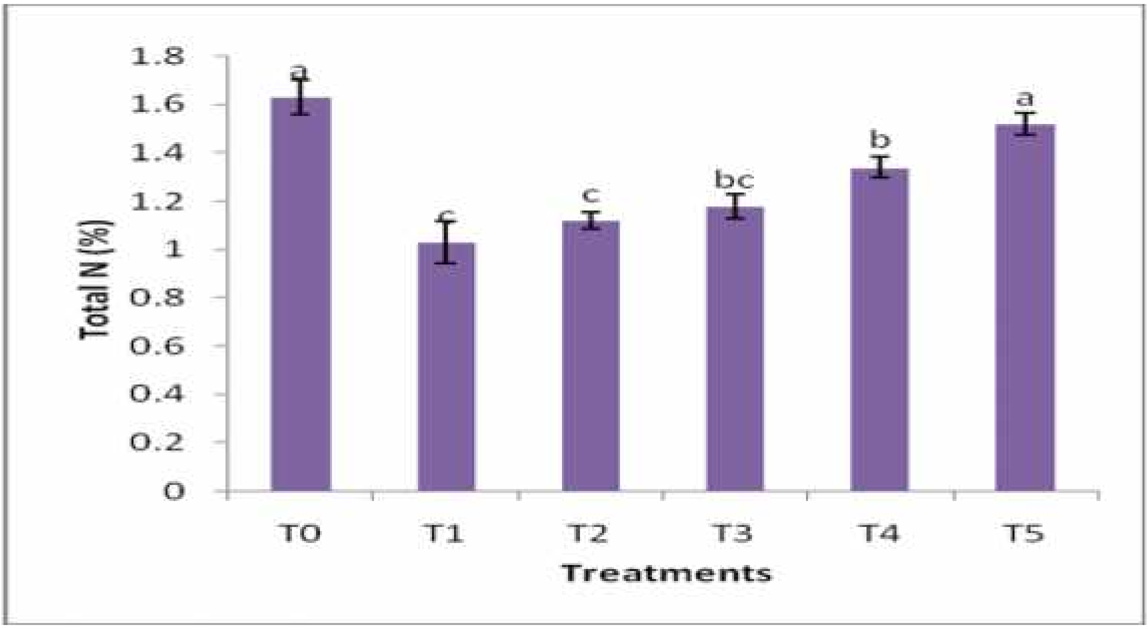


Fig 4.53. Total N in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

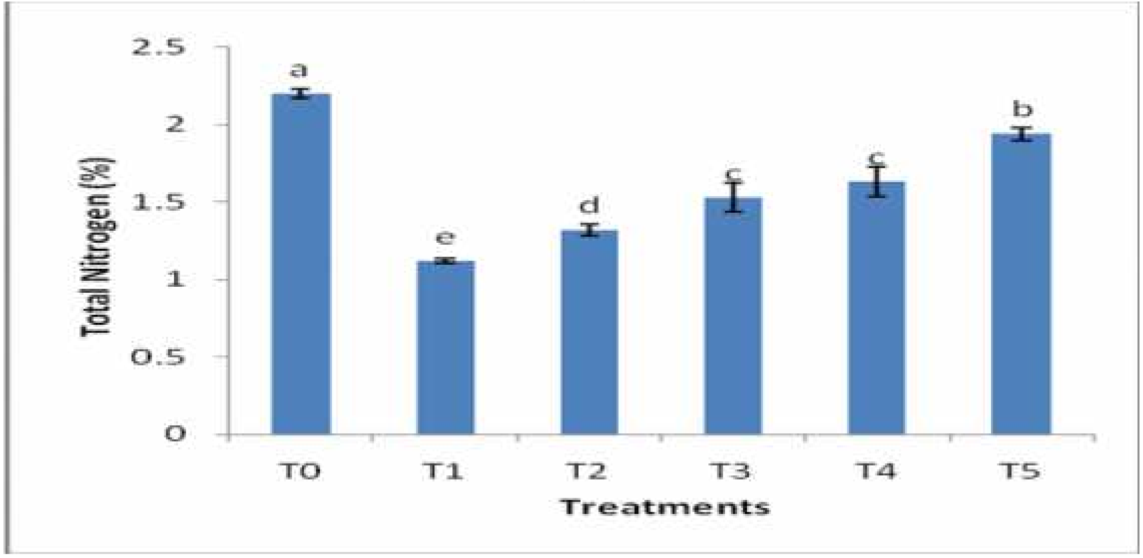


Fig 4.54. Total N in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

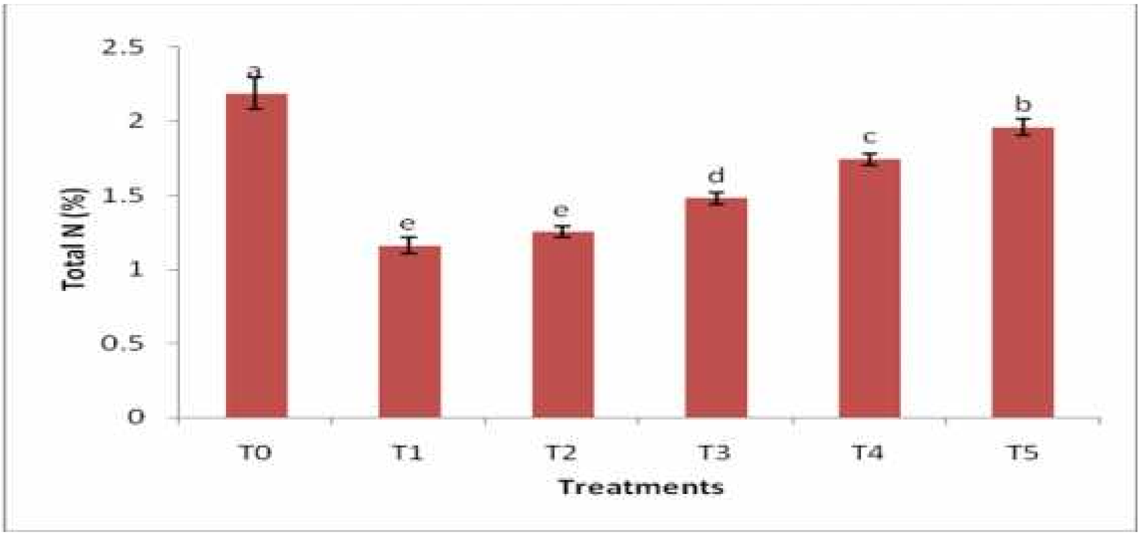


Fig 4.55. Total N in Water spinach (*Ipomoea aquitica*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

4.2.7.2. Phosphorus (P):

Phosphorous ranged between 118-285 mgKg^{-1} for RA, 136-284 mgKg^{-1} for SA and 116-289 mgKg^{-1} for WS. The highest P was in fresh water treated plants (T_0) for all test crops (285 mgKg^{-1} for RA, 284 mgKg^{-1} for SA and 289 mgKg^{-1} for WS). However lowest P was in fresh effluent treated plants T_1 (118 mgKg^{-1} for RA, 136 mgKg^{-1} for SA and 116 mgKg^{-1} for WS) (Table 4.12, 4.13 and 4.14). Results show that phosphorous was in test crops was statistically highly significant at 5% level against N in fresh water treated plants (F=30.41 for RA, 46.4for SA and 62.04 for WS) and (LSD= 31.69 for RA, 30.99 for SA and 26.1 for WS) (Table 8.18, 8.19 and 8.20). However the difference of P among treatments was statistically significant in T_0, T_1, T_2, T_3 for SA, T_0, T_1, T_3, T_4 for RA and T_0, T_1, T_2, T_3, T_4 for WS but insignificant in T_0, T_4, T_5; T_3, T_4, T_5 for SA, T_1, T_2; T_2, T_3; T_4, T_5 for RA and T_0, T_5 for WS (Fig. 4.56, 4.57 and 4.58). The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on phosphorous up to 50% dilution for SA, 90% dilution for RA and 75% dilution for WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Different plant species showing different level of responses in case of phosphorous accumulation due to the salt dilution effect in different treatment.

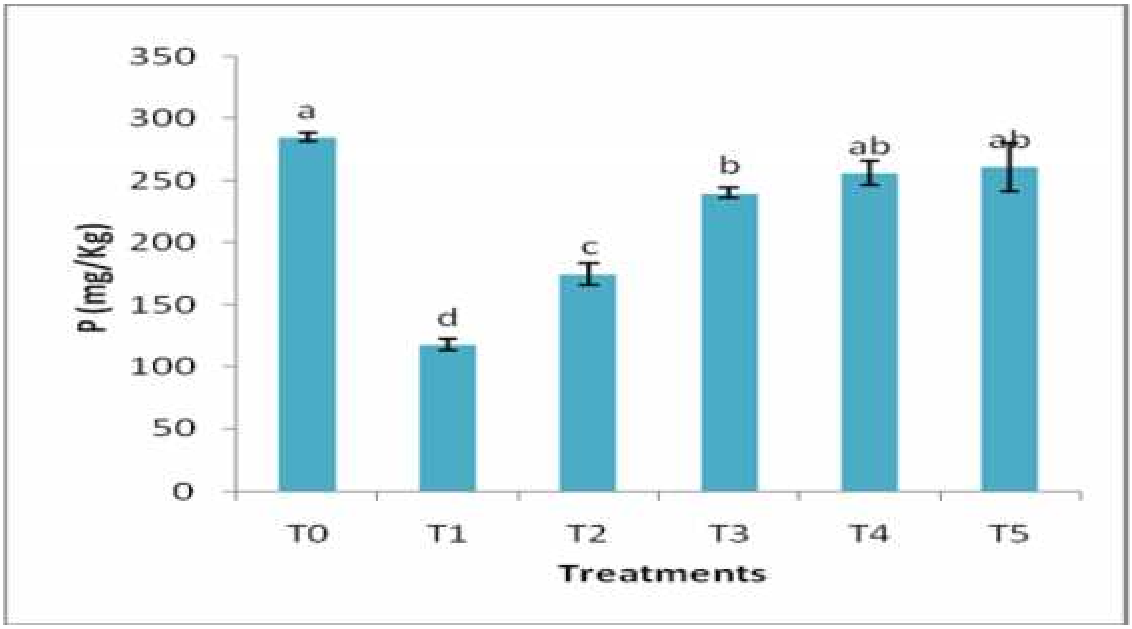


Fig 4.56. Phosphorous in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

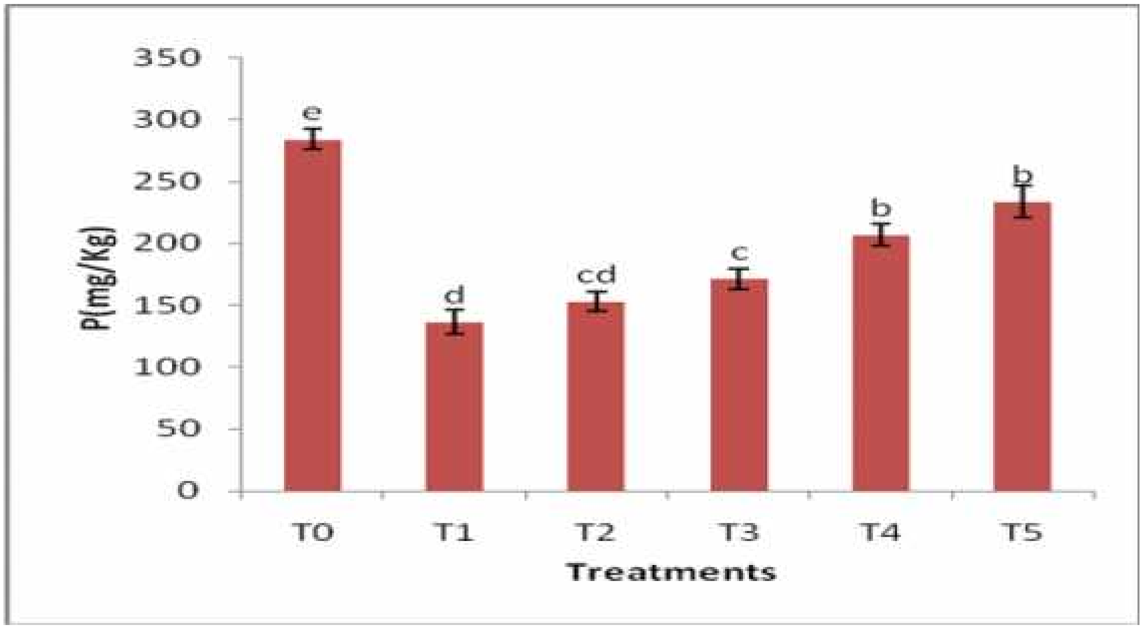


Fig 4.57. Phosphorous in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

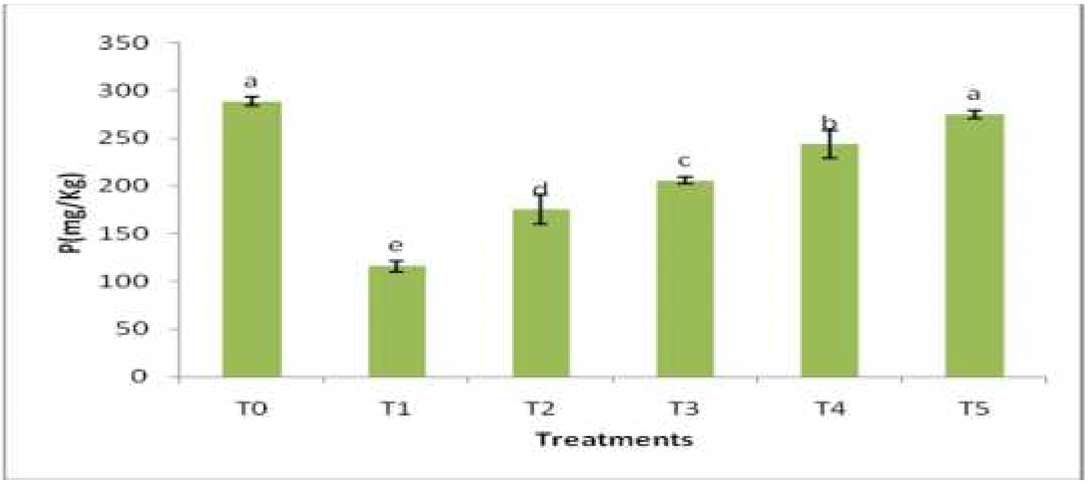


Fig 4.58. Phosphorous in Water spinach (*Ipomoea aquitica*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

4.2.7.3. Sulfur (S):

Sulfur ranged between 85-158 mgKg^{-1} for RA, 93-176 mgKg^{-1} for SA and 93-176 mgKg^{-1} for WS. The highest S was in fresh water treated plants (T_0) for all test crops (158 mgKg^{-1} for RA, 176 mgKg^{-1} for SA and 174 mgKg^{-1} for WS). However lowest S was in fresh effluent treated plants T_1 (85 mgKg^{-1} for RA, 93 mgKg^{-1} for SA and 108 mgKg^{-1} for WS) (Table 4.12, 4.13 and 4.14). Results show that sulfur was in test crops was statistically highly significant at 5% level against S in fresh water treated plants (F=41.64 for RA, 55.72 for SA and 698 for WS) and (LSD= 13.3 for RA, 21.06 for SA and 10.96 for WS) (Table 8.21, 8.22 and 8.23). However the difference of S among treatments was statistically significant in T_0, T_1, T_2, T_4, T_5 for SA, T_0, T_1, T_2, T_3 for RA and T_0, T_1, T_2, T_3, T_4 for WS but insignificant in T_2, T_3 for SA, T_0, T_5; T_3, T_4; T_4, T_5 for RA and T_0, T_5 for WS (Fig. 4.59, 4.60 and 4.61). The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on sulfur up to 90% dilution for SA, 75% dilution for RA and WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Different plant species showing different level of responses in case of sulfur accumulation due to the salt dilution effect in different treatment.

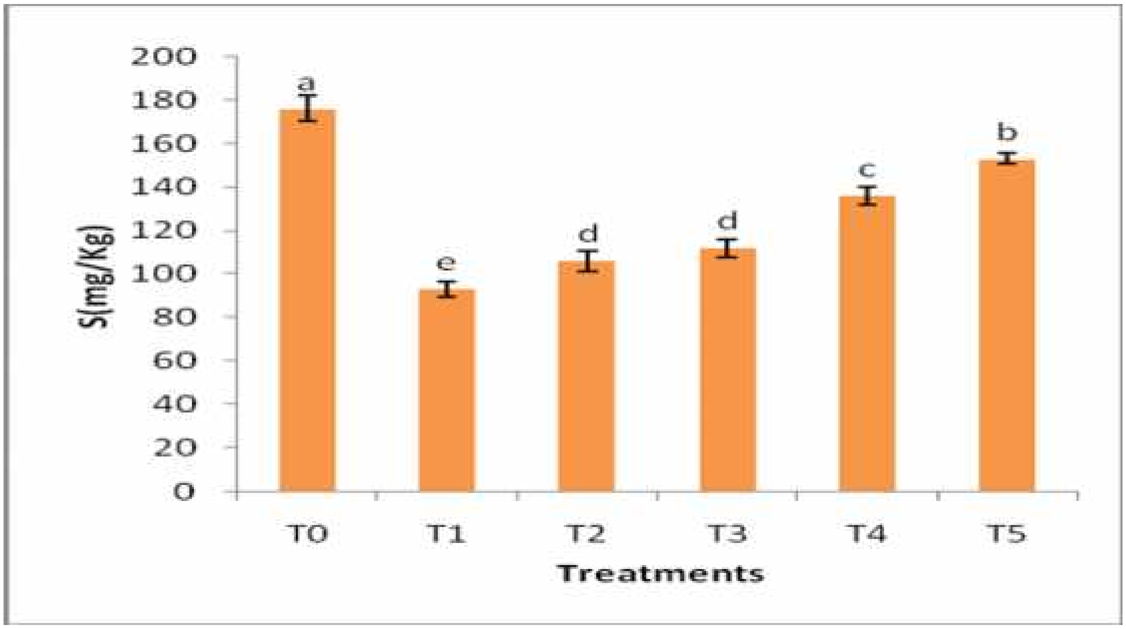


Fig 4.59. Sulfur in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

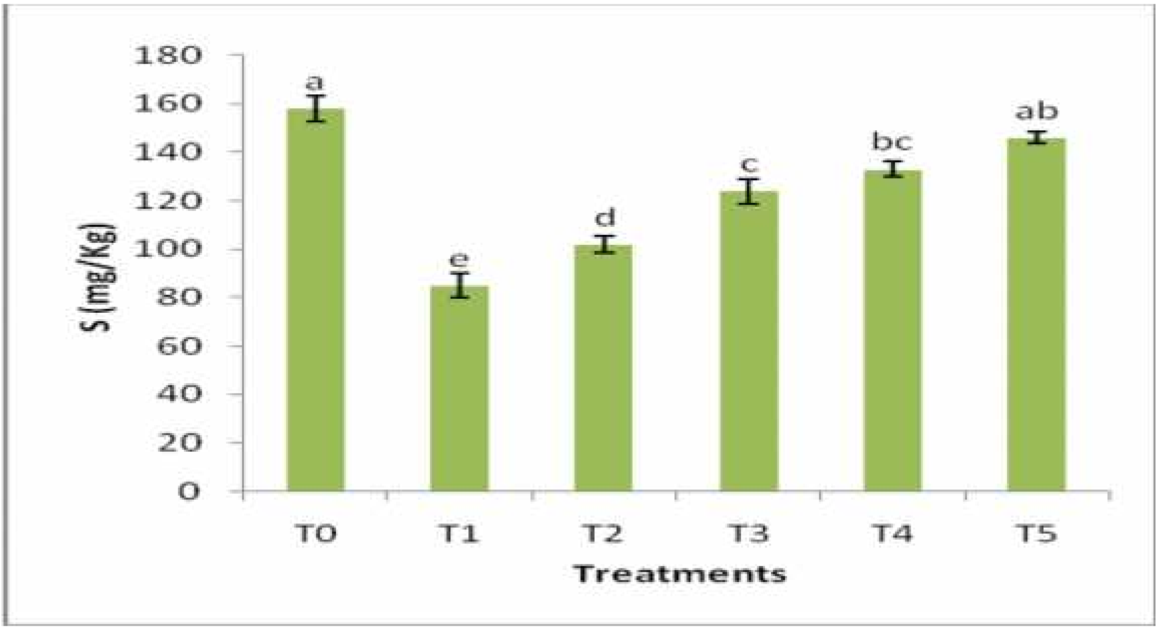


Fig 4.60. Sulfur in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

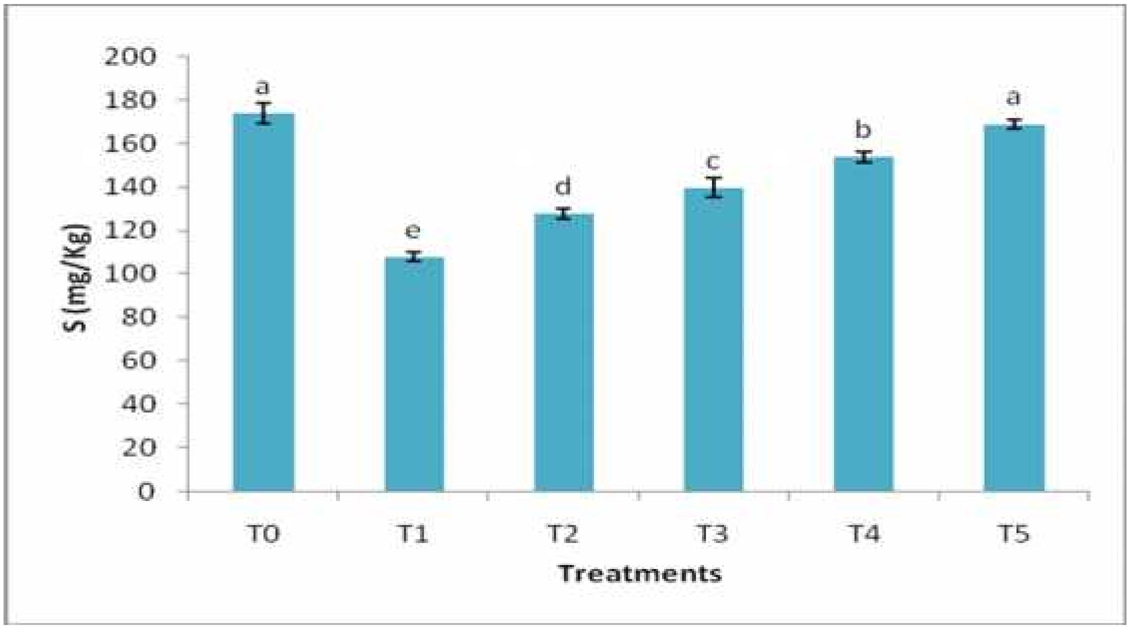


Fig 4.61. Sulfur in Water spinach (*Ipomoea aquitica*) from grown on treated with raw and diluted effluent of Shrimp Processing Industries

4.2.7.4. Nickel (Ni):

Nickel ranged between 3.79-8.4 mgKg^{-1} for RA, 1.4-7.51 mgKg^{-1} for SA and 4.39-11.7 mgKg^{-1} for WS. The highest Ni was in fresh water treated plants (T_0) for all test crops (8.4 mgKg^{-1} for RA, 7.51 mgKg^{-1} for SA and 11.7 mgKg^{-1} for WS). However lowest Ni was in fresh effluent treated plants T_1 (3.79 mgKg^{-1} for RA, 1.4 mgKg^{-1} for SA and 4.39 mgKg^{-1} for WS) (Table 4.12, 4.13 and 4.14). Results show that Ni was in test crops was statistically highly significant at 5% level against Ni in fresh water treated plants (F=24.83 for RA, 267.83 for SA and 7.7 for WS) and (LSD= 1.14 for RA, 0.4 for SA and 2.97 for WS) (Table 8.39, 8.40 and 8.41). However the difference of Ni among treatments was statistically significant in T_0, $T_{1,}$ T_2, T_3, T_5 for SA, T_0, $T_{1,}$ T_2 for RA and T_0, $T_{1,}$ T_3 for WS but insignificant in T_3, T_4; T_4, T_5 for SA, T_0, T_4, T_5; T_2, T_3 for RA and $T_{0,}$ T_4, T_5; $T_{1,}$ T_2; $T_{2,}$ T_3, T_4 for WS (Fig. 4.62, 4.63 and 4.64).

The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on Ni up to 90% dilution for SA, 50% dilution for RA and WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Different plant species showing different level of responses in case of Nickel accumulation due to the salt dilution effect in different treatment.

