Design and Performance Study of a Bench-Scale Biological Wastewater Treatment Plant for a Sea Food Processing Industry.

by

Pronab Kumar Debnath

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering in the Department of Civil Engineering

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Khulna, Bangladesh

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DECLARATION

This is to certify that the thesis work entitled "*Design and Performance Study of a Bench-Scale Biological Wastewater Treatment Plant for a Sea Food Processing Industry.*" has been carried out by *Pronab Kumar Debnath* in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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ABSTRACT

Shrimp industries are though important in respect of foreign earnings they are producing huge amount of wastewater that contain large quantities of biodegradable organic wastes and disposed directly to the environment without any treatment. It is noted that none of the industries are following ECR 1997 (Revised in 2010) and they do not have effluent treatment plant that designed based on the characteristics of shrimp processed wastewater so far. Conventional ETP is physico-chemical type and takes higher cost in operation. Therefore, the best possible biological wastewater treatment plant design and its performance analysis is the main goal of the study. Wastewater has been collected from a selected industry. The wastewater samples were characterized for the basic wastewater qualities. Based on the characterization and literature review the design criteria has been selected. A bench scale treatment plant has been designed and installed in the Environmental Engineering lab. The bench scale plant were run over a designed period of 12 to 13 months during July 2017 to May 2018. About 400 selected samples were collected and tested for were 12 different selected parameters. As found that the shrimp processed wastewater contains large amount of organic waste, thus decision has been taken to design suspended growth activated sludge biological treatment process. In bench scale plant, two clarifiers and an aeration basin have been designed as a completely mixed extended aeration activated sludge process. Collected wastewater from the selected industry and poured in to the bench scale plant. According to design the hydraulic retention time was nearly eight hours. The results show that the raw wastewater of shrimp processing industry contain average DO, $BOD_{5,}$ COD, TDS, SS and Chloride of 2.07, 177, 355, 2894, 383 and 821 mg/L respectively. The EC and pH was contain of 4.51 mS/cm and 8.03. The bench scale plant has removed remarkable organic loading. The BOD_5 reduction has been founded from 177 to 41 mg/L (77%) and COD from 355 to 117 mg/L (67%) respectively. The rest of all parameters have met the national standard. It can be said from the obtained analysis that the treatment was moderate level. Based on the foregoing result it may be said, this design criteria or bench scale plant can be effectively used in shrimp processed wastewater treatment.

INDEX

CONTENT		PAGE
Title Page		i
Declaration		ii
Approval		iii
Acknowledgement		iv
Abstract		vi
Index		vi
List of Tables		ix
List of Figures		x
Nomenclature		Xii
CHAPTER I	**Introduction**	**1**
	1.1 State-of-Art of the proposed study	1
	1.2 Objectives of the research work	2
	1.3 Coverage of the study	3
	1.4 Organization of the study	3
CHAPTER II	**Literature Review**	**5**
	2.1 Historical background	5
	2.2 Sea food processing industries and farming in Bangladesh	6
	2.3 Importance of shrimp process industries in Bangladesh	8
	2.4 Problem of shrimp processed industries	9

	2.5 Wastewater characteristics of shrimp process wastewater	10
	2.6 Technique for shrimp processed wastewater treatment	12
	2.7 Activated sludge process design, operation and control approach	15
	2.7.1 Brief introduction about Activated Sludge Process	15
	2.7.2 Design consideration of ASP	17
	2.7.3. Operational and control approach of ASP	20
	2.7.4 Microorganisms are involve in operation and control	24
	2.7.5 Various control mechanisms	28
CHAPTER III	**Methodology**	**31**
	3.1 Research design	31
	3.2 Industry selection	32
	3.3 Sampling point selection	35
	3.4 Sample collection and preservation	37
	3.5 Analysis of the physical and chemical properties of WW for the plant design	38
	3.6 Design basis	39
	3.7 Design procedure	39
	3.8 The bench scale plant design calculation	42
	3.9 Microbial growth	51
	3.10 Operation and maintenance	51
	3.11 Laboratory analysis	53
	3.12 Data tabulation and analysis	54

CHAPTER IV	**Result and Discussion**	**55**
	4.1 General	55
	4.2 Hydrogen ion concentration (ph)	56
	4.3 Dissolved oxygen	58
	4.4 Biochemical oxygen demand	59
	4.5 Chemical oxygen demand	62
	4.6 Solids	64
	4.7 Chloride	69
	4.8 Electrical conductivity	71
	4.9 Nitrate-Nitrogen and color	72
	4.10 Performance analysis of the bench scale plant	74
	4.10.1 BOD_5 & COD removal	75
	4.10.2 Solids removal efficiency	76
	4.11 Designed and resulted MLVSS	77
CHAPTER V	**Conclusion and Recommendation**	**80**
	5.1 Conclusion	80
	5.2 Recommendations	81
	5.3 Limitations of the study and scope of further work	81
References		**83**
Appendices		

LIST OF TABLES

Table N0.	Description	Page
2.1	Basic information about seafood industries farming and exports	7
2.2	Frozen shrimp and fish export from Bangladesh up to 2017	8
2.3	Operating characteristics and treatment system of biological method	14
2.4	The relationship among θ_c MLSS, DO and COD	20
3.1	Parameters that used for design basis	39
3.2	Range of parameters value that considered for design of the plant	39
3.3	Design information of Bench Scale Plant 01	40
3.4	Design information of Bench Scale Plant 02	41
3.5	Equipment and/or chemicals used in laboratory examined	53
4.1	pH value of raw sample	56
4.2	pH value from raw wastewater to effluent	57
4.3	Color in different sample	74
4.4	The relationship among θ_c , MLSS, DO and COD shown by Jamsed J (1971)	76
4.5	Response the various parameters with two different HRT	77

LIST OF FIGURES

Figure N0.	Description	Page
2.1	Completely mix activated sludge process diagram	16
3.1	Flow diagram for research methodology	31
3.2	Sea food processing zone and shrimp cultivation area of Bangladesh	33
3.3	Shrimp processing factories in Bangladesh	34
3.4	Atlas and Bright seafood processing industry	35
3.5	Wastewater producing unit processes	36
3.6	Sampling design	37
3.7	Sample collection	38
3.8	Process flow diagram	49
3.9	Plan and section of the bench scale plant (01)	49
3.10	Plan and section of the bench scale plant (02)	50
3.11	Designed laboratory bench scale plant	50
3.12	Wastewater holding tank (perforated head cover)	52
3.13	(a) Stone diffuser, (b) Aeration by perforated pipe	52
4.1	pH value of raw sample	56
4.2	pH value from raw wastewater to effluent	57
4.3	Dissolved oxygen of inlet wastewater	58
4.4	DO level measured in different stage of processes	59
4.5	The measured value of BOD_5 in every stage of the bench scale plant	61
4.6	The average BOD_5 value in different unit process of the bench scale plant	61
4.7	COD value in raw wastewater, primary aeration & secondary clarifier	62
4.8	COD value variation in different unit process	63
4.9	Arithmetic mean value of different units	64
4.10	Suspended solids of shrimp processed wastewater.	65
4.11	Suspended solids recorded for effluent wastewater of bench scale plant.	65

4.12	TDS of inlet and outlet of the bench scale plant	66
4.13	Comparison between wastewater and effluent for TDS and SS	67
4.14	Compare with national standard and the effluent quality of the bench scale plant	67
4.15	TS, TDS and SS concentration in raw wastewater	68
4.16	TS, TDS and SS concentration in effluent wastewater	69
4.17	Chloride in wastewater	70
4.18	Chloride in effluent after treatment by designed plant	70
4.19	Line graph of wastewater and effluent chloride concentration	71
4.20	EC value of raw wastewater and effluent of bench scale plant	72
4.21	Nitrogen concentration of raw waste water, aeration basin and effluent	73
4 22	Color concentration of raw wastewater, aeration and effluent	74
4.23	MLVSS measured and calculated MLVSS in aeration basin	78

NOMENCLATURE

AUSB	Aerobic Upflow Sludge Blanket
ASP	The Activated Sludge Process
BFFEA	Bangladesh Frozen Food Exporters Association
BOD	Biochemical Oxygen Demand
BSM	Benchmark Simulation Model 1
BSP	Bench Scale Project
BSR	Business for Social Responsibility
CAC	COD adsorption capacity
CCME	Canadian Council of Ministers of Environment
CFU	Colony Forming Unit
CH_4	Methane Gas
CO_2	Carbon-di-Oxide
COD	Chemical Oxygen Demand
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DoE	Department Of Environment
DOF	Department of Fisheries
EBM	Environmental Biological Model
EC	Electrical Conductivity
E-Coli	Escherichia Coli
ECR	Environment Conservation Rules
EIA	Environment Impact Assessment
EQT	Equalization Tank
ETP	Effluent Treatment Plant
EU	European Union
FC	Faecal Coliform
F/M	Food to Microorganism ratio
FOG	Fat-Oil-Grease
GDP	Gross Domestic Product
GOB	Government of Bangladesh
hr	Hour
Kn/m^2	Kilo newton per meter square
IQF	Individually quick-frozen or Initial icing
KW	Kilo Watt
MCRT	Mean Cell Residence Time
mg/l	Milligram per Liter
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
MPC	Model Predictive Control
mSC/m	Mili Siemens per meter
m^2, m^3	Meter square, cubic meter
NO3-N	Nitrate Nitrogen
OLR	Organic Loading Rate

PI	Pipe and Instrument
PL	Post Larvae
pH	Puissance of Hydrogen
Ph.D	Doctorate of Philosophy
PST	Primary Settling Time
PtCo	Platinum Cobalt
Qr/Q	Wastewater return and Wastewater Flow
RAS	Return Activated Sludge
RNA	Ribonucleic Acid
SBR	Suspended Biological Reactor
SPF	Shrimp Process Factory
SVI	Sludge Volume Index
SS	Suspended Solid
TDS	Total Dissolved Solid
TC	Total Coliform
TSS	Total Suspended Solids
US$	US Dollar
USA	United State of America
SA	Surface Area
T.HRT	Total Hydraulic Retention Time
WAS	Waste Activated Sludge
θ_c	Mean cell residence time
X	Mix Liquor Volatile Suspended Solids
Y	Yield coefficient which convert $BOD_5$to bacterial cell. The unit of Y is mg MLVSS/mg BOD_5 removed
S_0	Influent BOD_5
S	Effluent BOD_5
k_d	Decay rate of the bacteria
θ_c	Mean cell residence time

CHAPTER I

Introduction

1.1 State-of-Art of the Proposed Study

Shrimp culture is a key momentous of the fisheries sector in Bangladesh, particularly in the context of foreign earnings. One of the most important sources for foreign exchange earning in Bangladesh is processed shrimp. The shrimp industries are providing over 1 million people who in turn support well over 3.5 million of their dependents. In total 276,000 ha area is under shrimp farming. There are 162 fish processing plants in the country of which 48 are located in Khulna and around Khulna (Kabir, 2014).

Discharging of liquid and other wastes from any industry without any treatment is a common practice in Bangladesh. It is making the great concern in Bangladesh. Most of the industries in Bangladesh do not practice to follow the environmental compliance for liquid waste treatment plant (ETP) in their factories and discharge effluent direct to the environment.

One ground survey has performed and found that a shrimp processing industries are installed on the road side, nearby agricultural lands and surrounded by rivers and others small water bodies. Estimated effluents 47500L/day/plant generated are directly released in the environment (Billah, 2016). Shrimp processing activities are involved in generation of large amount of biodegradable organic effluents which contains salts, fat-oil-grease (FOG), , carbohydrates, proteins suspended and dissolved solids, high level of phosphates and nitrates, heavy metals etc. These waste streams are containing have extremely high Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD). Such untreated wastewater degrades the environment and it can be causes for oxygen depletion.

Seafood processing industries waste water contains different limit of wastes found in different articles. According to Billah (2016) COD is approximately 790 mg/L, BOD_5 490 mg/L, Dissolved Oxygen 0.15 – 1.82 mg/L, SS-780 mg/L, Total Dissolved Solids-1320-2350 mg/L, Total Organic Carbon-220 mg/L, Oil & Grease 65 mg/L, Salt-11mg/L etc. This contaminated wastewater should not be discharge in the environment. It is clear from the results that significant level of injured water quality and crop production for releasing of untreated effluents in the environment from different shrimp processing industries. The effluents analyzed for different physical, chemical, and biological parameters have shown the presence of chemical species and substances that have differential effects upon soil, biota and water bodies.

It is also noted that none of these industries have ETP that designed based shrimp processed wastewater characteristics and they are not following the environmental compliance of ECR-1997 (*as per citation of DoE Khulna*). The Department of Environment (Khulna) has advised to install ETP and they also provided a design to owner of industries however no industries installed or operated. This design of treatment process is consist with three chamber which can only separate solids. Khulna is the most fish producing region in the country, and the surface water quality of this area is very important. If this surface water quality is affected, the production and quality of fish may be also affected and can have negative impacts on export and our national revenue also. It seems to be clear that an effluent treatment plant is important for these industries. In Bangladesh, recently good practice has started in readymade garment, knitting and washing industries. They are installing ETP.

Usually sea food processing industries wastewater contain more biodegradable organic waste. Hence, biological effluent treatment plant tens to design for seafood processing industries in the area like Khulna and nearby. Therefore, an attempt has been undertaken to design and fabricate an effective bench-scale biological waste water treatment plant for a sea food processing industry.

1.2 Objectives of the Research Work

Specific objectives of this research work is given bellow -

- To determine the initial characteristics of a sea food processing (shrimp processing) industries wastewater.
- Determine solids removal rate by analyzing the result after installation and operation of a bench scale plant.
- To design the best possible biological wastewater treatment plant for a sea food processing industry.

1.3 Coverage of the study

The following investigations are the coverage of this study

1) The research area and industry was selected through a field survey and consultation with supervisor. The samples were collected as needed.
2) The indices of wastewater such as DO, BOD, COD, SS, TDS, pH, EC, NO_3-N etc of the collected samples were measured to characterize the wastewater of shrimp process industries.
3) The bench scale biological wastewater treatment plant has been developed based on the characteristics of raw wastewater.
4) In laboratory a series of tests were conducted to manipulate the plant.
5) The obtained data was decorated and used for performance analysis. The result has been graphically represented.
6) Finally recommendation and further scope of work has been shown for future development and practical application of the study.

1.4 Organization of the study

This study organized and decorated with five different chapters. Different contents and objectives are focused in these different sections. The organizations of the study are as following

The introductory discussions, objectives, coverage of the study are in first chapter. This chapter gives a view of the study aim and whole task of the thesis.

The literature has been studied in pre and during phase of the study has given in the literature review section. In this second chapter covers the sources from where information and statistical data has taken, definitions and some aspects are taken to develop the research.

How the study has conducted has discussed in next chapter of second chapter. How the information and data has collected, technique of investigations, research problems and rationale, methods are used etc has covered in the methodology chapter.

The result from this study has been discussed in the chapter four. Resulted data and graphical presentation has covered the chapter. Not only data show here but also discussion with each and every result placed in this section. The highest result, arithmetic mean of different value and the least value has presented in the fourth chapter.

In the final chapter draw conclusion of the study. What should be for future work and recommendation of the study has given here. The actual limitations were this study is also mentioned this chapter.

CHAPTER II

Literature Review

2.1 Historical Background

Shrimp (is also called prawn) cultivation has historical background as it is not a new sector in Bangladesh at all. It is an old practice in the coastal areas including Khulna, Satkhira, Bagerhat and Cox's Bazar districts. In the past, people trapped tidal water in low lying inter tidal lands and harvested shrimp and other fishes. Before 40 years, no shrimp seeds were firming. Now, there are mainly four types of shrimp species harvested in fish firm such as Black Tiger Shrimp (*Penaeus Monodon*, locally known as Bagda), Brown Shrimp (*Metapenaeus monoceros,* locally known as Horina), Indian White Shrimp (*Fenneropenaeus indicus*, locally known as Chaka) and Giant Freshwater Shrimp (*Macrobrachium rosenbergii,* locally known as Golda).

Shrimp culture in Bangladesh made its initial beginning in the coastal district of Satkhira in 1960s. Gradually, then expanded to the coastal belts of Khulna, Bagerhat, Cox's Bazar and Chittagong (Naureen et al., 2006)**.** Before the independence, it was not grow rapidly.

Rahman and Hossain, (2009) reported that after the independence of the country, rate of shrimp cultivation and production grew with rising price and demand in the world market. From the late 70's to early 80's, shrimp culture system expanded steadily. The industry grew rapidly to the mid 1990's. Hatcheries did not become established until the late 1990's. Freshwater shrimp or Golda farming started from the mid 1970's and achieved steady growth during the late 1980's and 1990's.

In 1973, the export earnings were US$ 3.17 million, which stands at US$ 420 million in 2004-05 financial year from export of 63,377 Metric Tons shrimp and other fishery products, in which shrimp alone contributed 89% of the total export in spite of having a severe price fluctuation in the international market (BFFEA, 2006).

The area under shrimp culture tripled in 10 years, from mid-1980s to mid-1990s covering 130,000 hectares by 1999 (UNEP, 1999). Another study showed that the area under shrimp culture has increased from 52,000 ha in 1982-83 to 141,000 ha in 1999-2000 (Mazid, 2002). About 75% of this land is located in the Khulna, Bagerhat and Satkhira districts in the south-eastern region of the country.

The government of Bangladesh recognized shrimp farming as an industry under the Second Five-Year Plan (1980-85) and adopted measures necessary for increasing shrimp production (Haque, 1994). In 1979-80, slightly more than 20,000 ha were under shrimp cultivation (Ahmed, 1988). Later, farming area was increased to 130,000-138,000 ha (DOF 1994, Rosenberry 1995). Bagda shrimp production has increased by 20% per annum in the last thirty years. There is also 30,000 ha of land under galda *(M. rosenbergi1)* shrimp culture with an average farm size of 0.28 to 4 ha comprising 105,000 galda farms, located mostly in the districts under Khulna division. The galda farm is expanding at a rate of 10-20% per annum in other parts of the country (Hasan 2004).

(Rahman and Hossain, 2009) has mentioned in their article that the industry grew rapidly to the mid 1990's. There was concomitant growth of other allied activities including establishment of processing plants, ice plants and shrimp depots. Local shrimp hatcheries did not become established until the late 1990's.

2.2 Seafood Processing Industries and Farming in Bangladesh

There are handsome numbers of seafood processing industries in Bangladesh. There are 162 fish processing plants in the country of which 96 plants are GOB licensed (Kabir, 2014). According to the website of Bangladesh Frozen Food Exporters Association (BFFEA) there are 106 members of BFFEA among which 66 are EU approved. There are 85 hatcheries and 75 feed mills also which 10 mils are producing exclusively fish feed only (BFFEA and Kabir, 2014). Shrimp farming has covered 2,75,509 hectares land currently. Which was 1,41,000 hectares in 2000. The Khulna region is major farming region (Mazid, 2002).

Total production of shrimp in Bangladesh is 66,900 tones/year (DOF, 2011) which is 2.5% of global production. There are 12% of export earnings of Bangladesh comes from shrimp sector. Total production of shrimp in Khulna region is 41,400 tones/year which is 62% of the total production of Bangladesh. There are 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% and contribution of shrimp in GDP is 4.7% whereas contribution of shrimp sector in Khulna in GDP is 2.91% (Billah, 2016).

About seafood processing industries, production, exports earnings and farming from Bangladesh is given in the following table. The information of the following table has collected from the BFFEA website.

Table 2.1: Basic information about seafood industries farming and exports (*source BFFEA – 2018)*

Basic information on Frozen Foods Industry in Bangladesh		
1	No. of BFFEA member units	106
2	Fish Processing Plant Approved by the EU	66
3	Total Plants Capacity	350000 Tons (5.5 times than 2004-2005 and 1.5 times than 2015-2016)
4	Export Earnings from Shrimp 2016-2017	TK 3,568.32 Crore
5	Export Earnings from Frozen Fish 2016-2017	TK 352.32 Crore
6	Shrimp Cultured Land	2,75,509 Hectare
7	Production of Shrimp (2015-2016)	2,34,188 Tons
8	Production of Shrimp & Fish (2015-2016)	38,78,324 Tons
9	Participation on Export Income (2015-2016)	1.97%
10	Participation on GDP (2015-2016)	3.65%
11	Participation on Agriculture Sector (2015-2016)	23.81%

2.3 Importance of Shrimp Processing Industries in Bangladesh

The importance of shrimp processing industries in Bangladesh may be categories in two aspects like economic and employment. Both two aspects are discussed precisely in the following sections.

In 1998, earnings from shrimp export was about US$ 260 million and export increased to US$ 446 million in 2007 (BFFEA, 2008). This growth rate was about 20% over a decade.

Table 2.2 shows the export statistics of frozen shrimp and fish from Bangladesh during 2001 – 2002 to 2016 – 2017. In the early 80's, Japan was the main importer of Bangladeshi shrimp (Rahman and Hossain, 2009). Now, USA is the highest importer of Bangladeshi processed shrimps.

Table 2.2: Frozen shrimp and fish export from Bangladesh from 2001 to 2017

Year	Qty (Tone)	Value (Million Dollar)	Taka (Crore)
2001-2002	40163	276.11	1585.25
2002-2003	33440	321.81	1863.27
2003-2004	38399	390.25	2300.92
2004-2005	43685	420.74	2587.90
2005-2006	49026	459.11	3200.00
2006-2007	50976	515.32	3558.78
2007-2008	50612	534.07	3663.70
2008-2009	53322	454.53	3127.16
2009-2010	59003	437.40	3025.93
2010-2011	81789	611.36	4351.02
2011-2012	96466	579.72	4585.60
2012-2013	92476	543.84	4241.95
2013-2014	77326	638.19	5105.52
2014-2015	83521	568.03	4430.63
2015-2016	75335	535.77	4286.16
2016-2017	68303	526.45	4211.60
Source: Frozen Shrimp & Fish From Bangladesh (2001 to 2016-2017), BFFEA website			

Processed shrimp sector is not only earns valuable foreign exchange, but also provides a livelihood for households throughout Bangladesh and employs significant numbers of rural workers, urban workers and foreign worker. The contribution series of upstream and downstream activities related to shrimp or prawn culture such as harvesting, culture, processing and exporting. The shrimps industry consists of distinct sub-sectors such as shrimp gher, shrimp hatcheries (or post larvae collection), inter mediate agent at the local growth later, transport, feed processing mills and shrimp processing and exporting agency. All these sub-sectors are linked together and constitute a horizontal integration of activities that create independent employment opportunities for males and females. Bangladesh

Shrimp and Fish Foundation estimate that there are over 600,000 people employed directly in shrimp aquaculture who support approximately 3.5 million dependents (Rahman et al., 2014).

2.4 Problem of Shrimp Processing Industries

Though shrimp farming and processing has great positive influence in economy of Bangladesh especially foreign earnings, it has massive impact on environment. Shrimp farming is making one of the major environmental problem in south west and south east part in Bangladesh. Shrimp processing industries are producing solid and liquid wastes and contribute to environmental degradation in their surrounding areas. It has little discussed about environmental problem by shrimp farming in next paragraphs, basically focused on problems regarding untreated liquid discharge by shrimp processed industries in this section. Unplanned and rapid expansion of shrimp farming in Bangladesh, is making some local environmental and ecological changes. It is increasing soil salinity, water salinity in canals and ponds, scarcity of source drinking water, loss of agricultural & grazing land, consequent reduction of livestock, destruction of mangroves, over exploitation of wild post larvae of shrimp, reduction of aquatic resources and bio-diversity, loss of trees and plants and adverse effects on cropping intensity, cropping pattern and crop diversity were identified as some of the important environmental problems (Rahman and Hossain, 2009).

Most of the industries in Bangladesh do not follow the environmental compliance for ETP in their plants and release untreated wastes in the environment. These industries are mainly involved in processing and packaging shrimps for exporting to the world market (Billah, 2016). Due to the nature of these industries, abundant quantity of liquid waste generated during processing and disposed off nearby river or agricultural land. Fish processed wastewater contains huge amount of biodegradable organic waste and inedible parts of fish. The wastewater has large amount of BOD_5, COD, salts and generates ad smell.

Billah (2016) conducted an EIA in Khulna region and managed on ground survey for doctoral research and found there is no industries have effluent treatment plant (ETP). None of these industries are following ECR 97.

Therefore, Khulna city is getting polluted by shrimp processing industries. The Khulna city and nearby is polluting by solid waste and largely by liquid wastes. There are many environmental regulations are existing, but no industries are following the regulations.

Shrimp processing industries are relying on ground water as their fresh water source. Hence they are impacting on fresh water source. The owners are uninteresting to installation wastewater treatment plant. Higher cost is the one reason .for this circumstance. It is assume that no research has conducted regarding this issue in Khulna. One of the vital objective of this study to find out the best solution for shrimp wastewater treatment for these industries with low cost and locally available materials.

2.5 Wastewater Characteristics of Shrimp Processing Wastewater

Generally high loading of organic wastes are seen in shrimp processed wastewater. There are numbers of papers has expressed about characteristics of wastewater of shrimp processing industry. These papers has been shown that generally high amount of BOD_5, COD, TSS and other parameters are present in wastewater.

Day by day wastewater discharging rate and amount is decreasing worldwide. Islam et al., (2004) has reported globally shrimp and other fish processing activity is steadily increasing. This frozen and processing industry is increasing rapidly and the demand of frozen fish is almost 40% of all production in developed country. Since long the pollution caused by the generated waste of this sector is not get enough attention globally. The characterization of wastewater of shrimp processing industries is not only for environment but also important itself.

Generally, the shell and tail portions of shrimp are removed during processing and these account for approximately 50% of the volume of shrimp and it directly mixed in wastewater and make also solid waste. It has been found in several examination from several sample over the world that the BOD_5 is 100-2000 mg/L, SS is highest in 12,000 mg/L, pH-3.5 to 11, Fat Oil and Grease (FOG) 20-5,000 mg/L COD 120-42,000 mg/L etc.

Reduce, Reuse and Recycle can be basic steps of waste minimization of seafood processing wastewater. Waste minimization is possible by several measures and discretion which can be best way. It is almost impossible to measure amount of pollution in near shore and water body due to shrimp and other fish processing industries. Already it has been started loss and damage in surrounding area of shrimp processing industry in Bangladesh.

