Managing and Monitoring Effluent Treatment Plants

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Acronyms and Abbreviations

AS	Activated Sludge
ASP	Activated Sludge Plant
BOD	Biochemical Oxygen Demand
BOD_5	5-day Biochemical Oxygen Demand
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
DFID	Department for International Development
DO	Dissolved Oxygen
ETP	Effluent Treatment Plant
F/M Ratio	Feed-to-Mass Ratio
MACH	Management of Aquatic Ecosystems through Community Husbandry
MLSS	Mixed Liquor Suspended Solids
NaOH	Sodium Hydroxide
SG	Specific Gravity
SSVI	Stirred Sludge Volume Index
SVI	Sludge Volume Index
TDS	Total Dissolved Solid
TSS	Total Suspended Solid

1 Introduction

All industrial operations produce some wastewaters which must be returned to the environment. Textile industries produce wastewater, otherwise known as effluent, as a by-product of their production. Effluent from the textile industry is a major source of environmental pollution, especially water pollution. Among the various stages of textile production, the operations in the dyeing plant, which include pre-treatments, dyeing and finishing, produce the most pollution. The textile dyeing wastes contain unused or partially used organic compounds, and high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). They are often of strong colour and may also be of high temperature. When disposed into water bodies or onto land these effluents will result in the deterioration of ecology and damage to aquatic life. Furthermore they may cause damage to fisheries and economic loss to fishermen and farmer, there may be impacts on human health.

The rise in the number of industries in Bangladesh, including textile dyeing operations, has seriously increased the pollution that the country is experiencing. Consequently national laws have been enacted to protect the environment from this pollution. In Bangladesh textile dyeing is categorized as a Red Category Industry under the Environmental Conservation Act (1995). In accordance with the Act and Environmental Rules (1997) it is mandatory for textile dyeing factories to install effluent treatment plants (ETPs) to treat wastewater before it leaves the factory premises.

International pressure for effluent treatment is also increasing and many international buyers are now showing more concern over whether or not textiles are produced in an environmentally friendly way. This trend means that in the future it is likely that installation and operation of an ETP will be essential to sustain business in the competitive world market.

It is a positive sign that many industries are also making progress in establishing and operating their own ETPs to comply with national and international requirements, and also because of increased personal awareness of the negative impacts of industrial effluent.

The difficultly that many of these industries face is that effluent treatment is not part of their daily business as textile manufacturers. However, in order for these ETPs to function effectively and meet national standards they require regular and proper monitoring. Untreated and treated wastewater characteristics need to be known and must be monitored regularly to evaluate the efficiency of the treatment plant. Different parameters in different units of the ETP also need to be checked to diagnose any internal breakdown of the system. It is hoped that this booklet will provide some guidance on what needs to be checked and how the checks can be made.

This booklet is intended to be read in conjunction with another booklet in the series, entitled “Choosing an Effluent Treatment Plant”, which provides information on the form of wastewater produced by textile dyeing processes, the components of ETPs, the design of ETPs and the national effluent discharge quality standards defined in the Bangladesh Environment Conservation Rules, 1997. The briefing note on “Environmental Clearance Certificates” also produced in this series may be of additional use.

2 Managing and Monitoring ETP Units

2.1 Why Manage and Monitor Effluent Treatment Plants?

By law factories must monitor the quality of their wastewater and stay within national limits for pollution. The Environment Conservation Rules, 1997 provide national standards for the quality of industrial wastewater being discharged into certain places including open water bodies, public sewers and irrigated land. They also provide specific discharge quality standards for key parameters from certain industries, including the textile dyeing industry (Table 1).

Table 1: Discharge Quality Standards for Classified Industries – Composite Textile Plant and Large Processing Units (Investment over TK 30,000,000)[1]

Parameter	**Limit (mg/L)**
pH	6.5 – 9
Total Suspended Solid (TSS)	100
BOD_5 20^0C	150*
Oil and Grease	10
Total Dissolved Solid (TDS)	2100
Waste Water Flow	100 L/Kg of fabric processing
Special parameters based on classification of dyes used	
Total Chromium (as Cr molecule)	2
Sulfide (as S molecule)	2
Phenolic compounds as C_6H_5OH	5

** BOD limit of 150 mg/l implies only with physico chemical processing*

Although the effluent discharged from textile dyeing units varies, it generally shows pollution indicators of far higher values than the desired level. Pollution indicator data collected from two industries in Bangladesh demonstrates this (Table 2). These values can vary with different processes as well as types and conditions of equipment used in the textile industries, but almost always show greater values than the standards set by the Department of Environment (DoE).