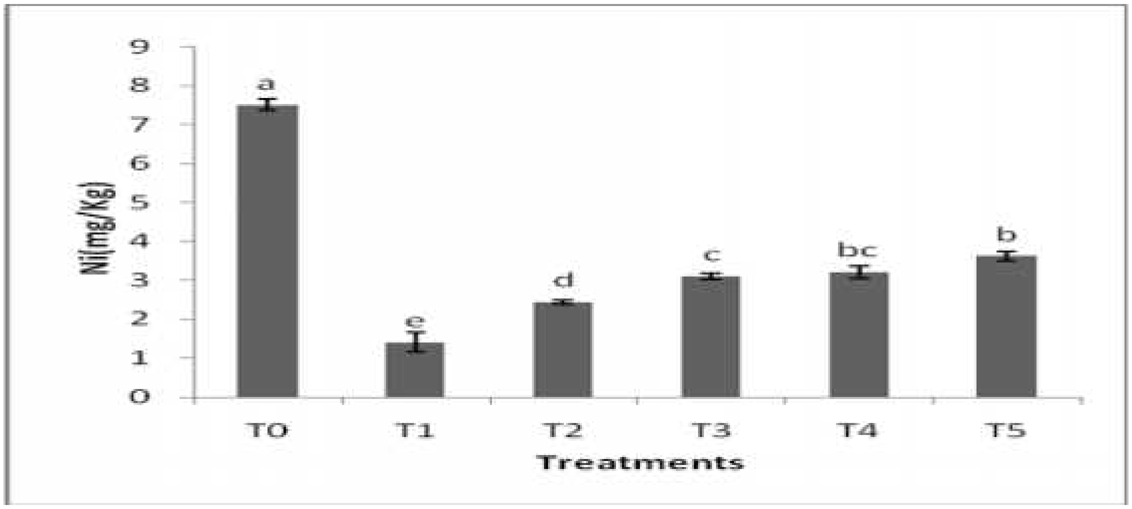


Fig 4.62. Nickel in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

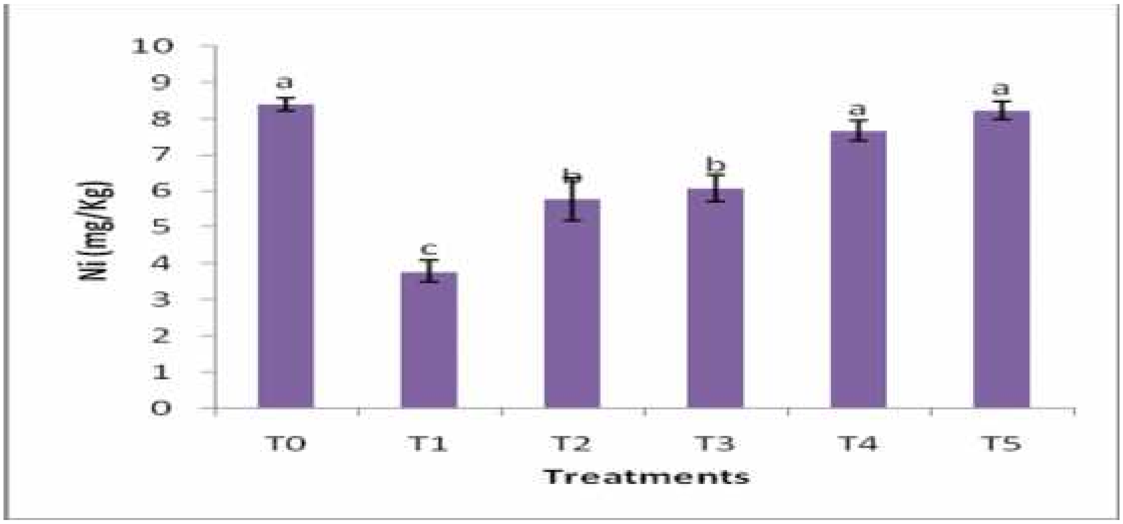


Fig 4.63. Nickel in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

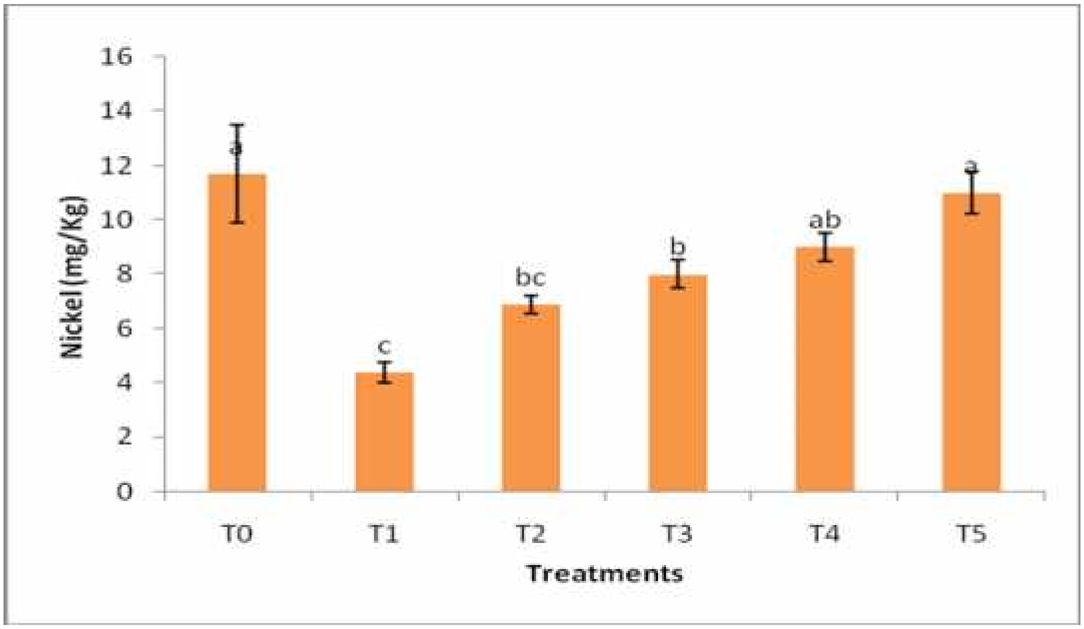


Fig 4.64. Nickel in Water spinach (*Ipomoea aquitica*) grown on soils treated raw and diluted effluent of Shrimp Processing Industries

4.2.7.5. Lead (Pb):

Lead in all treatments of all plant species was below detection limit (0.002mgKg^{-1}) for negligible presence of Pb in effluents and absent in reference soil.

4.2.7.6. Manganese (Mn):

Manganese ranged between 14.3-28.7 mgKg^{-1} for RA, 17-34.3 mgKg^{-1} for SA and 15.3-27 mgKg^{-1} for WS. The highest Mn was in fresh water treated plants (T_0) for all test crops (28.7 mgKg^{-1} for RA, 34.3 mgKg^{-1} for SA and 27 mgKg^{-1} for WS). However lowest Mn was in fresh effluent treated plants T_1 (14.3 mgKg^{-1} for RA, 17 mgKg^{-1} for SA and 15.3 mgKg^{-1} for WS) (Table 4.12, 4.13 and 4.14). Results show that Mn was in test crops was statistically highly significant at 5% level against Mn in fresh water treated plants (F=11.97 for RA, 79.6 for SA and 49.69 for WS) and (LSD= 4.45 for RA, 2.25 for SA and 2.01 for WS) (Table 8.27, 8.28 and 8.29).

However the difference of Mn among treatments was statistically significant in T_0, T_1, T_2, T_3, T_4, T_5 for SA, T_0, T_1, T_3 for RA and T_0, T_1, T_2, T_4 for WS but insignificant in T_1, T_2; T_2, T_3, T_4; T_3, T_4, T_5 for RA, T_0, T_5; T_2, T_3 for WS (Fig. 4.65, 4.66 and 4.67). The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on Mn up to 90% dilution for SA and RA and 75% dilution for WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Different plant species showing different level of responses in case of Manganese accumulation due to the salt dilution effect in different treatment.

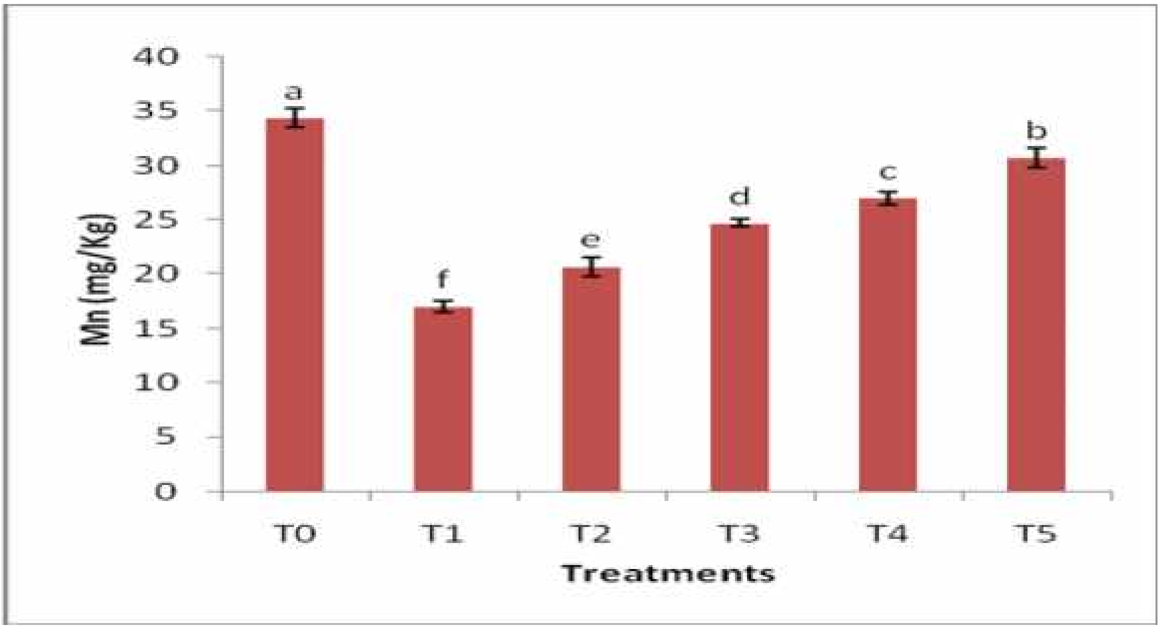


Fig 4.65. Manganese in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

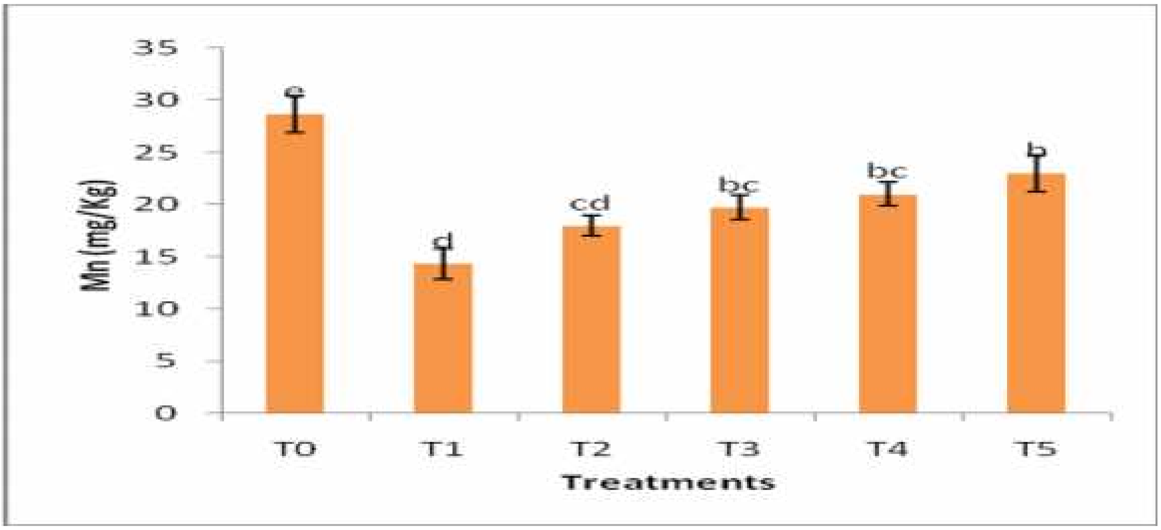


Fig 4.66. Manganese in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

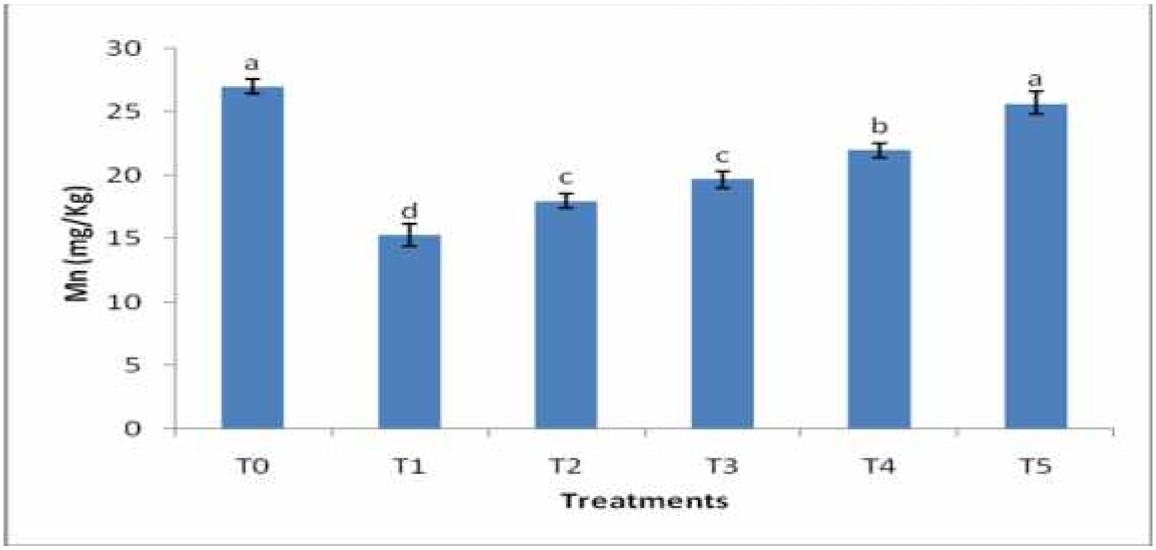


Fig 4.67. Manganese in Water spinach (*Ipomoea aquitica*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

4.2.7.7. Zinc (Zn):

Zinc ranged between 18.6-27.8 mgKg^{-1} for RA, 16.5-30.9 mgKg^{-1} for SA and 18.1-30.6 mgKg^{-1} for WS. The highest Zn was in fresh water treated plants (T_0) for all test crops (27.8 mgKg^{-1} for RA, 30.9 mgKg^{-1} for SA and 30.6 mgKg^{-1} for WS).

However, lowest Zn was in fresh effluent treated plants T_1 (18.6 mgKg^{-1} for RA, 16.5 mgKg^{-1} for SA and 18.1 mgKg^{-1} for WS) (Table 4.12, 4.13 and 4.14). Results show that Zn was in test crops was statistically highly significant at 5% level against Zn in fresh water treated plants (F=4.82 for RA, 19.98 for SA and 40.73 for WS) and (LSD= 4.63 for RA, 3.88 for SA and 2.32 for WS) (Table 8.24, 8.25 and 8.26). However the difference of Zn among treatments was statistically significant in T_0, $T_{1,}$ T_2, T_4 for SA, T_0, T_1 for RA and T_0, $T_{1,}$ T_3, T_4, T_5 for WS but insignificant in T_0, T_5; T_2, T_3; T_3, T_4 for SA, T_1, $T_{2,}$ T_3, T_4, T_5 for RA and T_1, T_2; T_2, T_3 for WS (Fig. 4.68, 4.69 and 4.70). The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on Zn up to 50% dilution for SA and 90% dilution for RA and WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Different plant species showing different level of responses in case of Zinc accumulation due to the salt dilution effect in different treatment.

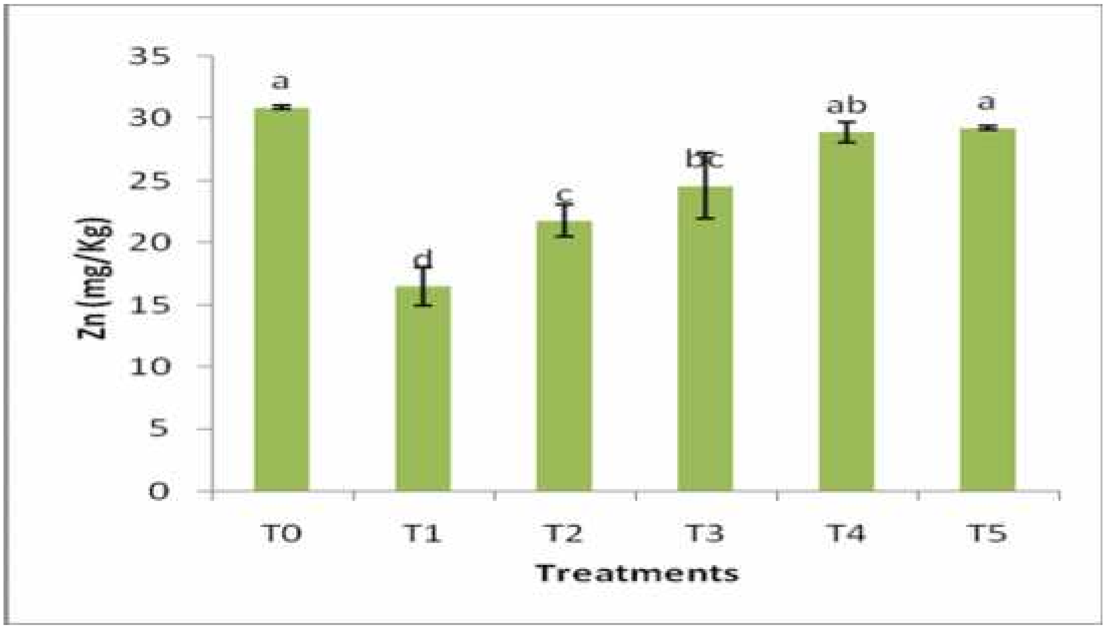


Fig 4.68. Zinc in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

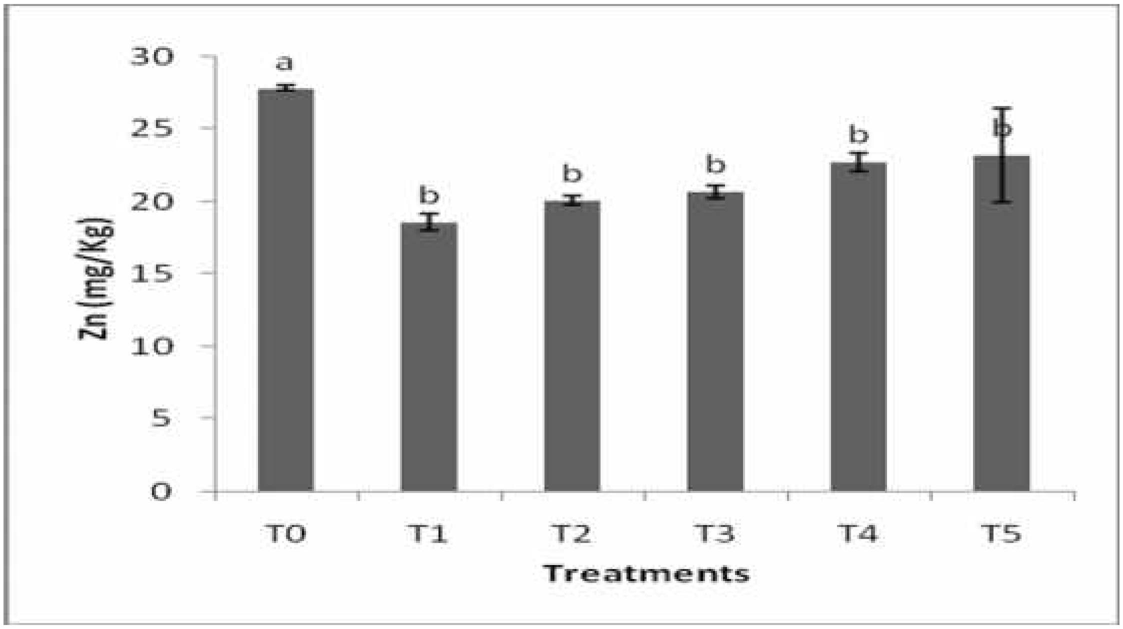


Fig 4.69. Zinc in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

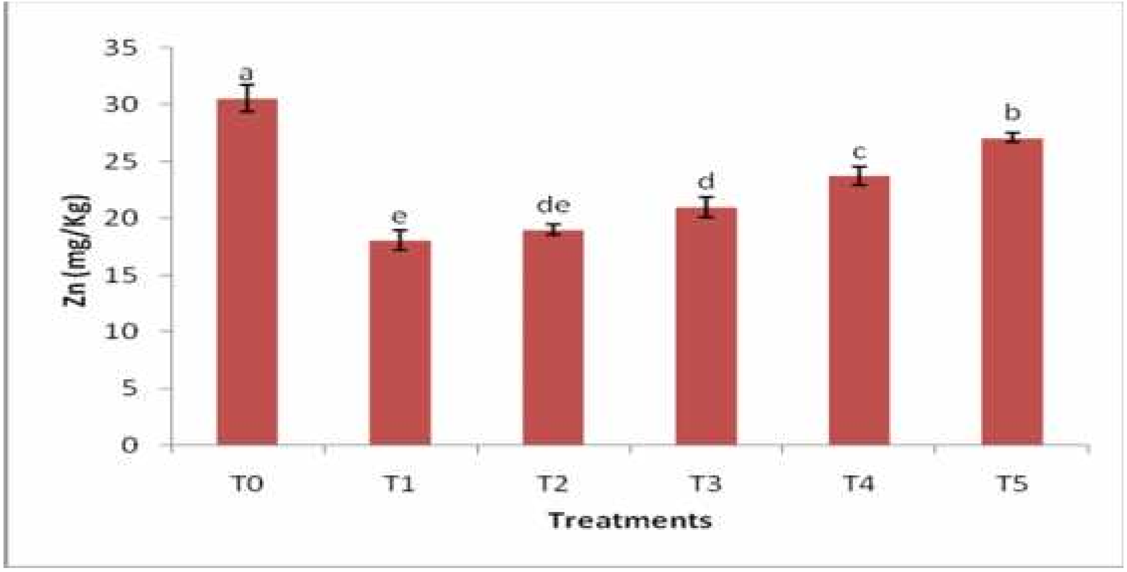


Fig 4.70. Zinc in Water spinach (*Ipomoea aquitica*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

4.2.7.8. Chromium (Cr):

Chromium ranged between 1.6-4.07 mgKg^{-1} for RA, 0.89-3.48 mgKg^{-1} for SA and 0.6-1.67 mgKg^{-1} for WS. The highest Cr was in fresh water treated plants (T_0) for RA and SA and 10 times diluted effluent treated plants (T_5) for WS (4.07 mgKg^{-1} for RA, 3.48 mgKg^{-1} for SA and 1.67 mgKg^{-1} for WS).

However, lowest Cr was in fresh effluent treated plants T_1 (1.6 $mgKg^{-1}$ for RA, 0.89 $mgKg^{-1}$ for SA and 0.6 $mgKg^{-1}$ for WS) (Table 4.12, 4.13 and 4.14). Results show that Cr was in test crops was statistically highly significant at 5% level against Cr in fresh water treated plants (F=24.43 for RA, 123.06 for SA and 11.04 for WS) and (LSD= 0.65 for RA, 0.28 for SA and 0.39 for WS) (Table 8.36, 8.37 and 8.38). However the difference of Cr among treatments was statistically significant in T_0, T_1, T_2 for SA, T_0, T_1, T_3 for RA and T_0, T_1, T_3 for WS but insignificant in T_0, T_5; T_2, T_3, T_4 for SA, T_2, T_3; T_1, T_2; T_3, T_4; T_0, T_5 for RA and T_1, T_2; T_2, T_3, T_4; T_0, T_5 for WS (Fig. 4.71, 4.72 and 4.73). The results show that the indiscriminate dumping of effluents and wastes has significant level of damaging effects on the receiving plants and confirmed detrimental effect on Cr up to 75% dilution for SA, RA and WS and magnitude of the difference was at the order of T0>T5>T4>T3>T2>T1 for all test crops (Table 4.12, 4.13 and 4.14). Different plant species showing different level of responses in case of Chromium accumulation due to the salt dilution effect in different treatment.

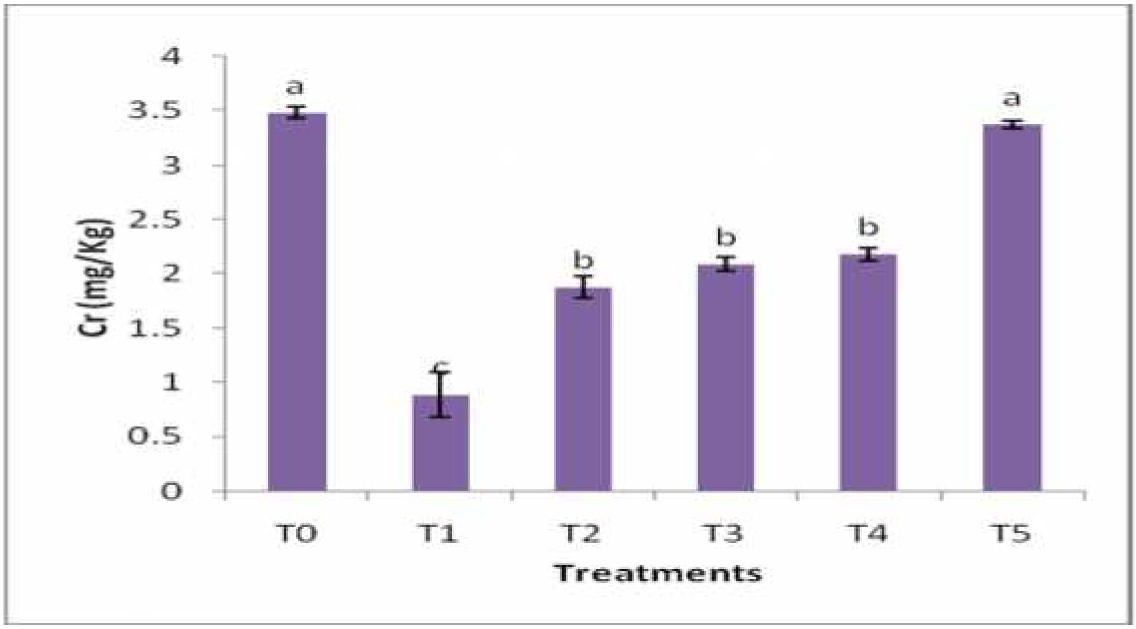


Fig 4.71. Chromium in Stem amaranths *(Amaranthus lividus)* grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

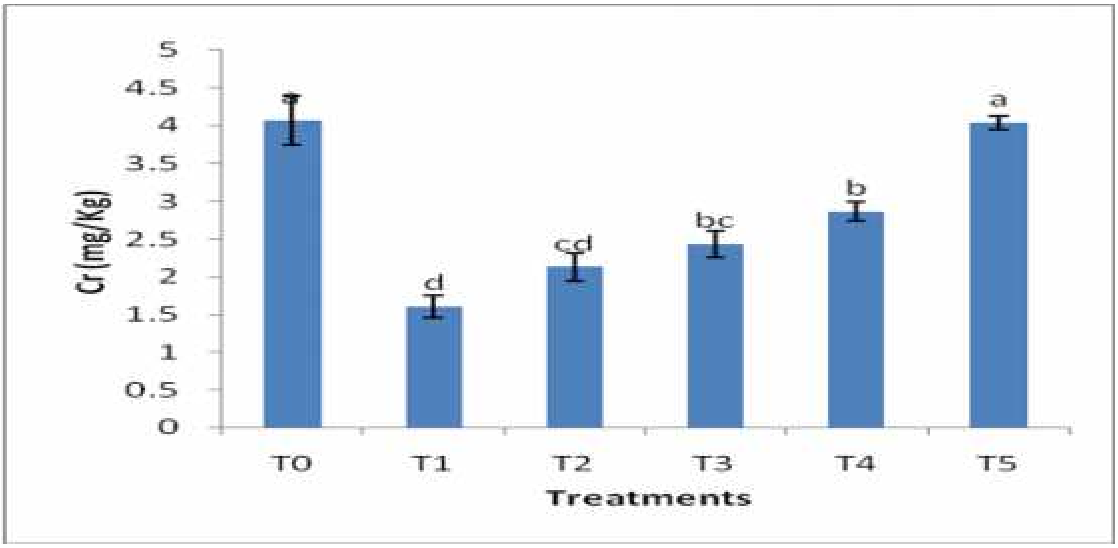


Fig 4.72. Chromium in Red amaranths (*Amaranthus curentus*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

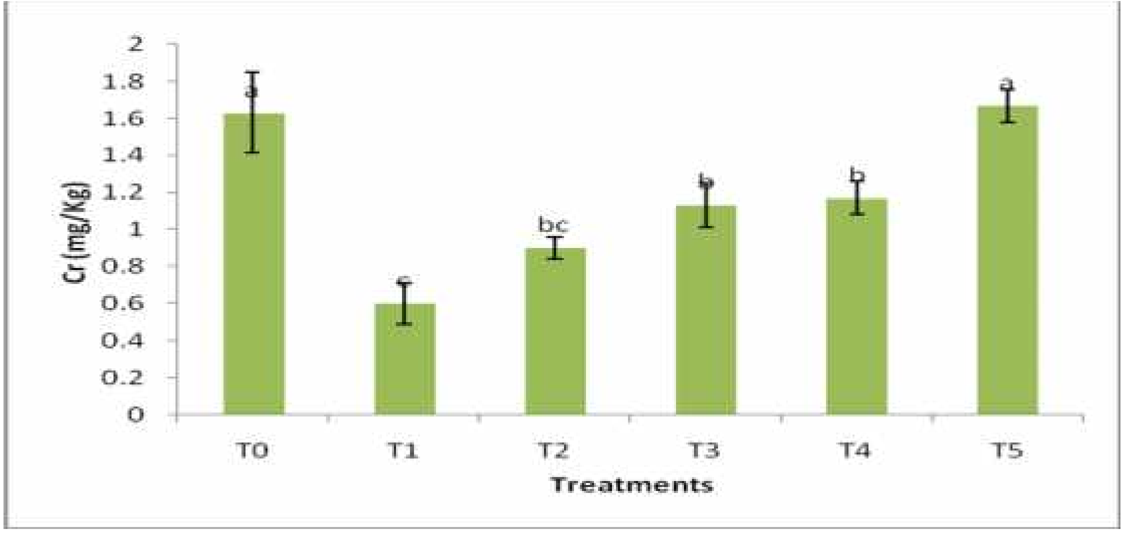


Fig 4.73. Chromium in Water spinach (*Ipomoea aquitica*) grown on soils treated with raw and diluted effluent of Shrimp Processing Industries

4.2.7.9. Cadmium (Cd):

Cadmium in all treatments of all plant species was below detection limit (0.002 mgKg^{-1}) for negligible presence of Cd in effluents and absent in reference soil.

