Improving Effluent Treatment and Management

Final Research Report – Section 7

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Md. Mohidus Samad Khan
Jerry Knapp
Alexandra Clemett
Matthew Chadwick

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Introduction

One of the outputs of the project was that wastewater management strategies determined and tested with industries and local community. This was to be achieved through four activities. The first was to provide advice on potential mitigation measures including microbiological methods. Once the mitigation measures were identified, the second was to, with industrial and community participation, then develop and pilot these revised wastewater management strategies. The project also has the task of monitoring the effluent from factories and water at community sites and the final activity was to hold local and national workshops and write a final report.

This report describes how each of these activities and their sub-components was undertaken over the course of the project. The mitigation measures were developed and piloted with two groups of industries. The first were industries considering installing a system for effluent treatment but currently without any form of treatment for their effluent. The work undertaken by the project with these industries is described in Section 1 of this report.

Section 2 describes the work undertaken with the few factories that did already have some form of effluent treatment. These activities related to looking at ways to modify the existing design to make the treatment units more efficient and cost effective and also activities to support the management, operation and monitoring of effluent treatment.

The final section of the report focuses on work undertaken to improve knowledge of effluent treatment in the sector and in Bangladesh more generally. This was achieved using a variety of means including workshops, information materials in English and Bangla and through the establishment of a web-based ETP network.

1. Facilitating the Development of New ETPs

1.1 Determine ETP Requirements

The efficiency and effectiveness of an effluent treatment plant (ETP) depends on several factors. The production capacity of the textile dyeing unit, the volume of effluent produced and over what timeframe and characteristics of effluent are all important factors in ETP design, construction and management. The first steps in ETP construction is to specify the requirements of an ETP with respect to quality of final treated effluent required and to determine the volume and quality of the effluent to be treated.

The project started by determining the volume and characteristics of wastewater produced by dye processes in each of the factories. This was done in collaboration with the factory management and operators. Each industry uses different volumes of water at different stages of the dyeing and bleaching processes depending on the machinery and fabric used. Moreover, the liquor ratio (the amount of water used per kg of fabric) varies with machine. Based on discussions with the operators and dye managers, an estimate was made of the amount of water that would be discharged from the factory over a 24 hour period.

The effluent discharged from the different stages of a dyeing process contains different types of chemicals. To obtain the composite value of pollution parameters from all those stages two different approaches were used.

1.1.1 Composite Sampling

The first method involved taking composite samples from the waste outlet using composite sampler machine. The methodology of composite sampling procedure is briefly discussed in Appendix A-1. Samples taken using the composite sampler were analyzed and the results obtained are shown in Table 1.1.

Table 1.1: Wastewater Parameters for different industries (samples were collected by using composite sampler machine, 2005)

Wastewater Parameters	Unit	Bangladesh Standard*	Factory ID							
			23 (n=3)		25 (n=3)		26 (n=3)		45 (n=3)	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
pH	----	6.5-9	10.50	0.01	9.39	0.03	9.86	0.03	9.23	0.64
TDS	mg/L	2100	2787.67	59.68			1446.67	14.57	2253.33	29.14
TSS	mg/L	100	94.67	67.68			149.00	52.51	100.33	12.06
BOD_5	mg/L	50 (/150†)	575.00	25.00	291.7	10.41	476.67	17.56	351.67	10.41
COD	mg/L	200	767.33	9.45	426.7	5.86	617.00	2.00	455.00	3.61
SO_4^{2-}	mg/L	400	1020.00	67.64	841.7	14.43	541.67	52.04	272.00	12.62
S^{2-}	mg/L	1	0.10	0.00	0.102	0.022	0.083	0.003	0.15	0.02
Cl^-	mg/L	600	72.67	5.77	67.3	1.15	456.67	140.12	706.67	30.55
Na	mg/L	200	791.53	137.77	279.0	13.45	338.27	111.89	896.37	181.88
NO_3-N	mg/L	5	0.74	0.03	6.5	1.50	1.57	0.54	0.93	0.11
NH_3-N	mg/L	10	1.40	0.10	2.1	0.06	0.60	0.10	0.63	0.06

* Huq, E.M. (Ed. 2003) *A Compilation of the Environmental Laws of Bangladesh Administered by the Department of Environment*, Department of Environment and Bangladesh Environmental Management Project, Department of Environment and Bangladesh Environmental Management Project, Dhaka.

† BOD limit 150mg/L implies only with physico-chemical processing.

1.1.2 Production Process Sampling

The other method was to take samples from the dye machine outlet. In this method, samples from each of the stages involved in any batch of dyeing process and analyzed them in laboratory. This method of sampling was used for a range of shades and a database developed of the different amounts of pollution generated for every stage of the dyeing and bleaching process. Based on these data it is possible to determine the concentration of different parameters for a particular industry based on information on the number of machines and frequency of operation. Details of this sampling procedure and method of calculation is discussed in Appendix A-2. This means of modelling the factory operation yields the amount of effluent discharged on a specific day and tends to generate more concentrated estimates as it does not take account of the additional water discharged into the waste water from other water points in the factory.

1.2 Review Proposed ETP Design Plans

The project team participated in several meetings with the industry owners who had shown a strong interest to establishing ETPs. The project provided information about how an effluent treatment plant works, the different methods of treatment process, different units involve in ETP, the parameters that indicate pollution intensity. On requests from industry owners, the project also reviewed proposed ETP designs provided to them by companies selling ETP systems. This process reviewed the plans on the basis of: a) whether the treatment process outlined was likely to meet the treatment requirements of the industry; b) whether the treatment components of the ETP were of the correct capacity; c) whether the units were likely to operate effectively; and d) whether the elements of the ETP being proposed were necessary. After completing a thorough review a short report of the findings was sent to the industry including a summary of the key issues which needed to be further discussed with the designers and proposals on ways to improve the design or operation. A sample report containing different suggestions and recommendations made by the project team to the industry management is appended in Appendix B.

1.3 Develop Knowledge of ETP Design

During the project period the project found that most of the textile industry owners are facing problems because of their limited knowledge of effluent treatment processes and ETPs. The project worked with several factories to provide information on ETP design and management. In addition, the project has published two booklets (Section 3.2). The first one entitled "Choosing Effluent Treatment Plant" and the second one is "Managing and Monitoring Effluent Treatment Plant". The first booklet illustrates different factors that important for choosing an appropriate ETP for any specific industry, whilst the second provides information on the management and monitoring of the various types of ETP, including how and where to conduct sampling, how to preserve samples and how to interpret the results.

The project also arranged several workshops and seminars during the project duration where the team provided information on how to determine the type of, and operate, manage, and monitor an ETP. Representatives from the textile industries in the project area, relevant members of the textile business associations, ETP designers and suppliers and local representatives of foreign based textile retailers were participated in those workshops and seminars.

2. Support to Existing ETP Operation and Management

Very few factories in the project area had an ETP at the start of the project. During the project period several others developed plans and constructed their ETPs after consulting with the project. The project has been assisting these industries by reviewing and monitoring the operating efficiency of ETPs and also providing support in ETP management. The purpose is to improve efficiency and where possible try to reduce the running costs of the ETP.

2.1 Adaptation of Design to Improve Efficiency and Reduce Cost

The project visited the existing ETPs in the project area and reviewed their process design and the units involve in the treatment process. Where possible, recommendations were made to the industries to adapt their ETPS. These changes included recommending bypassing the unnecessary chlorination unit, and segregating the different waste-streams to avoid the unnecessary treatment of waste already meeting discharge standards.

2.1.1 Omitting the Chlorination Unit

It is common in Bangladesh (especially in textile sector) that the conventional ETP includes a chlorination unit as a final stage. This is likely to be unnecessary as the bacteria involved in treatment of textile wastes are unlikely to be notable pathogens and, in the local context, release of un-chlorinated effluent is unlikely to represent a significant additional health risk. Chlorination is not a universal practice world-wide and for example in the UK is only used in a very few areas where release of sewage effluents will increase the number of faecal indicator bacteria to unacceptable levels for local bathing beaches and water abstraction (for drinking water). In the local context of Kaliakoir, the water is not used for drinking and although local people do come into contact with water in the *khal* the background levels of faecal pollution are so high that it is difficult to conceive that release of un-chlorinated treated textile-processing effluent presents an additional risk. Chlorination of dye house effluents may lead to production of AOX (chlorinated aromatic compounds which may be toxic) and so the process is undesirable. Omission of the chlorination will make savings in the cost of plant and in operating costs – however these saving are likely to be small.