Table 2: Effluent Water Characteristics of 5 ton Capacity Composite Textile Industry

Parameters	Limits for Textile Industries	Composite Textile Industry with Semi-automatic Machine (Year of sampling 2005)		Composite Textile Industry with Manual Machine (Year of sampling 2003)	
	mg/l of effluent	g/kg of fabric	mg/l of effluent	g/kg of fabric	mg/l of effluent
TDS	2100	825	6700	850	5730
TSS	100	13.5	110	57.5	390
BOD_5	150	63	510	67	445
COD	200*	200	1620	170	1150
SO_4^{2-}	**	465	3780	35	215
pH	6-9	9.5 -10.5		9.5 -11	
Waste water flow	100 l/kg of fabric processing	125 l/kg of fabric processing		150 l/kg of fabric processing	

* No specific standard exists for COD for textile industries but the general standard for discharge to inland surface water is 200 mg/l.
** There is no standard for sulphate but the standard for sulphide is 1 mg/l.

To reduce the pollution intensity a proper ETP should be installed on the premises of the industry to treat the effluent before it is discharged. The parameters set by the Bangladesh Government must be monitored in the effluent from the factory to ensure that the factory is complying with national standards.

It is also necessary and useful to monitor these parameters in the wastewater entering the ETP and at several stages in the ETP process. This enables the ETP manager to optimize the ETP process by adjusting chemical inputs, retention time and other factors. This can reduce costs by preventing excess chemicals from being used and will result in a more efficient plant that produces effluent that complies with national standards. Good ETP management therefore requires a certain level of understanding of the overall function of the ETP, how individual units work, how to monitor their functioning, and how to diagnose and address problems.

This chapter covers primary treatment, which prepares the wastewaters for biological treatment, as well as secondary (biological) treatment and briefly mentions tertiary treatments.

2.2 Screening

Screening is a mechanical process that separates particles on the basis of size. There are several types, which have static, vibrating or rotating screens. Openings in the screening surfaces range in size depending on the nature of the waste. In the case of textile dyeing industries they should be small enough to catch pieces of cloth, which may damage process equipment, reduce the effectiveness of the ETP or contaminate waterways.

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For good screening performance the openings of a screen have to be uniform. There should not be any leakage at the joint of the screen and water channel. Textile effluent water is corrosive in nature, so the design of the screen should make allowance for possible corrosion during use. Using corrosion resistant metal could be a solution but the price is higher than for mild steel.

It is highly possible that the openings of the screen will become clogged by pieces of fabric, grit and other particles. It should be monitored and cleaned every morning and evening so that the flow of effluent is not hampered by blockages.

2.3 Equalization

The many steps in the textile dyeing process (pre-treatment, dyeing and finishing) mean that wastewater quality and quantity varies considerably over time, however ETPs are usually designed to treat wastewater that has a more or less constant flow and a quality that only fluctuates within a narrow range. The equalization tank overcomes this by collecting and storing the waste, allowing it to mix and ensuring that it becomes less variable in composition before it is pumped to the treatment units at a constant rate. The purpose of equalization for industrial treatment facilities are therefore:

- To minimize flow surges to physical-chemical treatment systems and permit chemical feed rates that are compatible with feeding equipment.
- To help adequate pH control or to minimize the chemical requirements necessary for neutralization.
- To provide continuous feed to biological systems over periods when the manufacturing plant is not operating.
- To prevent high concentrations of toxic materials from entering the biological treatment plant.

Mixing usually ensures adequate equalization and prevents settleable solids from depositing in the tank. In addition, mixing and aeration may result in the oxidation of reduced compounds present in the waste-stream or the reduction of BOD.

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To determine the required volume of the equalization tank the hourly variation of flow needs to be determined. Generally the volume of the equalization tank should be sufficient to collect at least one third of total effluent water discharged in 24 hours (i.e. 8 hour retention time).

Regular observation is required to ensure that the tank does not overflow or is not leaking. The mixing and aeration system, if there is one, should be checked to ensure that it is functioning correctly.

Samples should be taken from the equalization tank to determine the quality of the effluent entering the plant. This will allow adjustments to be made to chemical dosing.