The similar scenario we can see in our sub continental area. A studies has been done by Thomas et al., (2015) to characterize physiochemical analysis of seafood industries wastewater in Kerala, India. This studies has been shown that seafood processing operations generate a high strength wastewater, which contain organic pollutants in soluble, colloidal and particulate form. It is difficult to generalize the extent of the problem created by the wastewater as it depends on the effluent strength, wastewater discharge rate and the absorbing capacity of the receiving water body. pH were measured maximum 7.63 and minimum 6.89 respectively. Total Solids where varied from1203 mg/L.

The highest TSS was 6754 mg/L. The overall ammonia concentration was determined ranged from 0.7 mg/L to 69.7 mg/L. The highest value of oil and grease observed is 12.25 mg/L. BOD_5 value were varies from 560 mg/L to 1226.6 mg/L. In this research COD in sample ranges from 1666 mg/L to 3666 mg/L. It is clear that these industries release heavy loads of organic wastes and are discharged into the nearby water bodies through discharge channels and are potentially hazardous to the receiving environments.

There are number of seafood industries in coastal region of Bangladesh and polluting nearby. Some of studies has been performed and found highly polluted wastewater from these industries. Wastewater characteristics of typical seafood industries are discussed here from some papers.

A Ph.D thesis by Billah (2016) did in Khulna region and it has shown feature of wastewater of seafood industries located in Khulna. As per this study shrimp processed wastewater 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 as well as effluents containing high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). A ground survey has shown seafood processing industries of Khulna release 47500L/day/plant directly in the environment. Effluent released from the studied area contains pH (8.06±1.12), EC (15.21±2 mSC/m), DO (1.7±0.12 mg/L), TDS (1777±553 mg/L), TSS (543±187 mg/L), BOD (377±15 mg/L), COD (593±10 mg/L), TC (2.9×103±0.6×103 (CFU/100 ml), FC (235±76 CFU/100 ml), and NO3 – Nitrogen (92.6±3.2 mg/L). This effluent characteristics significantly changed with distance travelled over a cross section of land.

2.6 Technique for Shrimp Processed Wastewater Treatment

There are many types of methods and techniques are available in worldwide. Some methods may be suitable for shrimp wastewater some are not. Each and every method has been developed based on different feature of wastewater. Different methods are used to shrimp processed wastewater in abroad. This thesis will carry a treatment method and try to find out the suitability of the method.

Barros et al., (2009) has expressed a technique for seafood industries wastewater treatment as per his studies in a typical shrimp process industry in Europe following points or techniques are given.

(a) Effluent may be segregated as high organic loading rate (OLR) and low organic loading and salt concentration from the reception of industries wastewater.

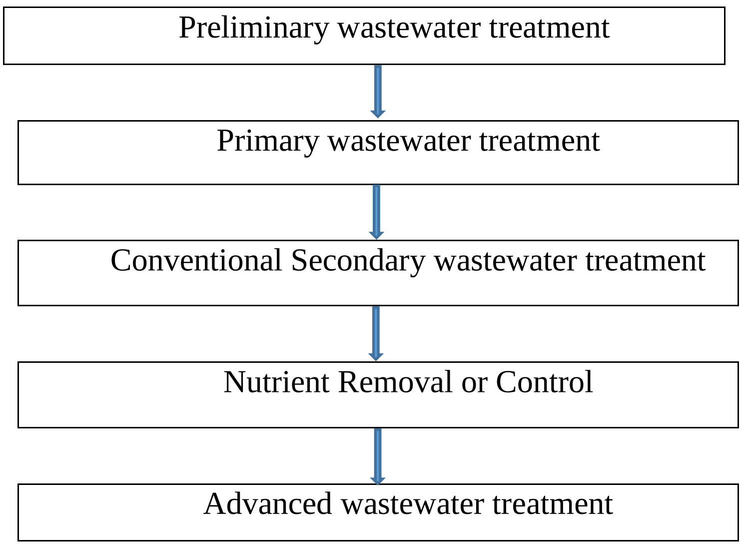
(b) According to the composition of effluents specific or individual treatment of divers featured wastewater.

(c) For high OLR screening, homogenization, flocculation, and anaerobic digestion treatment might be provided but only screening for low OLR.

(d) Fat oil and grease are recovered by means of a fat trap.

There are many methods and unit operations are in vogue now. Different types of unit operation to remove different type of wastes.

According to a book of Metcalf and Eddy, (1995) wastewater treatment methods are as follows.



Preliminary and primary treatment for removal coarse and fine materials that may disturb further treatment process and lost electro mechanical equipment. These methods are also known as physical treatment. Secondary treatment is mainly chemical and biological treatment and advanced treatment is composed with specific treatment.

There are many types of physical, chemical and biological treatment are available in practice. What facilities for what treatment and function of treatment is disused by Tay et al., (2016) in his paper. Seafood processed wastewater loading, treatment kinds, systems, microorganisms and removal percentage etc has disused in that paper. Precisely it has presented following.

Tay et al., (2016) Discussed in his research, seafood processed wastewater contains very high in BOD, fat, oil & grease (FOG), and nitrogen content. Primary treatment is recommended prior to a biological treatment for optimum waste removal. These units may be remove 85% of the total suspended solids and 65% of the BOD_5 and COD present in the wastewater. To accomplish biological treatment aerobic and anaerobic both type of bacteria are engaged. Some microorganisms mainly bacteria are Pseudomonas, Nocardia, Flavobacterium, Achromobacter, and Zooglea present in biological treatment process. Biological treatment can convert approximately one third of the colloid matter and dissolved organic matter and left two thirds convert into microbial cells. Aerobic treatment produce carbon dioxide and anaerobic treatment produce both CO_2 and methane (CH_4). Most of shrimp processed wastewater treatment is used extended aeration process. It is suitable when BOD_5 less than 800 mg/L is the suitability for various treatment facilities with operating characteristics is given below.

Table 2.3: Operating characteristics and treatment system of biological method

(A) Operating characteristics

System	Resistance to shock loads of organics or toxics	Sensitivity to intermittent operations	Degree of skill needed
Lagoons	Maximum	Minimum	Minimum
Trickling filters	Moderate	Moderate	Moderate
Activated	Minimum	Maximum	Maximum

(B) Cost considerations

System	Land needed	Initial costs	Operating costs
Lagoons	Maximum	Minimum	Minimum
Trickling filters	Moderate	Moderate	Moderate
Activated	Minimum	Maximum	Maximum

From above paragraph it is said, as shrimp processed wastewater convey high amount of organic loading which mostly biodegradable content. Therefore, biological treatment may be suitable for shrimp processed wastewater with physical treatment. It may be activated sludge process or another biological treatment method can be used. Some literature says biological treatment may be best solution for fish processing wastewater either seafood or fresh water food, Pankaj et al., (2010).

Biological treatment is the best option for treatment of fish processing wastewater. Aerobic processes such as activated sludge, rotating biological contactor, trickling filter and lagoons are also suitable for organics removal. The activated sludge technology is dominating over the bio-film process in the practical treatment of fish processing wastewater. Normally higher oxygen is required in fish processing wastewater compared to other food processing wastewater. Temperature, F/M ratio, sludge retention time and aeration rate are major influence that impact on treatment. Fish processing wastewaters including shrimp are characterized by BOD_5 100-3000 mg/L, COD 1000-18000 mg/L and nitrogen content 80-1000 mg/L.

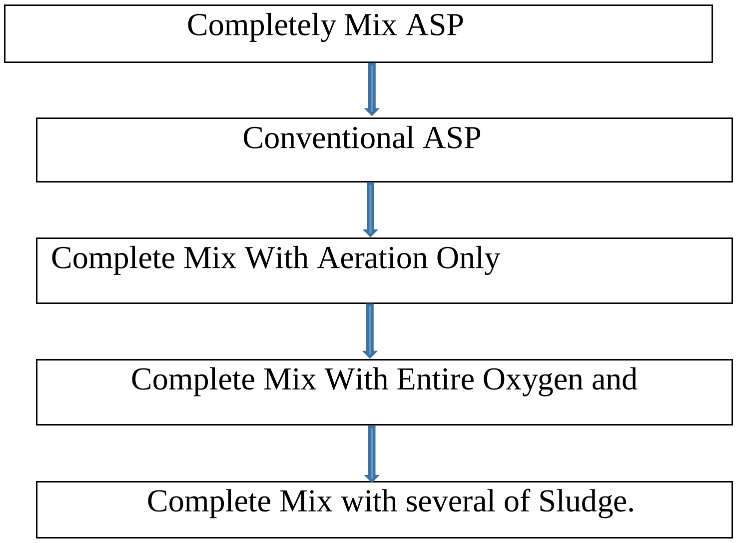
Therefore, biological treatment process are selected for this research. There are many types of biological treatment process like suspended growth process and attached growth process, aerobic and anaerobic process etc. Among many types of biological treatment process suspended growth and extended aeration biological treatment process was used for this study. Activated sludge process is widely used biological, suspended growth process. Some numbers of literature about activated sludge process reviewed during this research. The summarization of these literature reviewed is given in next section.

2.7 Activated Sludge Process Design, Operation and Control Approach

2.7.1 Brief Introduction about Activated Sludge Process

The Activated Sludge Process (ASP) is a system that widely used in worldwide. There are many modified and original forms of ASP are using now a days. It is mainly suspended growth biological process (Metcalfe and Eddy, 1995). This method established by two engineers (*Edward Ardern and W.T. Lockett*) of UK in 1913. They conducted a research for the Manchester Corporation Rivers Department at davyhulme sewage works (Wikipedia).

Joseph (2014) reported that organic matter is aerated in activated sludge method and microorganisms metabolize suspended and soluble organic matter. As a result organic matter converted into microbial cells and CO_2 and water produced. Resulted sludge with exuberant of bacteria or microbes known as activated sludge. A portion of activated sludge return into aeration tank again. The production of sludge is directly related with amount of wastewater. For process control F/M ratio, θ_c, SVI, and some nutrients are tested. MLVSS is checked for knowing of bacterial growth. Air is supplied by diffused aeration, surface aeration and pureO_2 aeration process. There are some types of ASP seen over the world. These are given in following flow diagram.



With several interrelated components consist a basic activated sludge process system. It has an aeration tank in where biological reaction is occured. A source of aeration provides oxygen and mixing for ASP. Solids settle and separated from wastewater in a tank namely clarifier. The sludge which return into the system is known as return activates sludge, and which part remove from the process known as waste activated sludge (WAS). Bacteria rapidly multiply their number with sufficient amount of food and oxygen. The organisms (bacteria) settle to the bottom of the clarifier. This sludge pumped back to the aeration tank where it is further mix with incoming wastewater. The relatively clear liquid above the sludge, the supernatant, is sent on for further treatment if required (Vargava, 2016). A typical completely mix activated sludge process diagram is given in following figure.

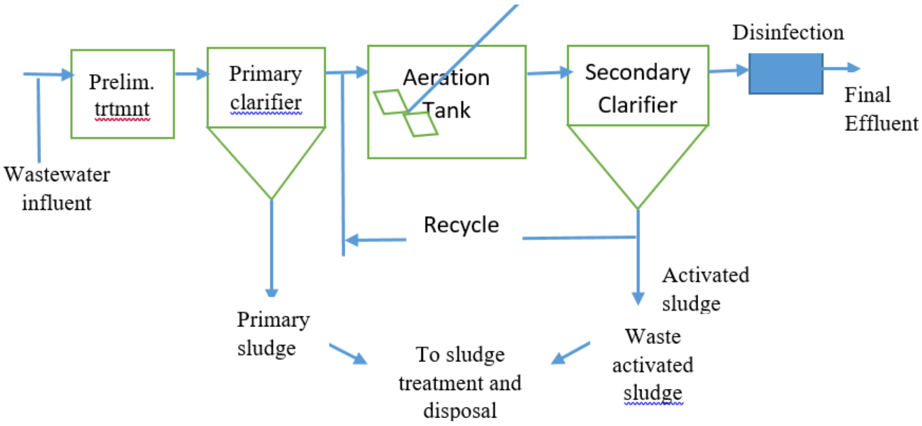


Fig. 2.1: Completely mix activated sludge proess diagram

2.7.2 Design Consideration of ASP

There are some rules and regulations existing in every countries. Some system is to be follow to design a waste water treatment plant. Wastewater treatment plant is not out of this manner. There are some considerations for water treatment plant design. To design an activated sludge process (ASP) it has some considerations. Before going to this discussion it may be need to brief about wastewater plant design consideration.

Canadian Council of Ministers of Environment (CCME) published a guideline in 2005 on water treatment plant design. American Society of Civil Engineers "*Wastewater collection and treatment systems, Manual of practice – 69*" is expressed about wastewater treatment plant design considerations. Frank (2003), mentioned design consideration in his book and according this book an engineering design is to be done with several continues steps. There are several aspects that are to be taken forward with consideration. These aspects are called design consideration. These considerations are – location, effluent quality, process selection, major design criteria, plant outfalls, essential facilities, safety, laboratory, chemical handling area etc. At first, it is necessary to select location. Selection of location it should be consider residential area nearby, electricity facilities, drinking water supply, soil condition, air flow, flood protection, plant size, further expansions etc. Discharging effluent quality, domestic regulations, buyers standard (if any) should be consider also. For process selection it have to be contemplate local condition, influent quality, economical issues etc. Organic loadings, sewage or wastewater flows, design periods etc envisage. Emergency power supply, water supply, sewer line, plant piping, personal facilities, building services, sanitary and stairway are under emergency facilities. It must be follow various design code as well as plant safety code should be attached on plant.

Activated sludge process design must be followed by some criteria. According to Karia (2010), and Davis (1998).

It will be 2 – 4 numbers of aeration tank

- ✓ Normally 3 to 4.5 meters depth for each aeration basin
- ✓ Free board will be consider 0.3 m to 1.5 m (for diffuse and surface aeration)
- ✓ L:B remain 5:1 (for larger tank) and B:D = 3:1 – 4:1
- ✓ 10 to 14 KW/1000 cubic meter power is needed for completely mixing.
- ✓ MCRT will be 1 – 15 days for completely mixing.
- ✓ MLSS will be 1000 – 6500 mg/l and Qr/Q will remain 0.25 to 1.0
- ✓ Food to Microorganism will 0.2 to 1.00

The process control is important for high level of treatment. Thus DO level is checked regularly. The bulking sludge and rising sludge are the major operational problem.

First, primary clarifier design should be done because how much BOD_5 reduce after primary treatment is need to know for aeration basin design. Either rectangular shape or circular shape clarifier can be choice. Primary clarifier design process are written by Thomas et al., (2005) as retention time 1.5 to 3 hr. Surface loading rate or overflow rate 24 to 48 $m^3/m^2/d$, velocity less than or equal 0.3 m/min, length to width ratio 3:1 to 5:1. There are 40 – 60% of suspended solids and 20 to 30% of BOD_5 can be redact in primary clarifier. Flow rate of wastewater, amount of solids, retention time, temperature, surface loading rate, shape of reactor etc are factor of primary clarifier tank design. The volume of bottom triangular part of clarifier will be not consider as clarifier volume. This triangular or trapezoidal part is known as sludge hopper. Surface area, diameter or dimension of reactor, volume calculation, side water depth calculation, sludge volume determination, sludge hopper bottom area and volume find out are the steps of primary clarifier design.

After the completion of primary clarifier design, aeration basin should be design. The retention time and mean cell residence time are the important two factors for aeration basin design. Karia and Christian (2010) have shown the formula to determined volume of aeration basin. Aeration basin volume determined by multiply retention time with flow rate.

Retention time determine by the following formula. This formula has taken from the book by Karia and Christian (2010).

Calculate θ value by this formula. $\theta = \frac{\theta_c (Y)(S_0 - S)}{X (1 + k_d \theta_c)}$.

θ_c	Mean cell residence time
X	Mix Liquor Volatile Suspended Solids
Y	Yield coefficient which convert $BOD_5$to bacterial cell. The unit of Y is mg MLVSS/mg BOD_5 removed
S_0	Influent BOD_5
S	Effluent BOD_5
k_d	Decay rate of the bacteria

Mean cell residence time is unknown which find by the following formula given by Davis & Cornwell (2006).

Mean cell residence time θ_c calculated from this formula

$$S = \frac{K_s(1 + k_d \theta_c)}{\theta_c (\mu_m - k_d) - 1}$$

Here, K_s, μ_m will be taken standard values. S is known value

Now, can be design secondary clarifier. It seem to be that primary and secondary clarifier are same but functionally they are different. Commonly secondary clarifier is larger than primary clarifier. Secondary clarifier design consideration is brief here based on article by Jeyanayagam

Secondary clarifier is important for high solids loading and its fluffy nature. Type III settling is occur in secondary clarifier. But some authors and researchers also say about type 1 and type 2 settling occurring here. Overflow rate 33 m/d for an average flow of wastewater. Weir loading rate is 125 – 250 m3/d/m for per meter of weir length. Diameter of circular tank is 12m to 42m or more. In that case side water depth will be 3 meter for 12 meter of diameter. Though primary clarifier only settle but secondary settler has mainly two function. First one, clarification and second one is thickening. Thickening is hold of sludge particles in bottom of clarifier. If sludge is not thicken and settle well it floats and it is called plummy or fluppy. The performance of clarifier is depend upon sludge settleability and concentration of MLSS. Over flow rate, solid loading rate and weir loading rate are major important to design secondary clarifier. Overflow rate calculate by Q/A and solids loading rate = (Q + Qr)/A = X, (X = MLSS). Weir loading rate = Q/L.

James, (1971) has shown in a research that mean cell residence time when increase soluble COD is decreased. On the other hand, mixed liquor suspended solids are decreased with increased of solids retention time. The relationship among θ_c MLSS, DO and COD of his research is given below.

Table 2.4: The relationship among θ_c , MLSS, DO and COD

$\boldsymbol{\theta_c}$ **(days)**	**pH**	**MLSS (mg/L)**	**Dissolved Oxygen (mg/L)**	**Soluble Effluent COD (mg/L)**
0.25	7.3	81	6.0	125
0.50	7.2	318	5.9	65
1	7.2	562	5.8	58
2	7.1	1052	5.8	41
3	7.0	1392	5.7	40
4	7.0	1559	5.8	45
6	6.9	1615	5.8	39
8	7.0	1959	6.1	40
10	7.0	2341	6.0	51
12	7.0	2294	6.1	52

2.7.3 Operational and Control Approach of ASP

Activated sludge process and control is not so difficult but require knowledge regarding basic principles of ASP. It is a biological process, a portion of sludge mixed with influent wastewater and remaining sludge left for further treatment. FM ratio is the one of controlling device. MLVSS, RAS ratio, Flow control etc are also controlling device for ASP.

This process convert non settleable dissolved and colloidal particles into settleable sludge. The ASP gives highest degree of treatment within the limit of economy and knowledge. The process performance or optimum result depend upon some matters. Microorganism is one of the most important matter for ASP. Again temperature, waste loading, pH value etc are also important for microorganism. Sludge recycle is also important factor for maintaining activated condition. Microorganisms are directly affected by temperature and pH value. So, these two factors should be maintain effectively.

Effect of temperature and pH on the growth rate constant of nitrifying bacteria in activated sludge process is studied by Painter et al., (1981). This study says under the pH value of 6 or above 10 no bacterial activity seen. There are six fill and draw activated sludge plant were used to perform the study. The precise result and discussion of this literature is given below.

There are a relation between growth rate of bacteria with inhibitory compound and DO concentration. The other parameter like temperature and pH also important factor. Previous some works have been shown that the growth rate is three times increase for increasing of temperature 10 degree. Recent data shows nitrifying bacterial growth is optimum at pH value 7.5 to 8.5. No activity is seen at pH value below 6.5 or over 10. In the research, there were six fill and draw activated sludge plants were used which temperature was fixed. Diffused air injected and mixed liquor volume was 1300ml. pH was controlled by acid or alkali use. For temperature controlling plant was partially immersed in water bath. From the research it has been found that least pH value for nitrification was 6.5 and highest was 8-8.5. Growth rate was changed very low between 7.5 to 8.5 values of pH.

Zhang et al., (2009) has researched on Environmental Biological Model (EBM) to see biodegradation rate and adaptation of microorganism. As day by day many advanced informatics technologies are involving in wastewater treatment to environmental pollution control and among these technologies, mathematical modelling, artificial neural network, fuzzy control, database construction and expert system are more popular. But in these systems microbial effect was ignored. Though plant can be more reliable by using of the relation between microbial growth rate with pollutant control. This studied has been developed a model namely Environmental Biological Model (EBM) by biodegradation rate with adaptation of microorganism in different wastewater.

This EBM model has been established by developing various equations. The data from EBM has compared with data obtained from many research and past activity. There are very little difference has been found from the comparison which was ignorable. From result it was shown very little error of experiment data with comparing data. The highest error was noted 15% of input wastewater Q cubic meter. From research result, it is shown Bioreactor volume is very important parameter which influence all the system. It is found that error is minimum in least volume design. So, EBM can be effective system to forecasting, optimum operation and regulation of activated sludge process.

Altogether keep effect on microorganism along pH, temperature, reactor volume, altitude etc. From above section it is a point that aeration tank volume is a factor which may influence the system. To calculate aeration basin volume θc is a variable which control the magnitude of volume. From 2.7.2 aeration basin design consideration, it is seen that if θc is more, then aeration basin volume will be more and vice versa.

But, what will be result for large θc and less θc? What θc lead for more settling? If mean cell residence time (θc) is so less then settling will not enough and similarly for so longer θc. The longer mean cell residence time (θc) can be the cause for deflocculated particles.

James et al., (1971) conducted a research on relationship between mean cell residence time with settling characteristics of activated sludge process. There were several units of ASP used. Each unit fed continuously. pH, DO, temperature, agitation etc kept constant. θc was used from 12 days to 0.25 day. The main focal point of result of this literature was given as follows.

1. Settling properties of activated sludge, i.e., the sludge volume index, percent dispersion and zone settling velocity, can be expressed as function of the biological solids retention time (θc) of the sludge.
2. Based on total biomass of the effluent, the best overall solid removal occurred at the values of θc in the range from 4 to 9 days.
3. The physical characteristics of the solids in the effluent was depend on the value of θc. i.e. short θc effluents contained dispersed settling whereas long θc contained pin point floc and small deflocculated particles.
4. At longer values of θc, settling and bioflocculation is accompanied by an accumulation of polysaccharide material.

Therefore, mean ell residence time for optimum solids settling is 4 days to 9 days. The results of this research appear to be generally applicable except in situations where the influent contains high percentages of colloidal matter and non-degradable settleable solids.

Lawrence and McCarty (1970) has been shown that the θc is related with some common parameters such sludge age, mean cell residence time, net specific growth rate, process loading factor, substrate removal velocity and food to microorganism ratio. Factors which affect the SVI, zone settling velocity and percent dispersion can be divided into two categories. Firstly, associated bacterial or like this organisms changes their physical or biochemical character. Secondly, extreme population shifts from the normal bacterial or zoogloeal type to a filamentous type population.

The pressure is an important factor to removal of solids from wastewater. Pressure due to be circumstance, altitude or elevated pressure, simulated pressure etc. Pressure influence organic loading reduction as well as settling capacity. Lawrance et al., (1971) has presented an investigation on the effects of pressure on the biological degradation of organic wastes. This investigation has done by constructed three pressure cylinders and pressurized 101, 203 and 304 $\mathrm{Kn/m^2}$ respectively. Each cylinder was arrayed with pressure gauge, pressure release valve, hydraulic release valve and air release valve. Activated wastewater filled in each cylinder and sampling after every 30 minutes to analyzed COD. It was found that COD removed 58% and 38% more than the first one.

Nusser (1975) attempted to test for showing the relation between organic removal efficiency with pressure variation. One examination was to find effects of the variation of air/wastewater ratio in the pressure cylinder. Thus air wastewater ratio was used as 0.00, 0.45 and 0.90. No significant reduction of $\mathrm{BOD_5}$was found with increasing of air.

Another test performed by Nusser was on response of wastewater to pressures 698, 1397 and 3493 Kn/m2 (100, 200 and 507 psi) applied for one hour. The $\mathrm{BOD_5}$ reduction was found 12.5%, 21.3%, and 25% respectively for 507 psi, 100 and 200 psi. It is clear that when pressure is increased then $\mathrm{BOD_5}$ reduction rate also increase but more increasing of pressure decreasing $\mathrm{BOD_5}$ reduction rate.

Nolte (1982) conducted a research on effects of elevated pressure on the activated sludge process. The literature by Nolte expressed wastewater treatment can be control in two ways by pollution control technology. One, by control of hardware or equipment and second, process alternate. $\mathrm{BOD_5}$ is consider as evaluation parameter of efficiency of wastewater treatment. To perform the research, technology was used activated sludge treatment that completely mixed and MLSS was 1000 mg/L and 3000 mg/L. 0.91m height and 0.31m diameter cylinder was used for the experiment. The cylinder was partitioned into an aeration chamber and a settling chamber. Wastewater was stored in a 208 L. feed tank and delivered to the activated sludge tank. Air supplied by air compressor. DO, temperature, MLSS and cylinder pressure was monitored continuously. It was found that $\mathrm{BOD_5}$ removal percentage increased with increasing pressure. It is clear from the result that, increased pressure accelerates substrate degradation and rate of oxygen utilization.

For decreasing of $\mathrm{BOD_5}$ or COD; pressure and altitude, pH and temperature as factor as like DO concentration is. The amount of dissolved oxygen is ascertaining the reduction of $\mathrm{BOD_5}$

and COD. Increasing DO level not only reduce BOD_5 and COD but also solved bulking sludge and so. DO is also related with sludge settling rate.