2.1.2 Flow Segregation

In the textile dyeing sequence there are several different distinct stages, for example, scouring, neutralization, dyeing, acid wash, softening and rinsing. The different stages involved in dyeing sequence are shown later in this report (Figure 2.1). Wastewater discharged from different stages has different characteristics. Some streams are alkaline in nature, some are acidic and some are almost neutral. General characteristics of different stages are shown in Table 2.1. According to the characteristics of different waste-stream the textile effluent can be classified into two types: highly polluted streams and less polluted streams. If wastewater from different stages can be segregated in terms of highly polluted and less polluted, then these two streams can be treated according to their characteristics, and that can lower the running cost of the ETP. For example, wastewaters with lower chemical oxygen demand (COD) and biochemical oxygen demand (BOD) can be treated only biologically; on the other hand highly polluted waste-streams are to be treated both physico-chemically and biologically. As example, effluents with high colour and suspended solids need physico-chemical treatment and those with low concentrations of soluble pollutants may only need biological treatment.

The research on flow segregation was undertaken with two textile-dyeing industries, one with dye fabrics with manually operated machines and other dyes with semi-automated machines. Samples were collected from the dyeing machine outfall at each stage and analysed. On basis of the test results (Appendix C) the effluent was classified as highly polluted and less polluted. The sampling methodology and calculation procedure is discussed in Appendix A-2. In the classifying procedure along with other parameters the COD/BOD ratio is also considered. A low value of this ratio indicates the effluent is likely to be biologically degradable.

After analysis of the sampling results several steps of textile dyeing sequence several steps in the process were identified as highly polluting: scouring, hot wash with soaping agent, neutralization or acid wash, enzyme wash, dyeing, softening. These steps are recommended to be treated both physico-chemically and biologically. The rest of the steps are less polluting with relatively low BOD, COD, suspended solids, colour, and a low COD/BOD ratio (suggesting they are relatively degradable) and it should be possible to treat these solely by biological methods at controlled pH (if required). The different characteristics of the two waste streams identified along with their proposed treatment procedure are shown in Figure 2.1.

Using the example of a semi-automated textile factory having dyeing capacity of five tonnes a day and annually producing approximately 35% dark shade fabric, 15% medium shade fabric, 30% light shade fabric and 20% white fabric it is possible to calculate the amount of waste of varying pollution levels.

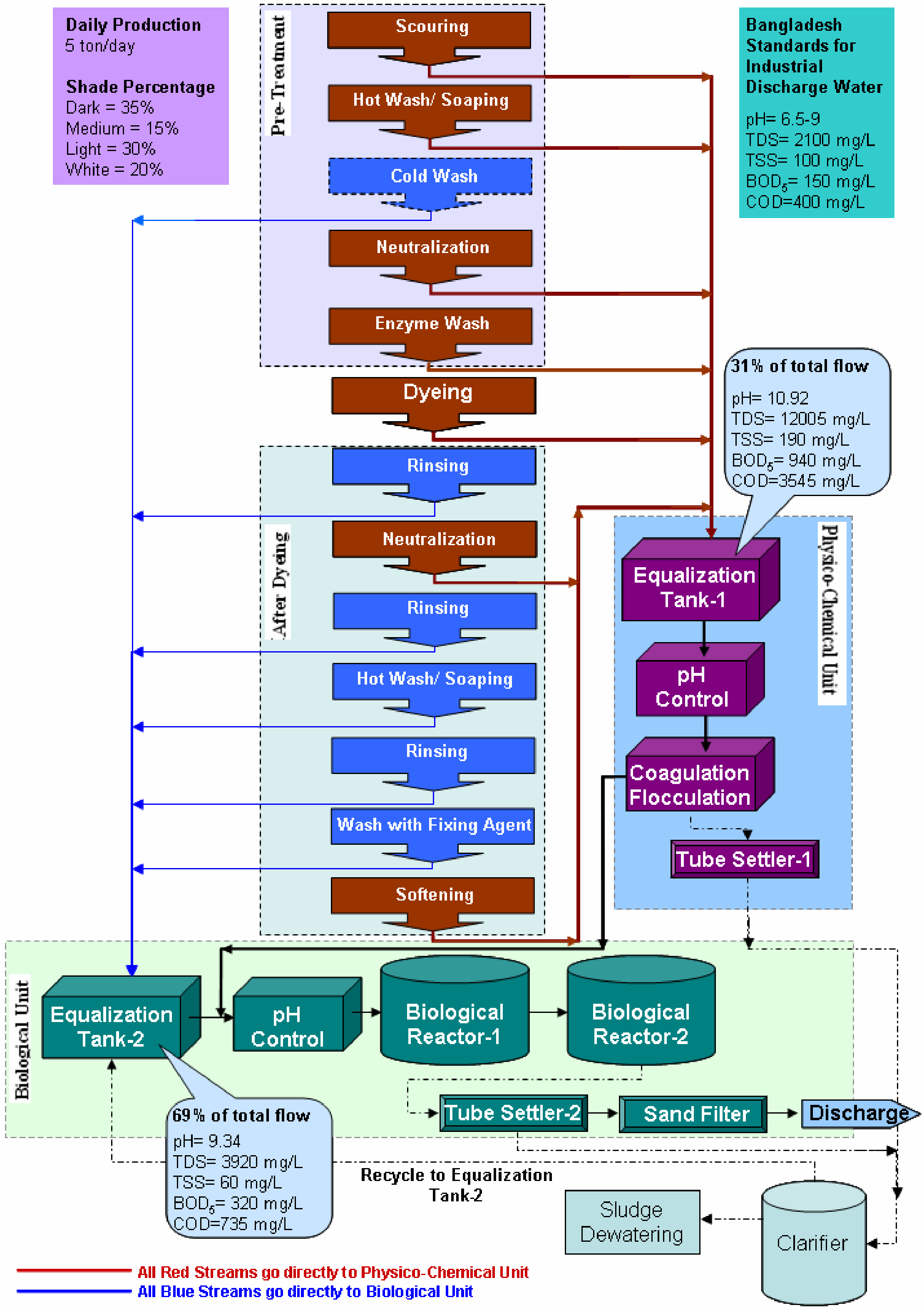

Figure 2.1: Dyeing Sequence and Effluent Treatment with Flow Segregation Option

On average such a factory would produce 1,750 kg dark shade fabric, 750 kg medium shade fabric, 1,500 kg light shade fabric and 1,000 kg white fabric.

Table 2.1: Characteristics of Wastewater Generating From Different Stages[3]

Processing Stages	Effluent Composition	Nature	Portion of total Waste Water
Sizing	Starch, waxes, carboxymethyl cellulose (CMC)	High in BOD, COD	Little
Desizing	Starch, CMC, PVA, fats, waxes, pectins	High in BOD, COD, SS, Dissolved Solids (DS)	Large
Bleaching	Sodium hypochlorite, chlorine, sodium hydroxide, hydrogen peroxide, acids, surfactants, sodium silicate, sodium phosphate, short cotton fibre.	High alkalinity, High SS	Large
Mercerizing	Sodium hydroxide, cotton wax	High pH, Low BOD, High DS	Large
Dyeing	Dyestuffs urea, reducing agents, oxidizing agents, acetic acid, detergents, wetting agents	Strongly coloured, High BOD, DS, Low SS, Heavy Metals	Small
Printing	Pastes, urea, gums, oils, binders, acids, thickeners, cross-linkers, reducing agents, alkali	Highly coloured, High BOD, Oily appearance, SS	Small
Finishing	Inorganic salts, formaldehyde	Slightly alkaline, Low BOD	Small

Based on previous data (Table C-1) the volume of water discharged at any specific stage for dark shade fabric is know allowing for projections of the volume of water that can be discharged for 1,750 kg dark shade fabric. Similarly we can calculate the amount of water produced in different stages for the every shade. Summation of liquid volume of individual shade will give the total volume of water discharged in 24 hours; at the same time summation of liquid volume of highly polluted stages will give the total volume of water that has to be treated by physico-chemically and then biologically. Similarly the volume of less polluted water and non-polluting wastewater can be determined.

Following a similar process for the other shades of dyeing and bleaching it is possible to determine the total volume of effluent in each pollution category.

In the similar way, it is possible to conduct flow segregation calculations for manually operated textile dyeing factories.

[3] Wynne, G., Maharaj, D., and C. Buckley (2002) *Cleaner Production in the Textile Industry – Lessons from the Danish Experience*. http://www.nu.ac.za/cleanerproduction/pdfs/Paper_Natcon_final.pdf

In the case of a semi-automated dyeing factory, nearly 70 percent of total wastewater can be segregated to be treated by biological unit only. Several industry owners have shown interest in the possibility of segregating e to identify any stages which show such characteristics that they can discharge effluent of that stage without any treatment. A few factory owners have inquired whether it is possible to discharge the less polluted effluents without any treatment; however it is suggested that effluents from all stages require at least neutralization and biological treatment before discharge. But the pollution team experts always advise the factory people to treat effluent water from every stage and not to discharge any stream without any treatment. Moreover for convenient operation the industry management have been advised to provide two equalization tanks (Figure 2.1) for the two types of effluent, which increases the construction costs.