2.4 Neutralization: pH Control

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

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The pH of the water after the equalization tank as well as water after coagulation, flocculation and biological treatment, and discharge water should be monitored regularly. For monitoring, a pH meter gives much more accurate result than pH paper, especially when the effluent is highly coloured, and therefore pH paper should not be used.

An automatic pH controller should be used so that the pH can be automatically tested and adjusted. If an automatic pH controller system is not fitted samples must be taken regularly (at least every 2 hours) to ensure the efficient functioning of the ETP. Ideally the fitting of an automatic system should be considered as it will significantly improve the operation of the plant and will prove to be cost effective.

Spare pH meters and electrodes should be kept in stock to replace damaged electrodes without delay as pH control is crucial to the success of the ETP.

The pH electrodes used should be selected carefully and should be guaranteed by the manufacturer to be suitable for use in an industrial ETP since not all electrodes can withstand conditions in an ETP.

Usually sodium hydroxide (NaOH) is used to neutralize acidic wastes or hydrochloric acid (HCl) to neutralize alkaline wastes, depending on the normal pH of the equalized effluent. Generally in the dyeing industry in Bangladesh effluents are highly alkaline (high pH) and require the addition of acid. However, provision should be made to be able to add both acid and alkali, as some dyeing processes may give acid effluents and addition of alkali may be needed. Proper precautions must be taken to protect workers when handling NaOH, HCl or other chemicals used to correct the pH, as they are strongly corrosive and potentially dangerous. HCl is corrosive to concrete and steel so precautions need to be taken to ensure that the acid is not spilt onto the fabric of the ETP.

2.5 Aeration

Aeration is required in biological treatment processes to provide oxygen to the microorganisms that breakdown the organic waste. It may also be applied in the equalization tank to provide mixing and to reduce oxygen demand by oxidizing the compounds present in wastewater. Two main methods are used for this: either mechanical agitation of the water so that air from the atmosphere enters the water; or by introducing air into the tank through blowers (to supply air) and diffusers (to diffuse the air uniformly).

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A blower (compressor) is used to supply oxygen (air) during the treatment process. If the blower malfunctions then the treatment process will have to be stopped while the blower is replaced. To overcome this problem a spare blower should be used while the primary blower is being repaired.

The aeration unit (diffuser or blower) can be clogged by particles or corroded by the wastewater, which will reduce the aeration performance. The condition of the diffusers should therefore be checked every three months. Stainless steel diffusers should have a longer life than ones made of mild steel but are more expensive.

Dissolved oxygen (DO) is an important parameter in effluent treatment and should be measured in the aeration units of ETPs to ensure sufficient oxygen is available for effective treatment. DO is best measured using an oxygen electrode. Such electrodes are delicate and need careful handling. DO electrodes that are used *in situ* in an ETP need to be rated for continual use in this environment. They need occasional but regular calibration, as per the manufacturer's instructions. Spare electrodes should be kept in stock to replace broken ones.

The 5-day biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) of the effluent after aeration should also be checked regularly to find out how effective the aeration unit is at reducing the oxygen demand. Ideally this should be every few weeks and no less than every three months. Analysis for BOD_5 and COD can only be performed in a suitably equipped laboratory. An explanation of how to collect and store samples is provided in Chapter 4 of this booklet.

2.6 Coagulation and Flocculation

Coagulation is used to remove waste materials in suspended or colloidal form. Colloids are particles over a size range of 0.1 – 1 nm (10^{-8} – 10^{-7} cm). These particles do not settle out on standing and cannot be removed by conventional physical treatment processes. In a small sample of wastewater there will be both settleable solids and dispersed solids. A significant portion of these non-settleable solids may be colloidal. Each particle is stabilized by negative electric charges on its surface, causing it to repel neighboring particles, just as magnetic poles repel each other. Coagulation is destabilization of these colloids by neutralizing the forces that keep them apart so that they can agglomerate [2,3] (come together). This is generally accomplished by adding chemical coagulants and mixing. Figure 1 illustrates how these chemicals reduce the electric charges on colloidal surfaces.