Jonathan et al., (1980) expressed the relation between organic loading, DO concentration and sludge settleability in a journal. According to this journal an activated sludge which poorly compacts and settles is called bulking sludge. An activated sludge that settles very rapidly is called 'pin-point' floc condition. In ideal condition, sludge will thickened and clear supernatant will get. There is a relation existing between DO concentration with sludge settle and organic loading. This relationship has been shown by experiment with a 14 cm diameter, 79 cm height (which liquid depth 69 cm) and 10 L volume of water and a settling basin which volume was 1 L. Aeration was provided in different level from 0.5 to 6 mg/L. COD was measured by analytical method. SVI was measured in 1L graduated cylinder. DO was measured in aeration basin by DO probe. DO level is increasing gradually with increasing of aeration rate from 1mg/L to 6mg/L. The sludge bulking was reduced with DO level increasing shown by various result. On the other hand it has been also shown that limited time is required to cure sludge bulking problem with less mean cell residence time (MCRT). Sludge bulking is occurred both high and low concentration of DO. In spite of that bulked sludge is rapidly huge amount when DO level is limited. From this research it has been found a lateral relation between COD removal rate and a DO level of aeration basin.

2.7.4 Microorganisms are Involve in Operation and Control

Exactly which types of microorganisms are involved and play vital role to solids liquid separation is still in research. It is clear that bacteria is the major participant in activated sludge process but there are numerous types of bacteria involved in wastewater treatment. They may be classified as based on aerobic and anaerobic state, nitrifying and denitrifying activity and again based on shape and size.

Holenda et al., (2007) mentioned there are two types of microorganisms like heterotrophic and autotrophic living in the activated sludge. The dissolved oxygen concentration was maintained in high to supply adequate oxygen to the microorganisms in the sludge. As a result, organic matter was degraded and ammonium was converted to nitrate. Contrariwise, an excessively high DO cause to a high energy consumption and deteriorate the sludge quality. Thus both are economical and process related, it is obtained by controlling DO. A model predictive control has been used to maintain DO concentration at a certain set point of the aeration basin. Model predictive control (MPC) is computer control algorithms which can predict the future response of a plan. However it has been based on the assumption of a multivariable control problem rather than focusing on the dissolved oxygen control. A set point change at t = 0.03 day and an input disturbance at t = 0.07 day were used. The first two chambers used was anoxic zone that's volume of 1000 cubic meter and three chambers create the aerobic zone with individual volume of 1333 cubic meter. The oxygen mass transfer coefficient rate was set to 240 l/day, which maintained the dissolved oxygen concentration at 2 mg/l. The flow rate of the internal recirculation was kept at 55338 m^3/day. The secondary settler has a conical shape with the surface of 1500 m^2 and the depth of 4m. The flow rate of the sludge recirculation was 18446 m^3/day and the excess sludge was removed from the settler at 385 m^3/day. Result hase shown that the performance of the controller can be considerably enhanced by decreasing the sampling time. This improvement has no significant impact either on the whole activated sludge process or the energy consumption.

DO concentration is important for another reason is filamentous control. Filamentous bacteria another types of bacteria that involves in low amount but increasing amounts of it creates a common problem known as bulking. So, DO concentration is a controlling parameter for filamentous bacteria controlling.

Benefield et al., (1975) experimented on filamentous bacterial growth pattern and its protection mechanism in activated sludge process. As per this research statements, excess amount of filamentous bacteria cause for sludge bulking. There are some factors are responsible for this but perhaps excessive amount of carbohydrates is the most common reason. pH also influence this growth. To show the relation between DO concentration and filamentous growth, there are three different completely mixed reactor were used. The volume of two reactor was 10.4 L and 4 L. Oxygen had provided in small one and a large one reactor and other reactor contained compressed air. Maintained DO in compressed air reactor in 1-2 mg/L and 8-9 mg/L in oxygen system reactor. Flow rate was kept 12 ml/min. pH 7.1 to 7.4 and temperature was maintained 20ºC constantly. It had been found that, pure oxygen chamber but high solid concentration there was not filamentous organism growth. It is shown from the investigation, the use of high purity oxygen in the activated sludge process induced filamentous growth when the process was operated below a solids concentration of 4060 mg/1. So, minimum a solid concentration should be maintained to protect filamentous growth. Filamentous growth influence with high DO concentration.

Activated sludge process is used not only for effective reduction of COD and BOD_5. It also efficient to nitrogen and other nutrients control. When sludge settling or organic solids removal mechanism and metabolism process are going on then nitrification and denitrification processes are also occurred in aeration basin in any phase. The bacteria takes part in nitrification – denitrification process. Nitrification and denitrification is one of the most important process of ASP. Some factors should consider when operates an activated sludge process.

Set-point can be good technique to reduce nitrogen. Over the years, set point is used for nitrification and de-nitrification is 1-3 mg/L. Vivekananda et al., (2016) has shown nitrate nitrogen concentration and dissolved oxygen is controlled according to prescribed level for maintaining these parameters as per environmental regulation. Generally, single input-output system is used broadly over the world. Set point is fixed according to effluent quality and operating cost. Set points and optimal set points is shown by Benchmark Simulation Model 1 (BSM1). According to BSM1, nitrogen is removed by two steps. Firstly, nitrification reaction and then de-nitrification reaction. There are two anoxic and three aerobic reactor has set in BSM1. First two anoxic chamber for de-nitrification and following three aerobic chamber is used for nitrification. Sludge recycle ratio was 0.37 and MLSS concentration 2405 was considered.

Peng (2007) showed the mechanisms, factors, control and removal of nitrogen by activated sludge process. There are many mechanisms for nitrification and denitrification such as the heterotrophic nitrification, aerobic denitrification and short-cut nitrification-denitrification. Simultaneous nitrification denitrification has shown in a journal with experimental results. According to the literature diffusing DO concentration has been controlled at 0.3-0.8 mg/L. Aeration tank volume was 8.5L and temperature was maintain at 23-28 C. pH has maintained 7.5 to 8.0. Synthetic wastewater has been used in this research. Initial MLSS concentration was 3-5mg/L in aeration tank. F/M ratio, C/N ratio and SRT were selected as the variable. DO concentration usually is above 0.5 mg/L in the mixing activated sludge system. As a result, high ammonia nitrogen removal efficiency obtained up to 93%. From this research it has been found that when F/M ratio 0.30 mg/L COD (g MLSS. D), then ammonia nitrogen was removed 55.4%, 7.3%, and 48.1% in a series. Three assumptions were provided to explain this. Firstly, the smaller biomass floc was observed through microscopic analysis, compared to those in general complete mixing systems and DO was available for nitrified. Secondly, SRT was so high such 30 days, 45 days and 60 days which reduced the degradation rate of carbon containing organics. Thirdly, Organic loading were very low. It is shown from this study, DO concentration is not important factor for denitrification but carbon is an important factor.

These all kinds of bacteria identification was not easy and almost impossible. Some techniques were used and now a day's technology is under updating. Molecular biological technology that recent developed technique to find out particular type of bacteria.

In-sook et al., (2003) shared about this technology what was used to identifying particular types of bacteria. According to statement of In-sook's article molecular biological technique is called rRNA technique. From this technology 16srDNA system was used more though it has some limitations. The study used different types of bacterial clone and it has sequenced and matching with natural bacteria. Then these clones were used in different processes in the study period. Denitrifying and phosphorus removal bacteria was grown in anoxic or anaerobic environment. These were developed in clarifier. Proteobacteria were used in aeration basin and for nitrogen removal, nitrifying and denitrifying bacteria were used which is called nitrosomonas bacteria. They were also known as beta-proteobacteria and nitrospira. Qualitative data has found from cloning. Each population distribution was similar that found from the study. Quantitative data from the study shown each population size vary on total population of bacteria. 16SrDNA technique were used to characterize of all community of bacteria in the study.

Activated sludge process not only consist with microorganisms but also many macro-invertebrates. Generally it is known, bacteria plays important role but protozoa also plays important. Colin (1973) has been expressed the role of protozoa in ASP. Commonly it was found almost 50,000 cells per milliliter in the mixed liquor of activated sludge, which was approximately 5% of dry weight of suspended solids. Ciliates type protozoa is commonly abundance in various types of protozoa. From experiment, it was obtained that when absence of protozoa then bacteria was found maximum in sludge. This study clearly shown, protozoa removes large amount of bacteria from activated sludge. Activated sludge can removes fecal bacteria like E-Coli up to 91-99% because here protozoa take part to remove bacteria. Experiment shows, E-Coli removes 54% without protozoa and with protozoa, E-Coli removes up to 95%. It is clear from the experiment that, protozoa especially ciliated protozoa is so important to get high quality of effluent. It is also found from the experiment, attached ciliates of sludge is cumulatively growing more with respect to time but free swimming ciliates of wastewater is increased first and then come down almost to zero.

2.7.5 Various Control Mechanisms

The activated sludge process is faced some difficulties. So, quality effluent obtained is impossible without solving the problem. Thus process, microbial, sludge etc should control during operation. Christina (1982) showed completely mixed reactor can be used as a parameter which characterize bacteria. Micro-organism activity in a biochemical process not only depends on environmental factors rather depends its physiological and morphological states as well. The biological state is known as biomass age might be problem during treatment. Which can be deduced from the volumetric residence times of the single reactors. In this regard CMR with multistage processes might be a solution.

Set point controller can be used as DO control and other parameters also. Lindberg et al., (1996) has used time varying set-point controller alternatively to control of DO, determined by the ammonia concentration in the last aerobic zone. As per the literature by Linderg et al., set point controller is PI controller. Set point controlled by maintaining DO level 1-5mg/l. Non-liner PI control is compared with linear PI control. Simulating is performed with Q = 1000l/h, V = 650 L, DO sat = 10 mg/L, DO in (t) = 0 mg/L, H = 10s. After 8 minutes the respiration rate was decreased from 40 mg O2/l/h to 5 mg O2/l/h. To accomplish a fair comparison between linear and non-linear controller, both controller were tune to give equal performance. It was obtained from examine that linear controller gave less stable the system, air flow rate and DO oscillated. On the other hand, nonlinear control maintained the system well. The reason was that the nonlinear controller decreased its gain to compensate for the increased gain of the system. Carbon source was controlled from outside to maintain the nitrogen concentration was 1 mg/L. Two simulation were used which one DO concentration has set 2 mg/l another one was controlled for maintaining ammonia concentration 0.5 mg/L. It was obtained from the research that higher ammonia set point means less amount of ammonia is nitrified. Nonlinear control was performed better in various concentration that found from different set points.

COD adsorption capacity (CAC) may be a good controller for ASP. Set point and CAC both controller are cost free controller for the plant. CAC can be applied in air supply control of aeration basin, feed pattern etc. CAC can be used in feed pattern of aeration unit and process decision. Tan et al., (1994) experimented and used CAC as controller. CAC determination has given information about control strategy of ASP as a result enhanced controlling. CAC was measured by settled sludge into the mixed liquor over a minute and then measure per unit COD immediately. Adsorption capacity defined as, biosorption = (C$OD_{t=u} - COD_t$)/MLSS. COD and SS were measured as per APHA method. Therefore, COD adsorption capacity found by CAC = Theoretical COD – Supernatant COD/MLSS. The studied HRT 7.5h and MCRT 5 day was kept. From the result, CAC is minimum in front part and maximum in back part. Its mean, in early phase of activated sludge process, cell surface is more loaded. Substrate metabolically removed as more adsorbing in the end phase of treatment.

Flocculated sludge is obtained from conventional activated sludge process which have some disadvantages such as high surplus biomass production, low sludge age, and continuous solid is need to separated. Granular sludge cultivation can be a good solution. Compared with that granular sludge is regular, compact and strong microbial structure, good settleability, high biomass retention, and the ability to withstand shock loading. Previously granular sludge cultivated either in aerobic upflow sludge blanket (AUSB) or SBR system. Actual mechanism of granulation is still the subject of discussion yet. Shear force, settling time, height to diameter ratio of reactor and microbial content of sludge are the factors of granular sludge cultivation. Though high DO concentration is needed but whether settling time less or high it is still under debate.

Xi chen et al., (2013) showed for the first time, the formation of granular sludge is possible in the Completely Mixed Activates Sludge system. Two conventional, continuous flow, completely mixed activated sludge systems were operated. Volume of 18 L, a height-to-diameter ratio of 1.0. Volume of the clarifier was 4.5 L. SVI was kept 140mg/L and synthetic wastewater was used. Mechanical stirrer was used that revolution 250 R/min and 568 L/min air is provided from bottom of the reactor. Average DO concentration has maintained 4.5mg/L and temperature 25-27C. Influent was 54 L/day, HRT 8h and settling time 2h was used. Microscopic analysis has shown obtained granular sludge was round shape and clean outer surface. Though many different study has shown high height to diameter ratio need but this study shown it is not mandatory. Also short settling time is not important.

Excess sludge production is common sludge treatment problem in conventional Activated Sludge Process. The excess sludge production influences to treatment of sludge as per treatment design. Yasui et al., (1996) hase given the solution of this problem by ozonation treatment of sludge. The ozonation treatment of sludge enhanced biological degradation of sludge. This treated sludge was decomposed in subsequent biological treatment. In ozonation system, sludge was treated with wastewater. One third of sludge volume was reduced by ozonation process. SS concentration was reduced in effluent and MLSS changed in aeration basin. Withdrawal of excess sludge was unnecessary in all the recirculation system. In ozonation process one line was drawn from sludge recirculation line and sent in aeration basin after ozonation of sludge.

Fuzzy creation is another common problem either in wastewater or sludge both. Tang et al., (1980) shown fuzzy control is possible by some of easy process control. A study has conducted by using two stage process control. Local control action has been used and removed excess biological solids. Fuzzy control action has been taken on two basic premise. Firstly, rely on information regarding conventional operations. Secondly, control by some predictions. Second one is called linguistic control which like as statement. Activated sludge process can't fuzzy control directly. Thus an algorithm was developed and closed loop operation was used. Fuzzy controller perform as following loop – Fuzzifier + Algorithm + Defuzzifier. Fuzzy control is easily possible by proper plant operation.

Chapter III

Methodology

3.1 Research Design

Following steps were considered during this study – samples were collected from the selected industry (*Figure 3.3)* according to standard sampling method. The samples were tested in Environmental Engineering Laboratory of KUET. Selected parameters namely Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Dissolved Solids, Total Suspended Solids, pH etc were measured for raw and treated samples. From five selected points samples were collected and tested routinely. Based on value of initial tested parameters, the treatment method and unit processes were selected and volume of reactors were calculated. A bench-scale plant were fabricated for the treatment of wastewater. Regular monitoring were maintained and parameters were measured in laboratory.

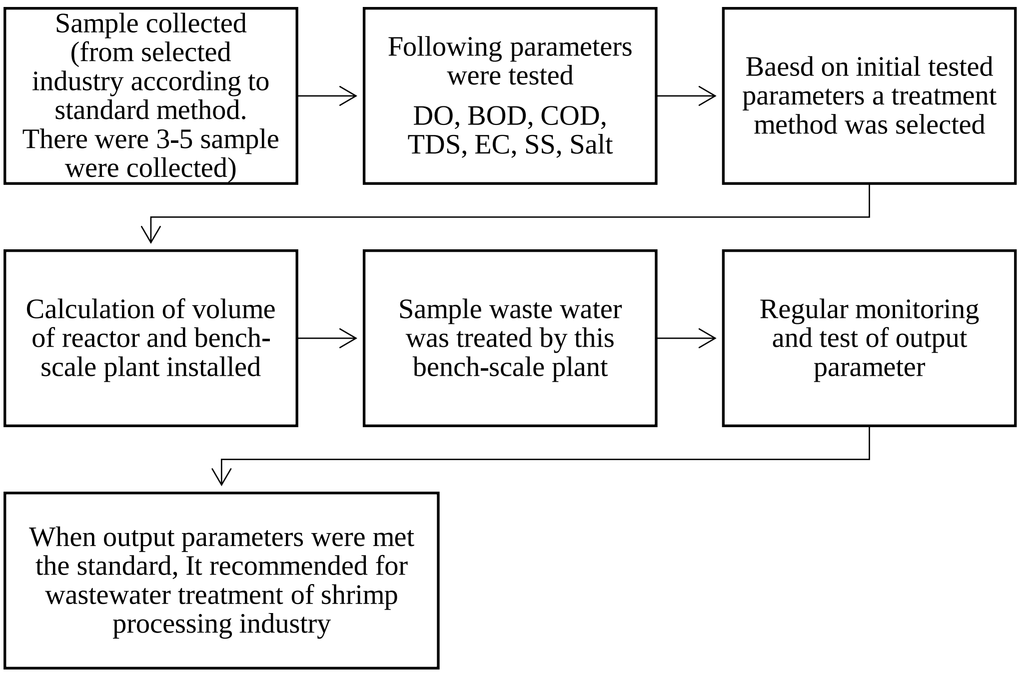


Figure. 3.1: Flow Diagram for Research Methodology

The bench-scale plant were fabricated and installed it on roof top of civil engineering building. Effluent parameters were measured on regular basis and when it was got satisfactory level then it considered as capable to treatment of wastewater of shrimp processing industry.

3.2 Industry Selection

There are two main region, in Bangladesh have been growing shrimp processing industries. These are south-western and south-east region of Bangladesh. There are total 20 districts and 52 Upazillas are involved in shrimp culture in Bangladesh (Kabir, 2014). But shrimp processing industries has established in only 10 districts. Almost 60% of processing industries are located in south western of Bangladesh. As well as about 75% of the shrimp culture land is located in the Khulna, Bagerhat and Satkhira districts in the south-eastern region of the country. Shrimp processing is almost exclusively concentrated in Khulna whereas shrimp cultivation is mainly concentrated in four districts namely Satkhira, Khulna, Bagerhat and Cox's Bazar (Nuruzzaman & Dev, 2006). Therefore, Khulna district has selected for this study. The following figure 3.2& 3.3 shows the fish processing zone and shrimp cultivation area of Bangladesh.
Maximum industries are located on Rupsha River in eastern part of the district. There are two sea food processing industries were selected. The location is shown in figure 3.4.

Figure 3.2: Fish Processing Zone and Shrimp Cultivation Area of Bangladesh

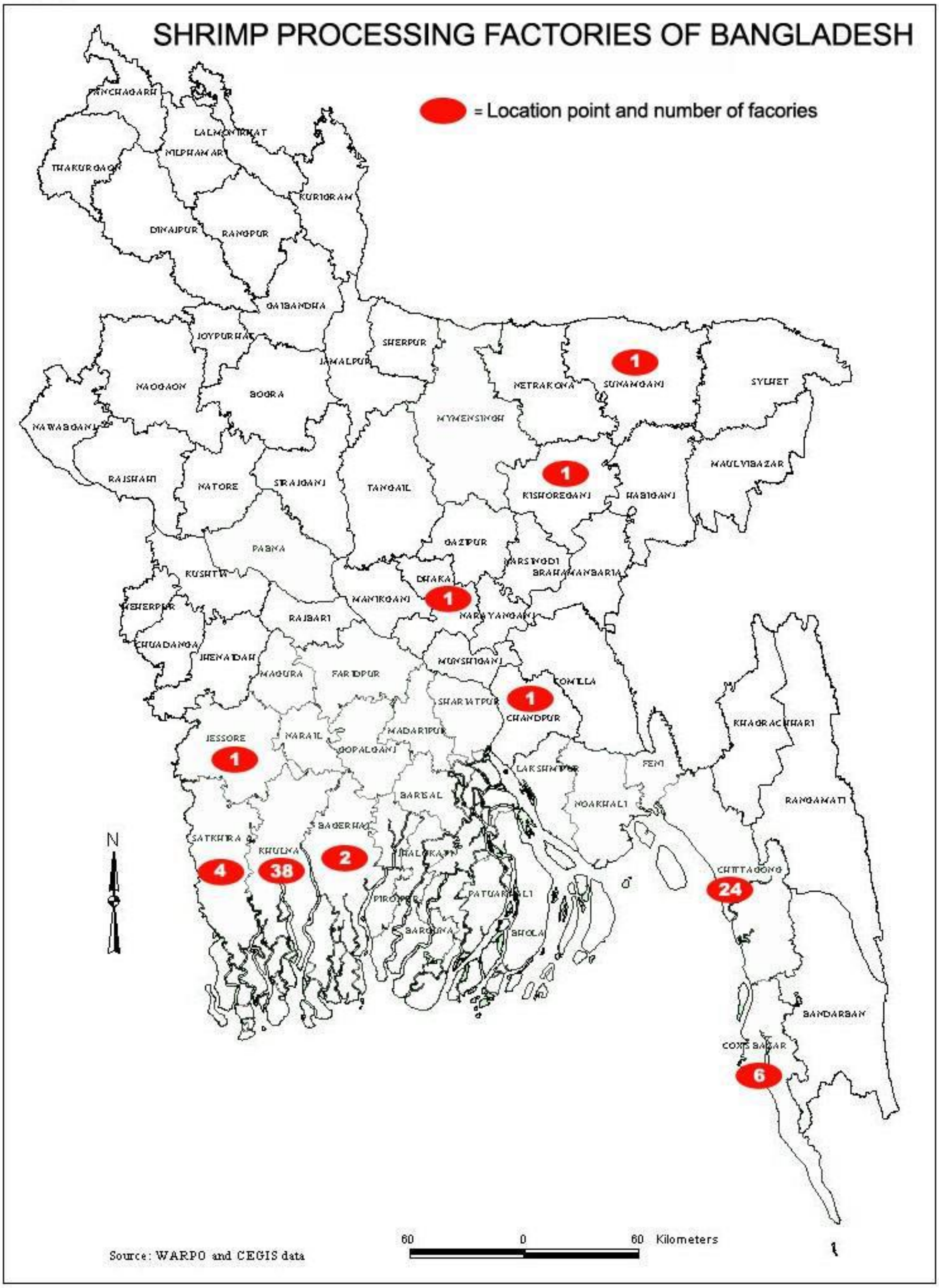


Figure 3.3: Shrimp Processing Factories in Bangladesh

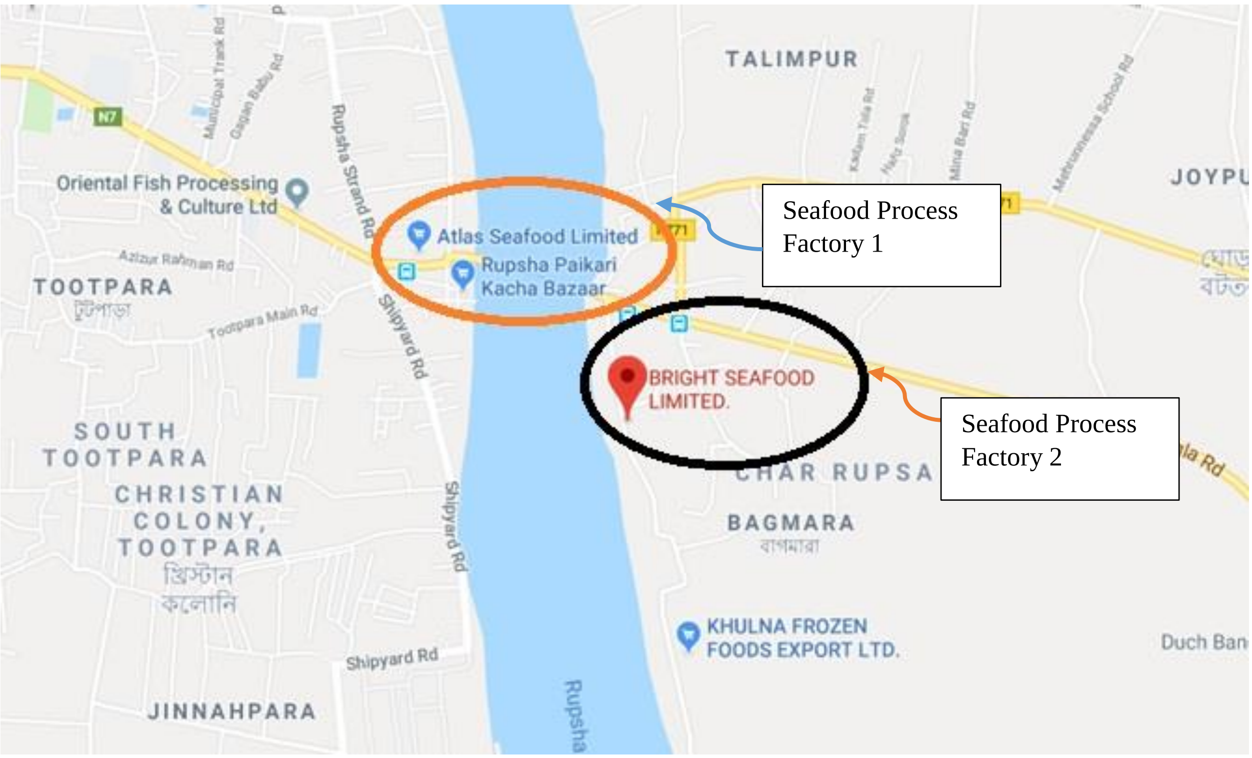


Figure 3.4: Atlas and Bright Seafood Processing Industry

3.3 Sampling Point Selection

There are several unit process are including in shrimp factory. Some of unit processes use water and produce wastewater. Following selected unit processes are considered as wastewater producing unit. Following figure (3.5) shows all unit processes and wastewater producing unit processes. Wastewater from each unit operation meet a common channel and then discharge by main channel to river or City Corporation's sewage line.