Table 2.2: Composite characteristics of effluent generated by a semi-automated dyeing industry in 24 hours[4]

Parameters	Unit	Streams from all stages	Highly polluted streams	Less polluted streams
Volume of water (litre)	tonne	638.5	200	438.5
Percentage of total volume	%	100	31	69
pH	---	10.44	10.92	9.34
TDS	mg/L	6449	12004	3916
TSS	mg/L	101	190	60
BOD_5	mg/L	513	941	317
COD	mg/L	1615	3543	737
COD/BOD_5	---	3.15	3.77	2.32
Sulphate	mg/L	3721	5772	2787
Sulphide	mg/L	0.37	0.65	0.24
Chloride	mg/L	223	465	112
Sodium	mg/L	3188	4388	2642
Magnesium	mg/L	8.53	13.96	6.06
Calcium	mg/L	20.03	15.35	22.17
NH_3-N	mg/L	4.93	7.76	3.56
NO_3-N	mg/L	4.10	2.91	4.65

4 Daily Capacity of Dyeing: 5000 Kg@ 35% Dark Shade, 15% Medium Shade, 30% Light Shad, 20% White

2.2 Improve Existing ETP Operation and Management

2.2.1 Determining effluent characteristics

The project conducted regular sampling of effluent to develop a baseline of effluent characteristics. The project also took regular samples from the different units making up the ETP including the treated water outlet to monitor the ETP performance as well as to diagnose individual units of ETP. The effluent characteristics and diagnosis of individual units of ETP are appended in Appendix B-2: Monitoring of Effluent Treatment Plant Report.

2.2.2 System Management and Improve ETP Monitoring

Control pH

Waste from textile industries is rarely pH neutral so the pH of the effluent should be adjusted to pH 6-8 during treatment. This is necessary, as the bacteria involved in biological treatment will not perform effectively outside this range and also consumption of chemicals for coagulation and flocculation increase when the pH is not neutral.

The use of an automatic pH controller is recommended. If an automatic pH controller system is not fitted then an effective pH control system would be hard to achieve. Samples could be taken with a pH electrode regularly (at least every two hours but this still may not be enough to ensure the efficient functioning of the ETP.

It was also recommended that proper precautions must be taken to protect workers when handling sodium hydroxide and sodium chloride or other chemicals used to correct the pH, as they are strongly corrosive. Precautions should also be taken to ensure that these chemicals do not corrode the treatment plant since acids, particularly sodium chloride are highly corrosive to both concrete and steel.

Improve Biological Unit Management

The project also tried to promote effective biological treatment process as the running cost for biological treatment is relatively little compared to physico-chemical plants. However, biological treatment plants must be carefully managed as they use live micro-organisms to digest the pollutants. For example some of the compounds in the wastewater may be toxic to the bacteria used and pre-treatment with physical operations or chemical processes may be necessary. It is also important to monitor and control pH as adverse pH may result in death of the micro-organisms. Ideally the pH should be maintained within pH 6.5-8.5 to ensure favourable condition for the micro-organisms. The ETP must be properly aerated and must preferably be operated 24 hours a day, 365 days a year to ensure that the bacteria are provided with sufficient "food" (i.e. wastewater) and oxygen to keep them alive. Brief breaks (for a few hours) in operation will probably do little harm but prolonged shut down will deprive the micro-organisms of their food and oxygen and will damage the process so that it will not operate effectively when feeding and aeration are resumed.

Like the other living creatures micro-organisms need a "balanced diet" with sources of carbon, nitrogen, phosphorus and sulphur. While textile wastes have enough carbon and sulphur (sulphate) they are generally lacking in nitrogen and phosphorous containing compounds. If the micro-organisms are to grow and work effectively they are likely to need addition of nutrients. Normally materials such as urea and ammonium phosphate are added. It is possible to replace these nutrients by substituting the liquid portion of effluent from toilets, which is rich in nitrogen and phosphorus containing chemicals (the solid portion may cause problems).

While most of the activated sludge in a biological treatment plant is recycled some may be surplus to requirements and needs to be disposed of. This material must be disposed of appropriately so that the pollutants present in this sludge do not enter the environment. The treated liquid is discharged to the environment.

The project developed and disseminated information on these issues to ETP managers and ETP operators to enable them to more effectively operate their biological treatment units.

Optimize the Chemical Dosing

The work explored ways to reduce the costs of effluent treatment; so that the running cost become more acceptable to the factory owners. The research has found that (exclusive of the labour cost) chemical consumption accounts for approximately 85% of the total running cost, of which 68% is the cost of running the coagulation/flocculation unit (Figure 2.2).

For effective treatment the chemical dosing should be optimum. To optimize the chemical dosing and set the dosing rate it is important the industry undertakes a for jar test, which assesses the correct dosage of coagulants in daily practice and helps maintain the optimum dosage in the daily operations of the ETP. In daily practice the ETP operators tend to use some set dosing rate. Usually this dosing rate is set for specific effluent characteristics, however, effluent characteristics may vary with the dyeing practice and dyeing shade as well as the time of the dyeing cycle. It was found that ETP operators often use more chemicals for highly coloured effluent and comparatively less chemicals for less coloured effluent. But visually clear effluents sometimes show more pollutant than the coloured effluents.

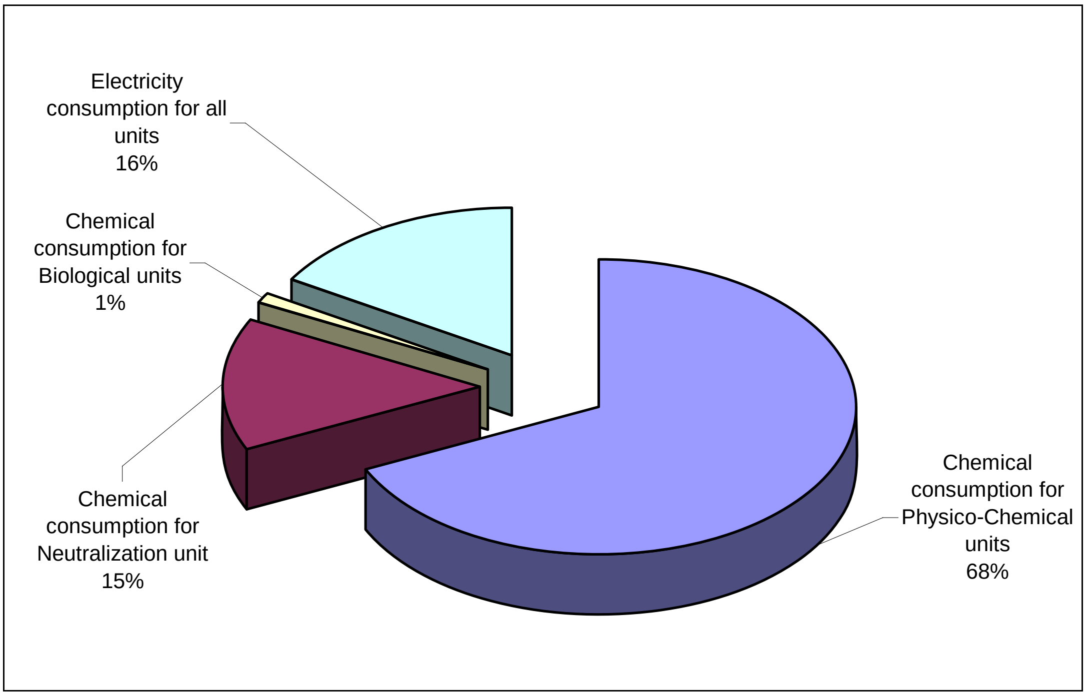

Figure 2.2: Breakdown for running cost of and biological and physico-chemical ETP.

2.2.3 Advice on Sludge Disposal

The sludge generated by effluent treatment needs to be further processed and disposed of safely. It is the by-product of the effluent treatment process, produced in form of solid waste. In fact the production of sludge is a good indicator as to out whether the ETP is running continuously or not. Sludge can be generated at different stages of treatment, including screening, primary settling, chemical precipitation, and the activated sludge or tricking filter stage, but most will come from the physico-chemical stage of treatment. The sludge collected from different stages has different characteristics and compositions. It may contain breakdown products of the original factory waste or compounds created from the waste products and chemicals added to aid the treatment process. For example, nitrogen or phosphorous compounds from chemicals that are added to the activated sludge process or sulphur compounds resulting from the large quantities of sodium sulphate used in dyeing. Despite the differences in the nature of the sludge from each process stage, all the sludge is usually combined and handled together.