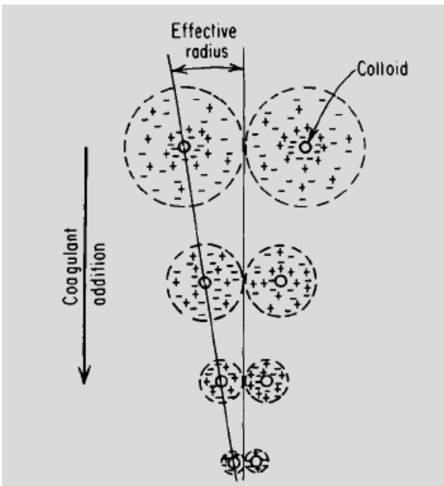

Figure 1: Illustration of Chemical Coagulation [4]

The term 'flocculation' may be taken to cover those processes whereby small particles or small groups of particles form large aggregates. Flocculation during wastewater treatment converts finely divided suspended solids into larger particles so that efficient, rapid settling can occur. The term is also used for the dramatic effect when polyelectrolytes are added and large stable flocs are formed very quickly (Figure 2).

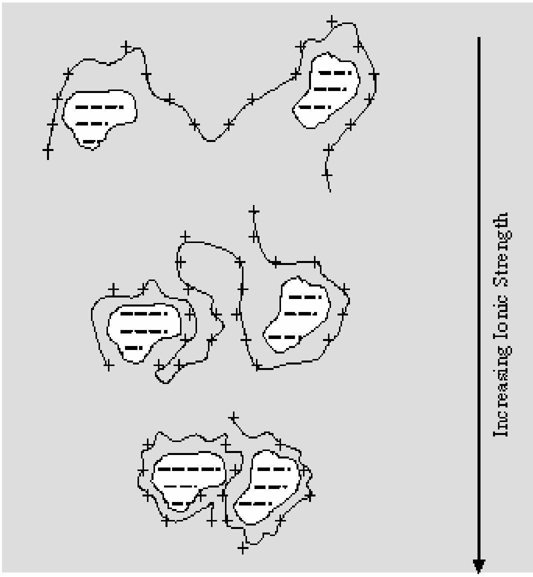

Figure 2: Flocculation by Charge Neutralization and Bridging [5]

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Coagulation and flocculation units are designed to reduce the pollution load by removing total suspended solids (TSS), and reducing BOD_5 and COD (since some of the suspended solids are organic chemicals and have BOD and COD). The dosing rate of chemical flocculants and coagulants is relative to the pollution load, with higher loads requiring higher dosing rates. In practice ETP operators try to determine the pollution load by observing the color of effluent entering the ETP. They consider dark wastewater to be more polluted and light wastewater to be less polluted. Research undertaken as part of this project shows that the actual situation is very different. For example at times the oxygen demand (BOD and COD) of effluent of a light shade is 1.5 to 2 times higher than that of a dark shade. In addition, each inflow, of either light or dark shade, mixes with the stored effluent in the equalization tank and thus the pollution load shows an average value.

For effective dosing of coagulant and flocculant the quality of the wastewater in the equalization tank should be monitored. For optimum dosing the ETP manager should perform jar tests for different combinations of waste-streams. This is a common laboratory procedure used to determine the optimum operating conditions for wastewater treatment. The jar test method allows adjustments to different parameters such as: pH; variations in coagulation or polymer dose; or alternating mixing speeds, on a small scale in order to predict the functioning of a large scale treatment operation. The results from the jar test should be recorded so that in future the ETP operator will know how much to dose based on analysis of the effluent in the equalization tank. Once this has been done a few times and effective protocols have been developed then only occasional checking will be necessary.

Zeta potential measurements have been used successfully to monitor plant coagulant dosages. Zeta potential is the voltage difference between the surface of a suspended particle and the surrounding electrolyte solution. Therefore a zeta potential value indicates a solution in which the particles are not very dense and long time may require to settle them down. To lower the value different types of polyelectrolyte can be used according to effluent characteristics. Zeta potential can be measured but observation of results in a jar test remains the best method of coagulant selection.

Addition of flocculant and coagulants should be via variable speed metering pumps so that it is possible to vary the dosing rates accurately. Some ETP operators vary flow rates by manually altering valves or taps but this is inaccurate and cannot be recommended; using this method it is impossible to develop standard operating practices to ensure standardized and effective treatment. Control of the costs of chemicals is only likely to be achievable if variable speed pumps are used and standard practices developed.

Samples should also be taken after treatment in the coagulation and flocculation units and tested for colour, TSS, BOD_5 and COD. It is recommended that this is done at least monthly.