During the operation periods sample was taken from each unit of bench scale plant. The total sample source can be classified as two types of source. One sampling from industry and another sampling from bench scale plant. Sample from industry were collected from following five sources

- ❖ Receiving shrimps and initial washing
- ❖ Initial icing (or IQF)
- ❖ Deheading and
- ❖ Dewatering or soaking or production room
- ❖ Common drain (for regular feed in the bench scale plant)

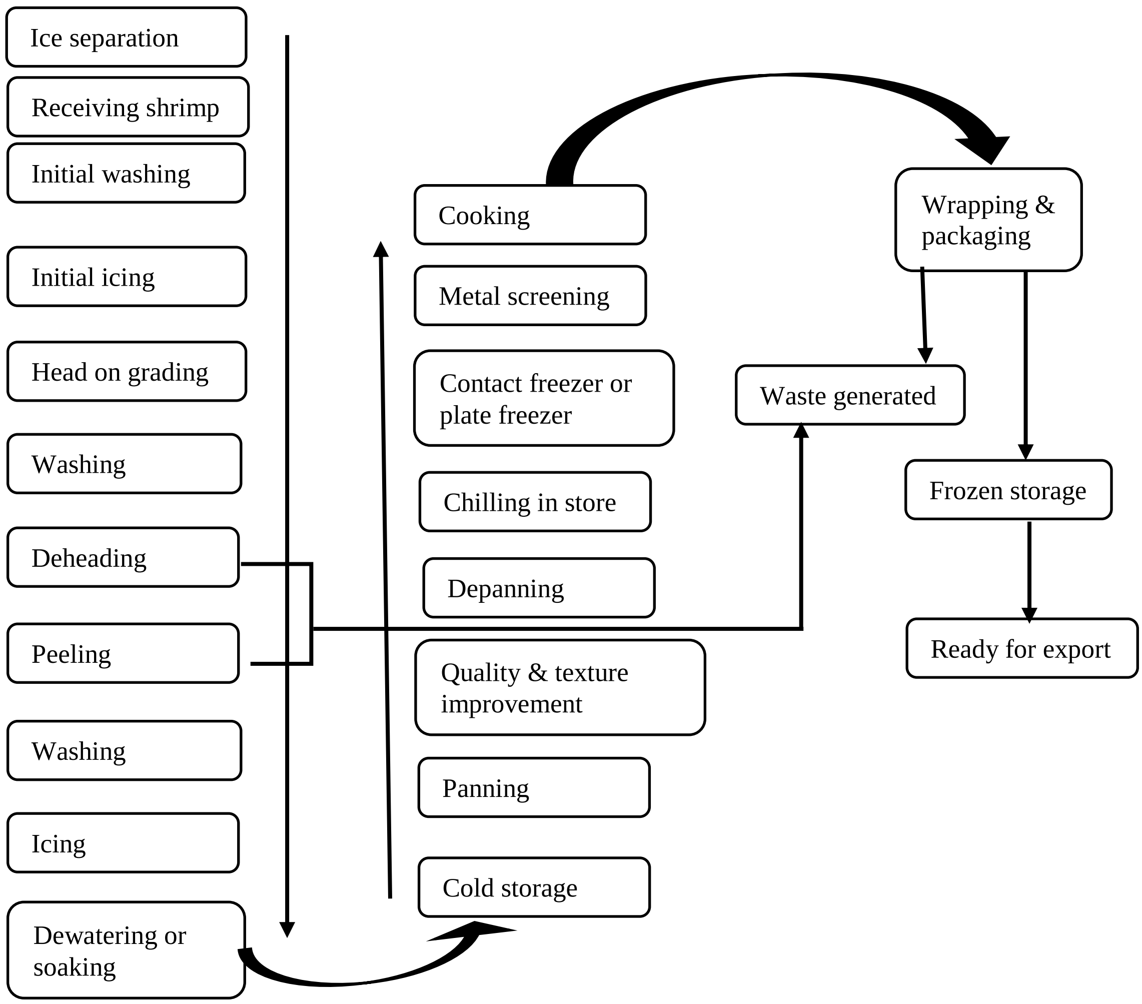


Figure 3.5: Wastewater Producing Unit Processes.

Above sampling points and wastewater discharge point were chosen for sampling. The result from this sample were used as design basis. On the other hand many samples were taken from only bench scale plants. Sample were collected from every point of the bench scale plant like EQT, primary clarifier, biological reactor and secondary clarifier. The result found from the bench scale were used to performance analysis of the bench scale. Following figure (3.6) gives clear concept about sampling.

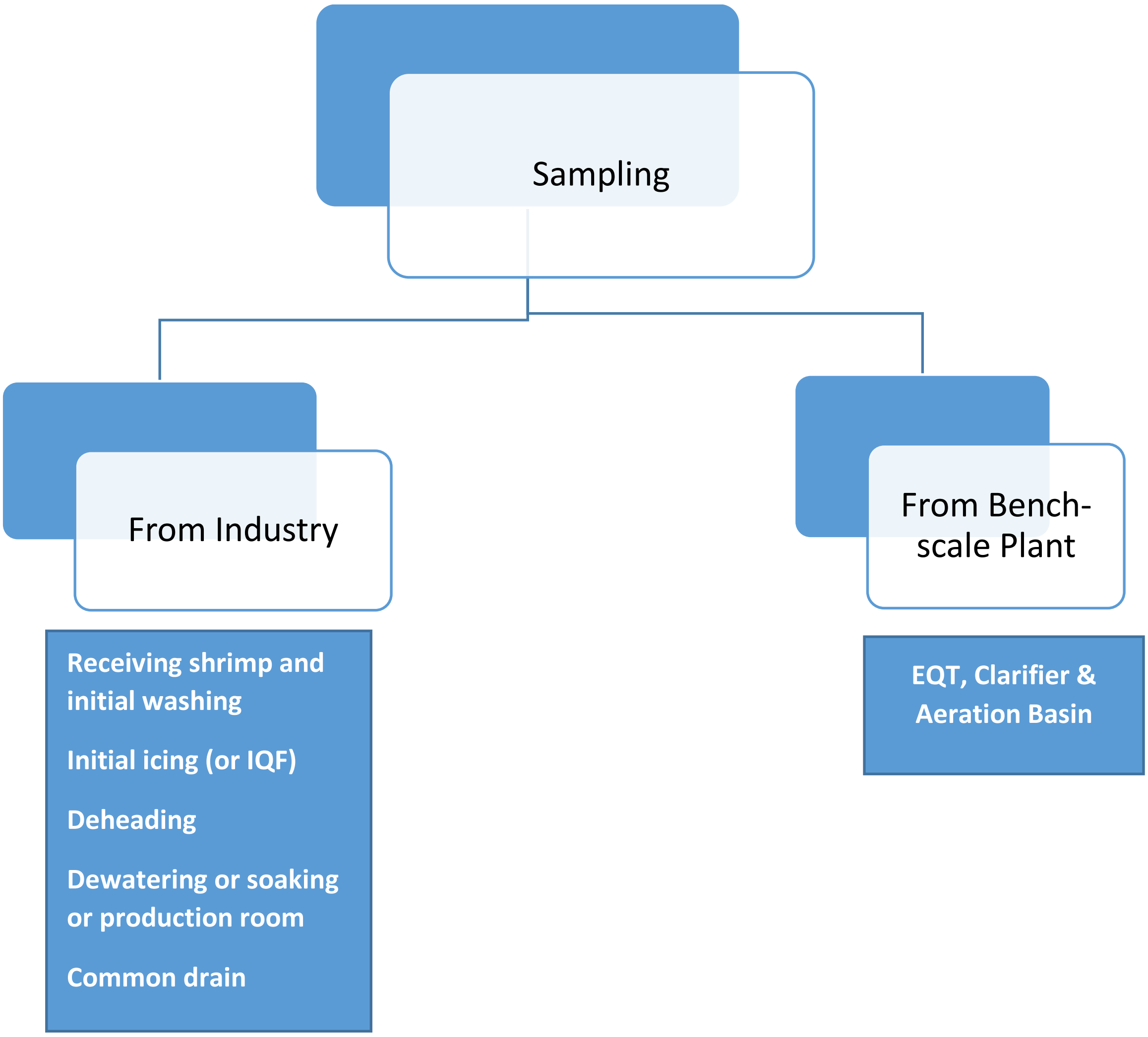


Figure 3.6: Sampling Design

3.4 Sample Collection and Preservation

Sample collection and preservation has attained according to standard method. Samples were randomly collected in washed plastic bottles of 500mL, 1000mL and 5L to cover most of the investigated area during study period. The bottles were completely filled with effluents in a way so that no air remains above the surface. Most of the sample were collected from the outlet drain of the industry. Each sampling bottle was cleaned thoroughly by rinsing with tap water followed by washing with distilled water to remove undesirable solids and suspended materials. The chemical analyses of effluents were performed as quickly as possible. All the samples were preserved (if necessary) into the refrigerator in laboratory.

Figure 3.7: Sample Collection point

3.5 Analysis of the Physical and Chemical Properties of WW for the Plant Design

Total Solids: Total solids were measured by evaporating the sample at 105 degree Celsius in evaporator.

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

Total Suspended Solids (TSS): Total Suspended Solids (TSS) was determined by subtracting between total solids and total dissolved solids.

Dissolved Oxygen (DO): The Dissolved Oxygen (DO) of the effluent samples was determined in the laboratory by DO meter *(Model: Hach: HQ-40d, multi).*

Biological Oxygen Demand (BOD): Biological Oxygen Demand (BOD) of the effluent samples was determined by DO meter (*Model: Hach: HQ-40d, multi*) and analytical method by MnSO4 solution, Alkali Iodide Azide, Sodium Thiosulfate and Starch.

Chemical Oxygen Demand (COD): Chemical Oxygen Demand (COD) of the effluent samples was determined by the spectrophotometer (*Model: Hach DR 2700, program no – 955 COD 171220, 600nm, Single wavelength*)

pH: pH of effluent samples was determined electrochemically with the help of glass electrode pH meter (*Model: Lovibond, Senso Direct, pH110*).

3.6 Design Basis

Following parameters were used for design of Bench scale plant. These parameters were found from la laboratory measurement of collected samples.

Table 3.1: Parameters that used for design basis *(see appendix for detail)*

Parameters/points	(1)	(2)	(3)	(4)	(5)
DO (mg/L)	1.39	1.26	1.83	1.46	1.5
BOD_5 (mg/L)	270	234	489	362	330
COD (mg/L)	756	655	1370	1013	256
TS (mg/L)	2430	3380	2430	4000	1720
TSS (mg/L)	640	80	50	480	40
TDS (mg/L)	2380	3300	2380	2900	1680
pH	7.5	7.51	7.61	7.66	8

N.B: Detail parameters of pre sampling are in Appendix 01

Though above data has found from laboratory analysis but a range has considered for bench scale plant design. According to following parameters design has done.

Table 3.2: Range of parameters that considered for design of the plant

pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	TS (mg/L)	TDS (mg/L)	TSS (mg/L)
7 – 9.5	1 – 2	250 – 450	450 – 650	2500 – 4500	1500 – 3500	≤ 600

3.7 Design Procedure

Two bench scale plant (called BSP1 and BSP2) were designed for the study. The flow of wastewater have been kept same for both plants. The variation between two bench scale plants were hydraulic retention time, volume of biological basin and clarifier, surface area of sedimentation tank and amount of air provided.

Though the objective of this study was best available design and performance operation of shrimp processed wastewater treatment through biological and physical treatment process. A little variation also maintained to comparison. Following table *(table 3.3 & 3.4)* are showing the design data that has used for this study and design calculation is given in the next following section.

Table 3.3: Design data for plant 1

Design Criteria	Plant 01		
Medium strength wastewater			
General			
Flow (Q), m^3/s	20 ml/min		
Clarifier		Aeration/biological Rector	
Influent SS, mg/l	300 mg/l	Influent SS, mg/l	150 mg/l
InfluentBOD_5	360 mg/l	Influent BOD_5,	250 mg/l
SS Removal Capacity (%)	50%	Effluent BOD_5, S	30 mg/L
BOD_5 Removal Capacity (%)	30%	Growth Constant,	100 mg/L BOD_5
Retention Period, hr	1.0 hr	μ_m	2.5 /d
Tank Type	Circular	k_d	0.05 /d
Composition of Tank	High Density Polyethylene (HDPE)	Y	0.50 mg VSS/mg BOD_5 remv.
Diameter	0.1 m or 4 inch	Composition of Aeration Basin	High Density Polyethylene (HDPE)
Surface Area	0.00785 m^2	Length & Width	37 cm & 18 cm or 14 inch & 7 inch
Liquid Depth	17 cm or 7 inch	Surface Area	0.0576 m^2
Free Board	10%	Liquid Depth	0.13 m or 5 inch
Volume of clarifier (process Zone)	0.00133 or 1.3 Liter	Free Board	10%
Unit	01	Unit of Aeration Basin	01
Surface Loading Rate (SLR)	3.66 m^3/m^2 d	Volume of Aeration Tank	0.007488 m^3
Weir Loading Rate (WLR)	0.09 m^3/m^2 d	Hydraulic Retention Time	6.25 hr
Sludge Hopper Volume	0.000525 m^3	Air Volume	3 L/min
Total Height of the Tank	0.23 m	Aeration System	Diffused Aeration (by Aquarium stone diffuser)
Sludge Removal	Mechanically (once in every 7 days)	Mixing	Continues and Completely mixed
Pipe Diameter	6 mm	Pipe Diameter	6 mm
Controlling Device Ball valve			

Table 3.4: Design data for plant 2

Design Criteria	Plant 02		
Medium strength wastewater			
General			
Flow (Q), m3/s	20 ml/min =		
Clarifier (Primary and Secondary)		Aeration/biological Rector	
Influent SS, mg/l	300 mg/l	Influent SS, mg/l	150 mg/l
Influent BOD_5	360 mg/l	Influent BOD_5,	250 mg/l
SS Removal Capacity (%)	50%	Effluent BOD_5, S	30 mg/L
BOD_5 Removal Capacity (%)	30%	Growth Constant,	100 mg/L BOD_5
Retention Period, hr	2.3 hr	μ_m	2.5/d
Tank Type	Circular	k_d	0.05/d
Composition of Tank	High Density Polyethylene (HDPE)	Y	0.50 mg VSS/mg BOD_5 remv.
Diameter	0.17 m or 7 inch	Composition of Aeration Basin	High Density Polyethylene (HDPE)
Surface Area	0.0227 m^2	Length & Width	35.56 & 18 cm (each) or 14 inch & 7 inch
Liquid Depth	0.125 m or 5 inch	Surface Area	0.064 m^2 (each) 14inch x7inch
Free Board	10%	Liquid Depth	0.1 m or 4 inch (each)
Volume of clarifier (process Zone)	0.0028 or 2.8 Liter	Free Board	20% (0.02m) (each)
Unit	01	Unit of Aeration Basin	02
Surface Loading Rate	1.27 m^3/m^2 d	Volume of Aeration Tank	0.0064 m^3
Weir Loading	0.053 $m^3/m.d$	Hydraulic Retention Time	10 hr
Sludge Hopper Volume	$0.0016m^3$	Air Volume	3 L/min
Total Height of the Tank	0.252 m	Aeration System	Diffused Aeration (by Aquarium stone diffuser)
Sludge Removal	Mechanically (once in every 7 days)	Mixing	Continues and Completely mixed
Pipe Diameter	6 mm	Pipe Diameter	6 mm
Controlling Device Was Ball Valve			

3.8 The Bench Scale Plant Design Calculation

The bench scale plant design calculation is given bellow-

Design calculation of plant 02

Design Criteria	Plant 02
Medium strength wastewater	
Flow (Q), m3/s	20 ml/min = $3 \text{ X } 10^{-7} m^3/S$
Influent SS, mg/l	300 mg/l
Retention Period, hr	1.5 hrs
SS Removal Capacity (%)	50%
BOD_5 Removal Capacity (%)	30%
Tank Type	Circular
Sludge Removal	Mechanically

Design calculation of plant 01

Step 01: Compute the volume of the tank

Volume of the tank (V) = Flow (Q) X Retention Time (T)

∴ V = QT = $3 \text{ X } 10^{-7} m^3/S$ X 5400 S (As 1.5 hr = 5400 S)

= 1.79 L ≈ **2 L**

Provide circular tank which diameter is 10 cm or 4 inch

So, area of the tank = $\pi D^2/4 = 3.14\ (0.1)^2/4$ = 0.00785 m^2

So, Necessary Height of the tank, H = V/A = 0.002 m^3/0.00785 m^3 (2L= 0.002 m^3)

Or H = 0.254 m = 25.47 cm

But, provided 17 cm or 7 inch height for the Tank. So, Effective volume of the primary sludge tank (PST)

V = AH

Or, V = 0.00785 m^2 X 0.1 m

Or, V = 0.00133 $\mathbf{m^3}$

= 1.33 L ≈ 1.3 L

Therefore, Effective Volume of PST = **1.3 L** considered

Hence, Effective HRT = V/Q

$$= \frac{1.3 \text{ L}}{\left(\frac{20}{1000}\right)\text{L/min}}$$

= 65 min ≈ **1 hr**

Step 02: Calculate the Surface Loading Rate (SLR)

$$\text{SLR} = \frac{\text{Flow (Q)}m^3/d}{\text{Surface Area }(A_S)m^2} = \frac{0.0288\ m^3/d}{0.00785\ m^2} = 3.66\ \frac{m^3}{m^2}.d$$

Weir Loading Rate (WLR) calculation

$$\text{WLR} = \frac{\text{Flow (Q)m}^3/\text{d}}{\text{Length of weir,m}} = \frac{0.0288\ \text{m}^3/\text{d}}{\pi \text{ x } 0.1\ \text{m}} = 0.09\ \text{m}^3/\text{md}$$

Step 03: Design of the sludge hopper bottom

Computation of Sludge Production

Computation of mass of primary sludge generated, M_{sl}

M_{sl} = 50% of SS in the influent

= 0.50 X 30 mg/L X 28.8 L-d (0.0288m3 = 28.8 L)

= 4320 mg/d

= 4.32 gm/d

= 0.00432 kg/d

= 0.0018 kg/h

 # Volume of Primary sludge produced

Assume Sg of primary sludge 1.03 and 6.0% of solids convert in sludge (i.e. 94% moisture content)

Therefore, volume of sludge production each day

$$V_{sl} = \frac{M_{sl}}{\rho_w\, S_d\, P_s}$$

$$= \frac{0.00432}{998.2 \text{ X } 1.03 \text{ X } 0.06}$$

= $0.0000700\ \text{m}^3/\text{d}$

= $0.000003\ \text{m}^3/\text{h}$

V_{sl} = Volume of Sludge, m3/d

M_{sl} = Mass of sludge kg/d

ρ_w = Density of water, kg/m3 (998.0 at 0ºC

S_d = SG of primary sludge = 1.03

P_x = % of solids in primary sludge, 0.06

Hopper Bottom

Assume every 7 days sludge will be collected once,

∴ 7days X 24 hrs = 168 h

First, find out the necessary capacity of sludge pocket, C

C = V_{sl} X Collecting hour (s)

$$\therefore C = 0.000003 \frac{\text{m}^3}{\text{h}} \text{X } 168\ \text{h}$$

= $0.000504\ \text{m}^3$

Now, Volume of hopper bottom, V_{HP}

V_{HP} = 1/3 H $(B^2 + AB + A^2)$

$= 1/3\ (0.115)\ [(0.1)^2 + (0.1\ X\ 0.025) + (0.025)^2]$

$=$ <u>0.000503</u> m^3

But we need 0.000504 m3 that found from value of C

Therefore, H will be provided 0.12 m

Now, Check V_{HP} = 1/3 X 0.12 X 0.013125

= 0.000525 m^3 OK

Step 04: Overall depth of the PST, H_{total}

H_{total} = Liquid Depth + Freeboard (10% usually) + Depth for the tank bottom slope + Hopper bottom depth

∴ H_{total} = 0.1 m + 0.01 m + 0.12 m

= 0.23 m

= 23 cm ≈ 9 inch

Aeration Basin Design

Design Criteria

Flow	20 ml/min = 3 X $10^{-7} m^3/S$
Influent BOD_5, S_0	250 mg/L
Effluent BOD_5, S	30 mg/L
Growth Rate Constant, K_s	100 mg/LBOD_5
μ_m	2.5 / d
K_d	0.05 / d
Y	0.50 mg VSS/mg BOD_5 remv.

Assuming that the secondary clarifier Effluent will contain only 30 mg/L SS and soluble BOD_5 will be 60% of SS.

S = BOD_5 allow – BOD_5 in SS

S = 30.0 – (0.6) (30) = 12 mg/L

Step 01,

The mean cell residence time was calculated by following formula

$$S = \frac{K_s\ (1 + K_d \theta_c)}{\theta_c(\mu_m - K_d) - 1}$$

$$12 = \frac{100\ (1+0.05\theta_c)}{\theta_c\ (2.5-0.05) - 1}$$

θ_c = 4.6 d ≈ <u>5 days</u>

Step 02,

MLVSS Calculation, We have $X = \frac{\theta_c\ Y\ (S_0 - S)}{\theta\ (1 + K_d\ \theta_c)}$

Or, X = $\frac{5\ d\ x\ 0.5\ (250-30) mg/L}{0.25\ d\ [1+(0.05\ x\ 5d)]}$

Or, X = <u>1760 mg/L</u>

Step 03, Considered MLVSS was 2500 mg/L and solve the Hydraulic Detention (also called Retention) time by following

X = $\frac{\theta_c\ Y\ (S_0 - S)}{\theta\ (1 + K_d\ \theta_c)}$

2500 = $\frac{5\ d\ 0.50\ (250-30)}{\theta\ (1+0.05\ x\ 5.0)}$

$\theta = 6$ hrs

Step 04 Volume of the aeration basin ∀

∀ = QT

= 3 X $10^{-7} m^3/S$ X 6hr X 3600 S/hr

= 0.00648 m3

= 6.48 L ≈ 6.5 Liter

But an 8L rectangular basin was provided. So, HRT now find 8L/1.2L.hr = 6.25 hr

The summary of design data is representing in the following tables

Design criteria of plant Two

Step 01: Compute the volume of the tank

Flow (Q) were kept 20ml/min continuously

Volume of the tank (V) = Flow (Q) X Retention Time (T)

∴ V = QT = 3 X $10^{-7} m^3/S$ X 5400 S (As 1.5 hr = 5400 S)

<u>= 1.79 L ≈ **2 L**</u>

Provide circular tank which diameter is 17 cm or 0.17 m (7inch)

So, area of the tank A= $\pi D^2/4$ = 3.14 $(0.17)^2/4$ = 0.02269 m^2 ≈ 0.0227 m^2

Therefore Necessary Height of the tank, H = V/A = 0.002 m^3/0.0227 m^3 (2L = 0.002 m^3)

Or H = 0.08814 m = <u>8.815 cm</u>

But, provided <u>12.5 cm (5 inch)</u> height for the Tank. So, Effective volume of the primary sludge tank (PST)

V = AH

Or, V = 0.0227 m^2 X 0.125 m

Or, V = 0.0028 m^3

= 2.8 L

Therefore, Effective Volume of PST = **2.8 L** considered

Hence, Effective HRT = V/Q

$$= \frac{2.8\ \text{L}}{\left(\frac{20}{1000}\right)\text{L/min}}$$

= 80 min ≈ 2.3 hr

Step 02: Calculate the Surface Loading Rate (SLR)

∵ 20ml/min = $0.0288\ \text{m}^3/\text{d}$

$$\text{SLR} = \frac{\text{Flow (Q)m}^3/\text{d}}{\text{Surface Area }(A_s)\text{m}^2} = \frac{0.0288\ \text{m}^3/\text{d}}{\mathbf{0.0227}\ \text{m}^2} = 1.27\ \text{m}^3/\text{m}^2\ \text{d}$$

Weir Loading Rate (WLR) calculation

$$\text{WLR} = \frac{\text{Flow (Q)m}^3/\text{d}}{\text{Length of weir,m}} = \frac{0.0288\ \text{m}^3/\text{d}}{\pi \times 0.17\ \text{m}} = 0.053\ \text{m}^3/\text{m.d}$$

Step 03: Design of the sludge hopper bottom

Computation of Sludge Production

Computation of mass of primary sludge generated, M_{sl}

M_{sl} = Assume 50% of SS in the influent

= 0.50 X 30 mg/L X 28.8 L-d (0.0288m3 = 28.8 L)

= 4320 mg/d = 4.32 gm/d = 0.00432 kg/d = 0.0018 kg/h

Volume of Primary sludge produced

Assume Sg of primary sludge 1.03 and 6.0% of solids convert in sludge (i.e. 94% moisture content)

Therefore, volume of sludge production each day

$$V_{sl} = \frac{M_{sl}}{\rho_w\ S_d\ P_s}$$

$$= \frac{0.00432}{998.2 \times 1.03 \times 0.06}$$

$= 0.0000700\ \text{m}^3/\text{d}$

$= 0.000003\ \text{m}^3/\text{h}$

V_{sl} = Volume of Sludge, m3/d

M_{sl} = Mass of sludge kg/d

ρ_w = Density of water, kg/m3 (998.0 at 20ºC)

S_d = SG of primary sludge = 1.03

P_x = % of solids in primary sludge, 0.06

Hopper Bottom

Assume every 7 days sludge will be collected once,

∴ 7days X 24 hrs = 168 h

First, find out the necessary capacity of sludge pocket, C

C = V_{sl} X Collecting hour (s)

$\therefore C = 0.000003 \frac{m3}{h} X\, 168\ h$

= $\underline{0.000504\ m^3}$

Now, Volume of hopper bottom, V_{HP}

V_{HP} = 1/3 H $(B^2 + AB + A^2)$

= 1/3 (0.12) $[(0.17)^2 + (0.17\ X\ 0.05) + (0.05)^2]$

= $\underline{\mathbf{0.0016\ m^3}}$

But we need 0.000504 m3 that found from value of C

Therefore, Sludge hopper area is **OK**

Notes: Though normally sludge bottom hopper volume will be less than water liquid depth but here I have provided readymade plastic bottle which contain that volume of trapezoidal part and used here as sludge holding part.

Step 04: Overall depth of the PST, H_{total}

H_{total} = Liquid Depth + Freeboard (10% usually) + Depth for the tank bottom slope + Hopper bottom depth

$\therefore H_{total}$ = 0.125 m + 0.007 m + 0.12 m

= 0.252 m = 25.2 cm ≈ 10 inch

Aeration Basin Design:

Design Criteria

	Plant 02
Flow	20 ml/min = 3 X $10^{-7} m^3/S$
Influent BOD_5, S_0	250 mg/L
Effluent BOD_5, S	30 mg/L
Growth Constant, K_s	100 mg/L BOD_5 (consider)
μ_m	2.5 / d (consider)
k_d	0.05 / d (consider)
Y	0.50 mg VSS/mg BOD_5remv. (consider)

Assuming that the secondary clarifier Effluent will contain only 30 mg/L SS and soluble BOD_5 will be 60% of SS.