Sludge handling and processing is becoming a big issue to the companies which are running their ETP continuously or intending to run it continuously. In fact it is such an important issue on which research is going on all over the world. Currently several different means of processing the waste sludge exist with each having a number of advantages and limitations. The management of the industries in project area who already have their own ETP or the industries with their ETPs under construction or construction work is going to be started in the recent future, are showing great interest in getting advice from the pollution team experts regarding how they could handle and process their ETP sludge. The pollution team participated in different meetings and seminars with the industry management where they disseminated their expert opinions on sludge processing and handling to the industry people.

Determine Sludge Characteristics

Some knowledge on the sludge characteristics is required to select the best appropriate means of sludge handling and processing. The project collected samples from factories and analyzed the samples in order to have a clear idea of the sludge characteristics (Table 2.3).

Table 2.3: Characterization of textile ETP sludge

Property	Value	Unit
Water Content	26.22	Percentage
Specific gravity	2.66	--------------
pH	8.5	--------------
Cadmium	4.89	mg/Kg
Copper	30	mg/Kg
Total Chromium	88.66	mg/Kg
Zinc	343.4	mg/Kg
Nickel	51.48	mg/Kg
Lead	59.1	mg/Kg
Ferrous (Fe++)	43100	mg/Kg
Bi-Sulphates	0.0565	Percentage
Calcium	2317.92	mg/L
Magnesium	600.32	mg/L
Chlorides	0.036	Percentage
Total volatile solids	15.30	Percentage

The amount of ferrous and calcium appears high in the sludge sample. The likely sources are ferrous sulphate and lime used as coagulant in the effluent treatment process. The report also shows that appreciable amount of other elements such as zinc, magnesium and trace amounts of chromium. Further analysis is required to be certain of the characteristics.

Current Practice of Sludge Disposal

The current practice of sludge disposal in Bangladesh is not very much favourable to the country. Most of the industries, generating sludge, dump their sludge into the adjacent low lands. Bangladesh is very prone to flood so there is always a high possibility that during wet season the flood water diffuse the sludge to the total flooded area, which could be hazardous for the aquatic life as well as the flood affected people. Though few industries fill-up their sludge into poly-bags, but the favourable condition can be achieved by lining the landfill site with an impervious layer of bentonite clay or high density polyethylene liner. Few other industries mixed different fertilizers with their sludge in different ratio and keep the total mixture in anaerobic condition for few days. After that they use the sludge mixture as compost fertilizer in gardening.

3. Knowledge Development of Effluent Treatment within the Sector

3.1 Workshops and Seminars

The project arranged several workshops for the textile industry owners and management, where representatives from ETP designers and suppliers, business, Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and Bangladesh Textile Mills Association (BTMA) staff and members, and representatives from international retailers. The workshops covered many aspects including the characteristics of textile effluent, the significance of different parameters used to indicate pollution such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solid (TDS), total suspended solids (TSS), and colour. The national and international standards of wastewater were also discussed as well as the different modes of effluent treatment that may be used to meet these standards. The workshops also discussed the frequent problems faced in ETP management and operation and how these common problems may be overcome. They also discussed about different possibilities to reduce the installation and operating costs of ETPs.

3.2 Booklets and Briefing Notes

In Bangladesh the concept of effluent water treatment and waste management is relatively new, especially in the textile sector. A common problem is uncertainty as to how exactly to operate the plant post-commissioning of the ETP. The project developed a series of publications in the form of booklets and short four-side briefing notes that aimed to help the industry owners and ETP managers in choosing ETPs, managing and operating, and monitoring an ETP.

3.2.1 Booklets

The project published two booklets. The first, entitled "Choosing Effluent Treatment Plant", illustrates the different factors that need to be considered when planning the development of an ETP. It also makes the readers aware of the national standards for wastewater. It outlines the different methods of effluent treatment, the units involve in those different types of treatment, the sequences of the treatment process, the area required for different treatment processes and also, least the likely costs of construction and operation of an ETP. The booklet has been published in both in English and Bangla and distributed to owners, mangers and operators in the textile companies through the relevant business associations. It has also been distributed in different workshops to textile buyers and owners.

The industries that already have an ETP also face problems regarding to operating and monitoring ETP. The second booklet explores these issues. It focuses on how to manage and monitor the different units of ETP, how to collect and preserve samples from different units of ETP and send it to the laboratory for analyzing, which parameters have to be analyzed, how frequent sample has to be taken from different units, and how to optimize chemical dosing rate and thus reduce the operating costs. It also includes succinct descriptions and procedures for the different in-house tests which will help the ETP operators to monitor their ETPs.

3.2.2 Briefing Notes

The project has also developed a briefing note on sludge processing. This briefing note outlines the options for sludge management and disposal. Four different methods of sludge disposal are described: land disposal, landfill, incineration, and stabilization and solidification. The pros and cons of each are outlined.

3.3 The ETP Network

Early on in the project it was clear there was relatively limited knowledge nationally on effluent treatment. The project has therefore developed a platform for the industrial personnel, ETP suppliers and designers, code of conduct (CoC) staff of garment retailers, academic personnel, and other people involved in textile dyeing operation, where they can share there knowledge, views and experiences. The platform is web-based. On September of 2005 the project team successfully launched web based ETP Network (www.sei.se/asia/etp; http://groups.yahoo.com/group/etp-network).

The web based ETP-Network has two elements: first part is a webpage (www.sei.se/asia/etp) that provides the necessary information about waste water treatment, different criteria of effluent treatment plant (ETP), advice when choosing an ETP, the approximate cost of installing an ETP, and management and monitoring of ETP. The platform also hosts a discussion group (http://groups.yahoo.com/group/etp-network), which provides a means of knowledge sharing.

Through the webpage the industrial personnel can exchange their knowledge and views to those people who are doing research on effluent treatment. The website also provides a good opportunity for ETP suppliers to introduce themselves to the industries and also can contribute in trouble-shooting problems. Although currently there is no mechanism for advertising on the site the idea of this as a means to sustain the site after the project funding ends is being explored.

Appendix A - Sampling Methodologies

Appendix A-1: Methodology of composite sampling by using composite sampler

The composite sampling machine was set in the drainage in the drainage of the dyeing unit and programmed the machine so that it took a sample from each 1000 litre of water discharged. Each time the machine took 100mL of samples and collected it into a jar of 8 litre capacity. The number of jars required to collect samples depends on the volume of effluent discharged by the factory. From each jar we took representative sub-samples which were collected and mixed to make homogeneous composite and from which representative samples were taken for laboratory analyses.

As example, let us consider one 5.5 ton composite textile industry (Industry ID 25) which discharged approximately 1,815,000 (=5.5×33×10,000) litre of wastewater per day. According to the set computer program against the total discharge of 1,815,000 litres of wastewater the composite sampler machine took samples from the waste stream 1,815 =1,815,000÷1,000) times. On the other hand as each time the composite sampler machine took 100mL of samples and the effective capacity of jar is 8,000mL; so the collecting jar can collect samples 80 (=8,000÷100) times. So according to composite sampling procedure to collect samples from the total discharge 23(≈1,815÷80) collecting jar was required (in practical two jars were used in rotation). From each jar we took representative sub-samples (1 litre from each jar) which were collected and mixed to make homogeneous composite and from which representative samples (2 litres) were taken for laboratory analysis. Each sub-sample as well as the representative samples were put in ice box to maintain the temperature below 4^0C and handed over to the laboratory in that condition.

Appendix A-2: Methodology of composite sampling on basis of sampling at machine outlet

The pollution load calculation was conducted by using the data collected by the sampling from machine outlet. In the sampling process samples were taken from each stage of the dyeing process for different dye shade (dark, medium, light and white). Different parameters such as pH, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Biochemical Oxygen Demand for 5 days (BOD_5), Chemical Oxygen Demand (COD), Sulphate (SO_4^{-2}), Sodium (Na) were measured for each sample. Except pH all other parameters are showing the concentration value (in milligram per litter, mg/L).

For any specific stage if the concentration value (mg/L) of any specific parameter is being multiplied with the corresponding liquid volume (litre), then the value of that parameter will be found in milligram (mg). The summation of each mg value from every stage will give the total value of that parameter for that specific dyeing process. On the other hand the total volume of liquid, used in the dyeing process, can be found by adding the liquid volume (litre) involved in each stage.