2.7 Gravity Separation: Clarifier

After coagulation and flocculation the wastewater is sent to a gravity separator, clarifier or sedimentation unit to remove any remaining suspended solids. Operating conditions that affect gravity separation are:

- Water temperature, which affects both viscosity and density of water.
- Specific gravity of the oil or suspended solids.
- Size and shape of suspended oil droplets, and size and shape of particles.

Settling velocities of particles will change with time and depth, as particles agglomerate and form larger floc sizes.

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If a sedimentation unit is being used for removing flocculated solids, it is important that the velocity in the influent channel is kept low, not exceeding about 0.61 m/sec (2ft/sec) to prevent breakup of flocs. Also if flow velocity is high this will cause turbulence which will hinder sedimentation. The surface area of a settling tank is one of the most important factors that influence sedimentation. The tank should be sized with a sufficient safety factor to produce a clarified effluent at minimum water temperature, and to allow for separating floc particles.

2.8 Secondary Treatment

The objective of secondary or biological treatment of industrial wastewater is to remove, or reduce the concentration of, organic and inorganic compounds. Biological treatment processes can take many forms but all are based on microorganisms, mainly bacteria. These microorganisms use components of the effluent as their "food" and in doing so break them down to less complex and less hazardous compounds, thus decreasing the BOD and COD. In the process the microorganisms increase in number.

The two most common forms of biological treatment are:

- Activated sludge plants (ASPs)
- Biofilm based systems (often these are trickling filter systems).

Activated sludge (AS) is an aerobic flocculent slurry of micro-organisms which remove organic matter from wastewater and are then removed themselves, usually by sedimentation. Activated sludge is best suited to the removal of soluble organic matter because insoluble organic matter can usually be removed more economically by physico-chemical means. Often, however, wastewaters will contain both soluble and insoluble organic mater.

AS leaves the reactor with the treated effluent but is settled out in a clarifier and returned to the aeration unit to recycle the bacteria. The amount of AS required for effective operation varies according to the design of the ASP and the concentration and nature of the effluent being treated. Suppliers of ASPs should be able to advise on the optimum amount of AS in the system. The ratio of the amount of effluent in terms of BOD and the amount of AS (known as the f/m ratio) is an important design and operating parameter and sometimes ASPs are operating so as to maintain a fixed f/m ratio. If there is more AS in the ASP than desired a portion is removed (this is called wasting) and disposed of.

A fixed film reactor is a packed bed of media covered with a biological film of microorganisms (slime or biofilm) through which wastewater is passed. As the wastewater passes through the filter, organic matter present in the waste is removed by the biological film. The trickling filter is a classical design much used in developed countries; the submerged film reactor is a type of fixed film reactor that is increasingly being used in Bangladesh.

As wastewater passes through the filter, nutrients and oxygen diffuse into the slimes, where assimilation occurs, and byproducts and carbon dioxide (CO_2) diffuse out of the slime into the flowing liquid. As oxygen diffuses into the biological film, it is consumed by microbial respiration, so that a certain depth of aerobic activity is developed (this may be as little as 0.05 mm in depth). Slime below this depth is anaerobic. In a manner similar to activated sludge, BOD removal through a trickling filter is related to the available biological slime surface and to the time of contact of wastewater with that surface.

In the ‘traditional’ trickling filter, the effluent is tricked over the surface of the slime-covered media and the space between the particles of media is occupied by air which passively diffuses through the filter (Figure 3). In the more recent design of the submerged fixed film reactor, the particles of media are submerged in the effluent and the air is blown into the reactor from below.

Both activated sludge and fixed film systems can produce high quality effluent but both have advantages and disadvantages. In the AS process the settling and recycling of AS to the aerobic reactor is vital, but the settling process can be difficult to accomplish. Fixed film systems do not require recycling of biomass and so do not present this problem. Surplus AS needs to be disposed of: this material must be disposed of appropriately so that the pollutants now present in this sludge do not enter the water cycle (see the briefing note “Management of Textile Dyeing Sludge” produced as part of this series for more information on this).

The treated liquid is discharged to the environment or taken for further treatment depending on the desired standard of effluent quality or the required use of the wastewater.