Fig. 4.74. Picture of the different treatments of Water Spinach (*Ipomoea aquatica*)

Fig. 4.75. Picture of the different treatments of Red Amaranths (*Amaranthus curentus)*

Fig. 4.76. Picture of the different treatments of Stem Amaranths (*Amaranthus lividus)*

4.2.8. Possibility of using effluent as irrigation water:

The standards for irrigation water, effluent characteristics and suitability of effluent for irrigation use are presented in table 4.16. Considering the standard values for irrigation water it can be concluded that the effluents of shrimp processing industries are not at all suitable for using as irrigation water. However dilution of effluent to a level of 50% can be used as irrigation water.

Table 4.16. Standards for irrigation use, effluent characteristics and suitability of effluent for irrigation use

Parameter	Unit	Standard value for irrigation	Reference	Effluent characteristics	Suitability
Turbidity	NTU	100	Ahmed and Rahman, 2000	344±14	Not Suitable
pH	-	7-7.5	WHO, 1993	8.06±0.12	Not Suitable
EC	$mScm^{-1}$	3-4	SANDEE, 2009	15.21±2	Not Suitable
DO	mgL^{-1}	4-6	NACA, 1995	1.7±0.12	Not Suitable
Cl^-	%	0.6	ECR, 1997	0.91±0.05	Not Suitable
TSS	mgL^{-1}	200	Ayers and Wescot, 1994	468±262	Not Suitable
TDS	mgL^{-1}	450-2000	ECR, 1997	1778±552	Not Suitable
BOD_5	mgL^{-1}	5	WHO, 2003	377±15	Not Suitable
COD	mgL^{-1}	400	Gupta and Gupta, 1987	593±10	Not Suitable
HCO_3^-	$meqL^{-1}$	1.5-8.5	ECR, 1997	28.8±6	Not Suitable
NO_3^-	mgL^{-1}	10	ECR, 1997	12±1.5	Not Suitable
NH_4^+-N	mgL^{-1}	15	Ayers and Wescot, 1994	50.17±32	Not Suitable
Na^+	$meqL^{-1}$	40	Ayers and Wescot, 1994	70±4	Not Suitable
K^+	$meqL^{-1}$	2	Ayers and Wescot, 1994	3.39±0.17	Not Suitable
Ca^{2+}	$meqL^{-1}$	20	Ayers and Wescot, 1994	26.87±0.4	Not Suitable
Mg^{2+}	$meqL^{-1}$	5	Gupta and Gupta, 1987	9.3±0.37	Not Suitable
SAR	mgL^{-1}	10-12	Gupta and Gupta, 1987	16.47±1.1	Not Suitable
SSP	%	60	Rowe and Fraser, 1995	66.94±1.5	Not Suitable
Zn	mgL^{-1}	10	WHO, 1993	94.48±21	Not Suitable
Mn	mgL^{-1}	5	WHO, 1993	128.5±19	Not Suitable
Cd	mgL^{-1}	0.1	WHO, 1993	0.19±0.14	Not Suitable
Cr	mgL^{-1}	1	ECR, 1997	16.6±0.3	Not Suitable
Ni	mgL^{-1}	1	ECR, 1997	7.25±6.05	Not Suitable
TC	c.f.u/10ml	1000	ECR, 1997	2.9×10^3	Not Suitable
FC	c.f.u/10ml	1000	ECR, 1997	235±76	Not Suitable

4.2.9. Effect of effluents on surrounding water

The ultimate route disposal and receiving points of the effluents of Shrimp Processing Industries are ponds, canals, rivers and the ground water (shallow tube wells) which was analyzed for turbidity, pH, EC, DO, TDS, TSS, BOD, COD, SO_4^{2-}, Cl^-, NO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+}. The results are presented in Table 4.17.

Table 4.17. Comparison of the water quality parameters of effluents and the receiving water bodies.

Source of water	Tubidity (NTU)	pH	EC $mSCm^{-1}$	Cl^-	DO	TDS	TSS	BOD	COD	SO_4^{2-}	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}.
				mgL^{-1}								$meqL^{-1}$			
Pond Water	117±5	7.3 ±0.2	7.8±0.7	0.4 ±0.07	3.3 ±0.2	872 ±18	166 ±6	97±2	162 ±16	86 ±11	6.7 ±.4	27 ±3	1.93 ±0.1	8.5 ±0.5	4.22 ±0.3
Canal Water	169±6	7.4 ±0.2	12.2±0.3	0.63 ±0.1	3.4 ±0.2	1227 ±27	203 ±9	261 ±6	402±7	193 ±6	11.5 ±0.5	51 ±3	2.27 ±0.3	18.2±0.8	6.7 ±0.5
River Water	152±8	7.5 ±0.2	11.5±0.4	0.61 ±0.03	3.18 ±0.4	1197 ±102	198 ±7	230 ±18	389 ±11	185 ±9	9.7 ±0.3	48 ±6	2.1 ±0.4	16±2	6.2 ±0.3
Ground Water	23±3	7.1 ±0.2	6.24±0.6	0.23 ±0.02	4.3 ±0.1	144 ±23	13.8 ±0.9	6.9 ±0.3	11.43 ±0.25	54 ±9	14.67±3.9	42 ±1	2.3 ±0.6	20.3±1.1	5.2 ±0.3
Effluent	421	8	15	0.96	1.4	2230	917	408	897	436	16.4	75	4	29	9

One of the aims of the present investigation was to measure any direct effect of the effluents on surrounding water bodies. It is evident from the results that the surrounding receiving water bodies which are canals, rivers, ponds, ground water are contaminated but it was not possible to asscertained whether the contamination is done by the release of effluents from the Shrimp Processing Industries located in the area. Effluents significantly affect the surrounding water sources compare to the non polluted condition notable of which are high turbidity, EC, TDS, BOD and SO_4^{2-} for pond water (Turbidity 117±5NTU, EC 7.8±0.7 $mSCm^{-1}$, TDS 872±18 mgL^{-1}, BOD 97±2 mgL^{-1} and SO_4^{2-} 86±11 mgL^{-1}) but low DO 3.3±0.2 mgL^{-1}. Excess turbidity, pH, EC, TDS, BOD, SO_4^{2-}, Na^+, K^+, and Mg^{2+} in canal water (turbidity 169±6 NTU, pH 7.4±0.2, EC 12.2±0.3 $mSCm^{-1}$, TDS 1227±27 mgL^{-1}, BOD 261±6 mgL^{-1}, SO_4^{2-} 193±6 mgL^{-1}, Na^+ 51±3 $meqL^{-1}$, K^+ 2.27±0.3 $meqL^{-1}$, and Mg^{2+} 18.2±0.8 $meqL^{-1}$) but low DO 3.4±0.2 mgL^{-1}.

High turbidity, pH, EC, TDS, BOD, COD, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} in river water (turbidity 152±8 NTU, pH 7.5±0.2, EC 11.5±0.4 $mSCm^{-1}$, TDS 0.61±0.03 mgL^{-1}, BOD 230±18 mgL^{-1}, COD 389±11 mgL^{-1}, SO_4^{2-} 185±9 mgL^{-1}, Na^+ 48±6 $meqL^{-1}$, K^+ 2.1±0.4 $meqL^{-1}$, and Mg^{2+} 6.2±0.3 $meqL^{-1}$) but low DO 3.18±0.4 mgL^{-1}. Excess NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} in ground water (NO_3^- 14.67±3.9 mgL^{-1}, SO_4^{2-} 54±9 mgL^{-1}, Na^+ 42±1 $meqL^{-1}$, K^+ 2.3±0.6 $meqL^{-1}$, Ca^{2+} 20.3±1.1 $meqL^{-1}$ and Mg^{2+} 5.2±0.3 $meqL^{-1}$).

4.2.10. Effect of effluents on surrounding soil

Soil samples contaminated by shrimp processing effluents were analyzed for physical and chemical properties. The results are presented in 4.18, 4.19, 4.20, 4.21 and 4.22.

Table 4.18. Results of Particle size analysis, Textural classes, Moisture content and Bulk density of the studied soil samples

Samples	Particle Size Analysis			Texural class	Moisture content (%)	Bulk density (gcm^{-3})
	Sand (%)	Silt (%)	Clay (%)			
RS	8	62	30	Silty Clay loam	28.54f	1.22a
AFP1	10	61	29	Silty Clay loam	34.28b	1.02bcd
AFP2	8	62	30	Silty Clay loam	39.73a	0.97cd
AFP3	9	61	30	Silty Clay loam	36.48a	0.99bcd
CFP1	12	60	28	Silty Clay loam	32.46cd	1.07bc
CFP2	10	60	30	Silty Clay loam	37.53a	1.02bcd
CFP3	10	61	29	Silty Clay loam	34.42b	1.05bc
FFP1	10	60	30	Silty Clay loam	30.52e	0.98bcd
FFP2	8	62	30	Silty Clay loam	36.37a	0.93d
FFP3	9	61	30	Silty Clay loam	34.74b	0.97cd
RFP1	11	60	29	Silty Clay loam	31.32de	1.09b
RFP2	9	61	30	Silty Clay loam	34.75b	1.04bc
RFP3	10	60	30	Silty Clay loam	33.06c	1.07bc

(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.19. pH, EC, % Salt and CEC of the studied soil samples of Shrimp Processing Industries

Samples	pH	EC (mScm^{-1})	Salt (%)	CEC (meq100g^{-1} soil)
RS	7.10g	1.88f	0.12g	7.01g
AFP1	7.40e	4.29e	0.27f	12.9f
AFP2	7.23f	4.48de	0.29ef	25.72ab
AFP3	7.20fg	5.13abc	0.33bcd	15.8def
CFP1	7.66ab	4.95bcd	0.32cde	12.2f
CFP2	7.53cd	4.62cde	0.30def	28.4a
CFP3	7.48cde	4.27e	`10.27f	14.1ef
FFP1	7.42de	5.69a	0.36b	17.8cde
FFP2	7.27f	4.9bcd	0.32cde	29.7a
FFP3	7.21fg	5.21abc	0.33bcd	21.4bc
RFP1	7.74a	6.47a	0.41a	18.5cde
RFP2	7.57bc	6.69a	0.43a	22.2bc
RFP3	7.43e	5.34ab	0.34bc	19cd

(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.20. OC, OM, Total N, Available N, C/N ratio, P and S of the studied soil samples

Samples	OC (%)	OM (%)	Toal N (%)	Available N (mgKg^{-1})	C/N ratio	Available P (mgKg^{-1})	Available S (mgKg^{-1})
RS	1.89e	3.25e	0.10d	19.02j	18.56a	7.27f	11.22g
AFP1	2.08de	3.58de	0.14cd	38.20i	14.97a	14.7e	18.75f
AFP2	2.79a	4.8a	0.16abc	110.43d	17.53a	24.1a	27.20c
AFP3	2.04de	3.51de	0.15bcd	48.17h	13.68a	16.5d	21.75e
CFP1	2.48bc	4.27bc	0.17abc	77.22g	15.78a	14.9e	19.40f
CFP2	2.76a	4.75a	0.16abc	127.90b	18.47a	23.8a	32.10a
CFP3	2.71ab	4.66ab	0.18abc	87.59f	15.42a	17.8cd	22.25de
FFP1	2.9a	4.99a	0.19abc	101.81e	15.36a	14.2e	18.95f
FFP2	2.98a	5.13a	0.21a	118.38cd	14.37a	20.3b	29.50b
FFP3	2.84a	4.88a	0.20ab	112.13d	14.28a	16.9d	23.35d
RFP1	2.17d	3.73d	0.17abc	113.27d	12.81a	15.0e	20.30f
RFP2	2.44c	4.19c	0.19abc	137.75a	12.82a	18.7c	26.57c
RFP3	2.72ab	4.68ab	0.18abc	122.97bc	15.46a	17.3d	22.48de

(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.21. Results of Na$^+$, K$^+$, Ca^{2+} and Mg^{2+} in the studied soil samples of different Shrimp Processing Industries

Samples	Na$^+$ (meq100g-1)	K$^+$ (meq100g-1)	Ca^{2+} (meq100g-1)	Mg^{2+} (meq100g-1)
RS	16.03i	0.63h	3.40e	1.76c
AFP1	77.19h	3.88e	10.92cd	2.96b
AFP2	120.96e	4.31d	11.91ab	3.16b
AFP3	139.40d	2.79g	11.61bc	3.02b
	.			
CFP1	98.59f	4.96b	11.03cd	2.90b
CFP2	157.80c	5.83a	12.37a	3.11b
CFP3	193.50a	3.23f	11.42bcd	2.99b
FFP1	86.41g	4.09dc	10.98cd	2.93b
FFP2	126.92e	5.61a	12.03ab	3.71a
FFP3	169.33b	3.44f	11.23cd	3.07b
RFP1	74.89h	4.53c	10.88d	2.88b
RFP2	118.96e	5.61a	12.41a	3.63a
RFP3	141.08d	4.09de	11.58bc	3.12b

(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Table 4.22. Zn, Mn, Pb, Cd, Cr and Ni content in the studied soil samples

Samples	Zn (mgKg^{-1})	Mn (mgKg^{-1})	Pb (mgKg^{-1})	Cd (mgKg^{-1})	Cr (mgKg^{-1})	Ni (mgKg^{-1})
RS	66.47i	97g	Nilg	Nile	14.05d	12.5g
AFP1	110.4ef	446e	4d	0.8d	38.6b	28.8de
AFP2	93.3h	690b	10a	0.2d	40.2b	36.0bc
AFP3	130.4c	928a	8b	0.2d	46.8a	47.0a
CFP1	97.2gh	698b	3de	0.2c	36.6bc	38.6b
CFP2	103.2fg	490de	6c	0.4d	32.4c	36.2bc
CFP3	88.4h	462de	8b	0.2b	40.14b	26.6e
FFP1	200.6a	572c	1fg	0.6c	41.4b	32.0cd
FFP2	150.8b	608c	2ef	0.4b	38.0b	30.0de
FFP3	118.8de	350f	1fg	0.6c	40.0b	25.8e
RFP1	122.0cd	508d	2ef	0.4c	41.0b	29.0de
RFP2	121.4cd	506d	3de	0.2d	49.3a	20.4f
RFP3	124.2cd	484de	4d	0.2d	39.8b	28.8de

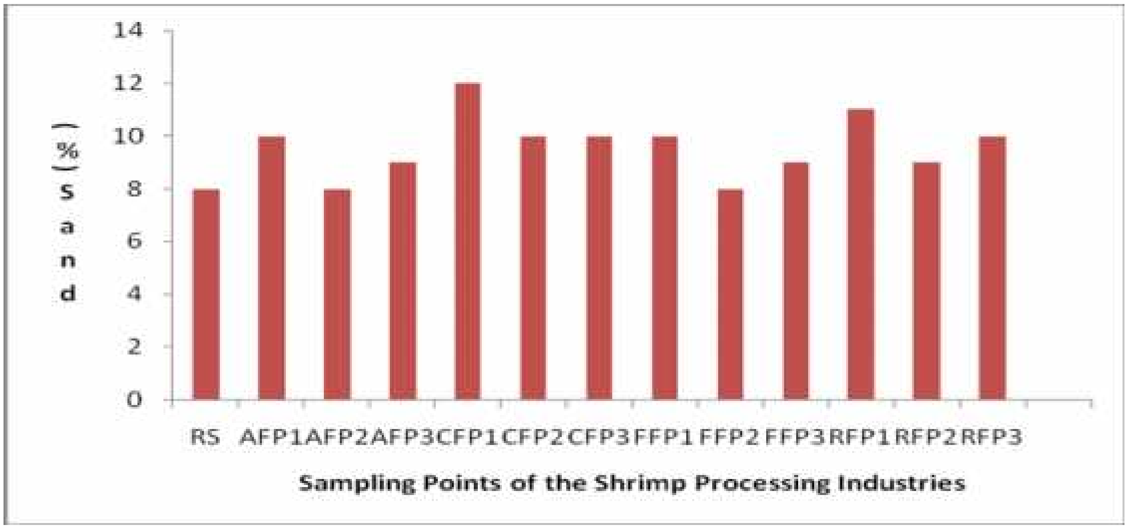
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

4.2.10.1. Physical characteristics of soil:

Physical characteristics such as particle size distribution, textural class, moisture content and bulk density were analyzed and the results are presented in table 4.18.

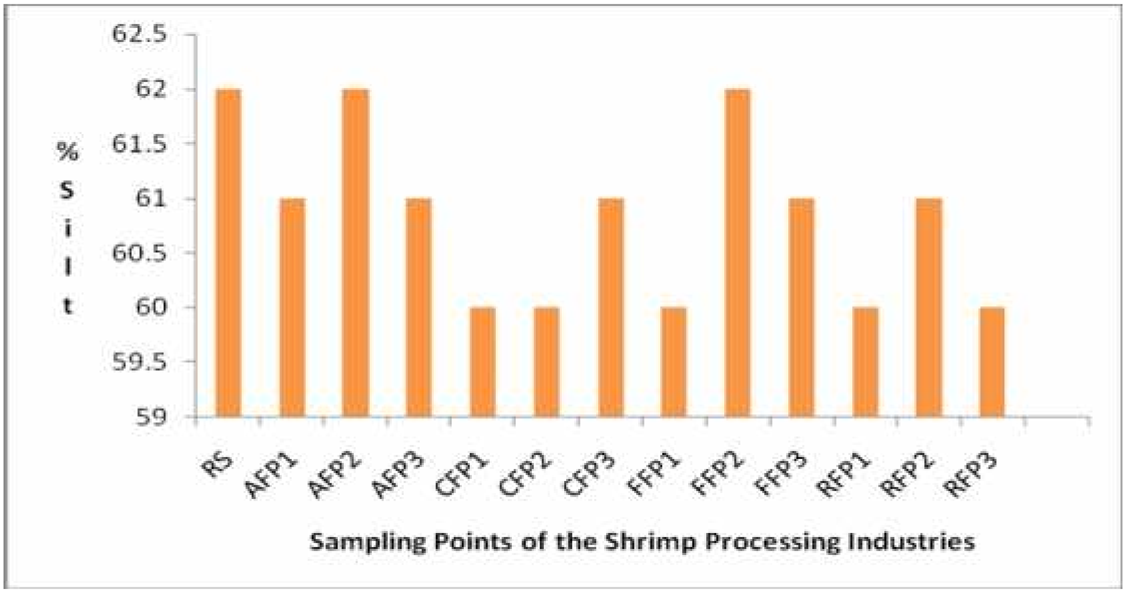
4.2.10.1.1. Particle Size:

The particle size distribution of the soils under investigation along with the textural classes is presented in table 4.18. The percent sand varied from 8 to 12, silt 60 to 62 and clay 28 to 30 in the contaminated soils. Percent sand, silt and clay in the reference soil were 8, 62 and 30 respectively. No significant differences in particle size distribution and textural class of the soils were observed as that of reference soil. However, slightly increased contents of silt and clay were noted for the soils analyzed probably because of the translocation of the fine particles.



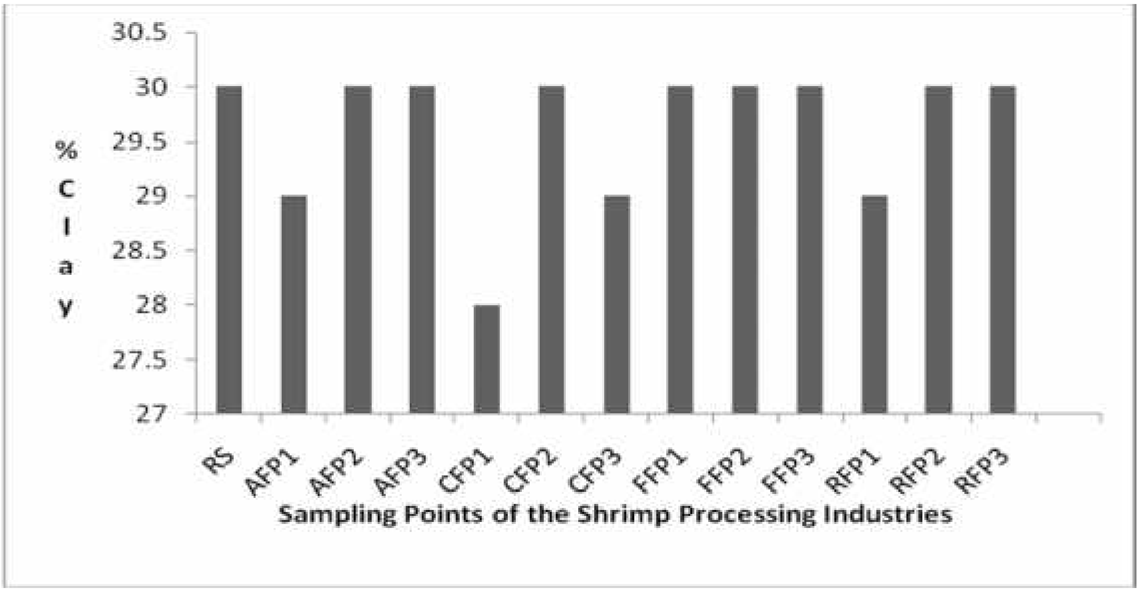
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.77. Percent sand in the soils receiving effluents from Shrimp Processing Industries



(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.78. Percent silt in the soils receiving effluents from Shrimp Processing Industries

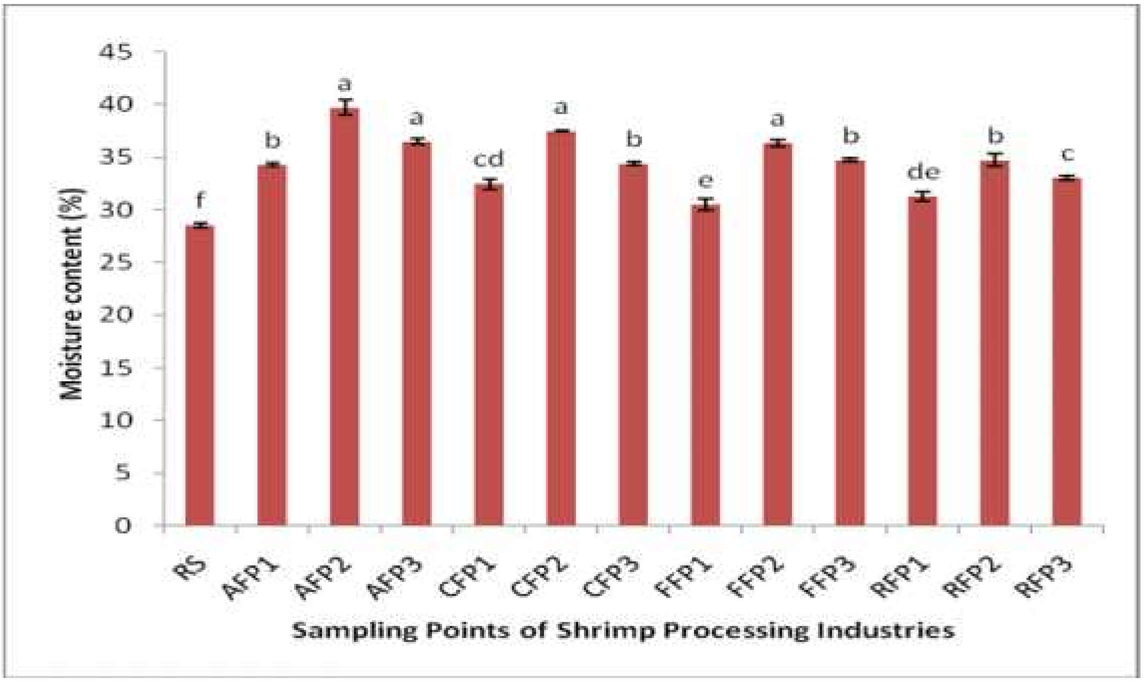


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.79. Percent clay in the soils receiving effluents from Shrimp Processing Industries

4.2.10.1.2. Moisture content (%):

Percent moisture measured for the soils at different points beginning from the source point to a distance of 350m is presented in table 4.18. The moisture content varied from 30.52 to 34.28% at P_1, 34.75 to 39.73% at P_2 and 33.06 to 36.48% at P_3 points. The percent moisture measured for the Reference soil was 28.54. The highest Moisture content (39.73%) was measured at I_2P_2 and the lowest (30.35%) at I_3P_1. The soils receiving fish processing effluents at different points confirmed significantly high levels of percent moisture content compare to the Reference Soil and the magnitude of the difference is at the order of P2>P3>P_1 (Table 4.18). The results show that percent moisture content in all soil samples was statistically significant at 5% level against the Reference Soil (F=58.65) and even within the sampling points (Table 8.2). However, the differences among the samples measured for different industries are statistically insignificant in most of the cases (Fig 4.80). Point P_2 is relatively lower/depressed and the high moisture contents could probably resulted from the accumulation of effluents along with organic residues retaining moisture.