Weighted average (i.e. weighted concentration in mg/L) of this specific parameter will be found by dividing its total amount (mg) by the corresponding total volume of liquid (litre). On the other hand dividing the total quantity (mg) by the corresponding mass of fabric (Kg) will yield the weighted concentration of that parameter in unit mg/Kg of fabric processed. Similar method can be applied to calculate the composite value of other parameters (except pH) of different shades. Dividing the total volume of liquid by the corresponding amount of fabric we will find the volume of liquid produced per kg of fabric processing.

Equation used to calculate weighted average

Weighted Average Concentration of specific parameter A in mg

$$= \frac{\sum(\text{Concentration of Parameter A}) \times (\text{Corresponding Volume of flow stream})}{\sum(\text{Volume of flow stream for individual stage})}$$

and Unit of Average Concentration of Specific Parameter A $= \left(\frac{\frac{mg}{L} \times L}{L} \right) = \frac{mg}{L}$

Again, Weighted Average Concentration of specific parameter A in mg/Kg

$$= \frac{\sum(\text{Concentration of Parameter A}) \times (\text{Corresponding Volume of flow stream})}{\sum(\text{Kg of Fabric being processed})}$$

and Unit of Average Concentration of Specific Parameter A

$$= \left(\frac{\frac{mg}{L} \times L}{Kg\,of\ Fabric\ being\ processed} \right) = \frac{mg}{Kg\ of\ Fabric\ being\ processed}$$

e.g. Let us consider some practical data to explain the calculation. For a semi-automated textile dyeing industry the BOD_5 values for Scouring, Soaping, Neutralization and Softener Wash stage involved in Whiting fabric are respectively 2700, 1600, 1000 and 900 mg/L. And the corresponding volumes of water involved are 2100 litre in each stage (Appendix C, Table C. 4). So Scouring of this dyeing sequence produces BOD_5 5670000 (=2700×2100) mg. The other stages of this dyeing sequence produces BOD_5 respectively 3360000, 2100000 and 1890000 mg. In total all these stages produce 13020000 (=5670000+3360000+2100000+1890000) mg biochemical oxygen demand. On the other hand this whiting of fabric produces 8400 (=2100×4) litre effluent water as a whole. So, the weighted average concentration of BOD_5 for this dyeing process is 1550 mg/L (=13020000mg÷8400lit). Similarly all other parameters can be calculated.

For average pH calculation the concentration of H^+ and concentration of OH^- have to be calculated first. After that we can calculate total value of H^+ and OH^- ions present in any particular stage by multiplying the concentration values with its corresponding water volume. In similar way we can calculate total number of ions for other stages as well as for the total process. Now by balancing H^+ and OH^- ions we can find out overall characteristics of the process: whether it is acidic or alkaline. Now using these values we can calculate the overall pH of this process. For acidic process we have to divide the value of (H^+ - OH^-) by the total volume of water discharged in the process to find out hydrogen ion concentration [H^+] and using this value we can calculate overall pH (= - log [H^+]). On the other hand for alkaline process we have to calculate hydroxyl ion concentration [OH^-] first by dividing the value of (OH^- - H^+) by total volume of discharged water in the process. Using this value we can calculate the pOH (= -log[OH^-]) first and then the overall pH (=14 - pOH) value.

All the corresponding data tables are given in the Appendix C.

Appendix B - Letter/Report to the Industries

Appendix B-1: Sample of feedback letter

Mr. XYZ
ZYX Knitting and Dyeing Industries Ltd.

Dear Mr. Z,

Re: Meeting with ZYX Knitting and Dyeing Industries Regarding their Proposed Effluent Treatment Plant (February, 2005)

It was a pleasure to meet you again and we were very pleased to see that you are still planning the construction of your ETP. Following our meetings with you and Mr. K of S Engineering Associates (ETP designer and provider) we have comments on, and queries concerning, the designs and the documentation you provided from 'S' Engineering Associates.

Comments on the Proposal Design

1. The size of the plant was discussed currently the designs appear to be for a textile factory producing 15 m^3 of effluents per day. This appears a little small, since other factories in the area have plants with production capacities of 5 to 7 tonnes per day, some are planning on 10 tonnes per day – implying greater effluent production and larger effluent designed. The design capacity is important since greater textile production will increase effluent production and it may be that increased flow rates through the ETP will adversely affect its performance. It is important that this issue be resolved, the designers should be asked to specify the range of flow rates over which the plant is likely to be able to operate effectively and XYZ needs to be certain what the expected tonnage of cloth per day will be and therefore the likely volume of effluent.
2. The situation concerning pH control is very important and it is currently unclear whether pH control will be applied and whereabouts in the ETP it will be located. Dyeing effluents are likely to be predominantly alkaline and pHs in the khal suggest that pHs in excess of 9 to 10 (sometimes higher) can be expected. Microbes in activated sludge can only tolerate a limited range of pHs and pH 9 to 10 is likely to be too high. It would be best to operate the biological treatment plant in the range 6 to 8 – probably nearer 8 would be better, and

certainly cheaper in terms of acid consumption. The type of pH controller to be used was discussed, notably the need for an expensive variable speed pump for the addition of acid was considered. Such a pump would be needed for a sophisticated 'PID' controller which would allow control to an exact set point without any 'overshoot'. The project team considered that such an expensive option was not essential and that a more simple 'on-off' control would probably suffice – this could use a fixed speed pump, if a pump of the correct speed was employed. For an 'on-off' control two pH set points would be specified, at the 'high alarm set point' the acid pump is activated and acid added until the pH falls below the 'low alarm set point' at which the acid pump is switched off. This means the pH will oscillate between a value a little higher than the high set point and a little lower than the low set point. While this is not perfect for a very sensitive system it should be perfectly adequate for an activated sludge system. The exact values at which the high and low alarm points are set and the degree of overshoot acceptable need to be determined and will depend on the volumes and flow rate of effluent being treated, the strength of the acid, the speed of the pump etc., but it is probably best to try to control the pH around 7.8 to 8. it is not clear which acid might be used for pH control, if it is intended to use HCl, the equipment used for acid handling and dispensing mush be resistant to HCl, HCl is probable better that sulphuric acid in terms of environmental impact but can cause more corrosion of some materials (e.g. some stainless steels). It is important to be certain that the equipment used for dispensing acid is resistant to HCl and we suggest you confirm this with 'S' Engineering Associates. Decisions on pH control are required.

3. We note that the biological stage of treatment employs an activated sludge process (ASP). With ASPs the settling of activated sludge (AS) after aeration and its subsequent recycling to the aeration tank are essential process. The settling of activated sludge can be difficult and is prone to a problem called 'bulking' – this is particularly so when effluents with a relatively low BOD are treated as this can lead to a low feed to mass ratio (f/m ratio) with encourages the growth of filamentous bacteria which make settling of the sludge problematic. The feed to mass ratio is a measure of the amount of nutrient (BOD) available to the micro organisms in the sludge. Give the fairly low BOD of dye house effluents (especially after physico-chemical treatment) it is possible that the inclusion of a selector tank or selector zone in the aeration tank might be useful to try overcome the likely effect of low f/m ratios on the settling of the activated sludge. The designers should be asked if they have considered this option.

The design includes a chlorination unit as a final stage. This is not likely to be necessary as the bacteria involved in treatment of textile wastes are unlikely to be notable pathogens and, in the local context, release of un-chlorinated is not a universal practice world-wide and for example in the UK is only used in a very few areas where release of sewage effluents will increase the number of faecal indicator bacteria to unacceptable levels for local bathing beaches and water abstraction (for drinking water). In the local context of Kaliakoir, the water is not used for drinking and, while local people do come into contact with water in the khal, the background levels of faecal pollution are so high that it is difficult to conceive that the release of un-chlorinated treated textile-processing effluent will present a significant additional risk. Chlorination of dye house effluents may lead to production of chlorinated aromatic compounds or AOX, which may be toxic, and so is a dubious process in environmental terms. Omission of the chlorination will make some savings in the cost of plant and in operating costs – however these saving are likely to be very small. It should be made clear whether or not a chlorination unit is included.

4. It is important to monitor the performance of the treatment plant regularly to ensure it is working effectively. Regular monitoring of pH, colour, COD and suspended solids can easily be done in-house and amount of activated sludge should also be monitored – this can easily done by measuring the volume of solids after settling for 30 minutes. Measurement of BOD is more difficult but can be done occasionally by outside laboratories like those at BUET. In addition to monitoring the final effluent it is also desirable to measure some of these parameters in the influent to the ETP and after the physico-chemical treatment plant, in this way you assess the performance of the whole plant and of the physico-chemical and biological components. Is provision made in your plans for monitoring performance of the ETP?