S = BOD_5 allow – BOD_5 in SS

S = 30.0 – (0.6) (30) = 12 mg/L

Step 01,

The mean cell residence time was calculated by following formula

$S = \frac{K_s\ (1 + K_d \theta_c)}{\theta_c(\mu_m - K_d) - 1}$

$12 = \frac{100\ (1 + 0.05\theta_c\ )}{\theta_c\ (2.5 - 0.05\ ) - 1}$

θ_c = 4.6 d ≈ 5 days

Step 02,

MLVSS Calculation, We have $X = \frac{\theta_c\ Y\ (S_0 - S\ )}{\theta\ (\ 1 + K_d\ \theta_c)}$

Or, $X = \frac{5\ d \times 0.5\ (\ 250 - 30) mg/L}{0.41\ d\ [\ 1 + (0.05 \times 5d)]}$ (Assume Detention time, θ = 0.25d)

Or, X = 1760 mg/L

Step 03, Considered MLVSS is 2500 mg/L and then recalculate the Hydraulic Detention (also called Retention) Time by the following calculation

$X = \frac{\theta_c\ Y\ (S_0 - S\ )}{\theta\ (\ 1 + K_d\ \theta_c)}$

$2500 = \frac{5\ d\ 0.50\ (250 - 30)}{\theta\ (1 + 0.05 \times 5.0)}$ Therefore, $\theta = 6$ hrs

Step 04: Volume of the aeration basin ∀

∀ = QT

= 3 X $10^{-7} m^3/S$ X 6hr X 3600 S/hr

= 0.00648 m3

= 6.48 L ≈ 6.5 Liter

But, it was provided two rectangular aeration basins of each 6 L.

Therefore, Total Volume of aeration basin is 12 L with free body.

So, HRT of aeration Basin was calculated, $\frac{12\ L}{1.2\ L/hr}$ = **10 hr**

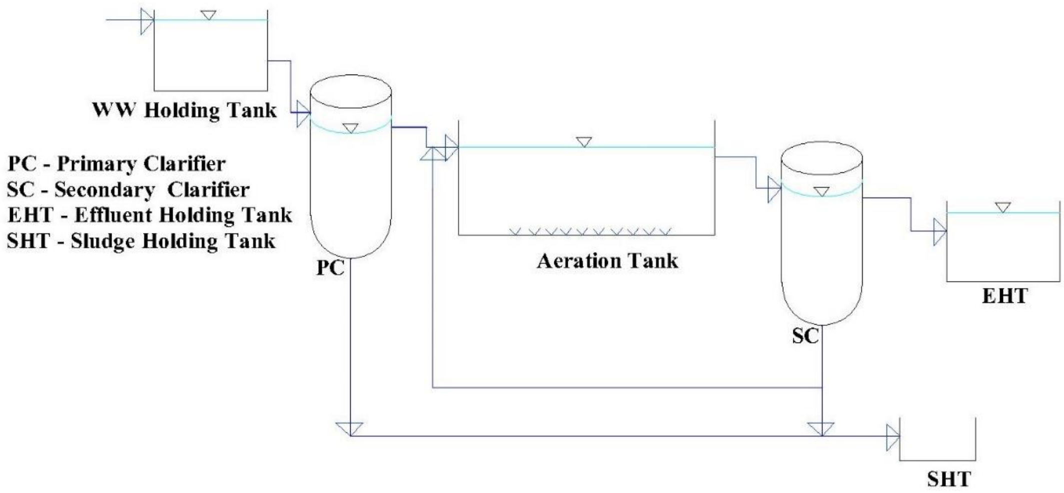


Figure 3.8: Process Flow Diagram

All the design has calculated by the according to the reference Davis & Conwell and Karia & Cristian.

According to the plant has been installed in the Department of Civil engineering. All equipment and tools were bought from local market. After the installation, the bench scale plant flow regime was checked by using tap water. Its mean fed tap water and run the plant. The reason of fresh water checking was to find any fault or leakage and then refit it. After completion of all checking, wastewater was fed.

N:B: (1) Secondary clarifier was same as primary. (2) Though required oxygen and air volume was so small and it is tough to manage such aerator. So, it was provided 3ml/min aerator. The next figure 3.9 is showing the plan and sectional view of the designed bench scale plant.

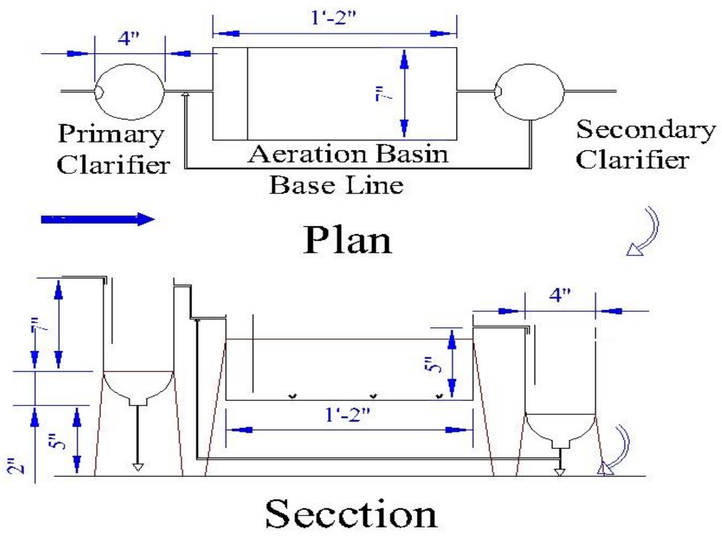


Figure 3.9: Plan and Section of the Bench Scale Plant (01)

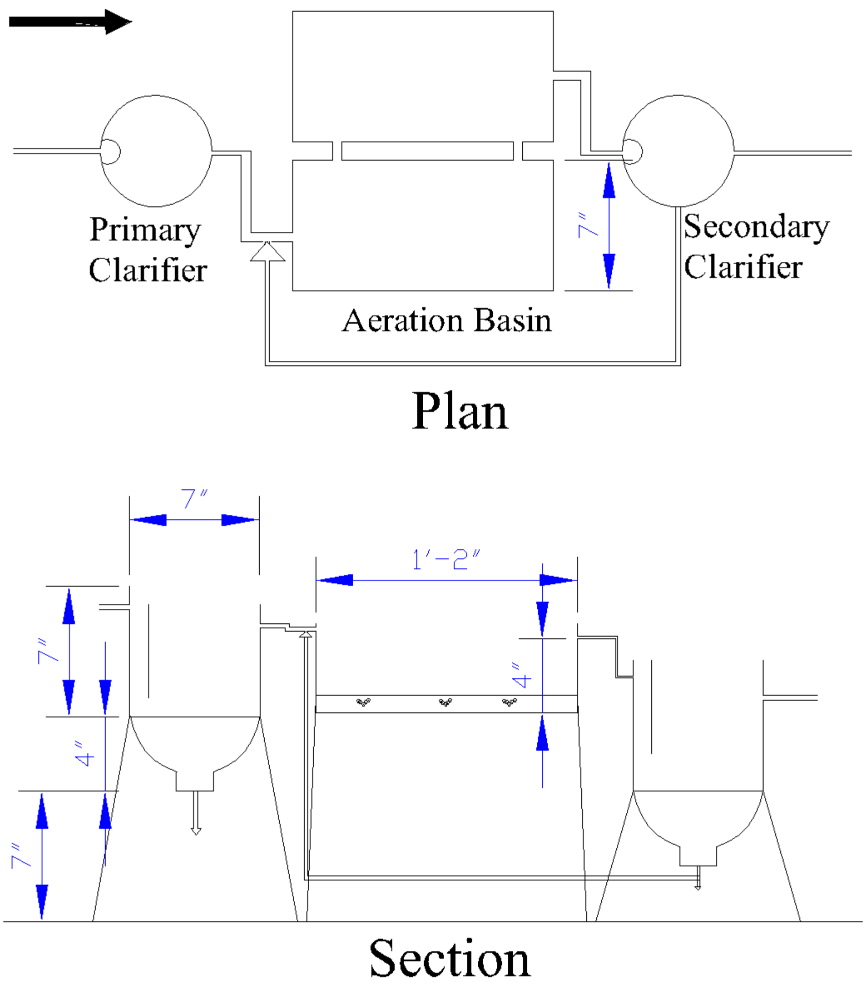


Figure 3.10: Plan and Section of the Bench Scale Plant (02)

The next figure is giving clear concept in support of above data. The bench scale plant (01) in real view is given bellow.


Figure 3.11: Photograph of Laboratory Bench Scale Plant 1

3.9 Microbial Growth

It is essential part to grow microorganism in biological treatment. Because, microorganism takes part to degrade biodegradable solids from wastewater. The microorganisms were grown up in aeration basin and then continue the process.

It was assumed, there was no microorganism present in wastewater. Another two assumption were considered. One, waste stabilization by the microorganisms occurs only in the reactor unit and two, the volume used in calculating the mean cell residence time for the system includes only the volume of the reactor unit (Metcalf, 1995).

In aeration basin, sample wastewater was poured and air was supplied by air pipe in wastewater of aeration basin. Continuously air was supplied. Wastewater poured and kept at least 5 days to grow microorganism. After 2-3 days MLVSS was checked in laboratory for observed the condition of microbial growth. Whether it was measured and recorded.

The calculated or required MLVSS was found 1073mg/L for run the system. When the MLVSS was found more than the required then the system was run. There were eight days took to growth microorganism in aeration basin. After this, continuously the bench scale plant was run.

No bacterial seed and additional excess nutrition or food supplied during bacterial culture in aeration basin. Assumed necessary nutrients and food were available in wastewater.

3.10 Operation and Maintenance

Wastewater was collected and delivered into the plant as soon as possible to avoiding undesired condition. It was continuous process and flow rate was maintained uniformly 20 ml/min. A holding tank or equalization basin was used to supply wastewater equally in to the primary clarifier. The flow was controlled manually setup. This basin was covered for protecting any fault. Cover was contained some hole to avoid anaerobic condition (*see figure 3.8*). Another type open holding tank were also used *(see the figure 3.7).*

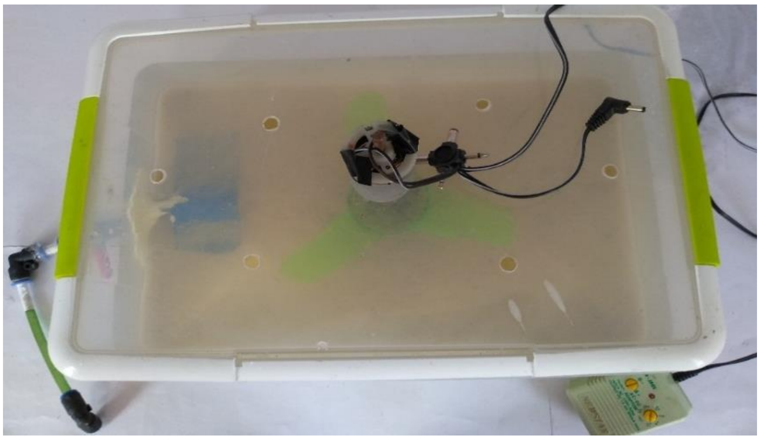


Figure 3.12: Wastewater Holding Tank (perforated head cover)

From equalization basin wastewater was flown to primary clarifier. A baffle wall was provided as flow can't disturb particle settling. Sludge was settled in settling zone and relatively clear wastewater go out for next treatment. Sludge was collected by collection pipe once in week normally. A controlling valve was used to open and close of sludge drain.

Then wastewater was flown to aeration basin. Organic solids was separated from wastewater biologically. Bacteria that was cultured before in microbial growth stage as discussed in section 3.9. Microorganism of aeration basin reduce BOD_5. No settling was occurred in the aeration basin. Air was supplied through diffused stone and perforated pipe *(see figure 3.9).* No manual stirring was done. An aerator was used as source of air. A baffle wall also provided to maintain down flow. From aeration basin, wastewater go through next unit by up flow (*see the plan and section or process diagram*).

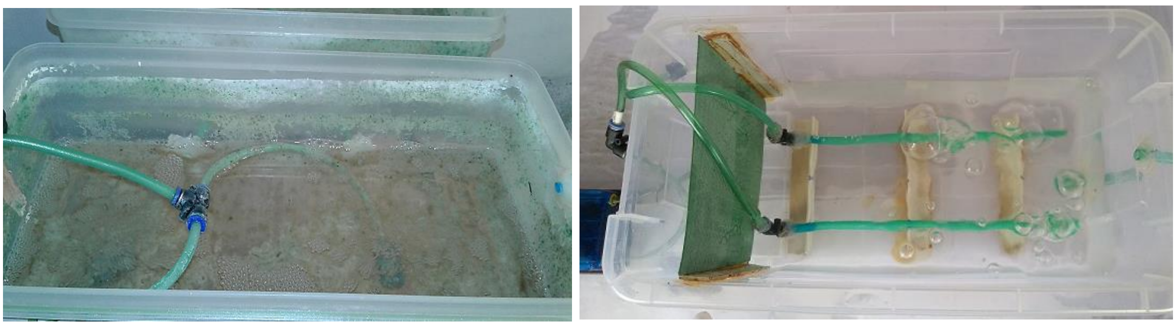


Figure 3.13: (a) Stone Diffuser, (b) Aeration by Perforated Pipe

Then organic solids or biomass finally settle down in secondary clarifier. The design of secondary clarifier was same as first one. Wastewater enter in secondary clarifier as down flow. Sludge was settle and left through bottom of the settling tank. Effluent was left as up flow through upper portion or weir of the clarifier. Recycling and sludge wasting was separated by controlling device. A recycling pump (40L/hr) was set up to maintaining recycling. Final effluent was collected in a collection tank for quality tests. Rest of effluent were discharged.

No specific pH condition was maintained. Because, pH of raw wastewater was found in 6.5 to 9 level.

3.11 Laboratory Analysis

Sample was collected from different units of bench scale plant. Samples were collected regular basis and examined. The result obtained from laboratory examined was used to performance analysis of the bench scale plant. The following twelve parameters were measured and analyzed in this study. The method outlined in the Standard Methods for the Examination of Water and Wastewater (APHA 21st Edition).

Table 3.5: Equipment and/or chemicals used in laboratory examined

SL	Tested Parameter	Unit	Used Equipment/Chemicals/Reagents
1	pH		pH meter (Lovibond, Senso Direct pH 110)
2	DO	mg/l	DO meter (Hach , HQ – 40d (multi)
3	BOD_5	mg/l	MnSO4, NaSO2SO4, KI, NaOH, H2SO4, Starch Solution
4	COD	mg/l	Spectrophotometer (HACH, DR 2700, program no – 955, 171220/600 n m, single wavelengths)
5	EC (Electrical Conductivity)	µs/cm2	Hach 1011 D
6	Chloride (cl^-)	mg/l	K2Cr207, AgNO3
7	TS (Total Solid)	mg/l	Evaporation Dish, Filter paper (0.2 micron), Drying Oven, Measuring scale
8	TDS (Total Dissolved Solid)	mg/l	
9	TSS (Total Suspended Solid)	mg/l	
10	MLVSS (Mixed liquor suspended solids)	mg/l	
11	TC/FC (Total Coliform/faecal coliform)		Petri dish, Auger, Filter paper
12	Nitrate	mg/l	Spectrophotometer (HACH, DR 2700, program no – 951, HR PP, 30 mg/L multi wavelengths)
13	Color	PtCO	Spectrophotometer (HACH, DR 2700, program no – 120, 455 n m, 500 units multi wavelengths)

3.12 Data Tabulation and Analysis

The collected data and results from the study were tabulated and compiled as well as presented in appropriate form. Now a days, there are many software are available for research analysis and presentation. Among these many software, MS Excel was used to data recording, analysis and presentation in this study.

CHAPTER IV

Result and Discussion

4.1 General

Lot of selected samples were collected from shrimp (seafood) industries and taken to the environmental engineering laboratory of the Department of Civil engineering of KUET and measured the parameters to get outcome for evaluation of the bench scale plant. Some samples were tested immediately after collection from the industry. Few were preserved as per standard method and it was tested later. Parameters of raw wastewater were measured from sample of industry and bench scale plant. To performance analysis, understand the condition of the plant and operational purpose, samples were taken from the bench scale plant and measured selected parameter. There were almost sixty different samples were collected and tested. It was almost six hundreds test performed to analysis the bench scale plant. The test data and records were kept in a notebook and spread shit program.

This chapter covers the result that found from this study and logical discussion regarding this issue. Difficult data and records has decorated and presented by different charts and tables. The reference data has given in appendix part.

There were twelve different parameters were tested to cover this study. All parameters were not checked in equal numbers. Few parameters likes color, chloride, nitrogen nitrate etc were tested only four or five samples. According to the objective of the study these parameters were not so important to performance analysis of the bench scale plant. There were some important parameters such as BOD_5, COD, solids etc were tested significant numbers of samples. Consistently the result of this study is discussed below. As well as performance basis deliberation is given in following section.

4.2 pH (Hydrogen Ion Concentration)

No much variation was found in pH of this study. In raw wastewater, pH measured typically 7.0 – 8.0. As pH condition was good for process design and bacterial growth, therefore no chemical needed to use. Since no mentionable chemicals are used in shrimp processing that may hamper the pH level of wastewater, as result it was found typically good range of pH. The lowest value of pH was found 7.31 whereas the highest one was 8.53. Billah, (2016) has shown in his Ph.D. research the pH value 8.06 (+/- 1.12). Another research by Thomas, (2016) has also found pH level are 7.5 and 7.4 in different two sources of shrimp process wastewater. There was thirteen raw samples were measured for pH and average arithmetic mean value was found 8.03 and geometric mean value was found 8.02 which standard deviation was 0.37. The pH value that found from raw sample (wastewater from discharge point) is given below.

Table 4.1 pH value of raw sample

Smple	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Value	7.9	8.3	8.2	7.3	8.3	7.7	7.3	8.01	8.19	8.03	8.5	8.2	8.3
Remark	Arith. Mean			8.03		Geo Mean		8.02		Stand Dev.		0.37	

Figure 4.1: pH Value of Raw Sample

From this graph easily see the pH value of raw wastewater. The study didn't found mentionable change of pH value in primary clarifier. The arithmetic mean value of pH was found 8.01. As no chemical was used for coagulation or flocculation so, pH variation was found very negligible.

In aeration basin air was added into the tank. Here also no much variation was found. Very little variation was seen during treatment period. In maximum case, the pH value was found little higher than the value of raw or primary clarifier. Not all the sample were found higher than raw or primary clarifier value. Somewhere pH value of aeration tank was remain less than previous unit process such primary clarifier. During the study period, pH value was found in aeration basin closed to 8.0. Once its pick 9.06 (*see appendix*) except this one, all values were found above 7.5 to near 8.5. The arithmetic mean value was found 8.20 and standard deviation was 0.46.

Finally, treated wastewater left through secondary clarifier. In secondary clarifier, final settlement was occurred and mainly biological sludge settled out. pH variation was state of being more or less 7 to 8. Arithmetic mean value was noted 7.73. Where standard variation was 0.31.

In Bangladesh the effluent quality must be maintained as per government rules. The standard value of pH is 6 – 9 *(see appendix).* Therefore, the designed bench scale plant fully meet the pH value requirement for effluent discharging. The following chart is shown the value from raw wastewater to effluent.

Table 4.2: pH value from raw wastewater to effluent

Raw or Sample WW	Primary clarifier	Aeration	Secondary clarifier	BD standard
8.03	8.01	8.20	7.73	6-9

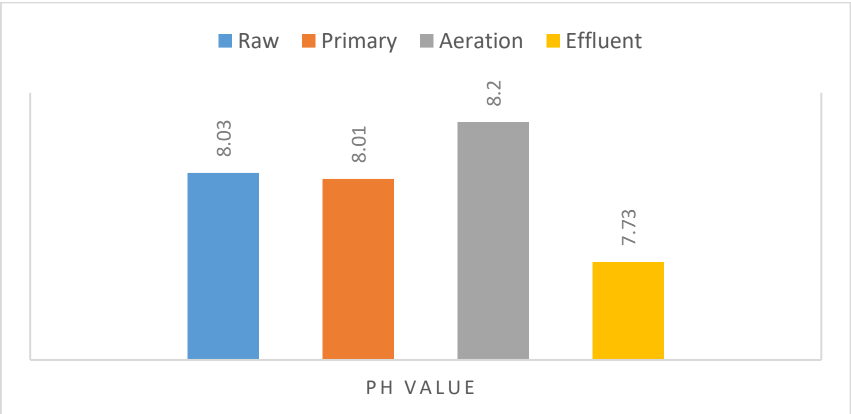


Figure 4.2: pH Values at Different Stages of Treatment

4.3 Dissolved Oxygen

Dissolved oxygen is very much important for effluent discharging. In Bangladesh guideline (*see appendix*) by Department of Environment (DoE), the standard value of DO is 4.5 to 8.0 mg/L. Others some standard of DO is almost near to this range.

There were 15 samples measured for influent Dissolved Oxygen (DO). Sometimes initially checked the DO value in laboratory after receiving the sample from industry or site. Its mean sample collected from industry and brought to project. Then first measured parameters and then pour into the equalization (EQT) or holding basin of bench scale plant. It was not taken more than 01 hour to measure sample from collection time. Sometimes first wastewater poured into the EQT and then samples collected for DO measuring. The below table is representing the DO value of raw wastewater of shrimp processed industry.

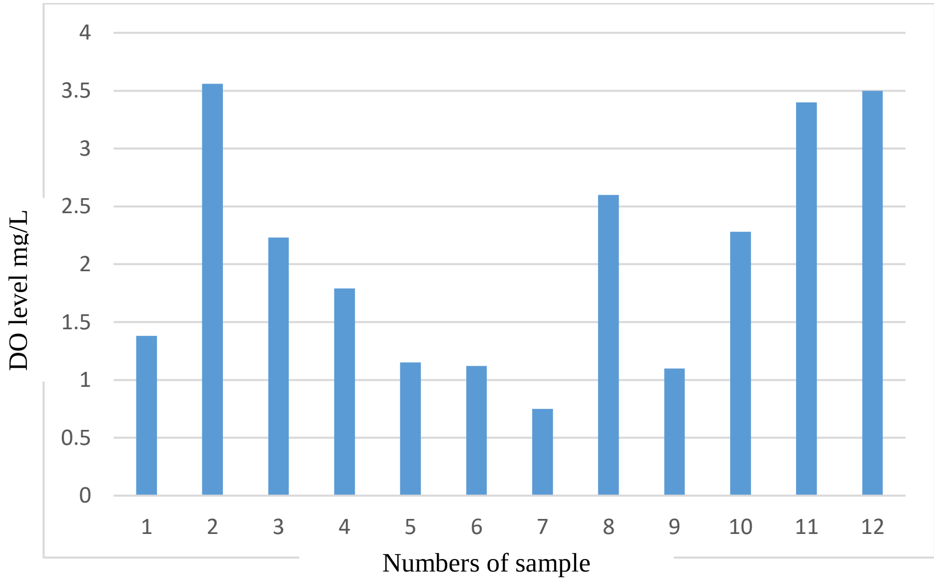


Figure 4.3: Dissolved Oxygen of Inlet wastewater

Here, the DO level is 0 to 4 mg/L shown in graph. This is given for only clear understanding the condition of inlet wastewater DO. The standard value mention above the 4.5 to 8.0. All the value of raw wastewater were found under 4mg/L.

The arithmetic average value of DO of raw wastewater was found 2.07 mg/L. Billah, (2016) has noted the DO value is 1.7 (+/- 0 .12) in his study.

Wastewater passed through primary clarifier, aeration basin and final clarifier. DO level was slightly increased in primary clarifier not mentionable. There were few sample was measured to see what the condition of DO in primary clarifier. The arithmetic mean value was found 2.08mg/L.

Normally DO level was increased in aeration basin due to additional oxygen inject and microorganism use biodegradable waste as food. Here also increase DO level significantly. The amount of air injected was maximum 3L/min. There were 12 samples taken under measurement for DO and found about 3.56 mg/L. Highest DO level noted 7.10 in aeration basin. Whereas minimum value was found 0.6 mg/L. This 0.6 is exactly was uncommon for aeration basin. But in general aeration basin DO level was higher than raw wastewater and from primary clarifier wastewater. The variation of DO level and data shown in a*ppendix.*

After final clarifier, samples were measured and found DO was above 4.5 mg/L. The higher one found 6.3 mg/L and lower one was 1.03 mg/L. except this minimum value all samples were found close to 4.0 to 5 or 6 mg/L of DO. The arithmetic average value was noted 4.68 mg/L. Though it was slight higher than the standard value but it is clear that the value was might be not actionable. But it might be said that it was possible to maintained effluent DO standard by the designed bench scale treatment plant. The following chart is representing the DO level (arithmetic mean value) of effluent and influent with unit processes.

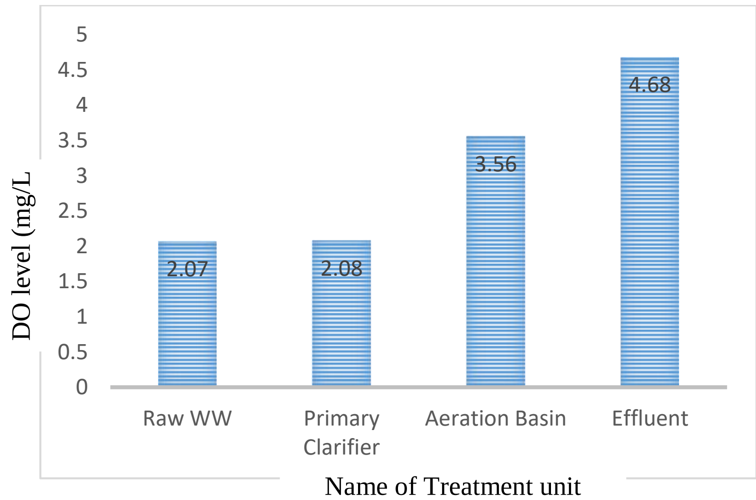


Figure 4.4: DO Level Measured in Different Stage of Processes

4.4 Biochemical Oxygen Demand

The Biochemical Oxygen Demand (BOD_5) is the most important parameter for effluent discharging in the environment. BOD_5 generated due to biological solids. As shrimp processing industries do not use chemicals (mentionable) and organic part found significantly in wastewater from shrimp processed effluent so, BOD_5 is normally high.