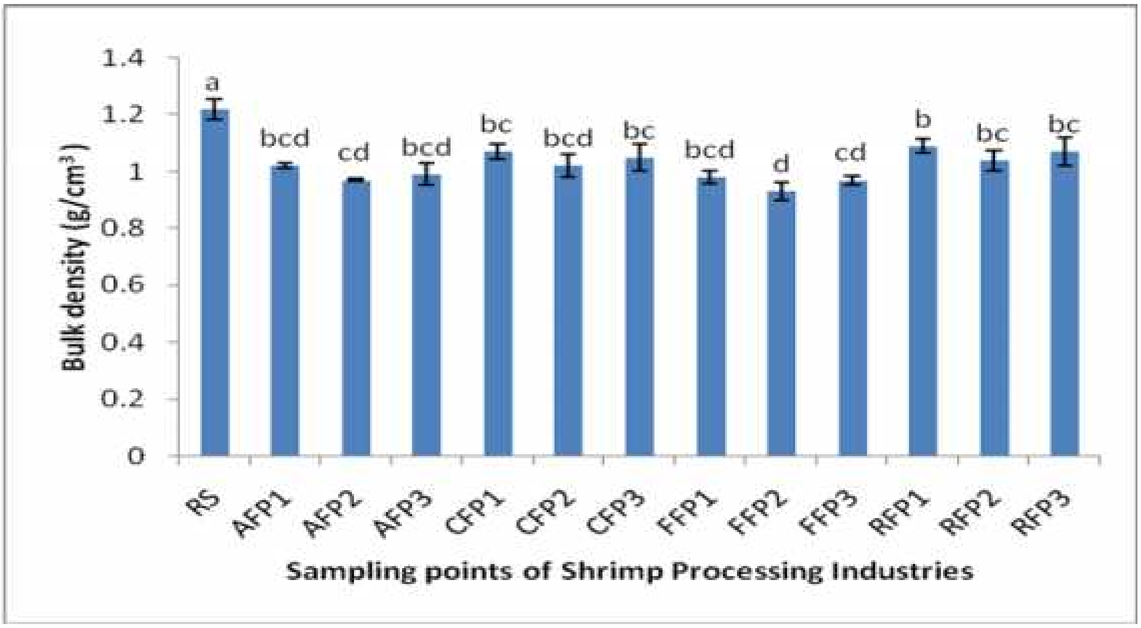


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.80. Percent moisture content in the soils receiving effluents from Shrimp Processing Industries

4.2.10.1.3. Bulk density (Db):

Bulk density (Db) measured for soils at different points beginning from the source to a distance of 350 m is presented in table 4.18. The results show that the Bulk Density varied from 0.98 to 1.09 gcm^{-3} at P_1, 0.98 to 1.04 gcm^{-3} at P_2 and 0.97 to 1.07 gcm^{-3} at P_3 and 1.22 gcm^{-3} was measured for the Reference Soil (Table 4.18). The highest Db (1.09 gcm^{-3}) was measured for soils at point I_4P_1 and the lowest (0.97 gcm^{-3}) at I_1P_2 and I_3P_3 (Fig 4.90). The Db measured for the contaminated soils varied significantly from the reference soil at 5% level (F=5.02) (Table 8.2). However, the differences in Db among the soils of different industries as well as points are statistically insignificant (Fig 4.81). Decreasing Bulk Density may have occurred due to the accumulation of OM in the soils. It is possible that the Dissolved Organic Carbon (DOC) in effluents might have contributed to lowering the bulk density of the soils.



(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

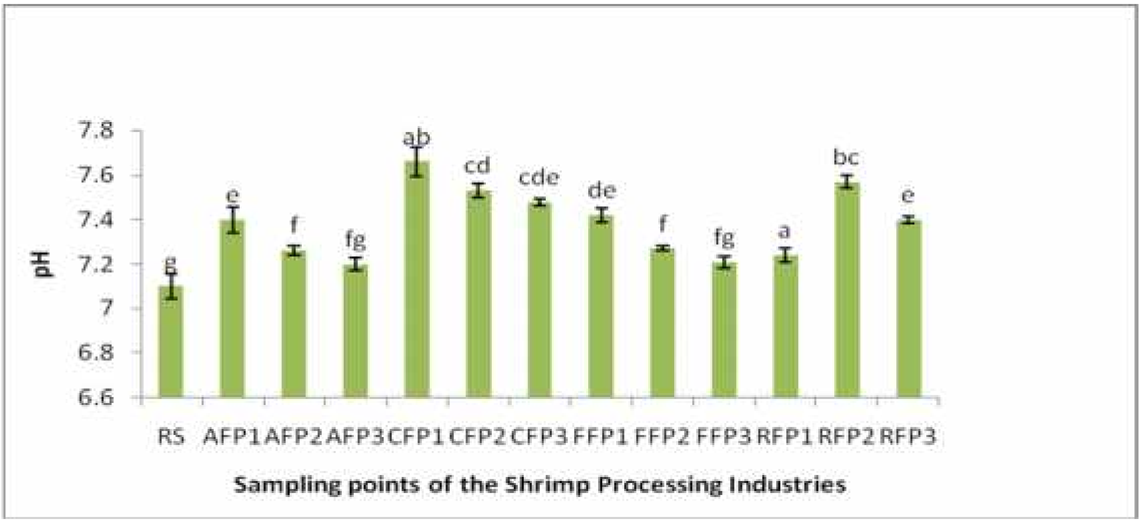
Fig. 4.81. Bulk density (D_b) of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2. Chemical properties:

Chemical properties such as pH, EC, CEC, % OC, Total and Available N, C:N ratio, Na^+, K^+, Ca^{2+}, Mg^{2+}, P, S, Zn, Mn, Pb, Cd, Cr and Ni were analyzed and the results are presented in table 4.19, 4.20, 4.21 and 4.22.

4.2.10.2.1. Soil pH:

The pH measured for different soils are presented in Table 4.19. Soil pH varied from 7.4 to 7.74 at P_1, 7.23 to 7.57 at P_2 and 7.2 to 7.48 at P_3 points. The corresponding reference soil pH value was 7.1. The highest pH value (7.57) was measured in soils at point I_4P_2 and the lowest (7.2) at I_1P_3. The results show that the differences of soil pH in all soil samples was statistically significant at 5% level against the reference soil (F=27.17) (Table 8.2). The pH of the soils measured at different points away from the source point (P_1) also varied significantly at 5% level and the magnitude of the differences is at the order of $P_1>P_2>P_3$ (Table 4.19). However, no significant differences were obtained for the pH values measured for soils around the industries in the present investigation (Fig. 4.82). The accumulation of effluents containing brine solution and salts applied during shrimp processing could possibly attributed to the changes in soil pH.

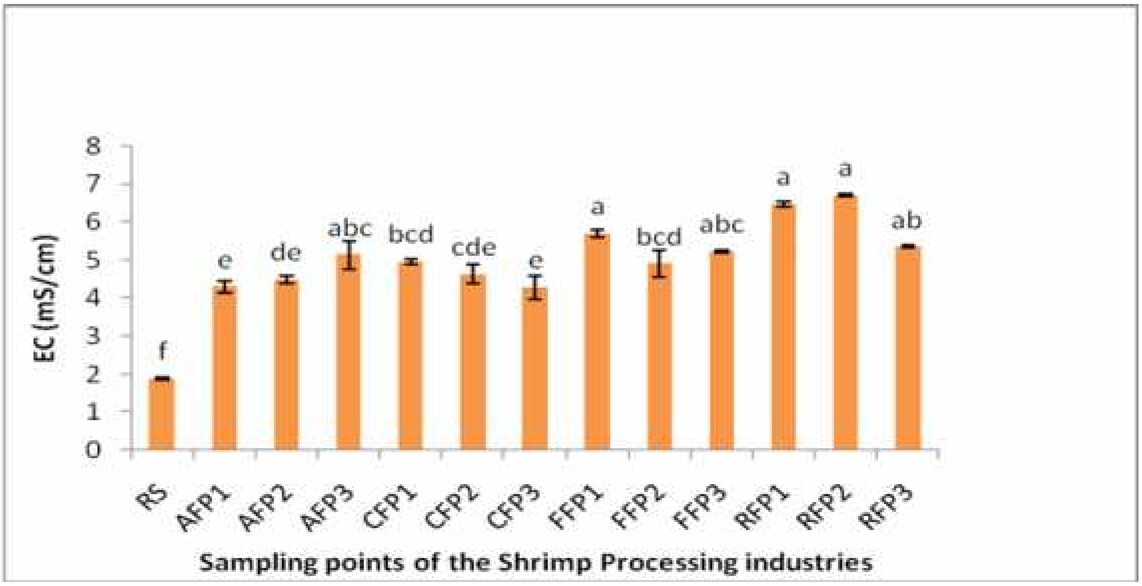


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.82. pH of the soils receiving effluents from Shrimp Processing Industries

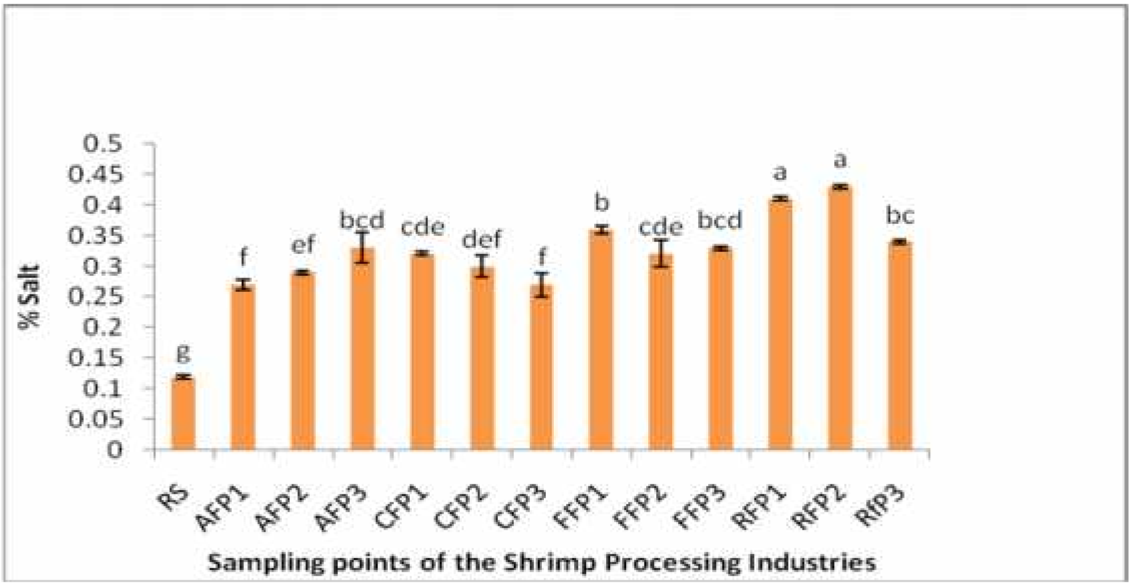
4.2.10.2.2. EC and Salinity:

The percent salt measured for soils at different points varied significantly and also with the Reference Soil and the Electrical Conductivity (EC) measured for the soils varied from 4.29 to 6.47 mScm^{-1} at P_1, 4.48 to 6.69 mScm^{-1} at P_2 and 4.27 to 5.34 mScm^{-1} for P_3. The corresponding reference soil EC value is 1.88 mScm^{-1}. The highest EC (6.69 mScm^{-1}) was measured in soils at I_4P_2 and the lowest (4.27 mScm^{-1}) at I_2P_3. Percent salt contents and the EC values in soils receiving effluents were statistically significant at 5% level against the Reference Soil (F=37.96 for EC and 37.21 for %Salt) (Table 8.2) and the magnitude of the differences is at the order of P_1>P_2>P_3. However, the differences in EC and salt contents among the samples of different industries as well as points are statistically insignificant in most of the cases (Fig 4.83 and 4.84). These differences are probably because of the application of brine solution and salts during fish processing and released in the environment with the effluents.



(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.83. Electrical Conductivity (EC) of the soils receiving effluents from Shrimp Processing Industries

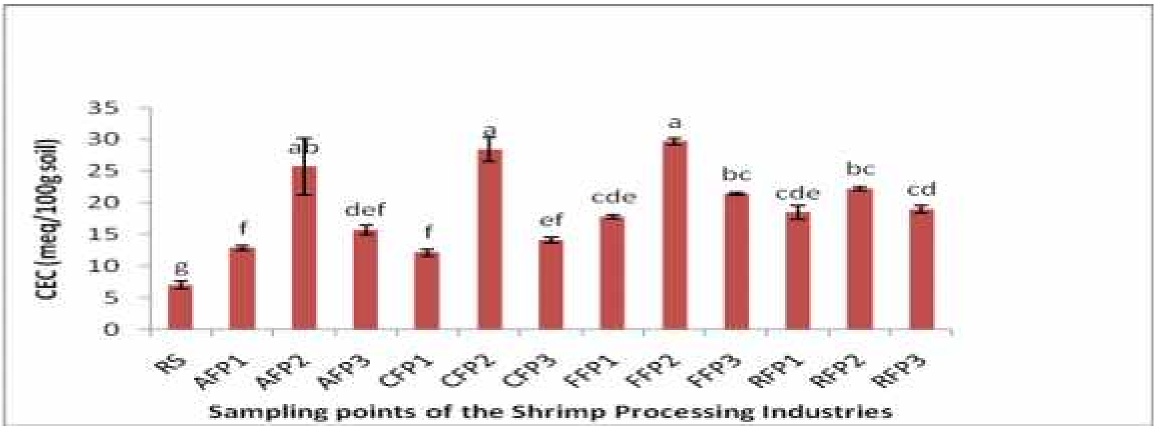


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.84. Percent salt of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.3. Cation Exchange Capacity (CEC):

Cation Exchange Capacity (CEC) measured for the soils varied from 12.2 to 18.5 meq100g^{-1} at P_1, 22.2 to 29.7 meq100g^{-1} at P_2 and 22.2 to 29.7 meq100g^{-1} at P_3 points. The corresponding CEC value for the Reference Soil was 7.01 meq100g^{-1}. The highest CEC (29.7 meq100g^{-1}) was measured at I_3P_2 and the lowest (14.17 meq100g^{-1}) at I_2P_3. All values of the studied soils are higher than that of Reference Soil values (Fig 4.85) and the magnitude of the difference is at the order of $P_2>P_3>P_1$. The results show that CEC in all soil samples was statistically significant at 5% level against the Reference Soil (F=20.58) (Table 8.2). However, the differences in CEC among the soils around different industries as well as points are statistically insignificant in most of the cases (Fig 4.85). The significantly high CEC in the soils receiving effluents may be attributed to the accumulation of dissolve organic carbon (See Table 4.3) and various cations (See Table 4.5). The subsequent decomposition of OM added to the soils generates sites for cation exchange and allows exchangeable cations from soil solution to be attracted (Brady and Weil, 2002).



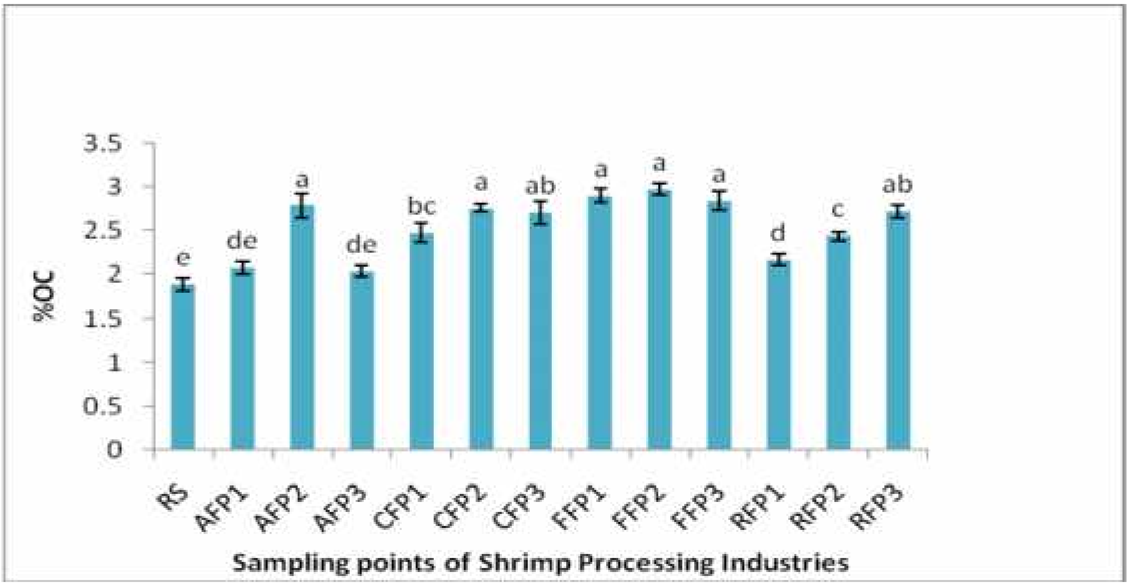
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.85. Cation Exchange Capacity (CEC) of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.4. Soil Organic Carbon and Organic Matter:

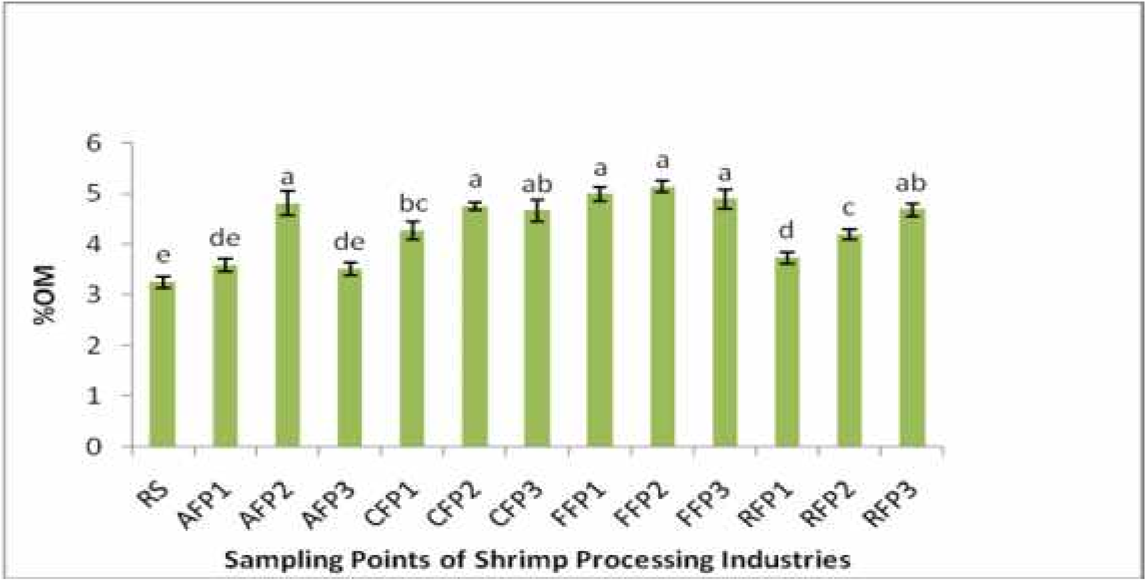
Soil Organic Carbon measured for the soils varied from 2.08 to 2.9% at P_1, 2.44 to 2.98% at P_2 and 2.04 to 2.84% at P_3 points. The corresponding Reference Soil OC measured was 1.89%. The organic matter content of the soils varied from 3.58 to 4.99% at P_1, 4.19 to 5.13% at P_2 and 3.51 to 4.88% at P_3 points and corresponding Reference Soil OM was 3.25%. The highest OC (2.98%) and OM (5.13%) were measured at I_3P_2 and the lowest OC (2.04%) and OM (3.51%) at I_1P_3. All values of the studied soils are greater than that of Reference Soil values (Fig 4.86) and the magnitude of the difference was at the order of $P_2>P_1>P_3$. The results show that OC and OM in all soil samples was statistically significant at 5% level against the Reference Soil (F=17.41 for OC and 17.58 for OM) (Table 8.2). However the differences in OC and OM among the soils of different industries as well as points are statistically insignificant except Rosemco Foods Ltd. (Fig 4.86 and 4.87). The high OM and OC contents measured for soils at P_2 around the industries under the present investigation are possibly because of the accumulation of biodegradable wastes and DOC with the effluents (See table 4.3). It appears that, point P_2 is comparatively lower than the other sampling points and very likely to accumulate suspended and/ or dissolved organic materials like a sink.

Fifty percent of the volume of raw materials of shrimp processing industries released as wastes and add high load of OM in receiving soils (Steven, 1996).



(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.86. Percent Organic Carbon of the soils receiving effluents from Shrimp Processing Industries

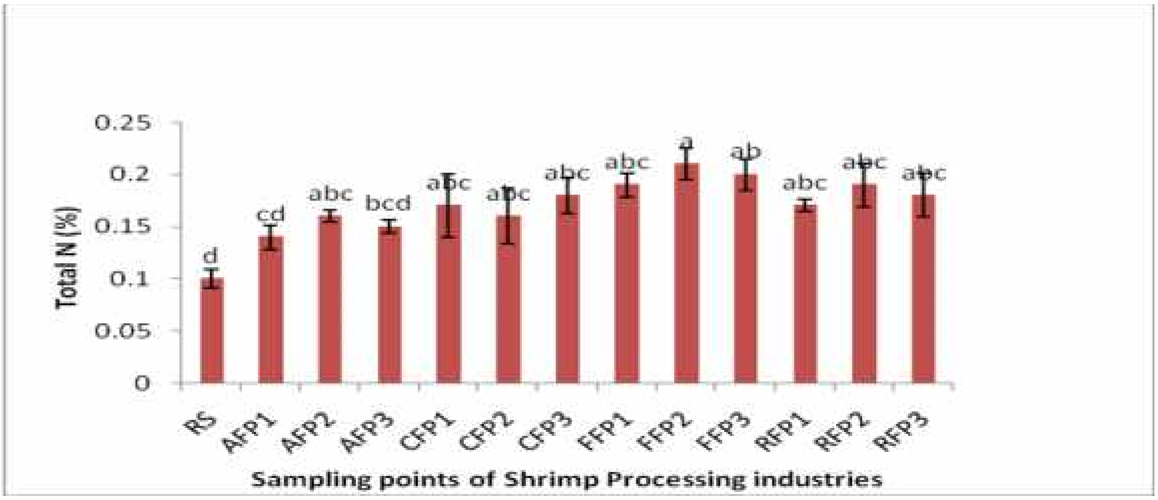


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.87. Percent Organic Matter of the soils receiving effluents from Shrimp Processing Industries

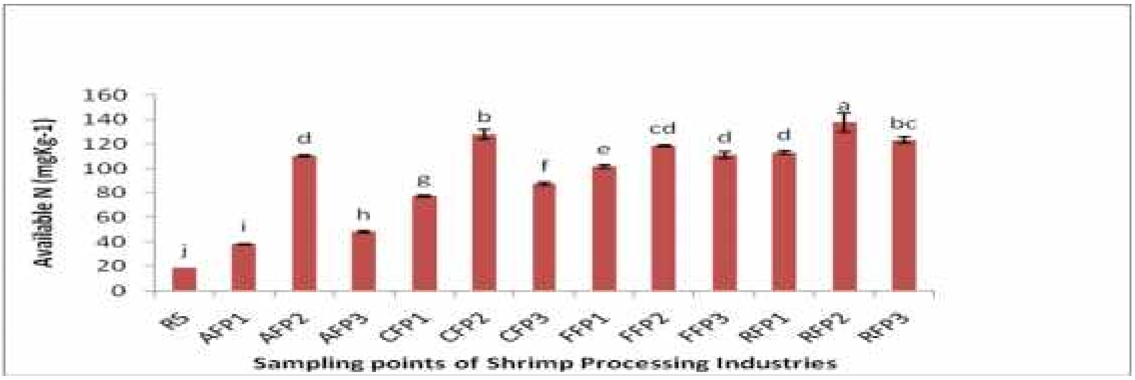
4.2.10.2.5. Total and Available Nitrogen (N) in soil:

Total nitrogen varied from 0.14 to 0.17% at P_1, 0.16 to 0.19% at P_2 and 0.15 to 0.20% at P_3 and total nitrogen of corresponding Reference Soil was measured 0.10%. The available nitrogen varied from 38.08 to 113.27 $mgKg^{-1}$ at P_1, 110.43 to 137.75 $mgKg^{-1}$ at P_2 and 48.17 to 122.97 $mgKg^{-1}$ at P_3 and available nitrogen of corresponding Reference Soil was measured 19.02 $mgKg^{-1}$. The highest Total nitrogen (0.21%) was measured at I_3P_2 and the lowest (0.14%) at I_1P_1. All values of the studied soils are higher than that of the Reference Soil values (0.10%). The mineralization of shrimp wastes and organic matter is likely to increase the N content (Fig 4.88) and the magnitude of the difference is at the order of $P_2>P_3>P_1$. The results show that total and available nitrogen in all soil samples was statistically insignificant at 5% level against Reference Soil (F=2.76 for Total N and 178.14 for Av. N) (Table 8.2). However, no significant differences in total nitrogen contents in the soils around the industries were observed. The high nitrogen contents in the contaminated soils may be resulted from the accumulation of dissolved/ suspended organic residues and other sources like application of nitrogenous fertilizers in paddy cum fish culture. The availability of total N is high in contaminated soils due to the fish parts, use of fish feed which contains 0.6% N (Lin and Nash, 1996).