5. No mention is made of the starting up of the ASP, as a source of micro-organisms will be required. It is common practice in South Asia to use cow dung, this is not particularly appropriate. The micro-organisms in cow dung are mainly adapted to life in the absence of oxygen and are adapted to degrade grass and straw etc. not textile-processing effluent. It would be advantageous to use a source of micro-organisms that are likely to be better adapted to degradation of textile effluents. Such organisms can be found in an activated sludge from a plant which is currently operating (any activated sludge will be useful but AS from a plant treating similar wastes will be particularly good), also water and sediment from a polluted river. While cow manure can be used it should at least be supplemented with these more appropriate

materials. While we are not in the position to make promises we can offer to arrange supply of a limited amount of AS from a textile company which is operating an ASP and has indicated its willingness to provide activated sludge – it is probably best to request that contact be made through the project team. **The designers should provide a protocol for 'star up' of the ETP and should comment on the suggestions made**.

6. In running ETPs there can be problems and it is important to find out the degree of after-sales service and advice available after construction and commissioning of the plant. It is very important that **expert advice** is available.
7. It will be important to appoint and employee to take charge of the ETP, and it will be necessary to organize suitable training in the operation of treatment plants and the monitoring of their performance. Has this appointment and training requirement been considered.

We hope these comments will be useful to you and we look forward to hearing of further progress with the design of your ETP and also to its construction and commissioning in the near future.

If you have any further information please feel free to contact with us.

Best wishes,

Dr. Jerry Knapp

Appendix B-2: Monitoring of Effluent Treatment Plant Report

The project team conducted two sets of sampling at the following points of a running ETP: M1-Before Physico-Chemical, M2-After Physico-Chemical, M3-End of Biological Reactor 1 (B-1), M4-After Biological Reactor (B-2), and M5-Treated Water. One set of sample was collected at morning and the other one was collected at evening.

It is interesting to found that the performance of ETP was quite stable over the time period though performances of few units were not satisfactory. Results of ETP analysis are shown in Table B. 1 and Table B. 2. The results are graphically represented in the following figures (Figure B.1 to Figure B.2)

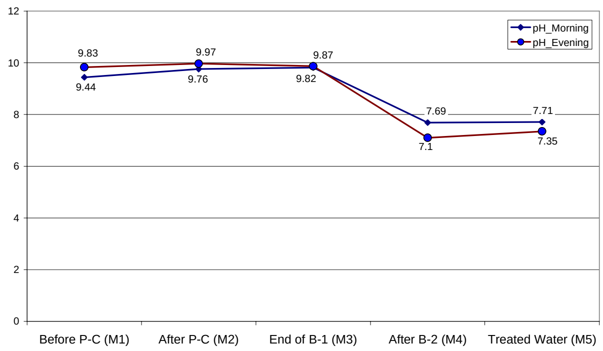

Figure B. 1 pH at different stages of ETP

From these data it is found that the pH value reduced to desire level after being treated by all units, though the value was quite high at the Biological Reactor -1 which is undesirable for the microbial activities. For microbial activity the favourable pH is 6-8. But the effluent entered into the biological reactor-1 was about to 10.

On the other hand the TDS value was gradually increased over the treatment process rather than reducing. As result the TDS value in treated water is much higher than the expected values (Bangladesh Standard for TDS is 2100 mg/L). Also the TDS trend is showing inconsistency in the few stages. The increasing trends of TDS suggest the necessity of reviewing chemical dosing rate and make the dosing rate optimum.

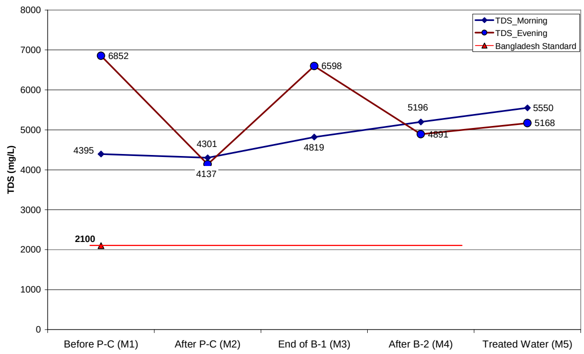

Figure B. 2 TDS at different stages of ETP

The trends of BOD_5 and COD show similar characteristics both in morning and evening sessions. Oxygen demand (both biochemical and chemical) fall down significantly fall down after physico-chemical treatment. About 52-55% BOD_5 and 50% COD are reduced during P-C treatment, which indicate satisfactory performance of physico-chemical unit. But on the other hand the biological reactor 1 could reduce the BOD_5 value only 10-12% of total BOD_5 where as the biological reactor 2 reduced the value only 7-11% of total BOD_5. The situation is very much alike for the COD values and biological reactor 1 and 2 reduced the COD values approximately 10-11%. Together biological reactor – 1 and 2 could only able to reduce the BOD_5 and COD values respectively 19-21% and 20-22%, which are less than the expected performance. So the BOD_5 and COD values of treated effluent remained above than the Bangladesh Standard. The BOD_5 and COD trends indicate that there is lots of scope to improve the overall treatment by improving the performance of biological reactors.

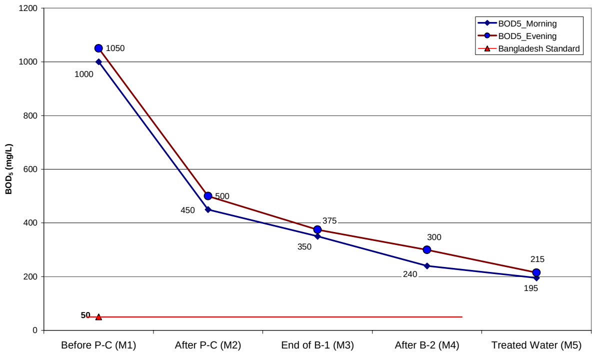

Figure B. 3 BOD_5 at different stages of ETP

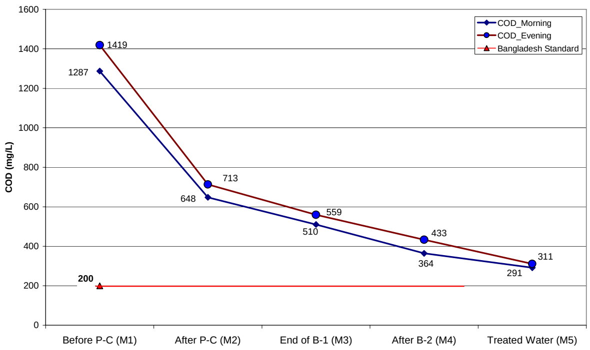

Figure B. 3 COD at different stages of ETP

Table B. 1 Monitoring Different Units of Effluent Treatment Plant

Factory ID: 24
Date of Sample Collection: 28th February, 2005
Session: Morning
Time of Sample Collection: 11:30 AM

Parameters	Units	Bangladesh Standards[**]	Site ID				
			M1	M3	M3	M4	M5
pH	-----	6.5-9	9.44	9.76	9.82	7.68	7.71
TDS	mg/L	2100	4395	4301	4819	5196	5550
TSS	mg/L	100	92	58	31	54	65
BOD_5	mg/L	50 (/150[††])	1000	450	350	240	195
COD	mg/L	200	1287	648	510	364	291
Sulfate	mg/L	400	2050	221	2595	2935	3065
Sulfide	mg/L	1	0.19	0.067	0.214	0.21	0.197
Chloride	mg/L	600	60	53	240	36	265
Sodium	mg/L	200	1211	1093	1001	1084	1351
NH_3-N	mg/L	5	0.16	0.103	0.26	0.256	0.29
NO_3-N	mg/L	10	0.5	0.4	1.1	0.6	0.4

Site ID

M1 Before Physico-Chemical (P-C)
M2 After Physico-Chemical (P-C)
M3 End of Biological Reactor 1 (B-1)
M4 After Biological Reactor 2 (B-2)
M5 Treated Water

[**] Huq, E.M. (Ed. 2003), A Compilation of the Environmental Laws of Bangladesh administered by the Department of Environment, Department of Environment and Bangladesh Environmental Management Project. DOE and BEMP, Dhaka.
[††] BOD limit 150mg/L implies only with Physico-Chemical processing.