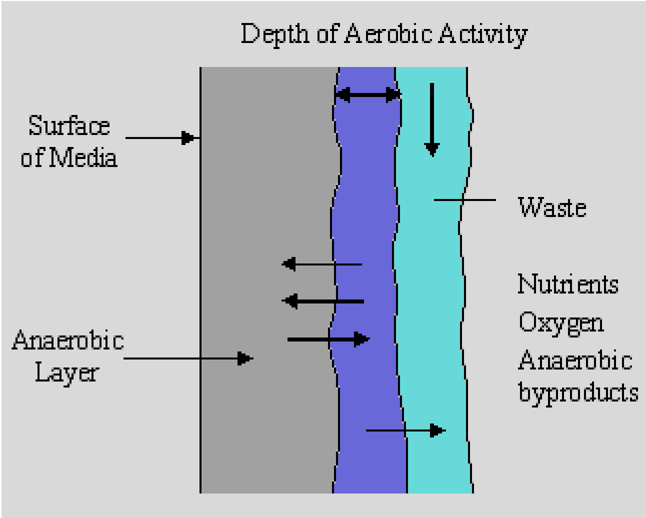

Figure 3: Mode of Operation of a Trickling Filter [7]

Managing and Monitoring

Biological treatment plants must be carefully managed as they use live microorganisms 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 microorganisms and will certainly prevent them from effectively treating the waste. Ideally the pH should be maintained within pH 6-8.

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 microorganisms of their food and oxygen and will damage the process so that it will not operate effectively when feeding and aeration are resumed.

Like humans microorganisms 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 microorganisms 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 however possible to replace these nutrients by using the liquid portion of effluent from toilets, which is rich in nitrogen and phosphorus containing chemicals (it is advisable not to use the solid portion as it may cause operating problems).

For proper functioning of the biological unit, the biomass in the reactor and the biomass in the clarifier need to be monitored regularly. For the ASP this monitoring is usually done by the mixed liquor suspended solid (MLSS) test, mixed liquor volatile suspended solid (MLVSS) test and examination of the microorganisms under the microscope. These tests are described in Chapter 4. Mixed liquor is the material undergoing aeration in the aeration tank of an ASP – it consists of AS and effluent being treated. MLSS is the concentration by weight, of AS undergoing aeration.

It should be noted that in Bangladesh ETP operators often measure the volume of sludge to monitor the biomass. This is done by taking a volume of mixed liquor from the ASP in a measuring cylinder and allowing settling for 30 minutes. After this the percentage by volume of sludge is determined. This method is recommended by ETP manufactures and can be useful but is not an ideal procedure as the sludge settling may be poor due to a condition called bulking and this will give an inaccurate estimate of the amount of AS. Controlling to a set MLSS is a much better method but it is more difficult.

For the submerged fixed film reactors it is not possible to measure biomass.

For the ASP it is useful to make occasional microscopic observations of the microorganisms in the activated sludge. Using a microscope it is possible to determine if the ‘floc’ structure is good and to determine whether filamentous microorgamisms are present. Excessive amounts of filamentous microbial growth are undesirable as they prevent the sludge from settling well due to a condition called bulking. The presence of other types of microorganism (notably protozoa – simple animals) can give some idea of the ‘health’ of the sludge. Although this is not so easy for fixed film reactors it is still possible to scrape some of the film off the substrate and to look at this under the microscope although microscopic observation is much less important than for AS.

Biological treatment units reduce TSS and oxygen demand to a great extent. So to find out the effectiveness of this operation regular monitoring of TSS, BOD_5 and COD, before and after treatment, is necessary. Details on this can be found in Chapter 4.

2.9 Tertiary Treatment

A combination of primary and secondary treatment is still the most widely used procedure for handling wastewaters prior to discharge, but sometimes this may not be sufficient for a few specific pollutants. The performance requirements for the various treatment technologies are being raised to new, higher standards by the advent of legislation aimed at regulating the amounts or toxic and hazardous substances discharged to different waterways and even non-hazardous chemicals that can cause ecological damage, such as the nutrients nitrate and phosphate. Tertiary-treatment processes are added on after biological treatment in order to remove specific types of residuals. These technologies include:

- Adsorption Processes - Granular Activated Carbon;
- Solvent Extraction;
- Chemical Precipitation;
- Chemical Oxidation;
- Membrane Processes; and
- Electro-dialysis.