The higher value of BOD_5 wastewater was found 354mg/L and the lower one was 75 mg/L. The average value of BOD_5 noted 177 mg/L noted *see appendix*. Billah, (2016) measured BOD_5 in his research is 377 (+/-15) mg/L. Other some literature shows the BOD_5 value is 490 mg/L (Michael et al., 1980) and 500-1550 mg/L (Steven, 1996). Another study found BOD_5 value 560-1226.6 mg/L in kerala by Sherly et al., 2015.

Primary clarifier settles inorganic solids normally. Primary settling tank or clarifier also reduces the level of BOD_5 and thus increases DO level. The primary clarifier of the study was reduced only the 5.64% of influent BOD_5.

In aeration basin normally steady variation was found and performance was flat rate to BOD_5 remove. Only few samples were found where BOD_5 didn’t remove significantly. The maximum numbers of sample was found under 100 mg/L of BOD_5. The peak value was found in aeration basin was 192 mg/L and least one was 3.6 mg/L. The average value was measured 89.6 mg/L in aeration basin. See the chart 3.5 and 3.6.

In final, clarifier the most important unit operation for removing BOD_5 value. In aeration basin bacteria degrades biodegradable matter as convert waste to energy and body cell. But microorganism still in aeration basin as living or dead cell. Then clarifier settles these all organic waste along inorganic waste also. Then waste or solids leave out as sludge. These waste or sludge called activated sludge. A portion of activated sludge again mixed with aeration basin.

All values of BOD_5 of secondary clarifier were measured and found below 50 mg/L. Only one value was found 56 mg/L in the study. The average value was noted 41.3 mg/L. This meet the maximum permissible value of ECR 1997 of Bangladesh Government. The permissible value of BOD_5 is 50 mg/L in regulation of the Bangladesh government (*see appendix*).

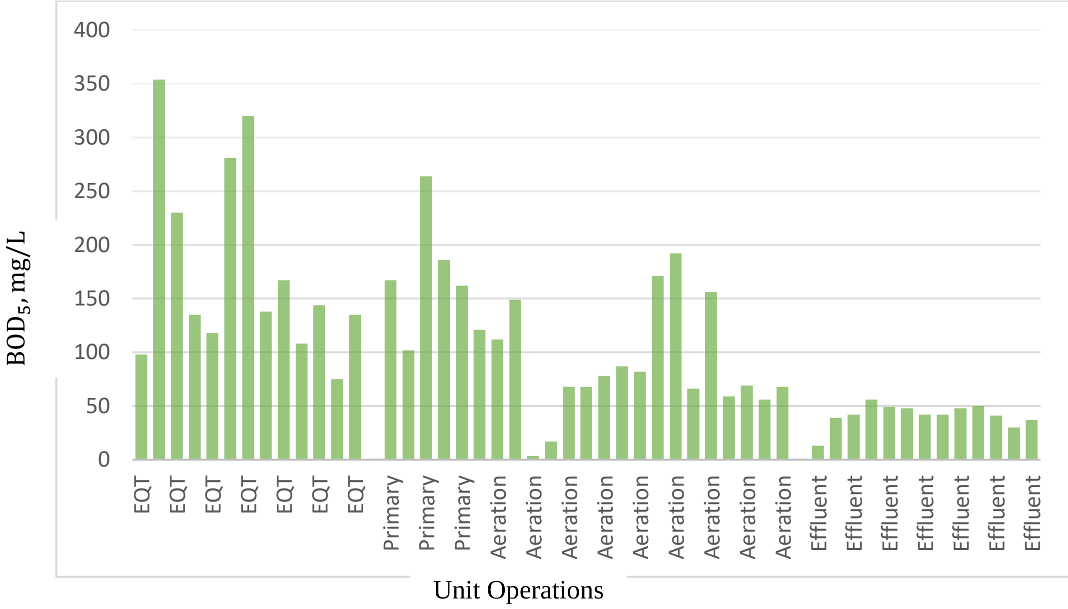


Figure 4.5: The Measured Value of BOD_5 in Every Stage of the Bench Scale Plant

The figure 4.5 is showing the BOD_5 value was found during the study. There were 48 samples has tested including of raw, primary, aeration and secondary clarifier. The maximum BOD_5 data was above 100 mg/L in raw wastewater (EQT) portion. In aeration basin the value has touched 50 mg/L line and stayed below 100 mg/Ln also. Final effluent results are showing below the 50 mg/L. The average reduction rate was calculated 77%. The following chart is contain only the average value of above different data.

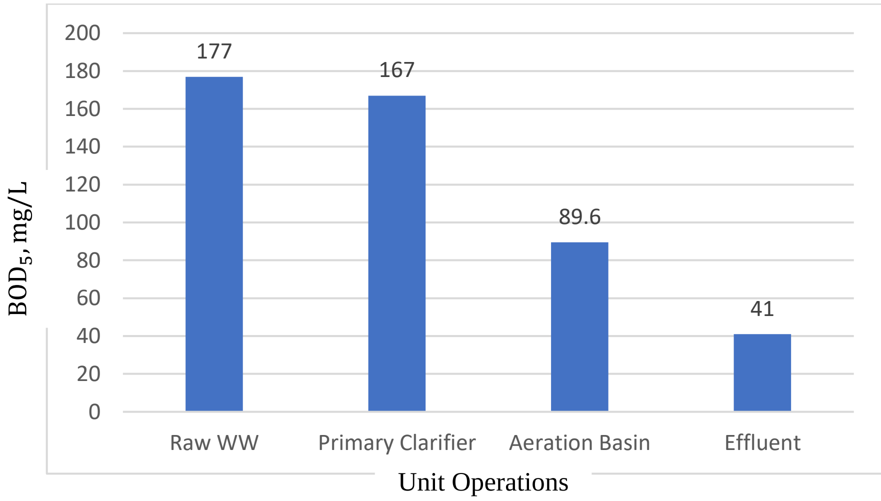


Figure 4.6: The Average BOD_5 Value in Different Unit Process of the Bench Scale Plant

4.5 Chemical Oxygen Demand

One of the most important parameter for wastewater is Chemical Oxygen Demand (COD). It is also refer the demand of oxygen to decompose organic waste of both biodegradable and non-biodegradable solids. Thus the COD value goes to higher than BOD_5 value. BOD_5 and COD both are indicator of organic waste that decomposed by oxygen. BOD_5 refers only oxygen demand for microorganism to decomposed only biodegradable solids whereas COD refers oxygen demand to decomposed organic solids chemically.

Previous some research in home and abroad find typical COD value in shrimp processing wastewater was 1300-3250 mg/L (Steven, 1981). Michael et al., (1980) has shown 790 mg/L COD value in shrimp processing wastewater. Saha, (2001) has reported in his paper 232 mg/L COD value of shrimp processing area in adjacent of Rupsha River. The standard level of COD for industrial effluent discharging is 200-400 mg/L as per WHO guideline 2003. Department of Environment (DoE), Bangladesh guideline shows COD value must less than or equal 200 mg/L .

The typical value of COD was found 160 mg/L to 950 mg/L. The highest value was recorded 948 mg/L of COD whereas 160 mg/L was measured as least value. Between this range maximum numbers of COD value were recorded above of 200 mg/L (*see the figure: 4.7*). The arithmetic mean value was calculated 355 mg/L.

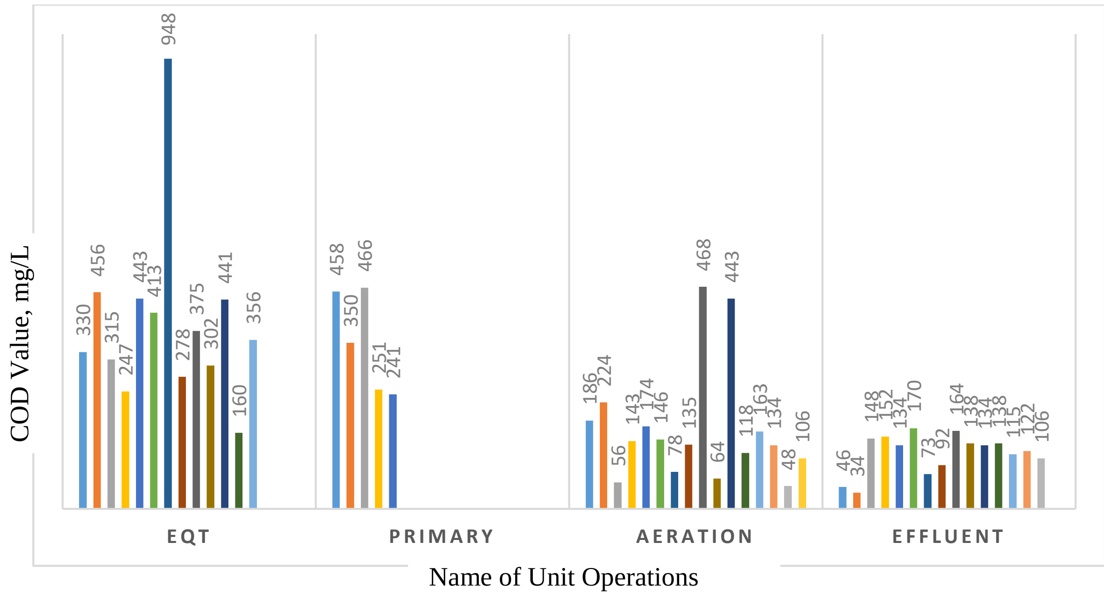


Figure 4.7: COD Value in Raw Wastewater, Primary, Aeration & Secondary Clarifier.

The primary clarifier has removed only little amount of COD. The mean value is representing this. Arithmetic mean value was found 353 mg/L. There was no many samples were taken under test. Only five samples were measured to see the condition after primary settling.

In aeration basin significantly removed COD from wastewater. Almost half of the value reduced in the aeration basin. Two plants perform almost same. There were few samples were tested for comparison. The variation of plant one and two has discussed later on in this chapter. Here all results has shown in the figure 4.7. The figure 4.8 is showing the variation and reduction of COD in chamber to chamber. There were 16 samples measured for COD from aeration basin. Maximum value was found 468 mg/L and minimum was 48 mg/L. The arithmetic mean was found 167 mg/L. The yellow line is representing the COD value of aeration basin in figure 4.8. Easily it is seeing the COD of biological reactor is going down than the COD level of EQT.

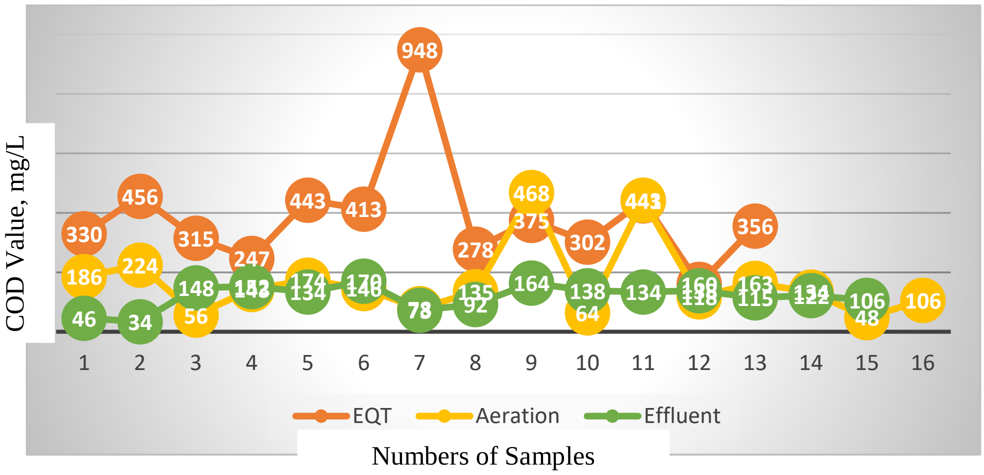


Figure 4.8: Variation of COD Value in Different Unit Process

The final stage, secondary clarifier has taken the final action and reduced COD significantly. The green line of figure 4.8 is showing the results found in laboratory test. The higher value was found 170 mg/L. The lower one was 34 mg/L. All values were found under 200 mg/L. Arithmetic mean value was found 117 mg/L. There were 15 samples tested from effluent. All arithmetic mean values are shown in the below chart (fig 4.9). The average rate of COD removal was found 67%.

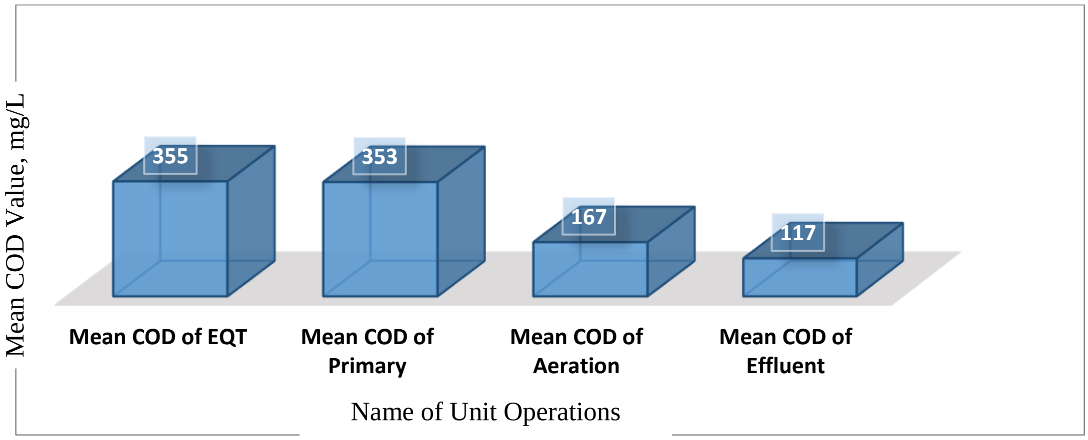


Figure 4.9: Arithmetic Mean Value of Different Units

Appendix is given all data about COD that measured during the study period.

4.6 Solids

Solids are common and vital parameters of wastewater. Summation of all types of solids like biodegradable, non-biodegradable, filterable, non-filterable, suspended, dissolved, organic, inorganic are called total solids (TS) in word. But total solids not consist with volatile solids. The main two portion of total solids are dissolved solids and suspended solids.

In shrimp process industries effluent contains 100-800 mg/L of TSS (Carawan, 1991). Another research in north Carolina has found 780 mg/L by Michael et al., (1980) & Billah (2016) shown 543 (+/- 187) mg/L in exactly shrimp processed wastewater in Khulna region. The standard value of TSS for inland discharging is 150 mg/L and 200 mg/L for irrigation use as per Bangladeshi rules. Others some guideline like BSR standards is 30 mg/L and ZDHC guidelines recommended 50 mg/L.

TSS was found in this study 383 mg/L as average value from 13 samples. The highest value of TSS was 960 mg/L and lowest one was 127 mg/L. Where the standard level is equal or less than 150 mg/L as per Bangladesh guideline of wastewater discharging. Shrimp process wastewater contain huge amount of organic solids. Thus most of samples result higher than standard level (150 mg/L). Figure 4.10 is showing suspended solids that found in laboratory test. Here all samples not showing the regular less variation data. Easily we are seeing from the chart that value fluctuate more. It is reality because all samples were not collect in the same time and same days. When more shrimps are processed normally solids are found more.

Only one sample was found under the standard level. The mean value is 383 mg/L which is 2.5 times more than the standard level.

The substances present in wastewater in the form of suspended are may be called suspended solids. Suspended solids (SS) are those solids which cannot remove by 2 micron size filter paper. It consists of organic debris and inorganic solids like sand, clay etc. It sometimes called total suspended solids (TSS). Increasing of SS hamper the water quality.

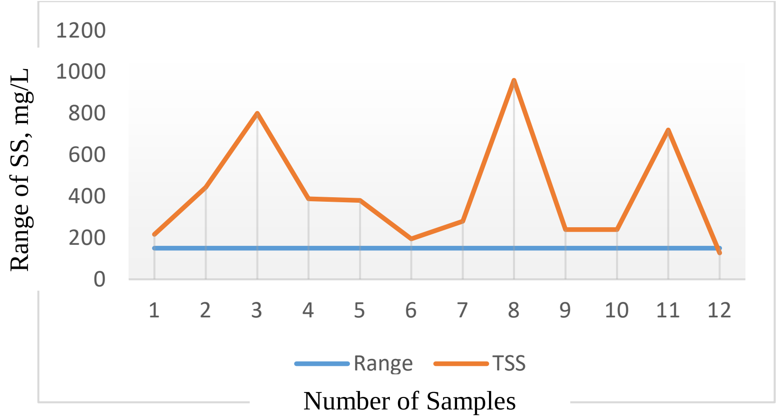


Figure 4.10: Suspended Solids of Shrimp Processed Wastewater.

Effluent water contains less than the standard level of SS. Fortunately designed plant has been working well though not in superb level. There were 13 samples taking under tested. Higher one was found 380 mg/L and lower one was 43 mg/L. There were three results among thirteen samples were found the higher than standard level. Except these three all were in under 150 mg/L *(see appendix)*. The arithmetic mean value was noted 137 mg/L.

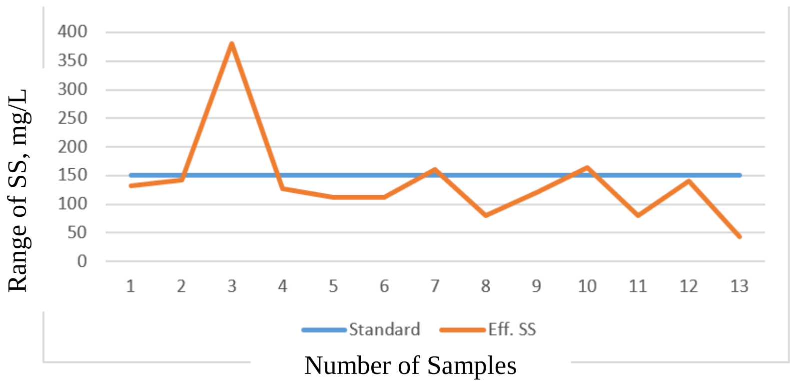


Figure 4.11: Suspended Solids of effluent of bench scale plan

The dissolved solids were found much more of wastewater. This study was recorded up to 4720 mg/L of dissolved solids. On the other hand the least value was recorded 1325 mg/L. The average value was calculated 2894 mg/L. Billah, (2016) noted TDS value 1777 (+/-553) mg/L. The Bangladesh standard for TDS is 2100 mg/L for wastewater discharge in environment or inlet water body. The other two common standard like ZDHC and BSR is not mention the TDS value in their guideline.

Significantly separated total dissolved solids from the wastewater in both primary and secondary clarifier. Thus the final effluents contain mentionable less amount than the inlet wastewater. Final effluent TDS value was measured 1805 mg/L. Similarly all thirteen samples did not maintain standard level. Two or three results find higher than the standard level. Figure 4.12 is showing the all results that obtain in laboratory test. Here easily get information about the value of inlet wastewater TDS and effluent TDS. The higher value was found 3160 mg/L and lower one was 840 mg/L.

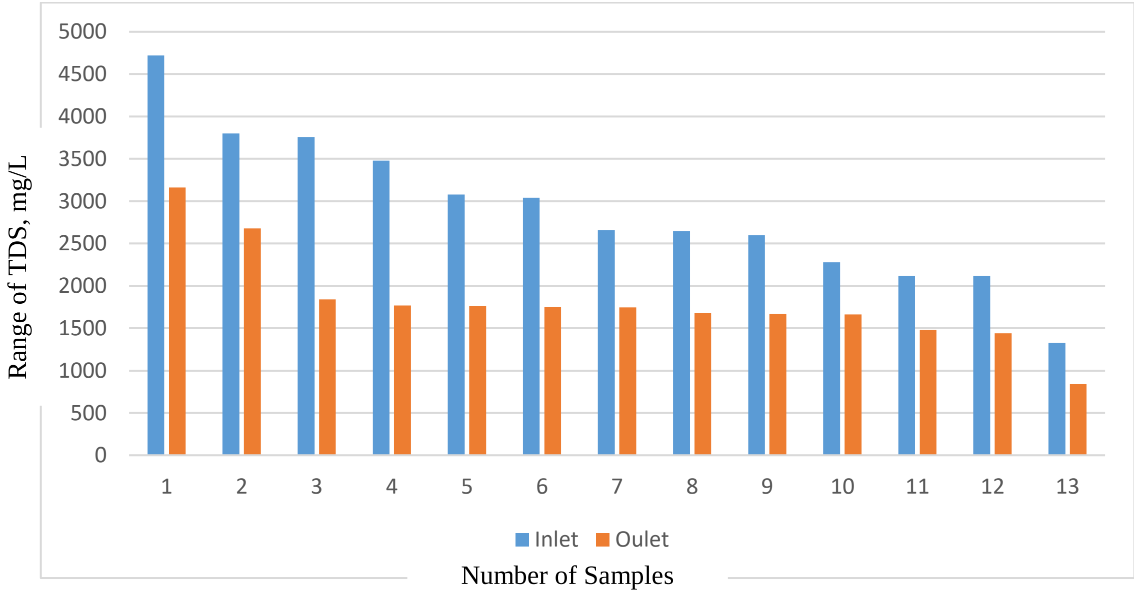


Figure 4.12: TDS of Inlet and Outlet of the Bench Scale Plant

TDS and SS is the more important parameter than the total solids. From above discussion it is said that effluent meet the national standard for discharging effluent. The figure 4.13 is showing just comparison between inlet wastewater characteristics and effluent with dissolved and suspended solids.

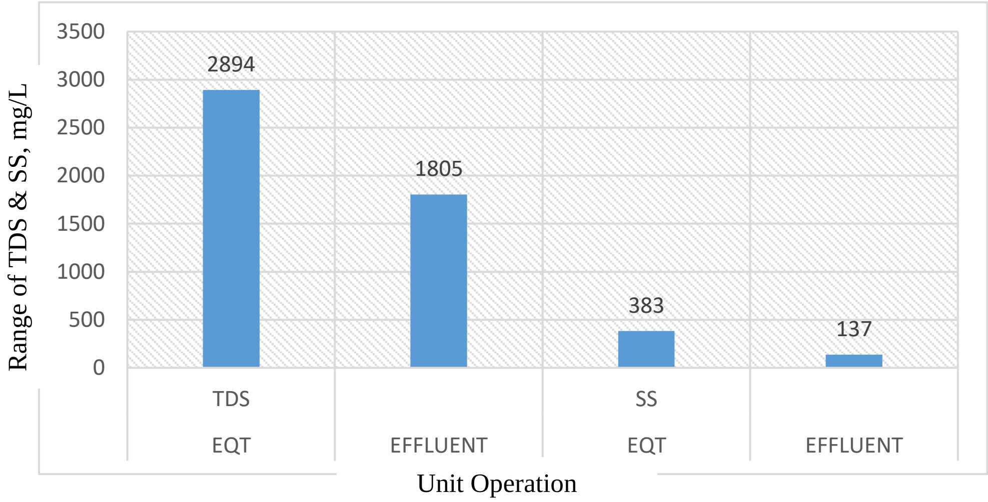


Figure 4.13: Comparison between Wastewater and Effluent for TDS and SS

Another figure (fig 4.14) is only showing the data that what the situation about to meet national standard. Left side bar is the standard of TDS and SS and the right side is quality of final discharge from the designed bench scale plant.

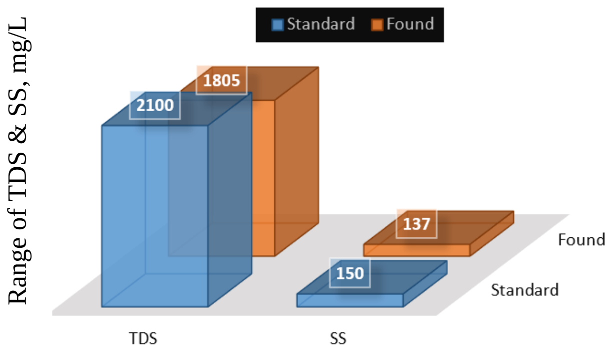


Figure 4.14 Comparison between National Standard and Effluent Quality of the Bench Scale Plant

Another one solids parameter is Total solids. Total solids mean the sum of suspended solids and dissolved solids. It is determined as residue remain after evaporation of wastewater that not filtered. There were significant variation found among different samples. Clarifier mainly takes part to separate solids from wastewater.

It was found 7600 mg/L total solids in raw wastewater as the highest value whereas least one was 1520 mg/L. The arithmetic mean value was determined 3595 mg/L. Sherly, (2015) has represented the highest value of shrimp process wastewater in kerala is 6754 mg/L in the month of April. Whereas the average value was 3779 mg/L in his six months research periods. The following figure 4.15 is giving data regarding all three TS, TDS and SS of inlet wastewater or sample from the study. TS, TDS and SS of raw wastewater or EQT is given in the following figure 4.15.

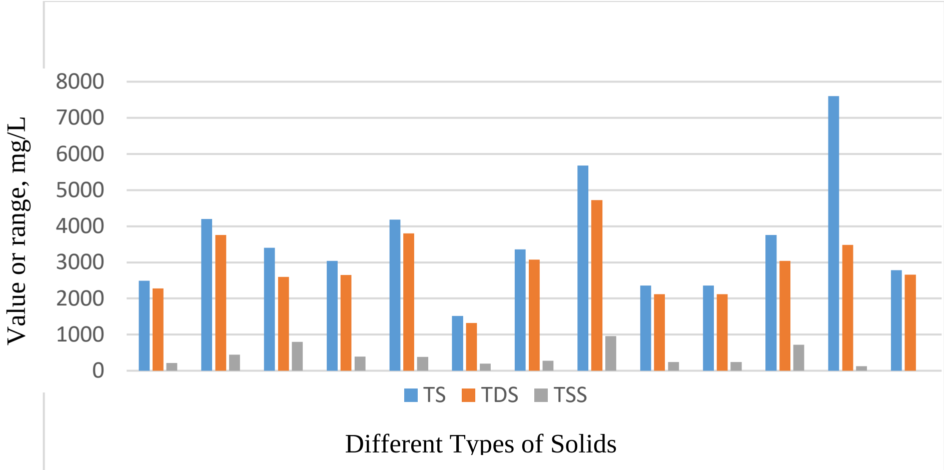


Figure 4.15 TS, TDS and SS Concentration in Raw Wastewater

No specific value were found in Bangladesh guideline for total solids. Basically it's no need. Because the TSS standard value is 150 mg/L and TDS is 2100 mg/L. As total solids is summation of suspended and dissolved solids therefore easily understand the level of total solids. The fig. 4 .15 is giving the value of TS, SS and TDS of raw wastewater.