Table B. 2 Monitoring Different Units of Effluent Treatment Plant

Factory ID: 24
Date of Sample Collection: 28th February, 2005
Session: Evening
Time of Sample Collection: 1:45 PM

Parameters	Units	Bangladesh Standards	Site ID				
			M1	M3	M3	M4	M5
pH	-----	6.5-9	9.83	9.97	9.87	7.1	7.35
TDS	mg/L	2100	6852	4137	6598	4891	5168
TSS	mg/L	100	133	64	80	92	79
BOD_5	mg/L	50 (/150)	1050	500	375	300	215
COD	mg/L	200	1419	713	559	433	311
Sulfate	mg/L	400	3950	2135	2140	4270	4360
Sulfide	mg/L	1	0.17	0.061	0.018	0.18	0.15
Chloride	mg/L	600	68	48	1160	315	290
Sodium	mg/L	200	1358	709	1002	837	1102
NH_3-N	mg/L	5	015	0.1	0.134	0.256	0.5
NO_3-N	mg/L	10	0.4	0.2	0.6	0.29	0.5

Site ID

M1 Before Physico-Chemical (P-C)
M2 After Phsico-Chemical (P-C)
M3 End of Biological Reactor 1 (B-1)
M4 After Biological Reactor 2 (B-2)
M5 Treated Water

Table B. 3 Diagnoses of Different Units of an Existing ETP

	Physico-Chemical Unit		Biological Reactor – 1		Biological Reactor – 2	
	mg/L	Percentage, %	mg/L	Percentage, %	mg/L	Percentage, %
Session	**Morning**					
Reduction of BOD	550	55	100	10	110	11
Reduction of COD	639	50	138	11	146	11
Reduction of TDS	94	2	-518	-12	-377	-9
Session	**Evening**					
Reduction of BOD	550	52	125	12	75	7
Reduction of COD	706	50	154	11	126	9
Reduction of TDS	2715	40	- 2461	-36	1707	25

Appendix C - Tables of Effluent Water Characteristics

Table C. 1 Characteristics of different stages of Black Shade Dyeing by a Semi-Automated Machine

<u>Amount of fabric:</u> 400 Kg

Name of the stages	Volume of water involved (litre)	pH	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SO_4^{2-} (mg/L)	S^{2-} (mg/L)	Cl^- (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	$\frac{COD}{BOD_5}$
Bleaching/ Scouring	2600	12	5850	396	2050	10120	180	0.18	230	1600	1.4	10.7	22.1	13	4.94
Hot wash	2600	11.4	3060	10	625	3050	100	0.008	180	830	8.8	1.4	2.7	3.6	4.88
Cold Wash	2600	10.3	693	8	490	2420	25	0.008	40	230	1	9.8	1.65	1	4.94
Neutralization	2600	5	536	4	290	1441	10	0.006	40	220	52	38.4	1.62	0.1	4.97
Dyeing	2800	11	57800	16	725	3520	33000	9	4800	25500	4.5	57	2	10	4.86
Rinsing	10400	10.1	6700	11	275	718	10000	1	380	2800	8	145	0.06	20	2.61
Cold Wash	2600	8.9	550	20	45	89	700	0.12	24	220	4.2	12	0.06	1	1.98
Hot Wash with Soaping Agent	2600	9.4	950	30	235	1164	1000	2.3	500	390	68	76	0.06	10	4.95
Rinsing	5200	8.8	445	23	215	428	1000	0.8	140	180	8.6	10.4	0.06	20	1.99
Rinsing	5200	7.6	196	15	32	63	100	0.07	24	140	2.4	7.1	0.06	2	1.97
Neutralization	2600	4.45	303	5	360	899	200	0.15	60	81	1.8	5.1	0.06	1	2.50
Rinsing	10400	5.3	204	10	175	344	50	0.04	18	76	2.8	9.9	0.06	3	1.97
Wash with Fixing Agent	2600	5.5	222	4	120	240	5	0.002	48	87	2.4	7.5	0.32	0.2	2.00
Softening	2600	4.6	244	477	76	162	30	0.01	23	82	1.8	15.9	0.52	1.2	2.13
Composite Value	**57400**	**10.81**	**4691**	**51**	**334**	**1296**	**3632**	**0.83**	**373**	**1963**	**9.58**	**40**	**1.45**	**8**	**3.88**

[grey box] Has to be treated Physico-Chemically and Biologically

[white box] Preferably be treated only by Biologically (at controlled pH, if necessary)

Table C. 2 Characteristics of different stages of Medium Shade Dyeing by a Semi-Automated Machine

Amount of fabric: 189 Kg

Name of the stages	Volume of water involved (litre)	pH	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SO_4^{2-} (mg/L)	S^{2-} (mg/L)	Cl^- (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	$\frac{COD}{BOD_5}$
Scouring	2100	10.54	9906	110	2250	8660	525	0.15	210	1217.2	20.56	14.4	18	1.4	3.85
Hot wash	2100	10.33	5407	174	1700	5780	275	0.19	170	614	21.99	8.44	10.2	0.3	3.40
Neutralization (Acid wash)	2100	5.97	2977	103	750	2480	25	0.05	39	305	38.24	9.83	4.5	0.4	3.31
Wash with Enzyme solution	2100	5.08	294	10	420	929	75	0.007	14	41.36	1.3	20.2	2.56	0.2	2.21
Dyeing	2000	9.48	61280	455	450	1118	25000	0.6	1160	13000	5.4	34.2	4.25	16	2.48
Rinsing-1	4200	9.25	22115	362	180	366	10750	0.2	330	4900	1.04	14.4	1.25	1	2.03
Rinsing-2	4200	8.66	2057	83	88	146	1125	0.075	58	460	1.06	9.9	0.5	1	1.66
Acid wash	2100	5.43	920	125	340	754	275	0.025	17	189	1	14.3	1.5	1	2.22
Rinsing	4200	6.21	482	15	180	358	175	0.003	16	93	0.8	6.05	0.75	0.1	1.99
Hot wash with soaping agent	2100	7.16	330	12	150	300	25	0.002	14	37	0.84	12.57	1	0.2	2.00
Hot wash Rinsing	4200	7.19	292	40	50	102	50	0.002	13	36	1.02	10.4	0.39	0.7	2.04
Softening	2100	5.32	340	32	650	1596	25	0.008	11	25	0.9	9.3	0.83	0.2	2.46
Composite Value	**33500**	**9.59**	**7496**	**127**	**373**	**1329**	**3053**	**0.086**	**153**	**1649**	**4.97**	**13.85**	**2.64**	**2.45**	**2.56**

[shaded box] Has to be treated Physico-Chemically and Biologically

[unshaded box] May be possible to treat only by Biological processes (at controlled pH, if necessary)

Table C. 3 Characteristics of different stages of Light Shade Dyeing by a Semi-Automated Machine

Amount of fabric: 600 Kg

Name of the stages	Volume of water involved (litre)	pH	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SO_4^{2-} (mg/L)	S^{2-} (mg/L)	Cl^- (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	$\frac{COD}{BOD_5}$
Scouring	4400	10.54	9906	110	2250	8660	525	0.15	210	1217.2	20.56	14.4	18	1.4	3.85
Hot wash	4400	10.33	5407	174	1700	5780	275	0.19	170	614	21.99	8.44	10.2	0.3	3.40
Neutralization (Acid wash)	4400	5.97	2977	103	750	2480	25	0.05	39	305	38.24	9.83	4.5	0.4	3.31
Dyeing	4200	9.49	55258	313	700	2300	47500	0.225	480	34920	25.88	15.52	29.75	5.5	3.29
Rinsing	17600	9.37	16396	295	390	1060	11000	0.1	116	20250	5.24	2.08	11.3	2.2	2.72
Acid wash (50^0C)	4400	7.93	4227	53	350	920	2500	0.025	13	861.1	0.38	1.02	4.8	0.2	2.63
Rinsing	17600	7.43	1167	4	210	460	625	0.005	21	216.8	0.13	1.16	1.6	0.1	2.19
Hot wash	4400	7.89	1123	9	440	1000	500	0.11	8	167.3	1.05	2.37	5.7	4.2	2.27
Rinsing	17600	7.74	471	41	390	600	25	0.015	10	77.93	0.26	1.18	16	1.6	1.54
Softening	4400	5.84	439	606	290	1840	1	0.005	18	69.44	0.02	1.28	0.9	0.1	6.34
Composite Value	**83400**	**9.56**	**7859**	**143**	**549**	**1654**	**5052**	**0.06**	**79**	**6265**	**6.83**	**3.68**	**9.92**	**1.45**	**3.01**

(shaded) Has to be treated Physico-Chemically and Biologically

(unshaded) May be possible to treat only by Biological processes (at controlled pH, if necessary)

Table C. 4 Characteristics of different stages of White Dyeing by a Semi-Automated Machine