(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.88. Total Nitrogen of the soils receiving effluents from Shrimp Processing Industries

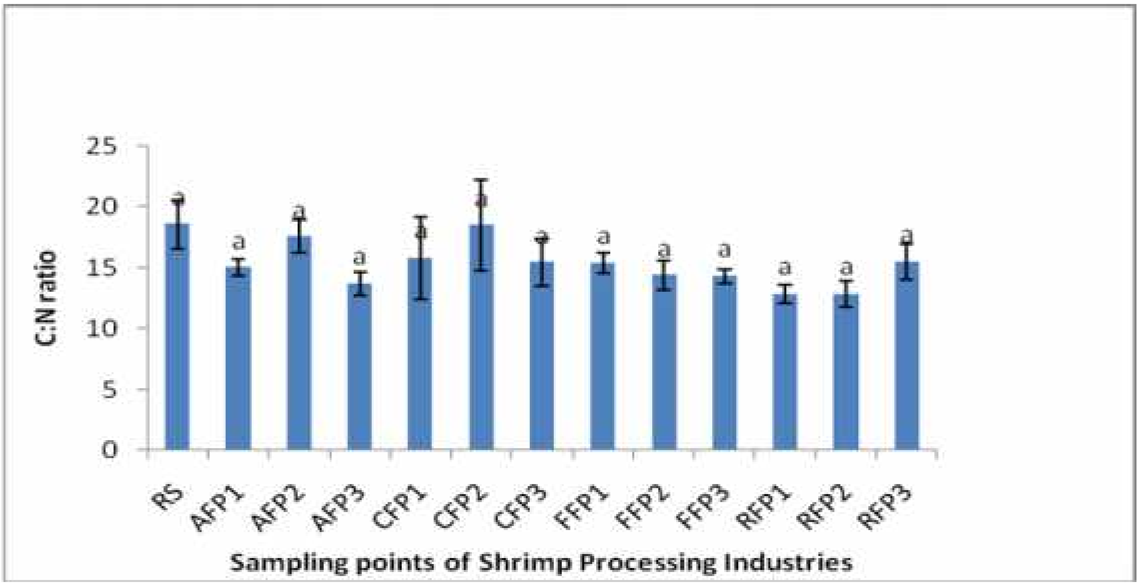


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.89. Available Nitrogen of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.6. C:N Ratio:

Carbon and Nitrogen Ratio (C:N) varied from 12.81 to 15.78 at P_1, 12.82 to 18.47 at P_2 and 13.68 to 15.78 at P_3 and 18.56 was measured for the Reference Soil. The highest C:N ratio (18.47) was measured for the soils at I_2P_2 and the lowest (12.81) at I_4P_1 (Table 4.20). All values of the studied soils were lower than that of the Reference Soil (Fig 4.90). The results indicate that the low C:N ratio of all soils under investigation was statistically insignificant at 5% level against the Reference Soil (F=1.1) (Table 8.2). However, the differences in C:N ratio among the samples of different industries as well as points are statistically insignificant in most cases (Fig 4.90). Lower the C:N ratio (<10), the more rapid is the decomposition and greater is the mineralization of organic nitrogen (Harler, 1956). Materials having higher C:N ratio are slow in decomposition, because they have no sufficient nitrogen in their tissues to sustain the microorganisms responsible for decomposition (Islam and Hossain, 1974).



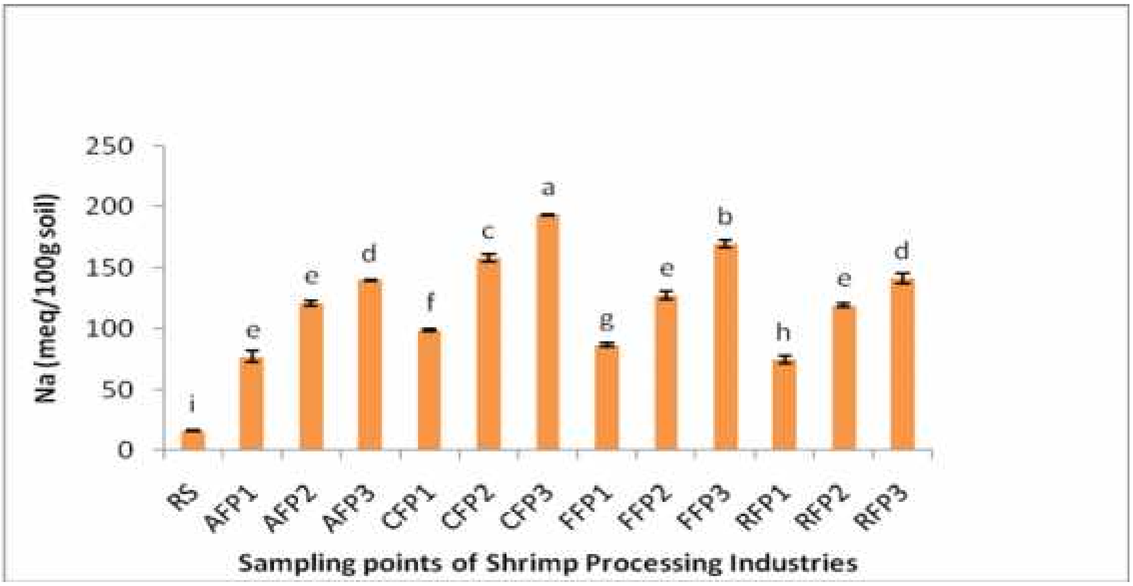
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.90. Carbon Nitrogen Ratio (C:N) of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.7. Exchangeable Sodium (Na^+):

Exchangeable Sodium (Na^+) varied from 74.89 to 98.59 meq100g^{-1} soil at P_1, 118.96 to 157.80 meq100g^{-1} soil at P_2 and 139.40 to 193.50 meq100g^{-1} soil at P_3 and 16.03 meq100g^{-1} soil Na^+ was measured for the Reference Soil. The highest Na^+ (193.50 meq100g^{-1} soil) was measured at I_2P_3 and lowest (74.89 meq100g^{-1} soil) at I_4P_1. All values of the studied soils were higher than the Reference Soil (Fig 4.91) and the magnitude of the difference is at the order of $P_3>P_2>P_1$. The results show that the exchangeable Na^+ measured for the soils was statistically significant at 5% level against the Reference Soil (F=312.84) (Table 8.2). Also the differences in Na^+ among the soils of different industries as well as points are statistically significant (Fig 4.91). The high levels of exchangeable Na^+ in the contaminated soils could possibly rendered from the effluents having saline water and brine solution used in the washing of shrimps and application of STP, SMBP, STPP, SMBS, lime, caustic soda, liquid soap, detergent and dyes in the various steps of shrimp processing (Ahmed *et al.,* 1973). As the proportion of exchangeable sodium increases, the soil tends to become more dispersed thereby causing poor aeration and water permeability becomes low.

Excess of sodium causes deficiency of K$^+$ and scorching of leaf-tips in addition to deterioration of soil physical conditions (Chhabra, 1996). As the measured values obtained for SAR is also high (16.65), the soils receiving effluents are very likely to be deteriorated faster.



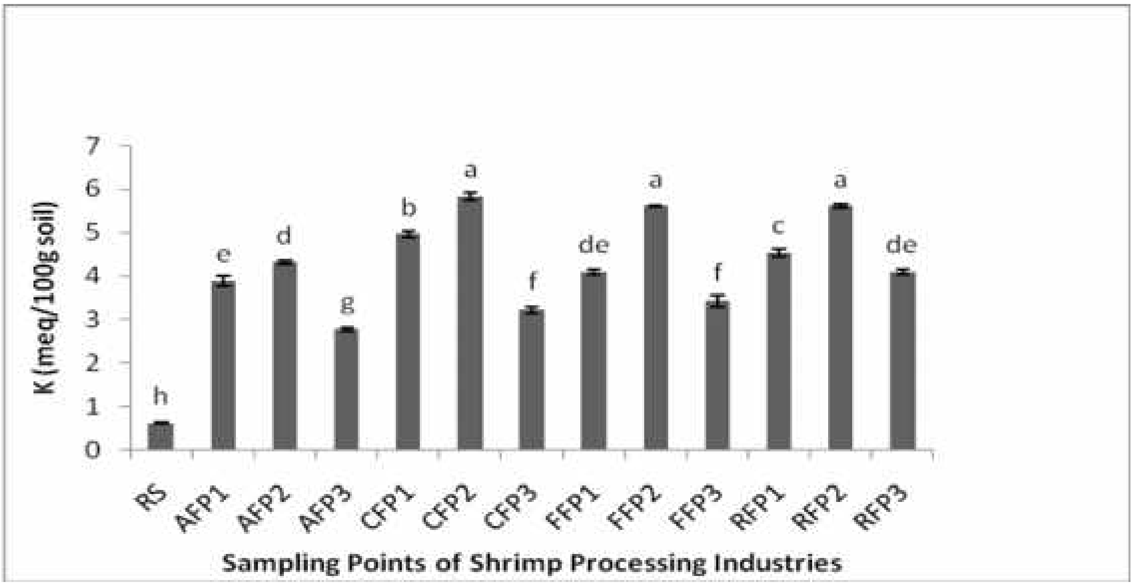
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.91. Exchangeable Na$^+$ of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.8. Exchangeable Potassium (K$^+$) in soil samples:

Exchangeable Potassium (K$^+$) varied from 3.88 to 4.96 meq100g^{-1} soil at P_1, 4.31 to 5.83 meq100g^{-1} soil at P_2 and 2.79 to 4.09 meq100g^{-1} soil at P_3 and 0.63 meq100g^{-1} soil measured for the Reference soil. The highest K$^+$ (5.83 meq100g^{-1} soil) was measured at I_2P_2 and lowest (2.79 meq100g^{-1} soil) at I_1P_3. All values of the studied soils are higher than the Reference Soil values (Fig 4.92) and the magnitude of the difference is at the order of $P_2>P_1>P_3$. The results show that the exchangeable K$^+$ measured for the soils was statistically significant at 5% level against Reference Soil (F=367.92) (Table 8.2). Also the differences in K$^+$ among the soils of different industries as well as points are statistically significant (Fig 4.92). Highest K$^+$ was in P_2 because of high OM increases K$^+$ in soil and high CEC in the studied soils reduces K$^+$ losses of soil (Abdel and Hussain, 2001).

The high levels of exchangeable K^+ in the contaminated soils could possibly rendered from the effluents having saline water and brine solution in the processing plants of shrimps (Ahmed *et al.,* 1973). Iron chlorosis and Magnesium deficiency are likely to be occured for high potassium in soil (Boynton and Burrel, 1944).



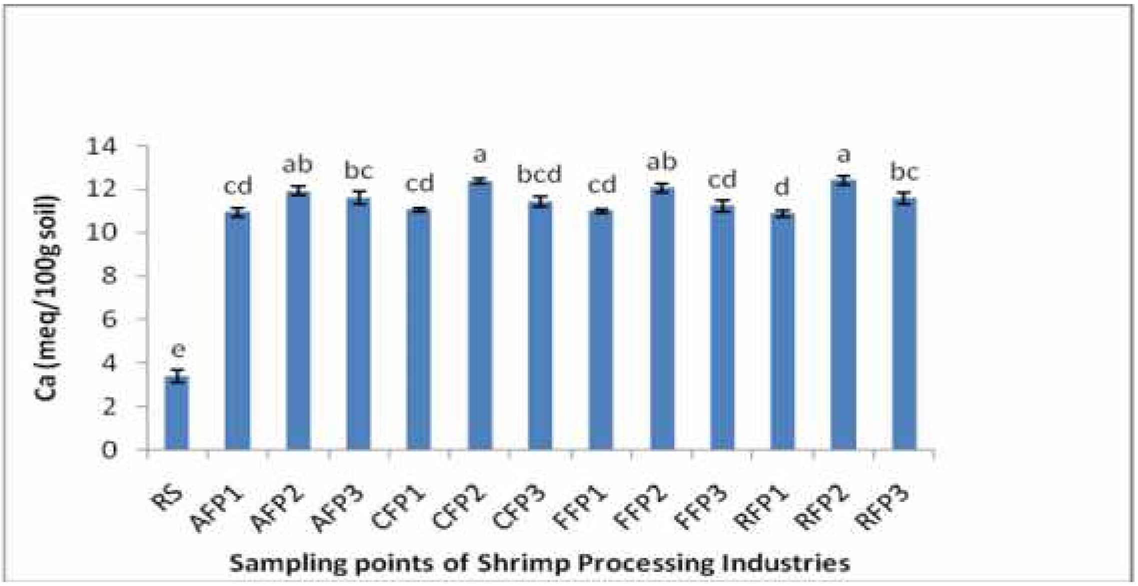
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.92. Exchangeable K^+ of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.9. Available Calcium (Ca^{2+}) in soil samples:

Calcium (Ca^{2+}) varied from 10.88 to 11.03 meq100g^{-1} soil at P_1, 11.91 to 12.41meq100g^{-1} soil at P_2 and 11.23 to 11.61 meq100g^{-1} soil at P_3 and 3.4 meq100g^{-1} soil measured for the Reference soil. The highest Ca^{2+} (12.41 meq/100g soil) was measured at I_4P_2 and lowest (10.88 meq/100g soil) at I_4P_1. All values of the studied soils are higher than the Reference Soil values (Fig 4.93) and the magnitude of the difference is at the order of $P_2>P_1>P_3$. The results show that the calcium measured for the soils was statistically significant at 5% level against Reference Soil (F=120.91) (Table 8.2). Also the differences in Ca^{2+} among the soils of different industries as well as points are statistically insignificant except Rosemco Foods Ltd. (Fig 4.93). Highest K^+ was in P_2 because of high OM increases Ca^{2+} in soil (Rosen *et al.,* 2005) and high CEC in the studied soils reduces Ca^{2+} losses of soil (Abdel and Hussain, 2001).

Increasing trend of Ca^{2+} due to the use of saline water, lime ($CaCO_3$), bleaching powder ($CaOClCl$) in various steps of shrimp processing and use of TSP fertilizer in the shrimp cum paddy culture. This excess Ca^{2+} may cause deficiency in Mg^{2+} and K^+ in plants (Benett and Linstedt, 1993).



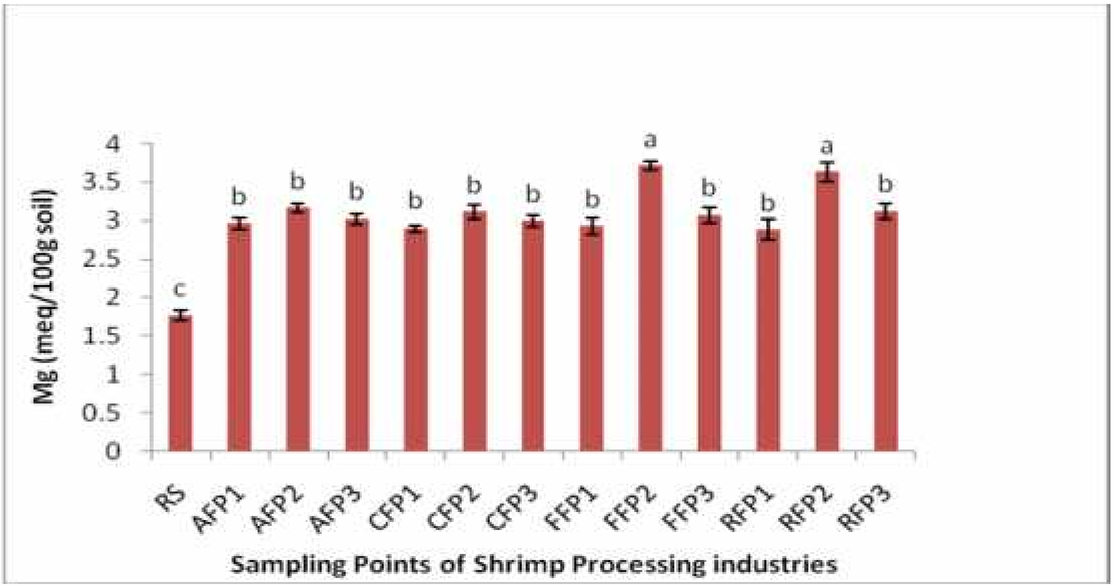
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.93. Calcium (Ca^{2+}) of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.10. Available Magnesium (Mg^{2+}) in soil samples:

Available Magnesium (Mg^{2+}) varied from 2.67 to 2.96 meq100g^{-1} soil at P_1, 3.11 to 3.71 meq100g^{-1} soil at P_2 and 2.99 to 3.12 meq100g^{-1} soil at P_3 and 1.76 meq100g^{-1} soil measured for the Reference soil. The highest Mg^{2+} (3.71 meq/100g soil) was measured at I_3P_2 and lowest (2.67 meq/100g soil) at I_4P_1. All values of the studied soils are higher than the Reference soil values (Fig 4.94) and the magnitude of the difference is at the order of $P_2>P_1>P_3$. The results show that the available Magnesium (Mg^{2+}) measured for the soils was statistically significant at 5% level against Reference Soil (F=27.29) (Table 8.2). Also the differences in Mg^{2+} among the soils of different industries as well as points are statistically insignificant (Fig 4.94).

Highest Mg^{2+} was in P_2 because of high OM increases Mg^{2+} in soil and high CEC in the studied soils reduces Mg^{2+} losses of soil (Abdel and Hussain, 2001). Increasing trend of Mg^{2+} in effluent contaminated soils due to the use of saline water and lime ($MgCO_3$) in various steps of shrimp processing.



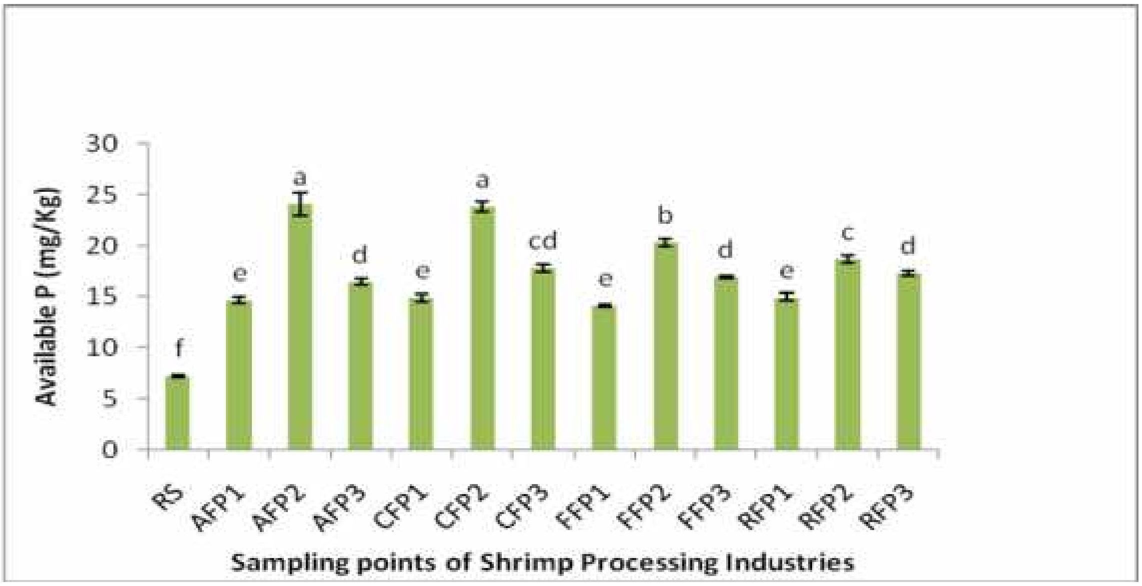
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.94. Available Mg^{2+} of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.11. Available Phosphorous (P):

Phosphorous (PO_4^{3-}) of the studied contaminated soils varied from 14.2 to 15.0 $mgKg^{-1}$ at P_1, 18.7 to 24.1 $mgKg^{-1}$ at P_2 and 16.5 to 17.8 $mgKg^{-1}$ at P_3 and 7.27 $mgKg^{-1}$ P was measured for the Reference Soil. The highest P (24.1 $mgKg^{-1}$) was measured at I_1P_2 and lowest (14.2 $mgKg^{-1}$) at I_3P_1. All values are higher than the Reference Soil values (Fig 4.95) and the magnitude of the difference is at the order of P_2>P_3>P_1. The differences are statistically significant at 5% level (F=102.86) (Table 8.2). Also the differences in P among the soils of different industries as well as points are statistically significant in most of the cases (Fig 4.95). Use of Sodium tri phosphate (STP), Sodium Meta bi phosphate (SMBP) and Sodium tri poly phosphate (STPP) in the various steps of shrimp processing may have contributed to the increasing level of phosphorous.

Use of fertilizer like TSP and pesticides like Diazinon, Parathion in the indigenous shrimp cum paddy culture on the same land may also contributed to the bioaccumulation of P in shrimp (Whalen *et al.,* 2000). The concentration of phosphorous measured for the soils in the present investigation could be hazardous. Similar concentration of P in soils receiving fish processing effluents was reported by Bremner and Bundy, 1974. Discharge of wastewater and industrial wastes with high level of P may increase soil phosphate level and may affect the availability of Zn in soils (Khan *et al.,* 1998) and cause eutrophication of receiving water bodies (Lenore *et al.,* 1998).



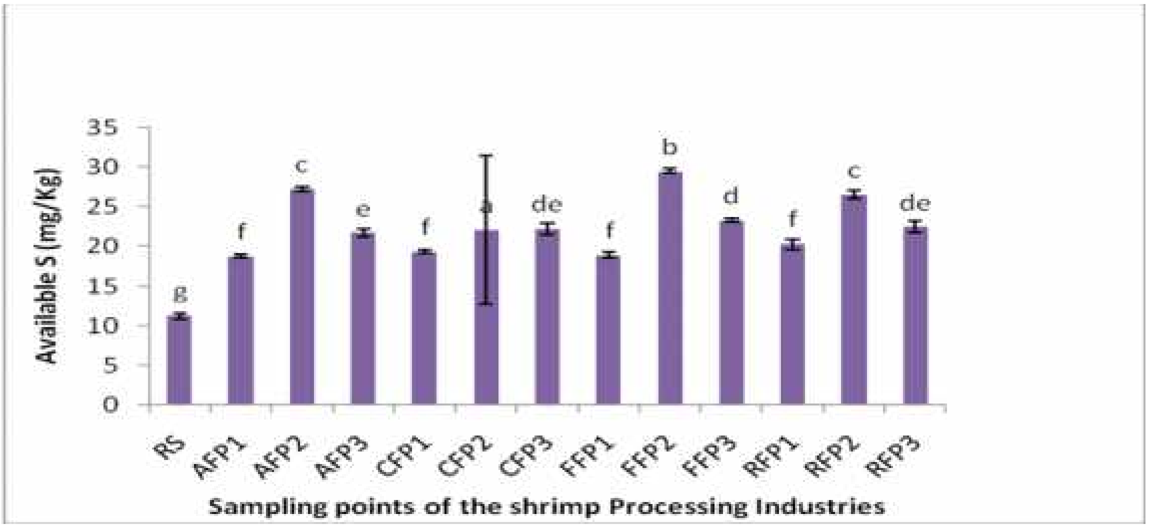
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.95. Available Phosphorus (P) of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.12. Available Sulfur (S):

Sulfur (SO_4^{2-}) of the studied contaminated soils varied from 18.75 to 20.30 mgKg^{-1} at P_1, 26.57 to 32.10 mgKg^{-1} at P_2, 21.75 to 23.35 mgKg^{-1} at P_3 and 11.22 mgKg^{-1} S was measured for the Reference Soil. The highest S (32.10 mgKg^{-1}) was measured at I_2P_2 and lowest (18.75 mgKg^{-1}) at I_1P_1. All values are higher than the Reference Soil values (Fig 4.96) and the magnitude of the difference is at the order of $P_2>P_3>P_1$. The differences are statistically significant at 5% level against Reference Soil (F=118.14) (Table 8.2).

Also the differences in Sulfur among the soils of different industries as well as points are statistically significant in most of the cases (Fig 4.96). Use of Sodium Meta bi sulfate (SMBS) and H_2SO_4 in the various steps of shrimp processing may have contributed to the increasing level of Sulfur. Not only this, decomposition of the shells of shrimp is a source of Sulfur in contaminated soil because Sulfur compounds of the shells are biodegradable and produce SO_2 and H_2S (Cheftel *et al.,* 1985). The concentration of Sulfur measured for the soils in the present investigation could be hazardous. A significant portion of alkaline sulfides contained in shrimp processing waste water might be converted to H_2S at pH below 8.5 to 9.0 may have contributed to damage and discoloration of leaves and higher concentration can be lethal (EPA, 1974).



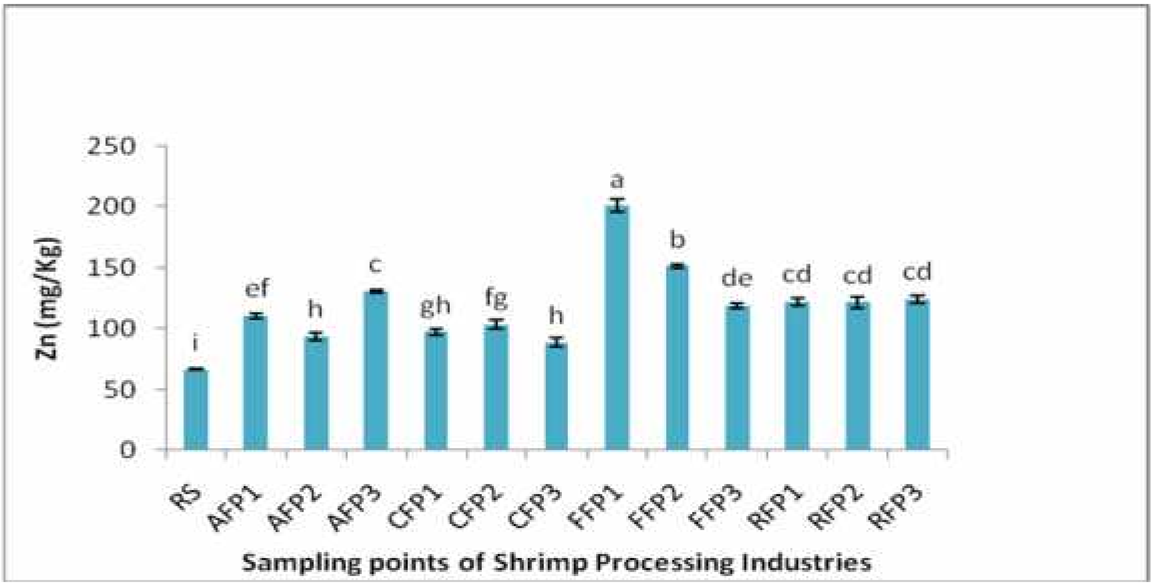
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.96. Available Sulfur of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.13. Zinc (Zn):

Zinc (Zn) of the investigated soils varied from 97.2 to 200.6 $mgKg^{-1}$ at P_1, 93.3 to 150.8 $mgKg^{-1}$ at P_2, 88.4 to 130.4 $mgKg^{-1}$ at P_3 and 66.4 $mgKg^{-1}$ Zn was measured for the Reference Soil. The highest Zn (200.6 $mgKg^{-1}$) was measured at I_3P_1 and the lowest (93.3 $mgKg^{-1}$) at I_3P_2. The values obtained are higher than the Reference Soil values (Fig 4.97) and the magnitude of the difference is at the order of $P_1>P_2>P_3$.