Effluents contained 3272 mg/L as the highest value of TS and the lowest was 1004 mg/L. The arithmetic mean value of total solids was measured 1963 mg/L. It was also thirteen different samples were taken in thirteen different times and date to test.

The following chart is giving the all value of TS, TDS and TSS in column graph. The highest one and the lowest one we find out from the chart as well as each and every value with their variation we may see from the chart. Not only this but also the comparison among total solids, suspended solids and dissolved solids can see at a glance. All tested data is given in *appendix.*

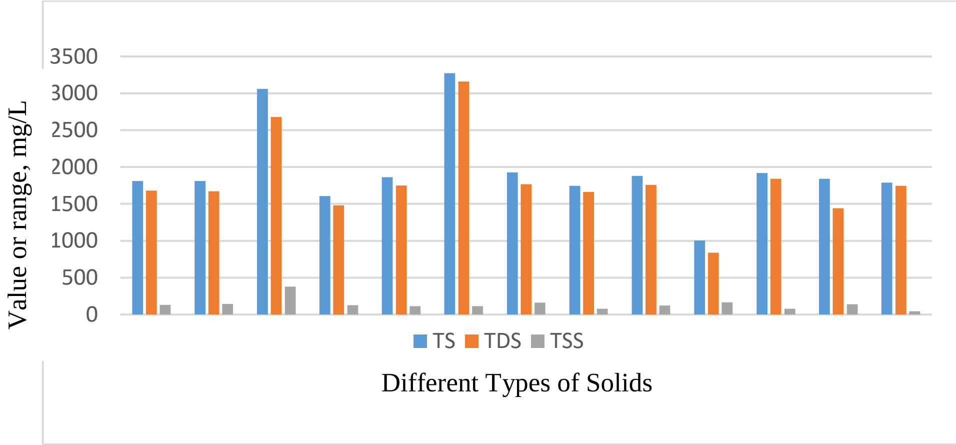


Figure 4.16 TS, TDS and SS Concentration in Effluent Wastewater

4.7 Chloride

Chloride is inorganic anions that major contributes in effluent characteristics. Excess content of brine solution like NaCl, KCL etc may be responsible to higher chloride in wastewater. The chlorides of Ca, Mg, Na and K are high degree of water soluble.

The chloride concentration in the river Rupsa located in the adjacent area of shrimp processing industries was measured 432 mg/L and 611 mg/L during low and high tide respectively by Begum et al., (2006). Sherely, (2015) conducted a research in Kerala, India upon shrimp process wastewater during six months. The literature presented the arithmetic mean value of chloride is 838 and 875 mg/L.

This study measured there were eight samples to see the chloride concentration. Some effluents contain more than 1000 mg/l of chloride. Few value was found more or less standard level. The national guideline of wastewater discharge by Bangladesh Government is 600 mg/L. Higher one was found 1475 mg/L and lower one was only 275 mg/L. The figure 4.17 is giving all about result of chloride for raw wastewater or effluent from the industry. The graph is present standard level as well as true concentration that found in laboratory test together.

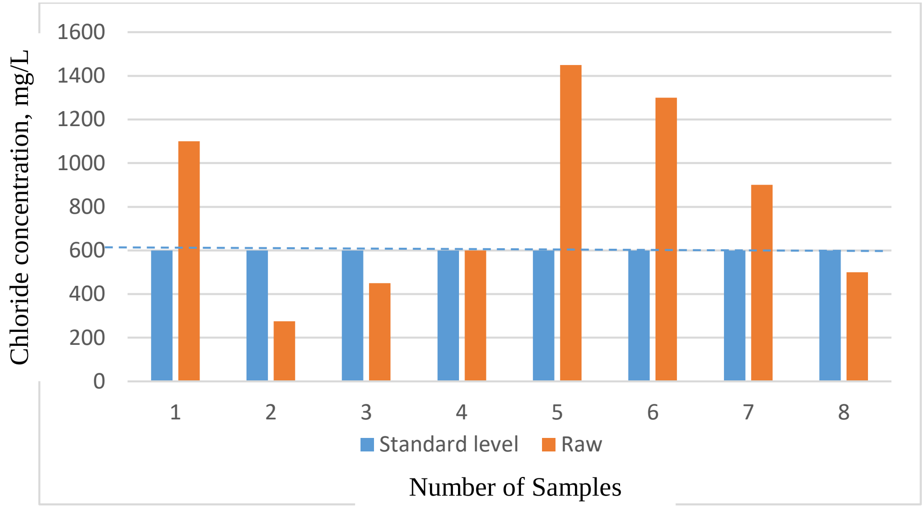


Figure 4.17: Chloride in Wastewater

After the treatment through the designed bench scale plant effluent wastewater contain average 292 mg/L. It was not that all value maintained the below level of standard. One samples among six samples was found 650 mg/L. Except this one all was found under standard level. The figure 4.18 is showing the result that measured from laboratory test. Same blue color representing standard value whereas brown color representing chloride concentration in raw wastewater.

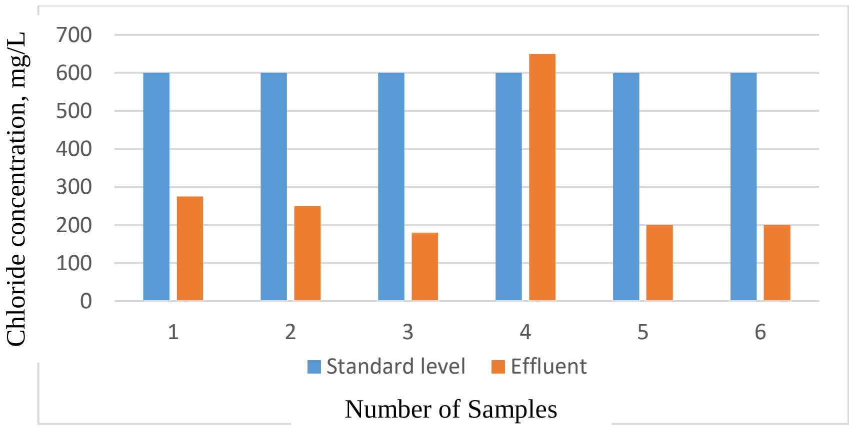


Figure 4.18: Chloride in Effluent after Treatment through Designed plant

The figure 4.19 is just showing the comparison between raw waste water chloride concentration and effluent concentration of chloride. Blue line is chloride concentration that found from raw wastewater and brown color bar is representing effluent chloride concentration. From the following figure easily understand that effluent of the designed bench scale plant meet the national effluent standard.

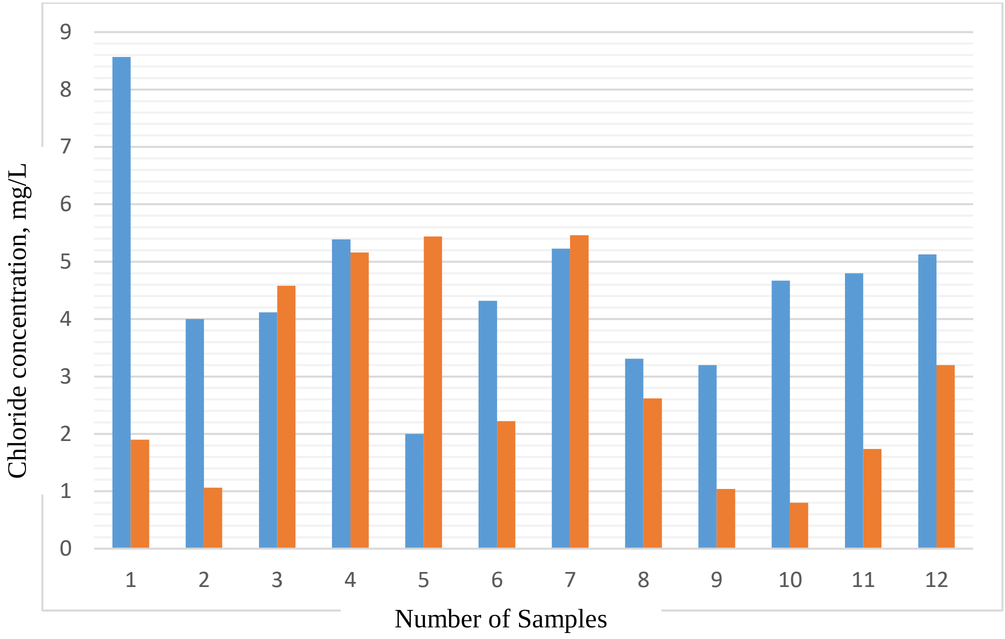


Figure 4.19: Line graph of Wastewater and Effluent Chloride Concentration

The arithmetic mean value was determined 821 mg/L of chloride in raw wastewater from the industry and 292 mg/L after treating through designed treatment plant. The result or test data is given detail in a*ppendix.*

4.8 Electrical Conductivity

The electrical conductivity is another important parameter of effluent characteristics. EC is indicator of salinity problem in soil and water. The effluent of shrimp processing industries contains high value of electrical conductivity (EC) (Saeed *et al.*, 2003). It is directly related with dissolved solids. So, sometimes EC can measure by only measuring of TDS and vice versa. One millisiemens per centimeter is equal of 640 ppm of TDS.

A handsome number of samples were taken to determined electrical conductivity. The EC was determined by electromagnetic sensor meter (HACH 1011 EC meter). All samples were not under sensor some were measured by using conversion factor of TDS to EC.
The Bangladesh standard guideline for discharging wastewater is recommended to maintain EC level 1200 mho/cm. Billah, (2016) was found EC in his research 15.21(±2 mSCm-1). This research conducted in exactly in Khulna region.

This study has found maximum 8.57 mS/cm that is 8577 µS/cm. The arithmetic mean value was recorded 4.56 mS/cm. That mean moderate higher of TDS or sault concentration. The minimum value was found 2 mS/cm. All values were not measured in mS/cm scale. Some were measured micro Siemens per centimeter but later on converted into mille Siemens per centimeter. The figure 4.20 is expressing the typical average value of EC in raw wastewater and effluent water graphically.

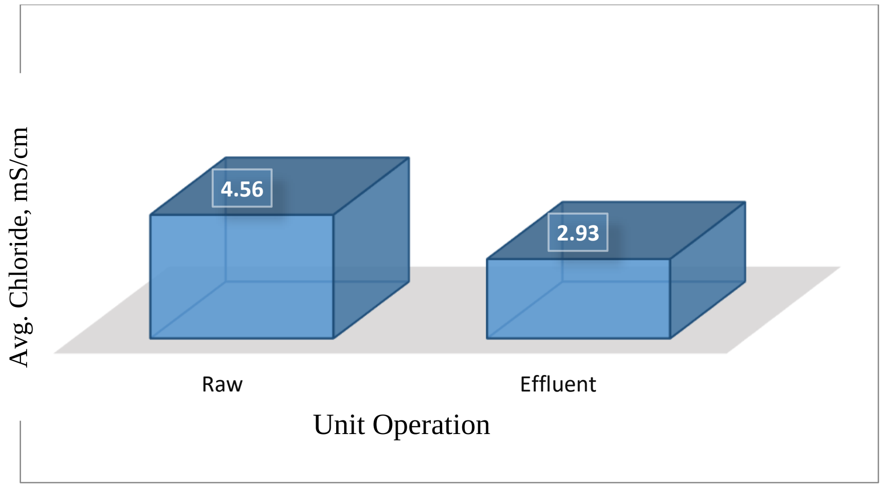


Figure 4.20: Average EC Value of Raw Wastewater and Effluent of Bench Scale Plant

The output waste water contain EC is almost half of the inlet wastewater. The arithmetic mean was found 2.93 (see the above graph) mS/cm. The higher one was noted 5.46 mS/cm and lower one 0.8 mS/cm. Detail data is given in a*ppendix*.

In the figure 4.20 the is representing the EC value in mS/m of raw wastewater and effluent.

4.9 Nitrate Nitrogen and Color

Nitrogen is one of the most nutrients of water body as well as most important parameter for wastewater discharging. Excess amount of nitrogen is the cause of eutrophication. So excess amount of nitrogen in effluent is prohibited. On the contrary it is significantly important for biological treatment. The concentration of nitrogen in the sea food processing wastewater is minimal in the most cases (Gonzalez, 1996). N and P concentration is recommended 5:1 for germane growth of the biomass (Eckenfelder, 1980; Metcalf and Eddy Inc., 1979). Michael, (1980) analyzed shrimp processing wastewater and found NO3-N 7.7 mg/L. Billah, (2016) noted 12 (+/- 1.5) mg/L nitrogen in shrimp processing industries wastewater that located in

Khulna. The standard value of nitrogen is 10 mg/L by DoE guideline and ZDHC guideline refer 5 for advance and 20 mg/L for basic level of effluent treatment.

In This study five samples were measured of raw wastewater, aeration basin wastewater and effluent. There were broadly variability found. See the figure 4.21 and here easily this scenario is shown. Raw sample contain less amount of nitrogen. Maximum value was recorded 3.8 mg/L. Next aeration process add air in water and microbes take part to degrade biodegradable wastes. Here, the concentration of N has gone long or higher than inlet wastewater. 2.9 mg/L was found as lower concentration and higher was 13.4 mg/L. After secondary clarification solids were separated from effluent and effluent contains quite less than the aeration basin.

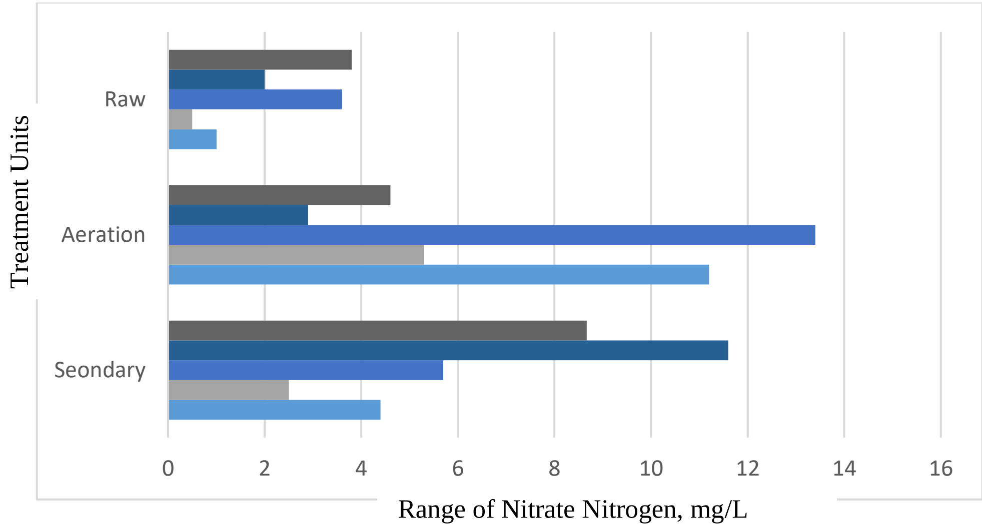


Figure 4.21 Nitrogen Concentration of Raw Wastewater, aeration basin and effluent

In final effluent found 2.5 mg/L as lower value and 11.6 mg/L as the higher one. May be stagnant condition less the N concentration in final effluent. As the average value was 6.57 mg/L of N. So, it can be said that effluent will not be cause for eutrophication. This is the good quality. The data that found in laboratory test is given in a*ppendix 10*.

Water has no color. But wastewater is sometimes blackish, sometimes gray is seen. Solids particle makes water color. Color is measured as platinum cobalt (PtCo) unit. It is measured by absorption of light. Spectrophotometer was used to determine color of sample. Only few samples were under tested. The Figure 4.22 is showing the result. Raw wastewater contain high color, aeration basin less but final clarifier contain quite higher than the biological reactor color concentration.

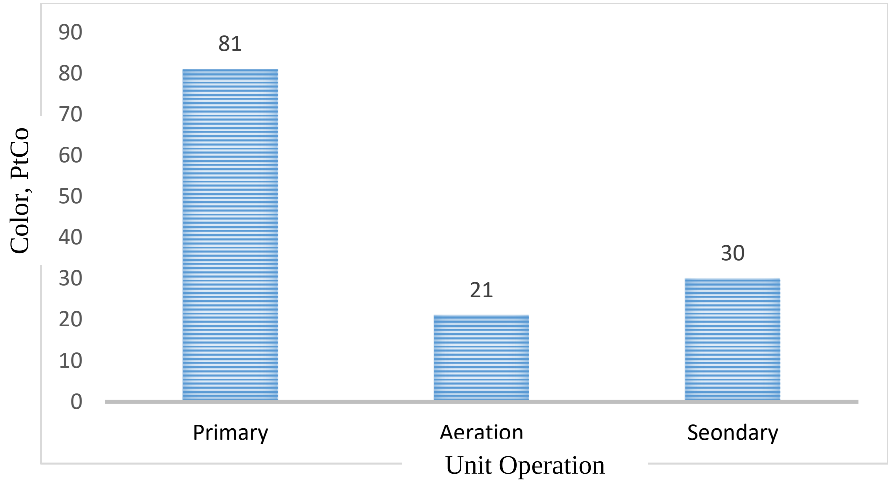


Figure 4 22: Color Concentration of Raw Wastewater, Aeration and Effluent

Table 4.3: Color in different samples

Primary	Aeration	Secondary	Unit
81	21	30	PtCo

Therefore, significantly color was removed from the wastewater through the designed bench scale treatment plant.

4.10 Performance Analysis of the Bench Scale Plant

There are many types of biological treatment is available. All types and sub types of biological treatment are classified as five major groups according to the book of "wastewater engineering: Treatment Disposal Reuse" (4th Edition) by Metcalf and Eddy 2004. These are aerobic processes, anoxic processes, anaerobic processes, combined aerobic anoxic and anaerobic processes and pond processes.

Among these biological processes activated sludge process is widely used as biological suspended growth process. In this study the activated sludge process has been selected due to consider as it is low cost, local technological based and good performance to remove carbonaceous biochemical oxygen demand. It was developed in 1914 in England and it was completely mixed activated sludge system (Metcalf, 1995).

Process flow was maintained 20 mm/minute. For plant No.1 the volume of primary clarifier was 1.2 Liter and retention period was 1 hr. It was same for the secondary clarifier also. The retention period for aeration basin was 6.25 hr and volume was 7.48 Liter. Another one plant has designed that retention time was 1.3 hr for primary clarifier and 10 hr for aeration basin.

The volume of clarifiers were 1.6 L and aeration basin volume was 6.4 liter. This extra plant has designed for just compare between solids separation and retention periods. Plant 2 was installed to compare how settling perform with the surface area and depth of clarifier. The detail about the design is given methodology chapter and a*ppendix*. The performance analysis of the bench scale plant was based on result. Therefore, performance analysis based on result is given below.

4.10.1 BOD_5 & COD Removal

The bench scale plant was performed to removal of BOD_5 & COD in mentionable level. The five days Biochemical Oxygen Demand of raw wastewater was measured and found average 177 mg/L. BOD_5 was decreased in primary clarifier, aeration basin and finally secondary clarifier. Primary clarifier was removed 5.64% of BOD_5. The aeration basin was removed almost 50% of BOD_5. The final effluent was contained 41.3 mg/L. The average reduction rate was calculated 77% of BOD_5. State of BOD_5 of the bench scale plant was good.

The typical value of COD of this study was found 160 mg/L to 948 mg/L. The arithmetic mean value was calculated 355 mg/L for raw wastewater. Between this ranges most values were recorded above of 200 mg/L. In aeration basin significantly removed COD from wastewater. Almost half of the total amount of COD was reduced in the aeration basin. In the final stage, secondary clarifier has taken the final action and reduced COD significantly. There were 15 samples tested from effluent. The average rate of COD removal was found 67% by the bench scale plant. This removal rate is good.

The above discussion is based on result of bench scale plant 1. The bench scale plant 2 was designed, installed and operated to see the removal variation with respect of variation of HRT. From the following table, it is seen that little variation of HRT can vary removal rate. When HRT is higher than removal also higher. The following table is given the removal rate of BOD_5 and COD with variation of HRT.

Table 4.4: Response the various parameters with two different HRT

Parameter (mg/L)	S1	S2	S3	S4	Mean	MCRT, θ_c	HRT
BOD_5	49	48	42	30	42.25	5 Day	10 hr
COD	134	76	164	87	115.25		
BOD	42	50	41	37	42.5	5 Day	6.25 hr
COD	136	140	115	106	124.25		

4.10.2 Solids Removal Efficiency

Solids (TDS, TSS and TS) were removed by the designed plant was good. The almost 50% of total solids and 40% of dissolved solids were removed by the plant. Though all parameters were not maintained the standard level (*see the section 4.6*) but maximum result was met the standard of Bangladesh guideline.

The following table is presenting the result of solids removal for only four samples. The result about all samples have shown in previous discussion. Plant No.2 has designed for only comparison with higher retention time and surface area. Percentage of removal with retention time and surface area is given in the below table. Other basis of performance analysis like MLVSS, performance of unit operation is discussing next paragraph.

There was no much more variation of solids removal was found for variation of HRT and surface area. From the following table it is drawn when surface area and retention time increased then rate of solids removal also increased.

Table: 4.5 Comparison and removal efficiency of TDS, TSS, TS

T.HRT= Total Hydraulic Retention Time, SA = Surface Area

Date of sampling	**Sample**	**TDS**	**TSS**	**TS**	**T.HRT**	**SA**
30/5/2018	Raw	2120	240	2360	8.25 hr (1 hr of each clarifier and 6.25 for aeration basin	0.00785 m^2
30/5/2018	Effluent	840	164	1004		
Removal %		60.37	31.66	57.45		
31/5/18	Raw	2240	269	2509		
31/5/18	Effluent	1000	40	1040		
Removal %		55.33	85.13	58.54		
4/6/2018	Raw	3040	720	3760		
4/6/2018	Effluent	1840	80	1920		
Removal %		39.47	88.88	48.93		
5/6/2018	Raw	2660	127	2787		
5/6/2018	Effluent	1745	43	1788		
Removal %		34.39	66.14	35.84		
Mean of Raw		2,515	339	2854		
Mean of effluent		1356	81.75	1438		
Removal %		46.08	75.88	49.61		
5/4/2018	Raw	2277	216	2493	12.6 hr (1.3hr for two clarifiers and 10 hr for aeration basin)	0.0227 m^2
5/4/2018	Effluent	1678	132	1810		
Removal %		26.30	38.88	27.39		
25/4/2018	Raw	2650	388	3038		
25/4/2018	Effluent	1750	112	1862		
Removal %		33.96	71.13	38.77		
30/5/2018	Raw	4720	960	5680		
30/5/2018	Effluent	1760	120	1880		
Removal %		62.71	87.5	66.90		
4/6/2018	Raw	3480	4120	7600		
4/6/2018	Effluent	1440	140	1840		
Removal %		58.62	96.60	75.78		
Mean of Raw		3281	1421	4702		
Mean of effluent		1657	126	1848		
Removal %		49.49	92.13	60.69		

4.11 Designed and Resulted MLVSS

Calculated MLVSS was 1760 mg/L. It was maintained average 1760 mg/L mixed liquor volatile suspended solids. Some samples were taken from aeration basin and checked the level of MLVSS. It is important for biological treatment and performance analysis. The condition about biological growth may be known by measuring MLVSS. Required MLVSS calculation is following and estimated MLVSS was recorded next table. All value of MLVSS in a*ppendix 11*

MLVSS Calculation, We have X = $\frac{\theta_c \, Y \, (S_0 - S)}{\theta \, (1 + K_d \, \theta_c)}$

Or, X = $\frac{5\,d\ x\ 0.5\ (250 - 30) mg/L}{0.25\,d\ [1 + (0.05\ x\ 5d)]}$ (Detention time is θ = 0.25d)

Or, X = 1760 mg/L

From this figure easily seeing that the calculated MLVSS value 1760 and some samples from aeration basin measured value in column type chart. The aeration basin could not maintained calculated value all the time but on an average it was maintained.

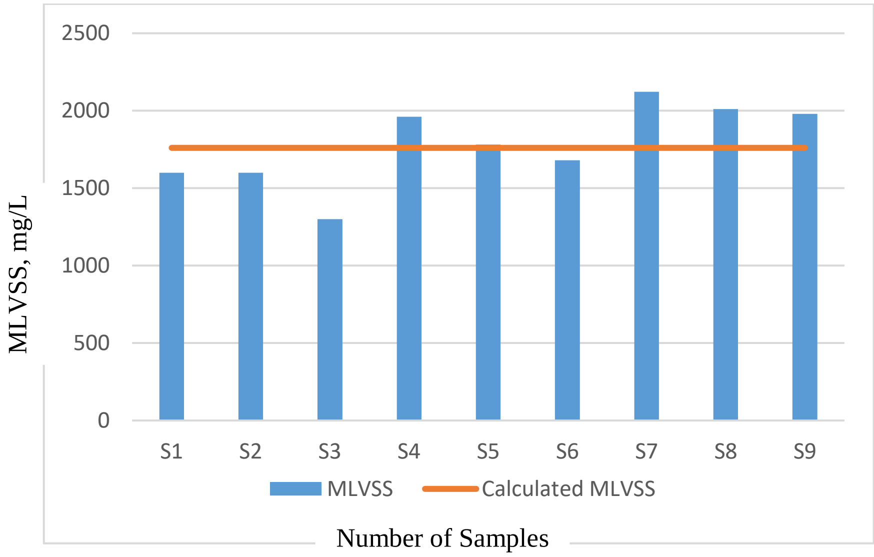


Figure 4.23: MLVSS Measured and Calculated MLVSS in Aeration Basin.

The following table (4.4) is showing BOD_5, COD and TSS for four samples of each two understand the response for HRT.