Amount of fabric: 286 Kg

Name of the stages	Volume of water involved (litre)	pH	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SO_4^{2-} (mg/L)	S^{2-} (mg/L)	Cl^- (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	$\frac{COD}{BOD_5}$
Scouring	2100	8.06	12728	620	2700	9400	1	0.004	680	1257	10.7	13.7	18.75	0.6	3.48
Soaping	2100	8.17	5864	8	1600	3570	1	0.004	380	628	19.9	5.3	7	0.7	2.23
Neutralization	2100	5.52	3016	10	1000	2256	5	0.005	116	239	26.3	1.3	3.25	3.9	2.26
Softener Wash	2100	5.78	1778	27	900	1660	1	0.005	38	87	10.1	0.4	3.5	2.1	1.84
Composite Value	**8400**	**6.29**	**5847**	**166**	**1550**	**4221**	**2**	**0.0045**	**303**	**553**	**16.75**	**5.18**	**8.13**	**1.83**	**2.72**

[grey box] Has to be treated Physico-Chemically and Biologically

[white box] May be possible to treat only by Biological processes (at controlled pH, if necessary)

Table C. 5 Composite characteristics of highly polluted stages of a Semi-Automated Machine

<u>Daily Capacity of Dyeing:</u> 5000 Kg@ 35% Dark Shade, 15% Medium Shade, 30% Light Shad, 20% White

Name of the Stages	Type of Shade	Amount of Fabric in one batch (Kg)	Volume of water involved in a batch (litre)	Amount of fabric produced in a day (Kg)	Amount of water discharged for specific dye shade (litre)	pH	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SO_4^{2-} (mg/L)	S^{2-} (mg/L)	Cl^- (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	$\frac{COD}{BOD_5}$
Scouring	Light	600	4400	1500	11000	10.54	9906	110	2250	8660	525	0.15	210	1217.2	20.56	14.4	18	1.4	3.85
	Medium	189	2100	750	8333	10.54	9906	110	2250	8660	525	0.15	210	1217.2	20.56	14.4	18	1.4	3.85
	Dark	400	2600	1750	11375	12	5850	396	2050	10120	180	0.18	230	1600	1.4	10.7	22.1	13	4.94
	White	286	2100	1000	7343	8.06	12728	620	2700	9400	1	0.004	680	1257	10.7	13.7	18.75	0.6	3.48
Hot Wash	Light	600	4400	1500	11000	10.33	5407	174	1700	5780	275	0.19	170	614	21.99	8.44	10.2	0.3	3.40
	Medium	189	2100	750	8333	10.33	5407	174	1700	5780	275	0.19	170	614	21.99	8.44	10.2	0.3	3.40
	Dark	400	2600	1750	11375	11.4	3060	10	625	3050	100	0.008	180	830	8.8	1.4	2.7	3.6	4.88
Neutralization (Acid wash)	Light	600	4400	1500	11000	5.97	2977	103	750	2480	25	0.05	39	305	38.24	9.83	4.5	0.4	3.31
	Medium	189	2100	750	8333	5.97	2977	103	750	2480	25	0.05	39	305	38.24	9.83	4.5	0.4	3.31
	Dark	400	2600	1750	11375	5	536	4	290	1441	10	0.006	40	220	52	38.4	1.62	0.1	4.97
Dyeing	Light	600	4200	1500	10500	9.49	55258	313	700	2300	47500	0.225	480	34920	25.88	15.52	29.75	5.5	3.29
	Medium	189	2000	750	7937	9.48	61280	455	450	1118	25000	0.6	1160	13000	5.4	34.2	4.25	16	2.48
	Dark	400	2800	1750	12250	11	57800	16	725	3520	33000	9	4800	25500	4.5	57	2	10	4.86
Acid wash	Light	600	4400	1500	11000	7.93	4227	53	350	920	2500	0.025	13	861.1	0.38	1.02	4.8	0.2	2.63
	Medium	189	2100	750	8333	5.43	920	125	340	754	275	0.025	17	189	1	14.3	1.5	1	2.22
	Dark	400	2600	1750	11375	4.45	303	5	360	899	200	0.15	60	81	1.8	5.1	0.06	1	2.50
Enzyme Wash	Medium	189	2100	750	8333	5.08	294	10	420	929	75	0.007	14	41.36	1.3	20.2	2.56	0.2	2.21
Softening	Light	600	4400	1500	11000	5.84	439	606	290	1840	1	0.005	18	69.44	0.02	1.28	0.9	0.1	6.34
	Medium	189	2100	750	8333	5.32	340	32	650	1596	25	0.008	11	25	0.9	9.3	0.83	0.2	2.46
	Dark	400	2600	1750	11375	4.6	244	477	83	162	30	0.01	23	82	1.8	15.9	0.52	1.2	1.95
			Total Values:	**5000**	**199904**	**10.92**	**12005**	**190**	**940.70**	**3545**	**5772**	**0.65**	**464.69**	**4388**	**13.96**	**15.35**	**7.76**	**2.91**	**3.77**

Table C. 6 Composite characteristics of less polluted stages of a Semi-Automated Machine

<u>Daily Capacity of Dyeing:</u> 5000 Kg@ 35% Dark Shade, 15% Medium Shade, 30% Light Shad, 20% White

Name of the Stage	Type of Shade	Amount of Fabric in one batch (Kg)	Volume of water involved in a batch (litre)	Amount of fabric produce d in a day (Kg)	Amount of water discharg ed for specific dye shade (litre)	pH	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SO_4^{2-} (mg/L)	S^{2-} (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	$\frac{COD}{BOD_5}$
Hot Wash with Soaping Agent	Light	600	4400	1500	11000	7.89	1123	9	440	1000	500	0.11	167.3	1.05	2.37	5.7	4.2	2.27
	Medium	189	2100	750	8333	7.16	330	12	150	300	25	0.002	37	0.84	12.57	1	0.2	2.00
	Dark	400	2600	1750	11375	9.4	950	30	235	1164	1000	2.3	390	68	76	0.06	10	4.95
	White	286	2100	1750	12850	8.17	5864	8	1600	3570	1	0.004	628	19.9	5.3	7	0.7	2.23
Cold Wash	Dark	400	2600	1750	11375	10.3	693	8	490	2420	25	0.008	230	1	9.8	1.65	1	4.94
Rinsing		400	10400	1750	45500	10.1	6700	11	275	718	10000	1	2800	8	145	0.06	20	2.61
Cold Wash		400	2600	1750	11375	8.9	550	20	45	89	700	0.12	220	4.2	12	0.06	1	1.98
Rinsing-1		400	5200	1750	22750	8.8	445	23	215	428	1000	0.8	180	8.6	10.4	0.06	20	1.99
Rinsing-2		400	5200	1750	22750	7.6	196	15	32	63	100	0.07	140	2.4	7.1	0.06	2	1.97
Rinsing-3		400	10400	1750	45500	5.3	204	10	175	344	50	0.04	76	2.8	9.9	0.06	3	1.97
Wash with Fixing Agent		400	2600	1750	11375	5.5	222	4	120	240	5	0.002	87	2.4	7.5	0.32	0.2	2.00
Neutralization	White	286	2100	1750	12850	5.52	3016	10	1000	2256	5	0.005	239	26.3	1.3	3.25	3.9	2.26
Softening		286	2100	1750	12850	5.78	1778	27	900	1660	1	0.005	87	10.1	0.4	3.5	2.1	1.84
Rinsing-1	Light Shade	600	17600	1500	44000	9.37	16396	295	390	1060	11000	0.1	20250	5.24	2.08	11.3	2.2	2.72
Rinsing-2		600	17600	1500	44000	7.43	1167	4	210	460	625	0.005	216.8	0.13	1.16	1.6	0.1	2.19
Rinsing-3		600	17600	1500	44000	7.74	471	41	390	600	25	0.015	77.93	0.26	1.18	16	1.6	1.54
Rinsing-1	Medium Shade	189	4200	750	16667	9.25	22115	362	180	366	10750	0.2	4900	1.04	14.4	1.25	1	2.03
Rinsing-2		189	4200	750	16667	8.66	2057	83	88	146	1125	0.075	460	1.06	9.9	0.5	1	1.66
Rinsing-3		189	4200	750	16667	6.21	482	15	180	358	175	0.003	93	0.8	6.05	0.75	0.1	1.99
Hot wash rinsing		189	4200	750	16667	7.19	292	40	50	102	50	0.002	36	1.02	10.4	0.39	0.7	2.04
Total Values:				**5000**	**438549**	**9.34**	**3916.33**	**60.65**	**317.28**	**736.92**	**2786.56**	**0.24**	**2641.76**	**6.06**	**22.17**	**3.65**	**4.65**	**2.32**