Zinc values measured for the soils were statistically significant at 5% level against the Reference Soil (F=113.29) (Table 8.2). However, the differences in Zn among the soils of different industries as well as points are statistically insignificant except Atlas and Fresh Foods Ltd. (Fig 4.97). The reason for the increasing level of Zn is not very clear. However, use of pesticides as a preservative during fish processing and the application of fertilizers like ZnO and $ZnSO_4$ during production of shrimp on the ground could possibly contributed to the increasing level of Zinc. Also, Zn forms stable complexes with soil OM (Khan *et al.,* 1998).



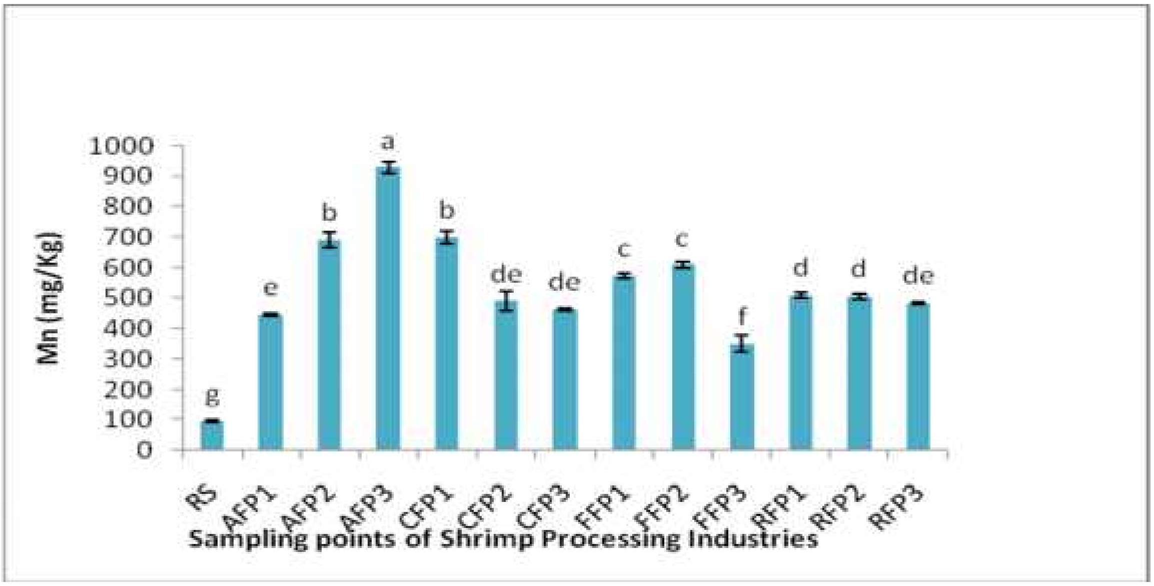
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.97. Zinc content of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.14. Manganese (Mn):

Manganese (Mn) of the investigated soils varied from 446 to 698 $mgKg^{-1}$ at P_1, 490 to 690 $mgKg^{-1}$ at P_2, 350 to 928 $mgKg^{-1}$ at P_3 and 97 $mgKg^{-1}$ Mn was measured for the Reference Soil. The highest Mn (928 $mgKg^{-1}$) was measured at I_1P_2 and the lowest (350 $mgKg^{-1}$) at I_3P_3. The values obtained are higher than the Reference Soil values (Fig 4.98) and the magnitude of the difference is at the order of P_3>P_2>P_1. Manganese values measured for the soils were statistically significant at 5% level against the Reference Soil (F=139.04) (Table 8.2).

However, the differences in Mn among the soils of different industries as well as points are statistically insignificant except Atlas Sea Foods Ltd. (Fig 4.98). Increasing trend of Mn in the soils of the contaminated sites is due to the use of pesticides during preservation of shrimps and use of dyes during coloring of shrimps and use of potassium permanganate as cooling agent of shrimp processing.



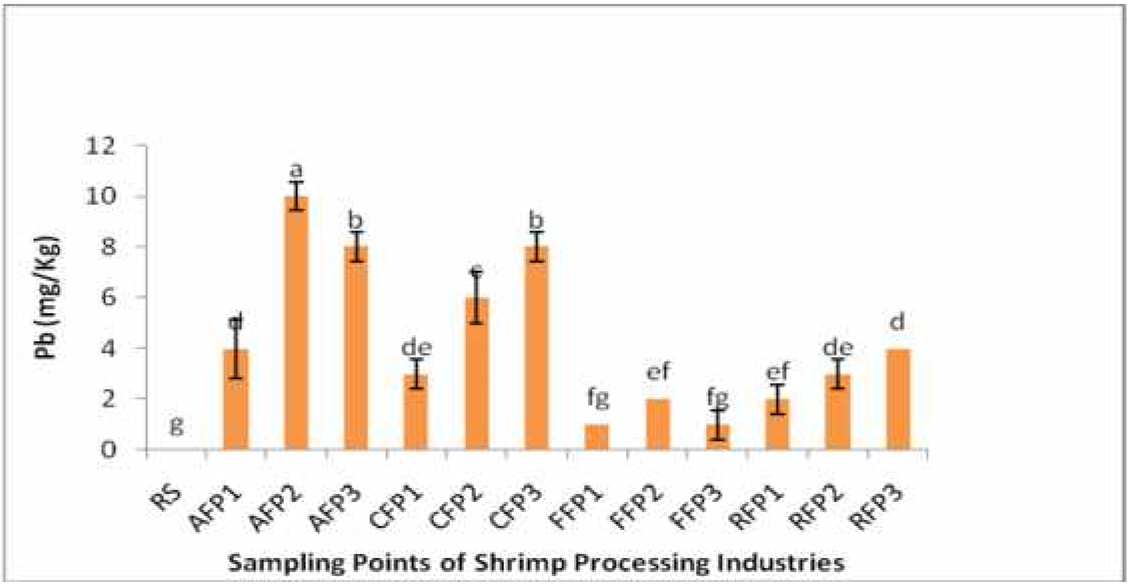
(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.98. Manganese content of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.15. Lead (Pb):

Lead (Pb) of the investigated soils varied from 1 to 4 mgKg^{-1} at P_1, 2 to 10 mgKg^{-1} at P_2, 88.4 to 130.4 mgKg^{-1} at P_3 and 0 mgKg^{-1} Pb was measured for the Reference Soil. The highest Pb (10 mgKg^{-1}) was measured at I_1P_2 and the lowest (1 mgKg^{-1}) at I_3P_1 and I_3P_3. The values obtained are higher than the Reference Soil values (Fig 4.99) and the magnitude of the difference is at the order of $P_2>P_3>P_1$. Lead values measured for the soils were statistically significant at 5% level against the Reference Soil (F=26.93) (Table 8.2). However, the differences in Pb among the soils of different industries as well as points are statistically insignificant except Atlas and Cosmos Sea Foods Ltd. (Fig 4.99). The reason for the increasing level of Pb is not very clear.

However, use of pesticides as a preservative during fish processing and the application of fertilizer like Pb Arsenate during production of shrimp on the ground could possibly contributed to the increasing level of Lead. (Khan *et al.,* 1998).

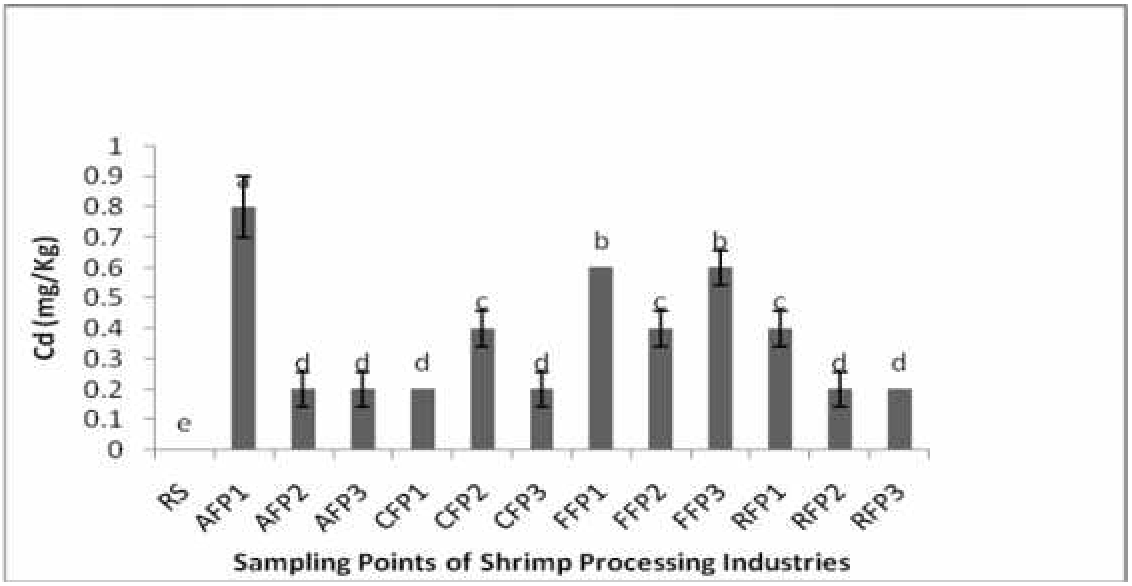


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.99. Lead content of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.16. Cadmium (Cd):

Cadmium (Cd) of the investigated soils varied from 0.2 to 0.8 $mgKg^{-1}$ at P_1, 0.2 to 0.4 $mgKg^{-1}$ at P_2, 0.2 to 0.6 $mgKg^{-1}$ at P_3 and 0 $mgKg^{-1}$ Cd was measured for the Reference Soil. The highest Cd (0.8 $mgKg^{-1}$) was measured at I_1P_1. The values obtained are higher than the Reference Soil values (Fig 4.100) and the magnitude of the difference is at the order of $P_1>P_3>P_2$. Cadmium values measured for the soils were statistically significant at 5% level against the Reference Soil (F=17.46) (Table 8.2). However, the differences in Cd among the soils of different industries as well as points are statistically insignificant (Fig 4.100).

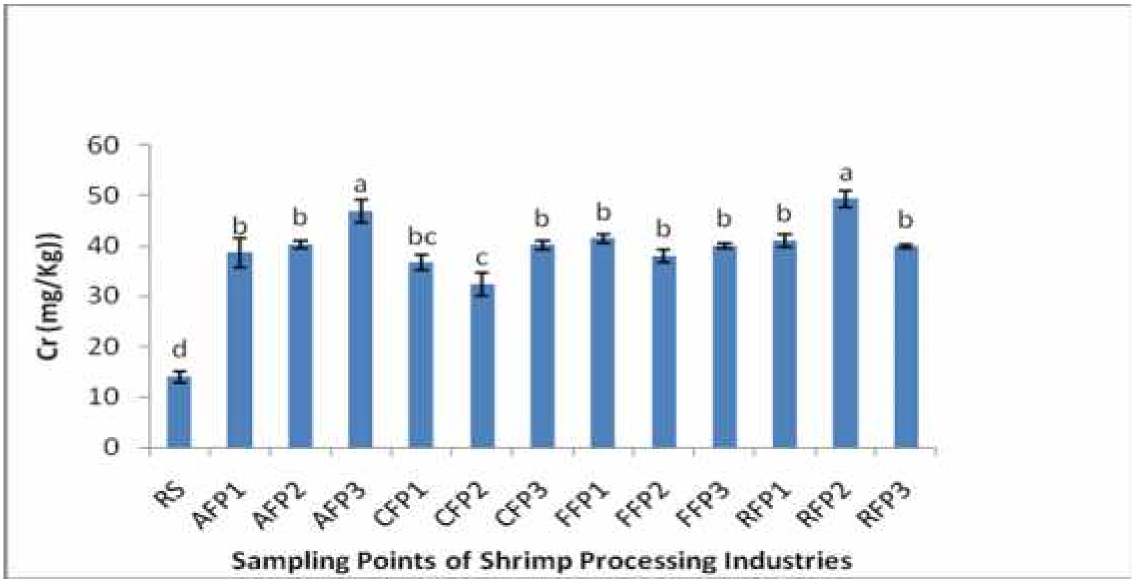


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.100. Cadmium content of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.17. Chromium (Cr):

Chromium (Cr) of the investigated soils varied from 36.6 to 41.4 mgKg^{-1} at P_1, 32.2 to 49.32 mgKg^{-1} at P_2, 39.8 to 46.8 mgKg^{-1} at P_3 and 14.05 mgKg^{-1} Cr was measured for the Reference Soil. The highest Cr (49.32 mgKg^{-1}) was measured at I_4P_2 and the lowest (32.2 mgKg^{-1}) at I_2P_2. The values obtained are higher than the Reference Soil values (Fig 4.101) and the magnitude of the difference is at the order of $P_3>P_2>P_1$. Chromium values measured for the soils were statistically significant at 5% level against the Reference Soil (F=30.42) (Table 8.2). However, the differences in Cr among the soils of different industries as well as points are statistically insignificant in most of the cases (Fig 4.101). The reason for the increasing level of Cr is due to the use of chromium compounds in the cooling water for corrosion control in Shrimp processing industries and release some Cr with effluents. Michael *et al.,* 1980 found 17 mgL^{-}1 Cr in the waste water released from the shrimp processing industries.

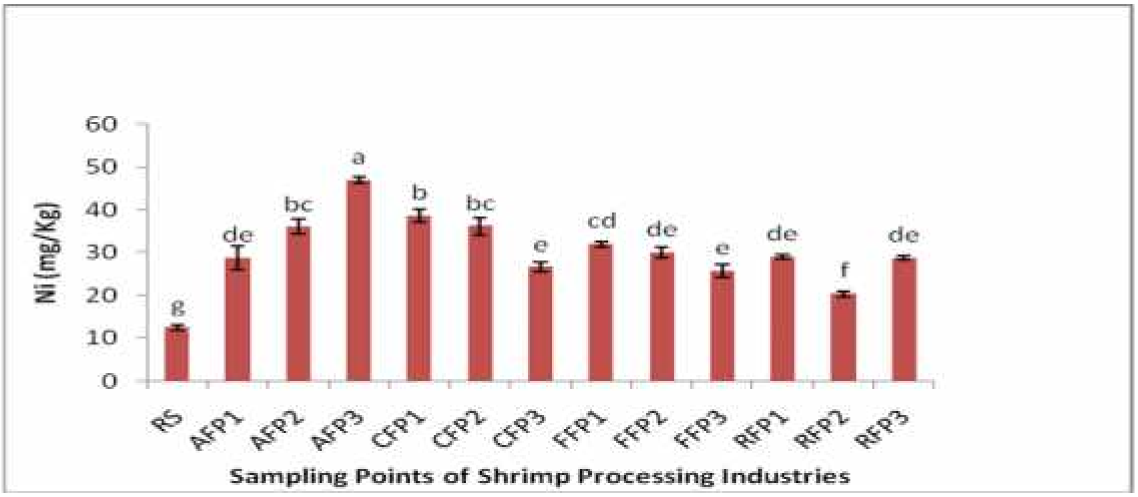


(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig 4.101. Chromium content of the soils receiving effluents from Shrimp Processing Industries

4.2.10.2.18. Nickel (Ni):

Nickel (Ni) of the investigated soils varied from 28.8 to 38 mgKg^{-1} at P_1, 20.4 to 36.2 mgKg^{-1} at P_2, 25.8 to 47 mgKg^{-1} at P_3 and 12.5 mgKg^{-1} Ni was measured for the Reference Soil. The highest Ni (47 mgKg^{-1}) was measured at I_1P_3 and the lowest (20.4 mgKg^{-1}) at I_4P_2. The values obtained are higher than the Reference Soil values (Fig 4.102) and the magnitude of the difference is at the order of $P_3>P_1>P_2$. Nickel values measured for the soils were statistically significant at 5% level against the Reference Soil (F=37.86) (Table 8.2). However, the differences in Ni among the soils of different industries as well as points are statistically insignificant except Atlas Sea Foods Ltd. (Fig 4.102). The reason for the increasing level of Ni is not very clear. However, use of pesticide (Nicolite) during production of shrimp on the ground could possibly contribute to the increasing level of Nickel and for the use of heavy machineries in processing.



(RS=Reference soil, AF=Atlas Foods, CF=Cosmos Foods, FF=Fresh Foods, RF=Rosemco Foods, P1=Point 1, P2=Point 2, P3=Point 3)

Fig. 4.102. Nickel content of the soils receiving effluents from Shrimp Processing Industries

4.2.11. Environmental Impact Assessment (EIA) of the shrimp processing effluents:

Table 4.23. Environmental Impact Assessment (EIA) of the shrimp processing effluents

Effects	Positive	Reasons	Negative	Reasons
Effect on soil physical properties	√	Decreased bulk density Lowering compactness	√	Loss of soil structure
Effect on soil chemical properties	√	The effluents add OC and chemical species like N, P, S, K^+, Na^+, Mg^{2+}, Ca^{2+}, Zn, Mn and enrich soil as a source and sink of nutrients for soil biota.	√	Increasing soil pH, EC, %Salt, K^+, Na^+, Mg^{2+}, Ca^{2+} and accumulation of meatls like Pb, Cd, Cr, and Ni.
Effect on pond water			√	Increasing turbidity, EC, %Salt, TDS, BOD and SO_4^{2-} and decreasing DO level in pond water.
Effect on canal water			√	Increasing turbidity, pH, EC, %Salt, BOD, SO_4^{2-}, Na^+, K^+, and Mg^{2+} and decreasing DO level in canal water.

Effect on river water			√	Increasing turbidity, pH, EC, %Salt, TDS, BOD, COD, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} and decreasing DO level in river water.
Effect on ground water			√	Levels of NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} are increased in ground water.
Effect on seed germination			√	Reduction of seed germination of leafy vegetables.
Effect on crop growth			√	Affecting growth of leafy vegetables.
Effect on nutrients and heavy metals uptake by crops	√	Reduced metals uptake in test crops	√	Reduced uptake of chemical species as nutrients in test crops.

Environmental Impact Assessment (EIA) of the wastes and effluents released from the fish processing industries confirmed potential negative impacts on soil physical and chemical properties and water quality around the industries.

5. Summary of the results

1. On ground survey of the shrimp processing plants in the present investigation are observed to be constructed on the road side agricultural lands surrounded by canals, rivers, ponds and small water bodies and the wastes (6800Kg/day/plant) and effluents (47500L/day/plant) generated are directly released in the environment. None of the industries are following the compliance of ETP as required by ECR-97.
2. Effluent released from the investigated shrimp processing industries contains various degrees of chemical species or substances that can affect soil and water, notable of which are pH (8.06±1.12), EC (15.21±2 $mSCm^{-1}$), DO (1.7±0.12 mgL^{-1}), TDS (1777±553 mgL^{-1}), TSS (543±187 mgL^{-1}), BOD (377±15 mgL^{-1}), COD (593±10 mgL^{-1}), HCO_3^{-+} (28.8±5.95 mgL^{-1}), SO_4^{2-} (372±46 mgL^{-1}), Cl^- (0.9±0.06%), NH_4^+-N (50.17±32.06 mgL^{-1}), NO_3^--N (12±1.5 mgL^{-1}), Na^+ (70±4 $meqL^{-1}$), K^+ (3.39±0.17 $meqL^{-1}$), Ca^{2+} (9.3±0.42 $meqL^{-1}$), Mg^{2+} (9.3±0.42 $meqL^{-1}$), SAR (16.47±1.03), SSP (66.94±1.45%), Hardness (105.29±1.09 mgL^{-1}), Zn (94.48±21.02 mgL^{-1}), Mn (129±19 mgL^{-1}), Pb (2.75±3.25 mgL^{-1}), Cd (0.19±0.31 mgL^{-1}), Cr (16.6±0.03 mgL^{-1}), Ni (7.25±6.05 mgL^{-1}), TC ($2.9\times10^3\pm0.6\times10^3$ c.f.u/100 ml), FC (235±76c.f.u/100 ml).
3. The effluents also found to contain different levels of NH_4^+ and NO_3^- Nitrogen (92.6±3.2 mgL^{-1}), PO_4^{3-} (26.5±2.6 mgL^{-1}), SO_4^{2-}-S (372±46 mgL^{-1}), K^+ (3.39±0.17 $meqL^{-1}$), Na^+ (70±4 $meqL^{-1}$), Mg^{2+} (9.3±0.42 $meqL^{-1}$), Ca^{2+} (9.3±0.42 $meqL^{-1}$), DOC (233.6±70 mgL^{-1}).
4. Effluent characteristics significantly changed with distance travelled over a cross section of land. Concentrations measured at a distance of about 350m from the source point were- turbidity (305-665 NTU), temperature (24-27.5 ^{0}C), pH (7.48-8.18), EC (12.1-17.21 $mScm^{-1}$), Salt (0.77-1.1%), DOC (186-328.67 mgL^{-1}), DO (0.15-1.82 mgL^{-1}), TDS (1320-2350 mgL^{-1}), TSS (366-966 mgL^{-1}), BOD (367-436 mgL^{-1}), COD (572-980 mgL^{-1}), HCO_3^- (16.02-34.75 mgL^{-1}), SO_4^{2-} (306-485 mgL^{-1}), Cl^- (0.73-0.96%), NH_4^+-N (7.57-92.87 mgL^{-1}), NO_3 -N (10.7-17.9 mgL^{-1}), Na^+ (42-71 $meqL^{-1}$), K^+ (2.7-3.91 $meqL^{-1}$), Ca^{2+} (23.72-27.22 $meqL^{-1}$), Mg^{2+} (6.75-9.72 $meqL^{-1}$), SAR (10.65-17.5), SSP (58.63-68.39%),

Hardness (87.16-106.38 mgL^{-1}), Zn (68.3-124.7 mgL^{-1}), Mn (99-165 mgL^{-1}), Pb (1-8 mgL^{-1}), Cd (0.05-0.59 mgL^{-1}), Cr (16.1-18.7 mgL^{-1}), Ni (3.3-13.3 mgL^{-1}), TC (2.3×10^3-4.75×10^3c.f.u/100 ml) and FC (110-411c.f.u/100 ml).

5. The chemical properties of the soils receiving effluents were also changed, notable of which are pH (7.2-7.74), EC (4.27-6.69 mScm^{-1}), Percent Salt (0.27-0.43), CEC (12.2-29.7 meq100g^{-1} soil), OC (2.04-2.98%), OM (3.51-5.13%), Total N (0.14-0.21%), Available N (38.2-137.75 mgKg^{-1}), C:N ratio (12.81-18.47), S (18.75-32.1 mgKg^{-1}), P (14.2-24.1 mgKg^{-1}), Na^+ (74.89-193.5 meq100g^{-1} soil), K^+ (2.79-5.83 meq100g^{-1} soil), Ca^{2+} (10.88-12.41 meq100g^{-1} soil), Mg^{2+} (2.88-3.71 meq100g^{-1} soil), Zn (88.4-200.6 mgKg^{-1}), Mn (350-928 mgKg^{-1}), Pb (1-10 mgKg^{-1}), Cd (0.2-0.8 mgKg^{-1}), Cr (32.4-49.3 mgKg^{-1}) and Ni (20.4-47 mgKg^{-1}).
6. Seed germination tests carried out with the raw and diluted effluent showed comparable results with three different plant species namely Red amaranth (*Amaranthus curentus*), Stem amaranth *(Amaranthus lividus)* and Water spinach (*Ipomoea aquitica*). The application of raw effluent significantly reduced seed germination of different species up to a level of 24%, however Stem amaranth *(Amaranthus lividus)* was mostly affected and the order was SA>RA>WS. The recovery of the effect on seed germination was observed at a dilution of 75%.
7. Pot experiments carried out to assess the effect of effluents with or without dilutions on growth and yield of Red amaranth (*Amaranthus curentus*), Stem amaranth *(Amaranthus lividus)* and Water spinach (*Ipomoea aquitica*) showed to have significant effects on the growth parameters and biomass production like the number of leaves/plant, Fresh weight/plant, dry weight/plant and percent moisture content compare to the control treatment (uncontaminated soil) and the order was SA>RA>WS. Soils treated with raw effluents reduced the number of leaves per plant (38.1%), fresh weight per plant (50.14%), dry weight per plant (42.57%) and percent moisture content (6%) in Red amaranth; reduced the number of leaves per plant (46.14%), fresh weight per plant (47.21%), dry weight per plant (47.49%) and percent moisture content (7.32%) in Stem amaranth and reduced the number of leaves per plant (48.51%), fresh weight per plant (27.79%),

dry weight per plant (35.51%) and percent moisture content (8.42%) in Water spinach. The effects were recovered at a dilution level of 75%.

8. Uptake of N, P and S was reduced in raw effluent treated crops and the effects were recovered at a dilution level of 50%. Treatment with raw effluent reduced uptake of N to a level of 49.09% in RA, 36.81% in SA and 47.03% in WS; Phosphorous up to 47.89% in RA, 58.6% in SA and 59.86% in WS and S up to 53.8% in RA, 52.84% in SA and 37.93% in WS.
9. Raw effluent treated plants accumulated reduced levels of Ni, Mn, Cr and Zn compared to the control treatment i.e. 54.88% reduction of Ni in RA, 81.36% in SA and 62.48% in WS; 50.17% Mn in RA, 50.44% in SA and 43.33% in WS; 60.69% Cr in RA, 74.43% in SA and 63.19% in WS and 33.09% Zn in RA, 46.6% in SA and 40.85% in WS.
10. Environmental Impact Assessment (EIA) of the wastes and effluents released from the fish processing industries confirmed potential negative impacts on soil physical and chemical properties and water quality around the industries.

6. Conclusion:

It is evident from the results that untreated effluents released in the environment from different shrimp processing industries can have significant level of damaging effects on soil and water quality and crop production though there were some positive effects as well. The effluents analyzed for different physical, chemical and biological parameters showed presence of elevated concentrations of salts, toxic chemical species and substances that can have detrimental effects on soil biota and can change physical and chemical properties of soils. The effluents also showed to contain chemical species like N, P, S, OC, K^+, Na^+, Mg^{2+}, Ca^{2+}, Ni, Zn and Mn that can be a potential source of nutrients if applied as irrigation water after removal of unwanted toxic chemical species and reduction of salt contents. It is also noted that none of the industries of shrimp processing plants have ETP and they are not following the compliance of ECR-1997. The installation of ETP required to be enforced for all industries. Khulna is the most fish producing region in the country, and the surface water quality of this area is very important. If the surface water quality is affected, the production and quality of fish may also be affected and can have negative impacts on export and thus on our national revenue.