CHAPTER V

Conclusion and Recommendation

5.1 Conclusion

It was the first study about wastewater treatment of shrimp process industries in Khulna using local treatment setup so far. It is clear from the study, no chemical coagulation is required. From the study of the bench scale plant, it has shown that treatment level was moderate in practical, when continuous treatment will be run with large amount of wastewater the efficiency of treatment will be increased. The design criteria can be consider for a biological treatment plant design for a typical seafood processing industry. From the obtained data and result it can be said that the shrimp processing industry wastewater is mid-level wastewater. The organic loading such BOD_5 and COD was found not more than 400 mg/L and 1000 mg/L. Mean value of these two parameters from the measured samples has been drawn respectively 177 mg/L and 355 mg/L. The dissolved oxygen or DO was found 2.07 mg/L in average of raw wastewater. No sample of DO was found more than 4 mg/L. The range of hydrogen ion concentration (pH) was found between 6.5-9. Solids like total dissolved solids (TDS) and suspended solids (SS) were measured 2894 mg/L and 383 mg/L. The chloride concentration was measured under 1500 mg/L but not less than 400 mg/L and averagely found 821 mg/L. Wastewater passed through the designed bench scale biological treatment plant and got treated effluent which met the national standard. pH value were not found mentionable change. Effluent BOD_5 was found averagely 41 mg/L and removal rate by the bench scale plant was measured 77%. On the other hand, effluent was contained COD value 117 mg/L average and reduction rate of COD was found 67%. DO level was improved in effluent 2.07 to 4.68 mg/L. The suspended solids removal percentage was measured 62% and thus final effluent was contained 137 mg/L. On the other side, dissolved solids was deducted 37% and hence effluent was contained 1805 mg/L. Chloride removal was calculated 64% and 292 mg/L in effluent. Therefore, bench scale plant was performed moderately in treatment.

5.2 Recommendations from the Study

Following recommendations have been drawn from the study

- The wastewater from shrimp processing or seafood processing industries are rising problem in Khulna and nearby.
- Untreated effluents are making polluted of wetland, water body, agricultural and barren land of industry area and nearby of Khulna.
- Owners are not interesting to install wastewater treatment plant due to relax of Environmental regulations and high cost they thought.
- The characterization is shown shrimp industries wastewater is medium type wastewater and it is contain high organic biodegradable part.
- The designed bench scale plant or the design criteria can be used for wastewater treatment or design plant for a typical shrimp industry.
- Without chemicals shrimp industrial effluent can be treatment. In the study has shown without chemical coagulation and flocculation activated sludge process met the required. So, no extra coagulation and flocculation unit needed. As a result no extra cost and land is required for plant installation.
- The designed bench scale plant is cost effective, locally available materials and equipment based can be better solution for shrimp process industries wastewater treatment in Bangladesh.

5.3 Scope of the Study and Further Work

Despite the success result of the studied bench scale plant there were some limitations. These limitations are scope of future development. The limitations and scope of further works are given in following discussion.

- In this study, both clarifier has used in same volume. It might be the secondary clarifier will be larger than primary one. So, further work can be met this issue and travel a study.
- Basically two or more chamber are used as aeration basin. This study conducted with a single aeration basin and also a double aeration basin to compare. Multi staged aeration basin may be used to analyzed.
- The air was used 3L/min in aeration tank. But calculated air volume was less of used amount. Because of market unavailability of very small aerator. To get more subtle result the exactly required air should be use.
- The studied plant was set up on the top of three stored slab. Though it has very minor effect but set up on ground may be more suitable.
- The temperature control and steady maintain can be further scope. The study room temperature was quit hot but it was under required level.
- Activated sludge mixing is so important for activated sludge process. Some limitations were occurred like sometimes manually mix the activated sludge. The sludge return pump was not automatic or timing based.
- In Bangladesh it is very tough to get absolutely perfect room environment to laboratory analysis. But so far possible should maintain the room environment in parameters measuring time.

REFERENCES

1. Ahmed, M., 1988. Bangladesh Agriculture: towards self-sufficiency, Winrock International. Dhaka,
2. Barros M .C., Maga A., S. Valin, P.M. Bello, J.J. Casares, J.M. Blanco, Identification of best available techniques in the seafood industry: a case study Journal of Cleaner Production 17 (2009) 391–399,
3. Begum, S; Ikejima, K; Ara, H and Islam, MZ. 2006. Alternative processing option from shrimp processing Biowaste in Khulna District -Southwestern Bangladesh. *Journal of applied Sciences*, 6(6): 1307-1313.
4. Benefield D. L., Clifford W. R. and Paul H. K., 1975, The stimulation of filamentous microorganisms in activated sludge by high oxygen concentration
5. Billah S. M., 2016, Impacts of Effluents and Wastes of Shrimp Processing Industries on Soil and Water Environment in and around Khulna city, PhD Theisis, Department of Soil, Water and Environment, University of Dhaka.
6. Carawan, R.E., 1991, Processing plant waste management guidelines for aquatic fishery
   products. Food and the Environment. Available online at
7. CCME: Canadian council of ministers of the environment, 2005, Guidelines for compost quality,
8. Chen Xi, Linjang Y, Wenjuan L. U, Yayou L. I, Pei L. I. U and Kun N. I. E, 2013, Cultivation of aerobic granular sludge in a conventional, continuous flow, completely mixed activated sludge system, Springer, DOI: 10,1007/s11783-014-0627-3.
9. Chhiddikur M. R., 2013, Australian Journal of Basic and Applied Sciences, 7(7): 281-286,
   ISSN 1991-8178, http://www.p2pays.org/ref/02/01796.pdf
10. Cristina A. M., 1982, Evaluation of biomass age in activated sludge, Universitgl di Roma via Eudossiana 18
11. Curds C. R., 1973, The role of protozoa in the activated sludge process, 161-169

12. Davis & Cornwell, 1998, Introduction to environmental engineering, 3rd edition, p: 352 – 355, 372 – 375, 361 – 363.Frank R.S., 2003, Handbook of water and wastewater treatment plant operations, lewis publications London.
13. DOF, 2011. Fisheries Resource information of Bangladesh In: Shharanika (Motssha Shaptaha-20011). Ministry of Fisheries and Livestock, Peoples Republic of Bangladesh.
Pp. 65-76.
14. DOF (Department of Fisheries), 1994. District-wise area and number of shrimp farms. Dhaka,
15. Frank R. S., 2003, Handbook of water and wastewater treatment plant operations, London.
16. Hasan, M., 2004. Achievable target for Bangladesh seafood export. International conference on aquaculture production and marketing of shrimp-finfish & Bangladesh Seafood Expo, November 28-29, Pan Pacific Sonargaon, Dhaka.
17. Haque, S.M., 1994. Annual report of Bangladesh Frozen Foods Exporters Associations (BFFEA). Special Bulletin, January 1994.
18. Holenda B, E. Domokos, A. redey and J. fazakas, 2007, Dissolved oxygen control of the activated sludge wastewater treatment process using model predictive control, Science direct, 32, 1270-1278.
19. In-Sook, M.W. Kim, H. Joon La, K.M. Choi, J.C. Kwan, 2003, Bacterial community comparison of activated sludge relative to type & efficiency of municipal wastewater treatment plants, Journal of microbiology & biotechnology, Vol 13 (1), 15-21.
20. Islam S. M., Saleh K., Masaru T., 2004, Waste loading in shrimp and fish processing effluents: potential source of hazardous to the coastal and near shore environments., Marine pollution bulletin 49 (2004), 103-110
21. James J B. & Lawarence A. W., 1971, Relationship between biological solids retention time and settling characteristics of activated sludge, water research pergamon press, 5, 753-763.
22. Jeyanayagam S., Design & Operation of final clarifier, file:///D:/MSC/Thesis/Abstract/clarifier%20design/design%20aroach%20of%202nd%20clarifier.pdfJonathan C. Palm, David Jenkins and Denny S. ParkerSource, 1980, Relationship between Organic Loading, Dissolved Oxygen Concentration and

Sludge Settleability in the Completely-Mixed Activated Sludge Process, Journal of Water Pollution Control Federation, Vol. 52, No. 10 (Oct.,), pp. 2484-2506

23. Joseph C. G., 2014, Activated sludge process for treating wastewater, Journal of water and wastewater engineering.
24. Kabir, SH. 2014. Presentation on Sea Food Export from Bangladesh and Current Status of Traceability. BFFEA meeting.
25. Karia G. L. & R. A. Christian, 2010,Wastewater treatment concepts and design approach, pp: 204 – 207, 217 – 220, 140 – 142, 250
26. Lawrence A. W. and McCarty P.L., 1970, Unified Basis for Biological treatment design and operation, J. Sanit. Engg Dw. ASCE NO.SA3, 757
27. Lindberg C. and Bengt c., 1996, Nonlinear and set-point control of the dissolved oxygen concentration in an activated sludge process, journal of water science and technology, vol-34, p: 135-142.
28. Mazid, M.A., 2002. Development of Fisheries in Bangladesh: Plans and Strategies for Income Generation and Poverty Alleviation. l 76p. BFFEA, 2006).
29. Metcalf and Eddy, 1991, Wastewater Engineering treatment disposal reuse, 3rd edition, Chap: 3, 8,9, McGraw Hill In.
30. M. M. Rahman and M. M. Hossain, 2009, Production and export of shrimp of Bangladesh: problems And prospects, Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, Dhaka ISSN 1017-8139
31. Naureen M., D.S. Kabir, M.S. Ali and M. Kamal; 2006, Status of the shrimp sector in Bangladesh in the context of HACCP and trade issues - A Review, *Bangladesh .f. Fish. Res.*, 10(2), 2006: 185-202
32. Nolte F. W., 1982, Effects of elevated pressure on the activated sludge process. Dept. of Civil and Environmental Engineering, New Jersey Institute of Technology, Newark, USA, NJ 07102
33. Nusser, D.: 1975, Effects of Pressure on Biodegradability of Sanitary Sewage, Unpublished thesis. Newark College of Engineering.
34. Painter H. A. and J. E. Loveless, 1981, Effect of temperature and pH value on the growth-rate constant of nitrifying bacteria in activated sludge process. Water research center, vol 17 (3), pp 237-248

35. Pankaj Chowdhury, T. Viraraghavan, A. Srinivasan; Biological treatment processes for fish processing wastewater – A review; 2010, Bioresource technology, 101, 439-449.

36. Palm J. C, David J and Denny S. P; Relationship between Organic Loading, Dissolved Oxygen Concentration and Sludge Settleability in the Completely-Mixed Activated Sludge; Journal: *Water Pollution Control Federation*, Vol. 52, No. 10 (Oct., 1980), pp. 2484-2506

37. Peng Z. & Zhoa Q., 2007, Simultaneous nitrification and denitrification in activated sludge system under low oxygen concentration, Frontal environmental science & engineering, 1(1), 49-52.

38. Present Status of Shrimp at the Stage of Production and Marketing: A Study in Khulna District of Bangladesh.

39. Rosenberry, B. (ed.), 1995. World shrimp farming 1995: Annual report. San Diego, Shrimp News

40. Saeed, A; Malik, TZ; Dasti, AA and Zaib-Un-Nisa, AS. 2003. Effect of Waste water Effluents on the Growth of Some Crop Plants. *Asian Journal of Plant Sciences*. 2(8): 623-626.

41. Stevens, W.F. Rao, M.S. and Chandrkrachang, 1996, A Compound in Biology and Bioprocess Technology, Second Asia Pacific Symposium. Pp. 13-21.

42. Tan K. N. and H. Chua, COD adsorption capacity of the activated sludge – its determination & application in the activated sludge process, 1994

43. Tay J.,& Kuan-yeow S. & Yung-Tse H., 2016, Seafood processing wastewater treatment, Publication of University of Sao Paulo

44. Thomas S, Harindranathan N. M.V. and Bright S.I.S., 2015, Physicochemical Analysis of Seafood Processing Effluents in Aroor Gramapanchayath, Kerala, *Volume 9, PP 38-44, ISSN: 2319-2399*

45. Thomas E. W., 2005, Clarifier design, 2nd edition, water environment foundation.

46. Tong R. M., M. . Beck and A. Latten, 1980, Fuzzy control of the activated sludge wastewater treatment process, International federation of automatic control, vol 16, pp 695-701.

47. Vivekanandan, B., A. S. Rao & R. Saravananae (2016), Enhanced control of activated sludge process using predetermined set-points, International journal of environmental science and technology, DOI: 10.1007/s13762-016-1157-2.

48. Yasui H, Nakamura K, Sakuma S, Iwasaki M & Sakai Y; A full scale operation of a novel activated sludge process without excess sludge production, 1996, Water science and technology, Vol-34, 395-404.
49. Zhang X. X., D. Y. Zhao, Z. X. Wany, B. Wu, W.X.Li, S.P. Cheng; 2009, Environmental biological model based or optimization of activated sludge process, International journal of environmental science & technology, Vol 6 (1), 69-76
50. www.wikipeida.com

Appendix A

Table A1

Sample from Different Point to Select Design Basis

Parameter	S1	S2	S3	S4	S5	S6
pH	7.5	7.51	7.61	7.66	8	7.9
DO	1.39	1.26	1.83	1.46	1.5	2.02
BOD	270	234	489	362	330	296
COD	756	655	1370	1013	256	352
EC	1.5	2.61	1.2	1.57	1.3	1.7
TDS	2380	3300	2380	2900	1680	2640
TSS	640	80	50	480	40	140
TS	2430	3380	2430	4000	1720	2780
Chloride	50	87.5	50		80	42.5
Nitrate N	1				0.5	3.6

S1 – Receiving shrimps and initial washing

S2 – Initial icing (or IQF)

S3 – Deheading

S4 – Dewatering or soaking or production room

S5 – Common Drain (1)

S6 – Common Drain (2)

Table A2

pH value of different units found during the study

Date	**Sample From**	**Value of pH**	**Date**	**Sample From**	**Value of pH**
8/2/2018	Raw	7.9	11/4/2018	Aeration	8.06
15/3/2018	Raw	8.34	15/5/2018	Aeration	7.89
19/3/2018	Raw	8.22	22/5/2018	Aeration	7.98
25/4/2018	Raw	7.31	28/5/2018	Aeration	7.98
20/5/2018	Raw	8.33	28/5/2018	Aeration	8.05
21/5/2018	Raw	7.75	30/5/2018	Aeration	8.03
22/5/2018	Raw	7.33	30/5/2018	Aeration	8.33
30/5/2018	Raw	8.01	31/5/18	Aeration	8.19
30/5/2018	Raw	8.19	31/5/18	Aeration	8.61
31/5/18	Raw	8.03	31/5/18	Aeration	8.03
4/6/2018	Raw	8.53	5/4/2018	Effluent	7.35
4/6/2018	Raw	8.23	9/5/2018	Effluent	7.26
5/6/2018	Raw	8.31	10/5/2018	Effluent	7.81
19/3/2019	Primary clarifier	8.66	11/5/2018	Effluent	7.56
21/5/2018	Primary clarifier	8.18	25/4/2018	Effluent	7.4
28/5/2018	Primary clarifier	7.4	23/5/2018	Effluent	7.84
29/5/2018	Primary clarifier	7.79	28/5/2018	Effluent	8.09
30/5/2018	Primary clarifier	8.06	29/5/2018	Effluent	8.11
30/5/2018	Primary clarifier	8.26	30/5/2018	Effluent	7.99
19/3/2020	Aeration	9.06	30/5/2018	Effluent	8.27
21/3/18	Aeration	8.6	31/5/18	Effluent	7.87
1/4/2018	Aeration	8.5	31/5/18	Effluent	8.27
2/4/2018	Aeration	8.4	4/6/2018	Effluent	8.01
9/4/2018	Aeration	7.94	4/6/2018	Effluent	7.89
			5/6/2018	Effluent	8.21

Table A3

Do value of inlet, primary clarifier, aeration and secondary clarifier

Date	Sample from	DO	Date	Sample from	DO
8/2/2018	Raw	1.38	11/4/2018	Aeration Basin	2.89
15/3/2018	EQT	3.56	15/5/2018	Aeration	2.63
19/3/2018	Raw	2.23	22/5/2018	Aeration	0.6
25/4/2018	Raw	1.79	28/5/2018	Aeration	1.38
20/5/2018	Raw	1.15	29/5/2018	Aeration	5.3
21/5/2018	Raw	1.12	30/5/2018	Aeration	7.1
22/5/2018	Raw	0.75	30/5/2018	Aeration	3.8
30/5/2018	EQT	2.6	3/6/2018	aeration	4.4
30/5/2018	EQT	1.1	3/6/2018	aeration	6.1
4/6/2018	EQT	2.28	3/6/2018	aeration	5.8
4/6/2018	EQT	3.4			
5/6/2018	EQT	3.5	5/4/2018	Effluent	1.03
			9/5/2018	Effluent	5.2
19/3/2018	Primary clarifier	2.13	10/5/2018	Secondary Clarifier	4.4
21/5/2018	Primary	1.17	11/5/2018	Secondary	3.8
28/5/2018	Primary	1.9	25/4/2018	Secondary	4.2
29/5/2018	Primary	2.2	23/5/2018	Secondary	5.38
30/5/2018	Primary	3	28/5/2018	Secondary	6
			29/5/2018	Secondary	5.7
19/3/2018	Aeration	3.46	30/5/2018	Secondary	4.8
20 & 21/3/18	Aeration	2.93	30/5/2018	secondary	3.7
1/4/2018	Aeration	3.47	31/5/20	Secondary	3.7
2/4/2018	Aeration	4.01	4/7/2018	Secondary	4.2
9/4/2018	Aeration	4.4	4/7/2018	Secondary	6.3
10/4/2018	Aeration	3.23	5/7/2018	Secondary	4.8

Notes: 1. The blue color represents data from plant 02 which diameter is higher than plant 01. Normally plant 01 was operated and plant 02 operated to compare performance between plant 01 and 02.

2. Raw wastewater and EQT wastewater is representing the same sample.

Table A3

BOD value of different unit operations of bench scale project

Date	Unit	BOD Value	Date	Unit	BOD Value
8/2/2018	EQT	98	10/4/2018	Aeration	78
15/3/2018	EQT	354	11/4/2018	Aeration	87
19/3/2018	EQT	230	15/5/2018	Aeration	82
25/4/2018	EQT	135	22/5/2018	Aeration	171
20/5/2018	EQT	118	28/5/2018	Aeration	192
21/5/2018	EQT	281	28/5/2018	Aeration	66
22/5/2018	EQT	320	30/5/2018	Aeration	156
30/5/2018	EQT	138	30/5/2018	Aeration	59
30/5/2018	EQT	167	31/5/18	Aeration	69
31/5/18	EQT	108	31/5/18	Aeration	56
4/6/2018	EQT	144	31/5/18	Aeration	68
4/6/2018	EQT	75			
5/6/2018	EQT	135	5/4/2018	Effluent	13
			9/5/2018	Effluent	39
19/3/2019	Primary	167	10/5/2018	Effluent	42
21/5/2018	Primary	102	11/5/2018	Effluent	56
28/5/2018	Primary	264	25/4/2018	Effluent	49
29/5/2018	Primary	186	29/5/2018	Effluent	48
30/5/2018	Primary	162	30/5/2018	Effluent	42
30/5/2018	Primary	121	30/5/2018	Effluent	42
			31/5/18	Effluent	48
19/3/2020	Aeration	112	31/5/18	Effluent	50
20 & 21/3/18	Aeration	149	4/6/2018	Effluent	41
1/4/2018	Aeration	3.6	4/6/2018	Effluent	30
2/4/2018	Aeration	17	5/6/2018	Effluent	37
9/4/2018	Aeration	68			

Table A4

The COD value that measured in different units during the study period

Date	Sample From	Value of COD	Date	Sample From	Value of COD
8/2/2018	Raw (EQT)	330	10/4/2018	Aeration Basin	146
15/3/2018	EQT	456	11/4/2018	Aeration Basin	78
19/3/2018	EQT	315	15/5/2018	Aeration Basin	135
25/4/2018	EQT	247	22/5/2018	Aeration Basin	468
20/5/2018	EQT	443	28/5/2018	Aeration Basin	64
21/5/2018	EQT	413	28/5/2018	Aeration Basin	443
22/5/2018	EQT	948	30/5/2018	Aeration Basin	118
30/5/2018	EQT	278	30/5/2018	Aeration Basin	163
30/5/2018	EQT	375	31/5/18	Aeration Basin	48
31/5/18	EQT	302	31/5/18	Aeration Basin	106
4/6/2018	EQT	441	5/4/2018	Aeration Basin	46
4/6/2018	EQT	160	9/5/2018	Aeration Basin	34
5/6/2018	EQT	356	10/5/2018	Aeration Basin	148
19/3/2019	Primary clarifier	458	23/5/2018	Aeration Basin	170
21/5/2018	Primary clarifier	350	28/5/2018	Aeration Basin	73
28/5/2018	Primary clarifier	466	29/5/2018	Aeration Basin	92
29/5/2018	Primary clarifier	251	30/5/2018	Aeration Basin	164
30/5/2018	Primary clarifier	241	30/5/2018	Aeration Basin	138
19/3/2020	Aeration	186	31/5/18	Aeration Basin	134
21/3/18	Aeration	224	4/6/2018	Aeration Basin	122
1/4/2018	Aeration	56	5/6/2018	Aeration Basin	106
2/4/2018	Aeration	143			
9/4/2018	Aeration	174			

Table A5

Solids in different form and their value

Date	Unit	TDS	TSS	TS
8/2/2018	EQT	2277	216	2493
15/3/2018	EQT	3757	443	4200
19/3/2018	EQT	2600	800	3400
25/4/2018	EQT	2650	388	3038
20/5/2018	EQT	3800	380	4180
21/5/2018	EQT	1325	195	1520
22/5/2018	EQT	3080	280	3360
30/5/2018	EQT	4720	960	5680
30/5/2018	EQT	2120	240	2360
31/5/18	EQT	2,120	240	2360
4/6/2018	EQT	3040	720	3760
4/6/2018	EQT	3480	127	7600
5/6/2018	EQT	2660		2787

TDS, TSS and TS value of raw wastewater that treated through the designed bench scale project. Here EQT or equalization tank mean the raw waste water. EQT was the wastewater holding tank not equalization basin in manner.

Table A6 (7)

Chloride concentration of WW and effluents of shrimp process wastewater in study area.

Date	Raw Wastewater	Date of Sampling	Effluent Chloride
27/11/17	1100	19/3/2018	275
5/12/2017	275	2/4/2018	250
8/2/2018	450	22/5/2018	180
22/5/2018	600	30/5/2018	650
23/5/2018	1450	30/5/2018	200
30/5/2018	1300	31/5/18	200
30/5/2018	900		
31/5/18	500		

Table A7

Electrolyte Concentration of Wastewater of shrimp processed wastewater and effluent

Date	Value of Wastewater	Date	Value of Effluent
15/3/2018	8.57	10/5/2018	1.9
19/3/2018	4	11/5/2018	1.06
25/4/2018	4.12	25/4/2018	4.58
20/5/2018	5.39	23/5/2018	5.16
21/5/2018	2	28/5/2018	5.44
22/5/2018	4.32	29/5/2018	2.22
30/5/2018	5.23	30/5/2018	5.46
30/5/2018	3.31	5/4/2018	2.62
31/5/18	3.2	30/5/2018	1.04
4/6/2018	4.67	31/5/18	0.8
4/6/2018	4.8	4/6/2018	1.74
		4/6/2018	3.2

Table A8

Nitrate nitrogen in different samples of Designed bench scale project

Secondary	**4.4**	**2.5**	**5.7**	**11.6**	**8.67**	**Mg/L**
Aeration	**11.2**	**5.3**	**13.4**	**2.9**	**4.6**	**Mg/L**
Raw	**1**	**0.5**	**3.6**	**2**	**3.8**	**Mg/L**

Table A9

Color in different samples

Primary	Aeration	Secondary	Unit
81	**21**	**30**	**PtCo**

Table A10

Sampling for MLVSS

Sampling	MLVSS	Calculated
11/4/2018	1600	1760
15/5/2018	1600	1760
	1300	1760
22/5/2018	1960	1760
	1781	1760
	1680	1760
28/5/2018	2123	1760
30/5/2018	2010	1760
31/5/18	1980	1760

Table A 11

Bangladesh Standard for Effluent Discharging

Parameter	Unit	Location of Final Disposal		
		Inland Surface Water[1]	Public Sewer[1]	Irrigated Land[1]
Ammonia (free ammonia)	mg/L	5	5	15
Ammoniacal Nitrogen (as N)	mg/L	50	75	75
Arsenic (As)	mg/L	0.2	0.5	0.2
BOD_5 20^{o}C	mg/L	50	250	100
Boron (B)	mg/L	2	2	2
Cadmium (Cd)	mg/L	0.05	0.5	0.5
Chloride (Cl^-)	mg/L	600	600	600
Chromium (hexavalent Cr)	mg/L	0.1	1.0	1.0
Chromium (total Cr)	mg/L	0.5	1.0	1.0
COD	mg/L	200	400	400
Copper (Cu)	mg/L	0.5	3.0	3.0
Cyanide (CN)	mg/L	0.1	2.0	0.2
Dissolved Oxygen (DO)	mg/L	4.5-8	4.5-8	4.5-8
Dissolved Phosphorus (P)	mg/L	8	8	10
Electrical Conductivity	µMho/cm	1200	1200	1200
Fluoride (F)	mg/L	7	15	10
Iron (Fe)	mg/L	2	2	2
Lead (Pb)	mg/L	0.1	0.1	0.1
Manganese (Mn)	mg/L	5	5	5
Mercury (Hg)	mg/L	0.01	0.01	0.01
Nickel (Ni)	mg/L	1.0	1.0	1.0
Nitrate (N molecule)	mg/L	10.0	Undetermined	10.0
Oil and Grease	mg/L	10	20	10
pH		6-9	6-9	6-9
Phenol Compounds (C_6H_5OH)	mg/L	1.0	5	1
Radioactive Materials	As determined by Bangladesh Atomic Energy Commission			
Selenium (Se)	mg/L	0.05	0.05	0.05
Sulfide (S)	mg/L	1	2	2
Temperature – Summer	o C	40	40	40
Temperature – Winter	o C	45	45	45
Total Dissolved Solids (TDS)	mg/L	2100	2100	2100
Total Kjeldahl Nitrogen (N)	mg/L	100	100	100

Total Suspended Solids (TSS)	mg/L	150	500	200
Zinc (Zn)	mg/L	5.0	10.0	10.0