Recommendations:

The results obtained in the present investigation confirm that fish processing plants in Khulna region are releasing solid wastes and effluent containing chemical species that can have damaging effect on soil and water quality. The impacts still appear to be in a reversible situation and hoped that the following mitigation options may reverse the situation and further deterioration of the conditions.

- Building awareness among the owners and workers of fish processing plants regarding cleaner production and 3R (Reduce, Re-use, recycle) concept.
- Enforcement of ETP in all plants
- Proper disposal and recycling of solid wastes
- Development of central fish processing zone with central ETP plant
- Central solid waste recycling plant

- Continuous monitoring and investigation on fish processing activities, generation of solid and liquid wastes, disposal methods and impact on the environment if any.

Scope and Limitations:

- The present study involved a post project EIA. As no pre project EIA of the fish processing plants in Khulna region was carried out since the initiations were taken back in 1987, it was not possible to compare the impacts on a temporal basis.
- The present investigation involved one-fourth of the total number of plants as representative of the fish processing activities in the region. It would have been useful if more plants were included in the study for having a comprehensive and reproduceable results. Because of the time constraints the number of fish processing plants was required to be kept in a reasonable size.
- The research was mainly concentrated on the effect of shrimp processing effluents on soil and water contamination.
- As the demand for shrimp and access in the world market is increasing, more fish processing plants are likely to be established in the region with increasing fish processing activities. The data generated in the present investigation can be used as a base line data for any future study or monitoring purposes.

7. REFERENCES:

Abdel, N.G. and Hussein, A.H.A. 2001. Effect of different manure sources on some soil properties and sunflower plant growth: Soil physical and Chemical Properties. *Alexandria Journal of Agricultural Research,* 46 (1): 227-251.

Aftabuzzaman. 2010. Sustainable environment Friendly aquaculture. In Centre for Policy dialogue, Environmental Consequences of Export Oriented Shrimp culture in Bangladesh, CPD Dialogue Report No. 18, Centre for Policy Dialogue, Dhaka, Bangladesh.

Ahmed, M.S. and Rahman, M.M. 2000. *Water supply and sanitation.* IPN Bangladesh, Dhaka. Pp. 228-338.

Ahmed, S.; Karim, A.Q.M.B. and Rahman, S.M. 1973. Fixation of added potassium at various depths in two soils. *Bang. J. Soil Sci.* 9: 1-16.

Ahsan, S.; Salam, MTB. and Billah, S.M. 2013. Impact of Shrimp Processing Industries on the chemical properties of soils of Rupsha Upazila, Khulna, Bangladesh. *Khulna University Studies,* 11(1 & 2) and 12 (1 & 2): 27-32.

Alauddin, M. and Tisdell, C. 1998. Bangladesh's Shrimp Industry and Sustainable Development: Resource-Use Conflict and the Environment. *Asian Fisheries Science,* 11: 97-110.

Anisul Huq, K.; Bazlur Rahaman, S.M.; Baharul Islam, M.; Biplob Kumar Saha.; Alokesh Kumar Ghosh and Ashkar Bin Sayeed. 2009. Quality aspects of frozen shrimp product in processing industry: A case study in Khulna Bangladesh. *Bangladesh Research Publications Journal,* 3(2): 945-962.

Anonymous. 2003. Seafood Bangladesh, Bangladesh Frozen food Exporters Association Magazine, 6: 1-30.

Ansari, T.M.; Malik, S.A. and Naeem, M. 2001. Characterization of wastewater of Tannery, fertilizer and textile industries in Multan region. *Pakistan Analytical Chem,* 2: 59-62.

Anwer, S.M. 2003. Effect of shrimp culture on Ecology in the Coastal areas of Bangladesh. MS thesis, Department of Biology, NTNU. 8pp.

Ariyani, F. 1989. The production of prawn head silage. M.S. Thesis, The university of South Wales, pp. 112.

ASCC, 1995. Asian Shrimp News. Third Quarter, Issue No. 23. Asian Shrimp Culture Council, Bangkok.

Ayers, R.S. and Wescot, D.W. 1994. Water quality for Agriculture, Irrigation and Drainage, paper-29 Rev. 1, FAO, Rome.

Banks, Richard, 2002. Brackish and marine water aquaculture. Report from the Fisheries Sector Review, DFID, July 2002. 19pp.

BARI. 2005. Recommendation of seed sowing for different leafy vegetables, Bangladesh Agricultural Research Institute, Joydevpur, Gagipur.

Barmon, B.K.; Muntasir Chaudhury. and Saiyeeda, S.M. 2011. Value Chain and Marketing Channels of Shrimp/ Prawn sector of Gher farming system in Bangladesh. *World Review of Business Research,* 1(1):10-24.

Bauer, A. and Black, A.L. 1992. Organic Carbon effects on available water holding capacity of three soils texural group. *Soil Science Society of American Journal,* 56: 248-254.

BBS. 2004. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS. 2010. Statistical Year Book of Bangladesh, 2010. Bangladesh Bureau of Statistics, Dhaka, Bangladesh. 19pp.

BCAS. 2001. The Costs and Benefits of Bagda shrimp farming in Bangladesh: an economic, financial and livelihood assessment. Prepared as Part of the Fourth Fisheries project, Bangladesh centre for Advanced Studies (BCAS), Dhaka, Bangladesh. 16pp.

Begum, A.; Billah, S.M.; Halder, M.; Alam, M.N. and Joardar, J.C. 2009. Fertility status and land use pattern of some soils at Bauphal Thana in the coastal area of Bangladesh. *South Asian Journal of Agriculture,* 4(1 & 2): 45-50.

Begum, S.; Ikejima, K.; Ara, H. and Islam, M.Z. 2006a. Solar drying as an Option for Shrimp Processing Biowaste in Khulna District-Southwest Bangladesh. *Journal of Applied Sciences,* 6(5): 1220-1224.

Begum,S.; Ikejima, K.; Ara, H and Islam, M.Z. 2006b. Alternative processing option from shrimp processing Biowaste in Khulna District -Southwestern Bangladesh. *Journal of applied Sciences,* 6(6): 1307-1313.

Bennett, W.F. 1993. *Nutrient deficiencies and toxicity in crop plants.* APS press, St. Paul, Minnesota. Pp. 50-129.

Bennett, E.R. and Linstedt, E.K. 1993. Individual home waste water characterization and treatment. Environmental Resources center, Colorado State University, Colorado.

Bhattacharya, D.; Rahman, M. and Khatun, F. 1999. Environmental impact of structural adjustment policies: The case export oriented shrimp culture in Bangladesh, Centre for policy (2002) 'Environmental and socioeconomic impacts of shrimp aquaculture in Bangladesh', Technical proc. BAU-NORAD Workshop, BRAC Centre, Dhaka, Bangladesh, Bangladesh Agricultural University, Mymensingh, Bangladesh, 5 March, 101pp.

Bhuiyan, N.I. 1988. Co-ordinated project on potassium studies progress report (1987-88). BRRI, Joydebpur, Gazipur, pp. 1-45.

Billah, S.M.; Nasrin, S.; Iqbal, K.R. and Uddin, M.A. 2008. Water quality parameters in shrimp culture system in Khulna region. *South Asian Journal of Agriculture,* 3(1&2): 61-65.

Billah, S.M.; Joarder, J.C. and Papy, F.S. 2010. Amelioration of the chemical properties of soil through application of green manure crops in Bajoa soil series. *Khulna University Studies,* 10 (1 & 2): 211-216.

Billah, S.M. 2010. *Environmental Biology* (1st eds.). Millennium Publications, Bishal Books Complex, Banglabazar, Dhaka . Pp.121-125.

Blay, E.T.; Danquah, E.Y.; Ofosu-Anim, J. and Ntumy, J.K. 2002. Effect of poultry manure on the yield of *S. hallot. Advanced Horticulture Science,* 16: 13-16.

Blake, G.R. 1965. In: C.A. Black (ed.). *Methods of Soil Analysis*. Part 1. Physical and Mineralogical Properties, Including statistics of Measurement and Sampling. ASA SSSA, *Agronomy Monograph,* 9 : 374-390.

Blake, G.R. and Hartge, K.H. 1986. Bulk Density, In: A Klute, (ed.). *Methods of Soil Analysis*. Part I. Physical and Mineralogical Methods: Agronomy Monograph no. 9 (2nd ed.). pp. 363-375.

Bonsdorff, E.; Blomqvist, E.M.; Mattila, J. and Norkko, A. 1997. Coastal eutrophication: causes, consequences and perspectives in the Archipelago areas of the Northern Baltic Sea Estuarine. *Coastal and Shelf Science,* 44: 63–72.

Boyd, C.F. and Tucker, C.S. 1998. *Pond aquaculture water quality management*. United States of America. Pp. 700.

Boyd, C.E. 2008. Pond Bottom Soil Analyses. *Global Aquaculture Advocate,* 11: 91-92.

Boynton, D. and Burrel, A.B. 1944. Soil Science, 58: 441, In: Hess P.R. 1994. *A text book of Soil Chemical Analysis.* Satish kumar Jain for CBS publishers and Distributors, Delhi, India.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agron J.* 54 : 464-465.

Brady, P.L. and Hunecke, M.E. 1985. Correlations of sensory and instrumental evaluations of roast beef texture. *J. Food Sci,* 50: 300-303.

Brady, N.C. and Weil, R.R. 2002. *The Nature and Properties of Soils*. 13th Edition. Prentice Hall, New Jersey, USA. 881 pp.

Brammer, H. 1971. *Bangladesh: Soil Resources.* AGL: SF/PAK-6, Technical report no. 3, FAO, Rome.

Bremner, J.M. and Bundy, L.C. 1974. Inhibition of nitrification in soils by volatile sulfur compounds. *Soil Biol. And Biochem,* 6: 161-165.

Briggs, M.R.P. and Funge-Smith, S.J. 1994. Unsustainable shrimp culture. a review of causes and potential solutions from experience in Thailand. In: Development of Strategies for Sustainable Shrimp Farming. ODA Research Project R4751. Institute of Aquaculture. University of Stirling. Scotland.

Carawan, R.E. 1991. Processing plant waste management guidelines for aquatic fishery products. Food and the Environment. Available online at http://www.p2pays.org/ref/02/01796.pdf

Carlile, B.L. and Phillips, J.A. 1976. Evaluation of soil systems for land disposal of industrial and municipal effluents. WRRI of UNC Report 118.

Chhabra, R. 1996. *Soil Salinity and Water Quality.* Raju Primlain for Oxford and IBH Publishing Company Private Limited, Najafgarh Road Industrial Area, New Delhi, India. Pp. 156-182.

Chadderton, R.A. 1988. An alternative to water pollution controls. *Wat. Res. Bull,* 24: 183-187.

Chandrkrachang, S.; Chinadit, U.; Chandayot, P. and Supasin, T. 1991. Profitable spin-off from shrimp seaweed polyculture. *Infofish Intl,* 6: 26-28.

Chen, Y. and Avenimelech, Y. 1986. The role of organic matter in modern Agriculture. *Soil Fertility Journal,* 50(7): 306.

Chowdhury, A.K.M. 1993. Dynamics of rural poverty: an overview, BIDS. In: *Poverty Issues in Bangladesh: A strategy Review,* DFID-Bangladesh.

Chowdhury, M.A.; Shivakoti, G. and Salequzzaman, M. 2006. A conceptual framework for the sustainability assessment procedures of the shrimp aquaculture industry in

Bangladesh. *International Journal of Agricultural Resource, Governance and Ecology,* 5(2/3): 162-184.

Cheftel, J.C.; Cuq, J. And Lorient, D. 1985. *Amino acid, peptides and proteins. In Food Chemistry,* (O. Fennema, ed.). Marcel Dekker, Inc., New York, NY. Pp. 245-370.

Cifuents, F.R. and Lindemann, W.C. 1998. Organic matter stimulation of elemental sulfur oxidation in a calcareous soil. *Soil Science Society of American Journal,* 57: 727-731.

Chopra, S.L. and Kanwar, J.S. 1980. *Analytical Agricultural chemistry.* Kalyani Publishers, Ludhiana, New Delhi, India. Pp. 148-289.

Common, M. 1988. *Environmental and resource economics: An introduction.* Longman, London.

Costa, R.W. 1977. Fertilizer value of shrimp and crab processing wastes. M.S. Thesis, Oregon State University.

Daily Purbanchal. 2012. Unethical fair trade practices in Khulna region.

Deb, A.K. 1997. Fake Blue Revolution: Environmental and Socio-Economic Impact of Shrimp Culture in the Coastal Areas of Bangladesh, Community Development Centre (CDC), Canada.

Department of Nutrition and Food Science. 1992. Nutritional value of fresh shrimp/ fresh shrimp waste and dry shrimp/ dried shrimp wastes. Department of Nutrition and Food Science, Dhaka, 1000.

Derm Flynn.; Catherine barrett.; Jessie bird. and Priscilla Boutcher. 2001. A call to action on environmental protection; Public consultations on waste management. Waste Management Advisory Committee. Newfoundland.

Dillon, M. 1993. The implications of EC legislation/regulations and harmonised technical standard norms to ACP exports. National Export Conference, December 1993, UMA, Uganda.

DOE (Department of Environment). 2004. Environment quality standards for Bangladesh Report.

DOF, 2011. Fisheries Resource information of Bangladesh In: Shharanika (Motssha Shaptaha-20011). Ministry of Fisheries and Livestock, Peoples Republic of Bangladesh. Pp. 65-76.

DOF, 2012. Shrimp Resources Statistics. Central Shrimp Cell, Department of Fisheries, Government of Bangladesh, Dhaka. 65pp.

Dogbe. 2010. *Green manure crops for sustainable agriculture in the inland valleys of Northern Ghana.* IDRC publishers, Canada.

Dreeling, N.; Allen, P. and Butler, F. 2000. Effect of cooking method on sensory and instrumental texture attributes of low fat beefburgers. *Lebensm. Wiss. Technol,* 33: 234-238.

Dzeizak, J.D. 1990. Phosphates improve many foods. *Food Technol,* 44: 80-92.

ECA (The Environment Conservation Act). 1995. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Gazette.

ECR (The Environment Conservation Rules). 1997. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Gazette, Extra-ordinary Issue of 28-8-1997 and amended by Notifications S.R.O 29-Law/2002, S.R.O 234-Law/2002 and S.R.O 88-Law/2003.

EJF. 2003. Draft protocol for sustainable shrimp production. Environmental Justice Foundation.

Enamul Haque, A.K. 2011. Sanitary and Phyto-Sanitary Barriers to Trade and its Impacts on the Environment, The case of Shrimp Farming in Bangladesh. North South University, Dhaka.

EPA. 1974. NTIS U.S. Department of Commerce, PB-238, 648pp.

Erdogdu, F.; Luzuriaga, D.A.; Balaban, M.O. and Chau, K.V. 2001. A predective model and yield loss in phosphate- treated, cooked tiger shrimp (*penaeus monodon). J. Aquat. Food Product Technol,* 10:31-44.

Escutia, Sergio. 1997. Current status and future development of shrimp Farming in Mexico from an Environmental standpoint. A Paper Presented at the World Aquaculture conference, February 19-23, 1997. Seattle, Washington.

FAO. 2002. Review of the state of world fishery resources, aquaculture, FAO Fisheries circular.

Fitz Patrick, E.A. 1986. *An introduction to Soil Science,* 2nd edition, Longman Group Limited, Hongkong.

Fujioka, M.; Jaynes, J. B.; Bejsovec, A. and Weir, M. 1999. Production of Transgenic *Drosophila*. In *Developmental Biology Protocols* (ed. R. S. Tuan and C. W. Lo). Humana Press Inc., Totowa, New Jersey.

Gerzabek, R. and Ullah, S.M. 1989. Humic substance in soils from Bangladesh, Namibia and Canada. *International Agrophysics,* 5(3-4): 197-203.

Gupta, S.C.; Dowdy, R.H. and Lorson, W.E. 1977. Hydraulic and thermal properties of a sandy soil as influenced by incorporation of sewage sludge, *Soil Science Society of America Journal,* 41: 601-605.

Gupta, S.K. and Gupta, I.C. 1987. *Management of saline soils and waters.* Oxford and IBH Publishing Co. Ltd, New Delhi. pp. 73-99.

Gupta, P.K. 1999. *Handbook of soil fertilizer and manure.* 2nd Edition, Agro botanica publishers, New Delhi.

Gupta, A.K. and Govindarajan, V. 2000. Knowledge flows within multinational corporations. *Strategic Management Journal,* 21: 473-496.

Hamid, M.A. and Alauddin, M. 2013. Coming out of their homesteads? Employment for rural women in shrimp aquaculture in coastal Bangladesh. *International journal of Social economics,* 25(2-4): 314-317.

Haque, S.M. 1994. Annual report of Bangladesh Frozen Foods Exporters Associations

(BFFEA). Dhaka, BFFEA Special Bulletin, January 1994.

Harler, C.R. 1956. *Tea culture and marketing of Tea* (2nd edition). Oxford University Press, London. pp. 28-31.

Harley, J.P. and Prescott, L.M. 2002. *Laboratory Exercise in Microbiology,* 5th edition, McGraw Hill Inc., New York.

http://en.wikipedia.org/wiki/sodium_triphosphate

Hayward, H.E.; Long, E.M. and Uhvits, R. 1946. The effects of Chlorides and Sulphate salts on the growth and development of the Alberta peach on shalil and Lovell root stocks. *Advan. Agron*, 1: 38-42.

Hayward, H.E. and Wadleigh, C.H. 1949. Plant growth on the saline and alkali soils. *Advan. Agron*, 3: 1-18.

Hossain, A.T.M.B. and Mc Conchie, D.M. 1994. Soil and siltation in some coastal areas of Bangladesh. *Journal of Asiatic Society bangladesh Science,* 20: 39-45.

Howard, G. 1997. Water usage and minimization in fish processing (paper 5). In: Proceedings of the Humber Waste Seminar, Seafish Report SR505, Seafish Industry Authority, Hull, 1997.

Hunt, D.T.E. and Wilson, A.L. 1986. *The Chemical Analysis of Water: General Principles and Techniques* (2nd edition). The Royal Society of Chemistry, The Science Park Cambridge. Pp.1-12.

Imamul Huq, S.M. and Didar-ul-Alam, M.D. (eds.). 2005. *A Handbook on Analysis of Soil, Plant and Water.* BACER-DU, University of Dhaka, Bangladesh. Pp. 43-100.

Islam, A.J.M.A. 1977. Sulfur deficiency – a new problem coming up in rice cultivation of Bangladesh. Paper presented at BRRI sulfur seminar in December-1977. 31pp.

Islam, M. and Hossain, M. 1974. *Cha.* Camellia agro Industrial services Ltd. Mogbazar, Dhaka. pp. 96-98.

Islam, M.S.; Khan, S. and Tanaka, M. 2004. Waste loading in shrimp and fish processing effluents: potential source of hazards to the coastal and nearshore environment. *Marine Pollution Bulletin,* 49 (1-2): 103-110.

Jackson, M.L.1962. *Soil Chemical Analysis.* Prentice Hall, Inc. Englewood cliffs, NZ.

Jackson, M.L. 1967. *Soil Chemical Analysis.* Prentice Hall of India Private Limited, New Delhi. 498pp.

Jackson, M.L.1973. *Soil Chemical Analysis.* Prentice Hall of India Pvt. Ltd. New Delhi, India, pp. 106-203.

Jensen, C.L. 1965. Industrial wastes from seafood plants in the state of Alaska. Proc. *20th Industrial Waste Conf. Purdue University Engg.* Ext. Series, No. 118, pp. 329-350.

Karanth, K.R. 1994. *Groundwater Assessment Development and Management,* Tata McGraw Hill Publishing Co Pvt. Ltd., New Delhi.

KDA. 2012. Drainage system of Khulna region. Khulna Development Authority, Khulna.

Kelling, K.A.; Peterson, A.E. and Walse, L.M. 1977. Effect of waste water sludge on soil moisture relationship and surface runoff. *Water pollution control federation journal,* 49: 1698-1703.

Ken Killham. 1994. *Soil Ecology,* Press Syndicate of the University of Cambridge, New York, 25pp.

Khan, Y.S.A. and Hossain, M.S. 1996. Impact of shrimp culture on the environment of Bangladesh. *Intl. J. Ecol. Environ. Sci,* 22:145-158.

Khan, Z.H.; Mazumder, A.R.; Hossain, M.S.; Mohiuddin, A.S.M. and Shaheed, S.M. 1998. Physical Properties of Some Benchmark soils from the Flood-Plains of Bangladesh. *J. Ind. Soil. Sc. Soc,* 46 (3): 442-446.

Kladivko, E.J. and Nelson, D.W. 1979. Change in soil properties from application of anaerobic sludge. *Water Pollution Control Federation Journal, 51: 325-332.*

Lenore, S.; Clesceri, A. E.; Greenberg. and Andrew, D Easton. 1998. *Standard Methods for the Examination of Water and Wastewater,* 20th Edition, American Public Health Association, pp. 3-65.

Lin, C.K. and Nash, G.L. 1996. Asian Shrimp News, Collected Columns, 1989-1995.

Asian Shrimp Culture Council, Bangkok, Thailand.

Macintosh, D.J. and Phillips, M.J. 1992. Environmental issues in shrimp farming.In: Shrimp '92. Proceedings of the 3rd Global Conference on the Shrimp Industry. Hong Kong. 14-16 September 1992 (ed. by H. de Saram and T. Singh). pp. 118-145. *Infofish*. Kuala Lumpur.

Manmathan, H. and Lipitan, N.L. 2013. Measuring germination percentage in seeds, *Bio-protocol,* 3(16):866.

Mauldin, A.I. and Szabo, A.J. 1974. Shrimp canning waste treatment. St. project no 8. Office of Research and Development, US SPA, Washington, DC.

Martin, F.F.; Cofrades, S.; Carballo, J. and Jimenez-Colmenero, F. 2002. Salt and phosphate effects on the gelling process of pressure/heat treated pork batters. *Meat Sci.* 61: 15-23.

McDonald, C.; Ince, M.E.; Smith, M.D. and Dillon, M. 1999. Fish processing in Uganda: waste minimization. In: 25th WEDC Conference on Integrated Development for Water Supply and Sanitation.

Meyers, S.P. 1986. Utilization of shrimp processing waste . *INFOFISH Marketing Digest,* 4: 18-19.

Michael, R.; Overcash. and Dhiraj Pal. 1980. Characterization and land application of seafood industry wastewaters. Department of Biological and Agricultural Engineering, North Carolina State University, North Carolina 27650.

Misra, R.D. and Ahmed, M. 1987. *Manual on irrigation agronomy.* Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, India.

Muslem, M.; Farid, A.T.; Miah, M.A.; Jahiruddin, M.; Rahman, A.M.; Quayyum, M.A.; Sattar, M.A.; Motalib, M.A.; Islam, M.F.; Ahsan, M. and Razia, M.S. 2005. *Fertilizer Recommendation guides.* Bangladesh Agricultural research Council. Farmgate, Dhaka-1205.

NACA (Network of Aquaculture Centres in Asia). 1995. Regional study and workshop on the environmental assessment and management of aquaculture development. FAO of UN and Network of Aquaculture Center in Asia-Pacific, Bankok, Thailand.

Nuruzzaman, M.; Islam, A.; Ullah, S.M.; Rashid, M.H. and Gerzabek, M.H. 1998. Contamination of soil environment by the tannery industries. *Bangladesh J. Soil. Sci.* 25: 1-10.

Nuruzzaman, M. 2006. Dynamics and diversity of shrimp farming in Bangladesh: Technical aspects. pp. 431-460. In: Rahman, A.A.; Quddus, A.H.G.; Pokrant, B. and Ali, M.L. (eds.), *Shrimp Farming and Industry: Sustainability, Trade and Livelihoods*, a book published by Bangladesh Centre for Advanced Studies (BCAS) and University Press Ltd.

Páez-Osuna.; Federico.; Saúl Guerrero-Galván. and Ana Ruiz-Fernández. 1998. *Waste Management Options for Mississippi Shrimp Processors.* Mississippi State University press. Pp. 38-42.

PDO-ICZMP. 2002. Previous Initiatives and Base Conceptual Documents, Working Paper WP001. Program Development Office-Integrated Coastal Zone Management, Water Resources Planning Organization, Ministry of Water Resources, Dhaka, Bangladesh. May 2002.

Portman, J.E. and Riley, J.P. 1964. Determination of Arsenic in seawater, marine plants and silicate and carbonate sediments. *Anal. Chim. Acta.* 31:509-519.

Piper, C.S. 1950. *Soil and Plant Analysis.* The University of Adelaide Press, Adelaide, Australia.

Pokrant, B.; Reeves. and Rahman, A.A. 2002. The Organization and Development of Coastal Brackish- Water Export – Oriented Shrimp production in Bangladesh: A Critical Review of the Literature, In Delivered at the ISA XV World Congress of Sociology in Brisbane, Session 7, Australia.

Primavera, J.H. 1993. A critical review of shrimp pond culture in the Philippines. *Reviews in Fisheries Science*, 1:151-201.

Rabalais, N.N.; Wiseman, W.J. and Turner, R.E. 1994. Comparison of Continuous records of near bottom dissolved oxygen from the hypoxia zone along the LA coast. *Estuaries,* 17:850-861.

Ramesh, R. and Anbu, M. 1996. *Chemical Methods for Environment analysis-Water and Sediment.* Macmillan India Ltd. pp-15-67.

Ramírez, Juan Carlos. 1999. Contaminación a "Ojos Vista." El Debate. August 23rd. Pp. 1-6.

Rao, B.K.; Panchaksharajah, S.; Patil, B.N.; Narayana, A. and Raiker, D.L. 1982. Chemical composition of irrigation water from a selected parts of Bijoypur District, Mysore, Karnataka, *Journal of Agricultural Science,*16(4): 426-432.

Rashid, M.A.; Ahmed, M.K. and Khan, Y.S.A. 2000. Critical Control Points in the shrimp processing plant of Bangladesh for quality control of frozen shrimp. *Bangladesh Journal of Zoology,* 28 (1): 55–61.

Rattan Lal and Monoj K. Shukla. 2002. *Principles of Soil Physics.* Marcel Dekker Inc. New York, USA. Pp. 288-290.

Reza, I. and Rahman, R. 2015. Removal of heavy metal from contaminated soil. B.Sc Engineering Thesis, Civil and Environmental Engineering Department, Shahjalal University of Science and Technology, Sylhet, Bangladesh.

Rezaul Karim, M. and Selina Ahmed. 2010. Livelihood pattern and security of women working in Shrimp processing industries located in southwest Bangladesh. National Conference on The Sunderbans and Environment of Southwest Bangladesh. Khulna University research Cell, Khulna University

Rhoades, J.D. and Bernstein, L. 1971. Chemical, Physical and Biological Characteristics of irrigation and soil water. (*In: Water and Water pollution handbook,* Vol 1 Ed. Ciaccio, L.L) Marcel Dekker, New York, pp. 141-222.

Riegman, R. 1995. Nutrient-related selection mechanisms in marine plankton communities and the impact of eutrophication on the plankton food web. *Water Science Technology*, 32: 63–75.

Rosen, C.J. and Bierman, P.M. 2005. *Maintaining Soil Fertility in an Organic Fruit and vegetable crops system.* IDRC publishers, Canada.

Rowe, R.K. and Fraser, M.J. 1995. Effect of Uncertainty in the Assessment of the Potential Impact of Waste Disposal Facilities. *Geoenvironmental 2000, Proceedings of a ASCE Specialty Conference*, Geotechnical Special Publication No. 46, Vol. 1, New Orleans, Louisianna, USA, February 1995, pp. 270-284.

Ruhlmann, J.; Korchens, M. and Graefe, J. 2006. A new approach to calculate the particle density of soils considering properties of the soil organic matter and the mineral matrix. *Geodarma,* 130: 172-183.

Saeed, A.; Malik., T.Z.; Dasti, A.A. and Zaib-Un-Nisa Abidi, S. 2003. Effect of Waste water Effluents on the Growth of Some Crop Plants. *Asian Journal of Plant Sciences,* 2(8): 623-626.

Saha, S.K. 2001. A project report on water quality assessment of the Rupsha river around Khulna city corporation. Khulna University Research cell, Bangladesh. 40pp.

Salam, M.T.B. and Billah, S.M. 2013. Assessment of irrigation water quality as deteriorated by effluent discharged from major Shrimp Processing Industries of Rupsha Upazila, Khulna, Bangladesh. *Khulna University Studies,* 11(1 & 2) and 12 (1 & 2): 121-127.

SANDEE (South Asian Network for Development and Environmental Economics). 2009. Shrimp, Salinity and Sustainability - An Assessment from Southern India. SANDEE Policy Brief. Pandit Jawaharlal Neheru College of Agriculture and Research Institute, Karaikal, India.

Shafiqur Rahman, Sk.; Begum, N.N. and Rahman, M.M. 2010. Status of stakeholders of shrimp marketing channel in Bagerhat district with a view to environmental protection and management. *Khulna University Studies,* 10(1&2): 99-105.

Silviera, D.J. and Sommers, L.E. 1997. Extractability of Cu, Zn, Cd and Pb in soils incubated with wastes. *Journal of Environmental Quality,* 6: 47-52.

Sodrul Amin, M. 1998. *Poribesh Bigwan o Mrittika Rosayon,* Bangla Academy, Dhaka, 1000. 72pp.

Soeb Mahmud, M. 2007. *Manual for Shrimp Processing,* Jalalabad Frozen Foods Ltd. pp. 36.

Soni, Rajendra. and Abbasi, S.A. 1981. Mortality and reproduction in earthworms *Pheretima Posthuma* exposed to Cr^{6+}. *Int. J. Environ. Stud,* 17(2): 147-149.

SRDI (Soil Resource and Development Institute). 1989. *Vumi o mrittika Sompod Babohar Nirdeshika, Rupsha upazilla, khulna.* SRDI, Farmgate, Dhaka-1215. 40pp.

Steven, O.W. 1981. Seafood waste management in the 1980s. Conference Proceedings Report. Number 40. Florida Sea Grant College.

Stonich Susan. 1995. The Environmental Quality and Social Justice Implications of Shrimp Mariculture Development in Honduras. *Human Ecology,* 23(2):143-168.

Stevens, W.F. 1996. Chitosan; a Compound in Biology and Bioprocess Technology., Stevens, W.F.; Rao, M.S. and Chandrkrachang, S. (Eds.) *Chitin and Chitosan-Processings of the Second Asia Pacific Symposium.* Pp. 13-21.

Steinhauer, J.E. 1983. Food phosphates for use in meat, poultry and sea food industry. *Dairy Food Sanitat*, 3: 244-247.

Stomberg, A. L.; Hemphill, D.D. and Volk, V.V. 1984. Yield and elemental concentration of sweet corn grown on tannery waste- amended soil. *J. Environ. Qual,* 13(1): 162-166.

Subashinghe, S. 1999. Chitin from shellfish waste health benefit overshadowing industrial uses. *Infofish Intl,* 3:57-63.

Superno and Poernomo, A. 1992. Fish waste utilization in Indonesia. *ASEAN Food J.* 7: 67-72.

Szabo, A.J.; Larry, F.L. and Felon, R.W. 1979. Dissolved air flotation treatment of gulf shrimp cannery wastewater. Industrial Environmental Research Laboratory, Office of Research and Development, US EPA Cincinnati, OH.

Tan Kim, H. 1994. *Environmental Soil Science,* Mercel Dekker, Inc. Newyork, pp. 236-237.

Todd, D.K. 1980. *Ground water hydrology,* (1st edition). John Wiley and Sons. New York, USA. Pp. 205-215.

Todd, D.K. 2001. *Ground water hydrology,* (2nd edition). John Wiley and Sons. New York, USA. Pp. 267-315.

Trivedi, P.R. and Gurdeep, R. 1992. *Environmental water and soil analysis.* Akashdeep publishers house, Delhi, India, pp. 141-152.

USDA (United States Department of Agriculture). 1951. *Soil Survey Manual*. Soil Survey Staff, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, Washington, Handbook 18.

USDA (United States Department of Agriculture). 2004. *Soil survey Laboratory Manual.* Soil Survey Investigation, Report no. 42, Version 4, USDA-NRCS, Nebraska, USDA, USA.

Umeda, Y. and Yamada, N. 1980. Changes in the physical and chemical properties of soil with irrigation and drainage, *Technical Bulletin of Faculty of agriculture, Kagawa University,* 32(1): 41-46.

Unal, S.B.; Erdogdu, F. And Ekiz, H.I. 2006. Effect of temperature on phosphate diffusion in meats. *J. Food Eng,* 76: 119-127.

Vallini, G.; Pera, A.; Cecchi, F.; Brigla, M. and Perghem, F. 1989. Waste Management and Research. *J. of waste management,* 7: 277- 290.

Waldon, M. 1991. Bayou Grand Caillou water quality study: shrimp processor discharge impact assessment. Baton Rouger Office of Water Resources. Lotasiana Department of Environmental Quality.

Watson, D.J.; Thom, G.N. and French, S.A. 1958. Physiological causes of differences in grain yield between verities of barley. *Annual Botany,* 22:234-352.

Weather Observation Center. 2013. Monthly mean rainfall (mm) and Monthly mean temperature (◦C) during last 20 years in Khulna region, Weather observation center, Gallamari, Khulna.

Wheatley, A. (Ed.). 1991. Anaerobic Digestion: A waste Treatment Technology, Critical Reports on Applied Chemistry, Vol. 31. Elsevier Applied Science, London, UK.

WHO (World Health Organization). 1993. *WHO guidelines for drinking water quality,* vol:l. Genera, Switzerland.

WHO (World Health Organization). 2003. *WHO guidelines for drinking water quality,* Genera, Switzerland.

Widarto. 1989. Utilization of shrimp waste as head meal in Muara, Ankejakra. *Tech. Rep. Diplomaiv. Fish. Acad,* 55pp.

Williams, D. and Khan, N.A. 2002. Freshwater prawn farming in gher systems: Indigenous technology developed in south-west Bangladesh. Greater options for local development through aquaculture (GOLDA) project, CARE-Bangladesh, GPO Box No. 226, Dhaka 1000.

Zahurul Haque, M. and Saifuzzanman, M. 1991. Social and Environmental effects of shrimp cultivation in Bangladesh: Notes on study Methods. Globalization, Environmental Crisis Social change in Bangladesh, Edited by Matiur Rahman.

8. Statistics:

8.1. Oneway ANOVA table for effluents.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Turbidity	Between Groups	887967.692	12	73997.308	890.708	.000
	Within Groups	2160.000	26	83.077		
	Total	890127.692	38			
pH	Between Groups	1.683	12	.140	10.008	.000
	Within Groups	.364	26	.014		
	Total	2.047	38			
EC	Between Groups	420.870	12	35.073	250.624	.000
	Within Groups	3.638	26	.140		
	Total	424.509	38			
Salt	Between Groups	1.724	12	.144	254.641	.000
	Within Groups	.015	26	.001		
	Total	1.738	38			
DO	Between Groups	37.903	12	3.159	477.464	.000
	Within Groups	.172	26	.007		
	Total	38.075	38			
TDS	Between Groups	6416618.308	12	534718.192	654.798	.000
	Within Groups	21232.000	26	816.615		
	Total	6437850.308	38			
TSS	Between Groups	2414144.769	12	201178.731	329.884	.000
	Within Groups	15856.000	26	609.846		
	Total	2430000.769	38			
BOD	Between Groups	294371.077	12	24530.923	202.735	.000
	Within Groups	3146.000	26	121.000		
	Total	297517.077	38			
COD	Between Groups	2265911.077	12	188825.923	484.551	.000
	Within Groups	10132.000	26	389.692		
	Total	2276043.077	38			
CO3	Between Groups	.000	12	.000	.	.
	Within Groups	.000	26	.000		
	Total	.000	38			
HCO3	Between Groups	2975.685	12	247.974	228.065	.000
	Within Groups	28.270	26	1.087		

		Sum of Squares	df	Mean Square	F	Sig.
HCO3	Total	3003.955	38			
SO4	Between Groups	396805.692	12	33067.141	72.438	.000
	Within Groups	11868.667	26	456.487		
	Total	408674.359	38			
Cl	Between Groups	1989.851	12	165.821	1.006	.471
	Within Groups	4283.808	26	164.762		
	Total	6273.658	38			
NO3	Between Groups	544.062	12	45.339	253.386	.000
	Within Groups	4.652	26	.179		
	Total	548.714	38			
Na	Between Groups	7664.769	12	638.731	25.787	.000
	Within Groups	644.000	26	24.769		
	Total	8308.769	38			
K	Between Groups	13.588	12	1.132	58.367	.000
	Within Groups	.504	26	.019		
	Total	14.092	38			
Ca	Between Groups	1361.844	12	113.487	147.817	.000
	Within Groups	19.962	26	.768		
	Total	1381.805	38			
Mg	Between Groups	123.339	12	10.278	216.595	.000
	Within Groups	1.234	26	.047		
	Total	124.573	38			
Zn	Between Groups	21134.571	12	1761.214	144.608	.000
	Within Groups	316.660	26	12.179		
	Total	21451.231	38			
Mn	Between Groups	46670.769	12	3889.231	192.977	.000
	Within Groups	524.000	26	20.154		
	Total	47194.769	38			
Pb	Between Groups	173.077	12	14.423	9.698	.000
	Within Groups	38.667	26	1.487		
	Total	211.744	38			
Cd	Between Groups	1.417	12	.118	49.676	.000

		Sum of Squares	df	Mean Square	F	Sig.
Cd	Within Groups	.062	26	.002		
	Total	1.479	38			
Cr	Between Groups	94.980	12	7.915	39.124	.000
	Within Groups	5.260	26	.202		
	Total	100.240	38			
Ni	Between Groups	590.788	12	49.232	176.314	.000
	Within Groups	7.260	26	.279		
	Total	598.048	38			
SAR	Between Groups	174.622	12	14.552	9.012	.000
	Within Groups	41.983	26	1.615		
	Total	216.605	38			
SSP	Between Groups	825.756	12	68.813	8.732	.000
	Within Groups	204.891	26	7.880		
	Total	1030.647	38			
Hardness	Between Groups	18303.758	12	1525.313	272.689	.000
	Within Groups	145.433	26	5.594		
	Total	18449.191	38			

8.2. Oneway ANOVA Table for soil samples.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
MC	Between Groups	331.084	12	27.590	58.647	.000
	Within Groups	12.232	26	.470		
	Total	343.316	38			
Db	Between Groups	.194	12	.016	5.017	.000
	Within Groups	.084	26	.003		
	Total	.278	38			
pH	Between Groups	1.315	12	.110	27.165	.000
	Within Groups	.105	26	.004		
	Total	1.420	38			
EC	Between Groups	50.269	12	4.189	37.957	.000
	Within Groups	2.869	26	.110		
	Total	53.138	38			
Salt	Between Groups	.206	12	.017	37.214	.000

	Within Groups	.012	26	.000		
	Total	.218	38			
CEC	Between Groups	1580.385	12	131.699	20.575	.000
	Within Groups	166.422	26	6.401		
	Total	1746.807	38			
OC	Between Groups	4.862	12	.405	17.414	.000
	Within Groups	.605	26	.023		
	Total	5.466	38			
OM	Between Groups	14.327	12	1.194	17.582	.000
	Within Groups	1.766	26	.068		
	Total	16.093	38			
TN	Between Groups	.028	12	.002	2.756	.015
	Within Groups	.022	26	.001		
	Total	.051	38			
AvN	Between Groups	49930.779	12	4160.898	178.137	.000
	Within Groups	607.303	26	23.358		
	Total	128.473	12	10.706		.401
CN	Between Groups	128.473	12	10.706	1.1	.401
	Within Groups	253.428	26	9.747		
CN	Total	381.901	38			
Na	Between Groups	78847.680	12	6570.640	312.841	.000
	Within Groups	546.082	26	21.003		
	Total	79393.761	38			
K	Between Groups	70.539	12	5.878	367.919	.000
	Within Groups	.415	26	.016		
	Total	70.954	38			
Ca	Between Groups	193.073	12	16.089	120.910	.000
	Within Groups	3.460	26	.133		
	Total	196.532	38			
Mg	Between Groups	7.568	12	.631	27.291	.000
	Within Groups	.601	26	.023		
	Total	8.169	38			
P	Between Groups	682.848	12	56.904	102.862	.000
	Within Groups	14.383	26	.553		
	Total	697.231	38			
S	Between Groups	1048.147	12	87.346	118.135	.000
	Within Groups	19.224	26	.739		
	Total	1067.370	38			

		Sum of Squares	df	Mean Square	F	Sig.
Zn	Between Groups	38903.537	12	3241.961	113.289	.000
	Within Groups	744.033	26	28.617		
	Total	39647.571	38			
Mn	Between Groups	1368662.769	12	114055.231	139.040	.000
	Within Groups	21328.000	26	820.308		
	Total	1389990.769	38			
Pb	Between Groups	348.000	12	29.000	26.929	.000
	Within Groups	28.000	26	1.077		
	Total	376.000	38			
Cd	Between Groups	1.772	12	.148	17.455	.000
	Within Groups	.220	26	.008		
	Total	1.992	38			
Cr	Between Groups	2544.577	12	212.048	30.424	.000
	Within Groups	181.212	26	6.970		
	Total	2725.789	38			
Ni	Between Groups	2618.003	12	218.167	37.856	.000
	Within Groups	149.840	26	5.763		
	Total	2767.843	38			
DOC	Between Groups	140081.077	12	11673.423	47.752	.000
	Within Groups	6356.000	26	244.462		
	Total	146437.077	38			
NH4	Between Groups	37686.804	12	3140.567	192.752	.000
	Within Groups	423.627	26	16.293		
	Total	38110.431	38			
Cl	Between Groups	1.509	12	.126	56.359	.000
	Within Groups	.058	26	.002		
	Total	1.567	38			

8.3. ANOVA table for Number of leaves/Plant of Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	19.78	5	3.96	210.43	5%=3.33	Cal>Tab	Sig	0.25
Replication	18.34	2	9.17	487.71	5%=4.1	Cal>Tab	Sig	
Error	0.188	10	0.0188					
Total		17						

8.4. ANOVA table for Number of leaves/Plant of Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	61.51	5	12.3	102.5	5%=3.33	Cal>Tab	Sig	0.63
Replication	0.54	2	0.27	2.25	5%=4.1	Cal<Tab	Insig	
Error	1.19	10	0.12					
Total		17						

8.5. ANOVA table for Number of leaves/Plant by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	53.85	5	10.77	76.93	5%=3.33	Cal>Tab	Sig	0.68
Replication	0.27	2	0.135	0.96	5%=4.1	Cal<Tab	Insig	
Error	1.4	10	0.14					
Total		17						

8.6. ANOVA table for Fresh weight/Plant of Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	3.65	5	6.13	116.98	5%=3.33	Cal>Tab	Sig	0.49
Replication	0.018	2	0.009	0.172	5%=4.1	Cal<Tab	Insig	
Error	0.524	10	0.0524					
Total		17						

8.7. ANOVA table for Fresh weight/Plant of Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	27.69	5	5.54	24.53	5%=3.33	Cal>Tab	Sig	0.86
Replication	1.785	2	0.8925	3.95	5%=4.1	Cal<Tab	Insig	
Error	2.2586	10	0.2259					
Total		17						

8.8. ANOVA table for Fresh weight/Plant by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	1.81	5	0.362	21.94	5%=3.33	Cal>Tab	Sig	0.23
Replication	0.015	2	0.0075	0.45	5%=4.1	Cal<Tab	Insig	
Error	0.165	10	0.0165					
Total		17						

8.9. ANOVA table for Dry weight/Plant of Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	1.93	5	0.38	82.6	5%=3.33	Cal>Tab	Sig	0.1
Replication	0.02	2	0.01	2.17	5%=4.1	Cal<Tab	Insig	
Error	0.046	10	0.0046					
Total		17						

8.10. ANOVA table for Dry weight/Plant of Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	3.44	5	0.69	23	5%=3.33	Cal>Tab	Sig	0.31
Replication	0.22	2	0.11	3.66	5%=4.1	Cal<Tab	Insig	
Error	0.32	10	0.03					
Total		17						

8.11. ANOVA table for Dry weight/Plant by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	0.4776	5	0.0955	0.91	5%=3.33	Cal<Tab	Insig	0.59
Replication	0.0004	2	0.0002	0.0019	5%=4.1	Cal<Tab	Insig	
Error	0.0542	10	0.1054					
Total		17						

8.12. ANOVA table for %MC of Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	34.3	5	6.86	0.83	5%=3.33	Cal<Tab	Insig	5.22
Replication	11.66	2	5.83	0.83	5%=4.1	Cal<Tab	Insig	
Error	82.23	10	8.223					
Total		17						

8.13. ANOVA table for %MC of Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	53.45	5	10.69	1.44	5%=3.33	Cal<Tab	Insig	4.96
Replication	10.79	2	5.4	0.73	5%=4.1	Cal<Tab	Insig	
Error	74.34	10	7.43					
Total		17						

8.14. ANOVA table for %MC by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	58.86	5	11.77	2.39	5%=3.33	Cal<Tab	Insig	4.04
Replication	7.05	2	3.53	0.72	5%=4.1	Cal<Tab	Insig	
Error	49.32	10	4.93					
Total		17						

8.15. ANOVA table for % N uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	2.37	5	0.47	4.18	5%=3.33	Cal>Tab	Sig	0.6
Replication	0.02	2	0.01	0.89	5%=4.1	Cal<Tab	Insig	
Error	0.11	10	0.113					
Total		17						

8.16. ANOVA table for % N uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	0.826	5	0.165	26.19	5%=3.33	Cal>Tab	Sig	0.085
Replication	0.0126	2	0.006	0.58	5%=4.1	Cal<Tab	Insig	
Error	0.1095	10	0.01095					
Total		17						

8.17. ANOVA table for % N uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	2.52	5	0.5	62.5	5%=3.33	Cal>Tab	Sig	0.16
Replication	0.04	2	0.02	2.5	5%=4.1	Cal<Tab	Insig	
Error	0.08	10	0.008					
Total		17						

8.18. ANOVA table for P uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	46150	5	9230	30.41	5%=3.33	Cal>Tab	Sig	31.69
Replication	220.4	2	110.23	0.36	5%=4.1	Cal<Tab	Insig	
Error	3035.5	10	330.56					
Total		17						

8.19. ANOVA table for P uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	60369.1	5	12073.8	46.4	5%=3.33	Cal>Tab	Sig	30.99
Replication	971.44	2	445.72	1.87	5%=4.1	Cal<Tab	Insig	
Error	2601.89	10	260.19					
Total		17						

8.20. ANOVA table for P uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	64026	5	12805.25	62.04	5%=3.33	Cal>Tab	Sig	26.1
Replication	1070.11	2	535.06	2.59	5%=4.1	Cal<Tab	Insig	
Error	2063.89	10	206.39					
Total		17						

8.21. ANOVA table for S uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	11140	5	2228	41.64	5%=3.33	Cal>Tab	Sig	13.3
Replication	92	2	46	0.86	5%=4.1	Cal<Tab	Insig	
Error	335	10	53.5					
Total		17						

8.22. ANOVA table for S uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	14774.4	5	2954.88	55.72	5%=3.33	Cal>Tab	Sig	21.06
Replication	120.44	2	60.22	1.13	5%=4.1	Cal<Tab	Insig	
Error	530.23	10	53.023					
Total		17						

8.23. ANOVA table for S uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	9492.94	5	1898.59	698	5%=3.33	Cal>Tab	Sig	10.96
Replication	5.44	2	2.72	0.075	5%=4.1	Cal<Tab	Insig	
Error	362.78	10	36.28					
Total		17						

8.24. ANOVA table for Zn uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	156.3	5	31.26	4.82	5%=3.33	Cal>Tab	Sig	4.63
Replication	4.92	2	2.46	0.38	5%=4.1	Cal<Tab	Insig	
Error	64.8	10	6.48					
Total		17						

8.25. ANOVA table for Zn uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	445.55	5	91.11	19.98	5%=3.33	Cal>Tab	Sig	3.88
Replication	25.84	2	12.92	2.83	5%=4.1	Cal<Tab	Insig	
Error	45.64	10	4.564					
Total		17						

8.26. ANOVA table for Zn uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	365.4	5	71.28	40.73	5%=3.33	Cal>Tab	Sig	2.32
Replication	5.88	2	2.94	1.68	5%=4.1	Cal<Tab	Insig	
Error	17.47	10	1.75					
Total		17						

8.27. ANOVA table for Mn uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	353.11	5	70.62	11.97	5%=3.33	Cal>Tab	Sig	4.45
Replication	12.11	2	6.06	1.01	5%=4.1	Cal<Tab	Insig	
Error	59.89	10	5.99					
Total		17						

8.28. ANOVA table for Mn uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	608.94	5	121.79	79.6	5%=3.33	Cal>Tab	Sig	2.25
Replication	3.44	2	1.72	1.12	5%=4.1	Cal<Tab	Insig	
Error	15.28	10	1.53					
Total		17						

8.29. ANOVA table for Mn uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	303.61	5	60.72	49.69	5%=3.33	Cal>Tab	Sig	2.01
Replication	6.778	2	3.389	3.02	5%=4.1	Cal<Tab	Insig	
Error	11.22	10	0.122					
Total		17						

8.30. ANOVA table for Pb uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	16.66	5	3.33	68.98	5%=3.33	Cal>Tab	Sig	0.37
Replication	0.1	2	0.05	1.15	5%=4.1	Cal<Tab	Insig	
Error	0.42	10	0.04					
Total		17						

8.31. ANOVA table for Pb uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	17.57	5	3.514	106.48	5%=3.33	Cal>Tab	Sig	0.33
Replication	0.0767	2	0.038	1.15	5%=4.1	Cal<Tab	Insig	
Error	0.33	10	0.033					
Total		17						

8.32. ANOVA table for Pb uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	21.81	5	4.36	400.15	5%=3.33	Cal>Tab	Sig	0.19
Replication	0.27	2	0.0135	1.24	5%=4.1	Cal<Tab	Insig	
Error	0.109	10	0.0109					
Total		17						

8.33. ANOVA table for Cd uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	0.152	5	0.03	10.25	5%=3.33	Cal>Tab	Sig	0.01
Replication	0.0055	2	0.003	0.93	5%=4.1	Cal<Tab	Insig	
Error	0.0296	10	0.00296					
Total		17						

8.34. ANOVA table for Cd uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	0.1826	5	0.0365	2.07	5%=3.33	Cal<Tab	Insig	0.24
Replication	0.00253	2	0.00127	0.072	5%=4.1	Cal<Tab	Insig	
Error	0.1762	10	0.01762					
Total		17						

8.35. ANOVA table for Cd uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	0.145	5	0.029	6.042	5%=3.33	Cal>Tab	Sig	0.13
Replication	0.00053	2	0.000265	0.055	5%=4.1	Cal<Tab	Insig	
Error	0.048	10	0.0048					
Total		17						

8.36. ANOVA table for Cr uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	15.39	5	3.08	24.43	5%=3.33	Cal>Tab	Sig	0.65
Replication	0.01	2	0.005	0.04	5%=4.1	Cal<Tab	Insig	
Error	1.26	10	0.126					
Total		17						

8.37. ANOVA table for Cr uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	14.24	5	2.8476	123.06	5%=3.33	Cal>Tab	Sig	0.28
Replication	0.151	2	0.0754	3.26	5%=4.1	Cal<Tab	Insig	
Error	0.2314	10	0.0231					
Total		17						

8.38. ANOVA table for Cr uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	2.5914	5	0.5182	11.04	5%=3.33	Cal>Tab	Sig	0.39
Replication	0.09335	2	0.0467	0.99	5%=4.1	Cal<Tab	Insig	
Error	0.46935	10	0.04694					
Total		17						

8.39. ANOVA table for Ni uptake by Red amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	47.67	5	9.53	24.83	5%=3.33	Cal>Tab	Sig	1.14
Replication	0.52	2	0.26	0.68	5%=4.1	Cal<Tab	Insig	
Error	3.84	10	0.384					
Total		17						

8.40. ANOVA table for Ni uptake by Stem amaranth

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	65.82	5	13.12	267.83	5%=3.33	Cal>Tab	Sig	0.4
Replication	0.26	2	0.13	2.65	5%=4.1	Cal<Tab	Insig	
Error	0.49	10	0.049					
Total		17						

8.41. ANOVA table for Ni uptake by Water spinach

SV	SS	df	MSS	F value	T value	Relation	Sig/Insig	LSD value
Treatment	102.33	5	20.47	7.7	5%=3.33	Cal>Tab	Sig	2.97
Replication	3.56	2	1.78	0.67	5%=4.1	Cal<Tab	Insig	
Error	25.59	10	2.66					
Total		17						