In general, suspended or colloidal solids are removed by filtration, and organic compounds are removed by adsorption by granular activated carbon (GAC) as well as by chemical oxidation. The main drawback of tertiary treatment process is that these systems are generally expensive.

The Problems with Chlorination

Chemical oxidation of a wastewater may be employed to oxidize pollutants to terminal end products or to intermediate products that are more readily removable by adsorption. Common oxidants are chlorine, ozone, hydrogen peroxide, sodium hypochlorite and potassium permanganate.

In Bangladesh many ETPs are designed with chlorination units, however the purpose of chlorination is often to destroy disease-causing microorganisms (pathogens). If an ETP, designed to treat textile liquid waste is not used to also treat the human sewage of the factory, then it is very unlikely that the factory effluent will contain any significant numbers of pathogens. In Bangladesh, release of un-chlorinated effluent is unlikely to represent a significant additional health risk. Moreover, chlorination of effluents such as those from dye houses may produce cancer causing chemicals due to the reaction of chlorine with aromatic chemicals in the effluent. These chlorinated organic chemicals are part of a group of chemicals known as **AOX** (aromatic organic halides), and are undesirable. It is therefore recommended **not** to use chlorine in an ETP that treats textile dyeing wastewater.

2.10 Managing and Monitoring Mechanical Equipment

Mechanical instruments demand careful attention, especially the rotating instruments such as blowers, pumps and centrifugal separators. Regular checking has to be done when the ETP is being operated. Malfunctioning machinery often makes a different sound than machinery that is functioning correctly and this can be the first sign of faults. ETP operators must make themselves aware of the normal sound of equipment so that they can easily detect faults.

The ETP operator should also have a clear conception about the oil-level and grease-level of rotating equipment. Adverse temperature (the limiting condition should be mentioned in the instrument manual) can affect the oil and grease level, and can reduce the lifetime of these machines. Regular checks need to be made to ensure that no oil is being lost from machine bearings. To avoid unwanted shutdown of the ETP, spare parts of vital units should be readily available either on the factory premises or with good suppliers.

Acid is often used during the treatment process and as discussed previously must be handled carefully to prevent corrosion of mechanical parts of the ETP. It may be advisable to replace stainless steel with plastic or appropriately coated pumps and pipes, in certain places such as the pH dosing equipment.

3 When, Where and What to Monitor

Regular testing of water from different units of an ETP is evidently important to ensure its optimal functioning. Chapter 2 identified some of the units of an ETP in which monitoring is required. This chapter provides guidance on the frequency of sampling, how sampling should be conducted, how samples should be handled and what parameters should be tested for. Chapter 4 describes in more detail how the analyses can be performed.

Bangladesh law dictates legal standards that should be achieved and the parameters listed under the regulations must be measured. However if these are only monitored once a year you will have no idea whether your plant is working well and no data to help optimization of operation to ensure good quality effluent. More frequent monitoring is therefore required, but how frequent and what should be monitored? It is difficult to give a definite answer to this as it will depend to some extent how constant the composition of the effluent is, how dangerous the effluent is (this will establish the risks to the environment should the ETP malfunction) and how likely it is that the ETP will be damaged. It is a good idea to monitor very frequently when an ETP is set up to ensure it is working effectively and then when its performance has stabilized it is alright to decrease frequency. A regular regime of monitoring is essential if good quality effluents are to be achieved and maintained.

3.1 How and when should samples be taken?

No single sample can be truly representative of the effluent stream which will vary with time – even with flow equalization. Composite samples are best but are not always easy to arrange. Composite sampling devices, which continuously collect and mix small amounts of sample, can be purchased but they are expensive. Alternatively a composite sample can be made up by taking samples of the same volume at set times (perhaps hourly) throughout the day and then mixing thoroughly – this gives an average composition. If this is done the samples once taken should be kept stored at low temperature until sampling is complete. However, if composite samples cannot be taken it is important to take samples at times representative of 'normal operations' when the factory is in normal production.

The exact regime of what and when to assay should be decided in consultation with DoE and other specialists but a possible sampling regime is suggested below:

- Daily – pH (if not continuous); DO in biological reactor (if not continuous); half hour settled solids (ASP only); colour.

- Weekly – MLSS and SVI (for ASP only); TSS; TDS; and COD.
- Monthly – BOD.
- Quarterly or less frequently (e.g. annually) – Heavy metals (this is probably enough for most effluents unless metals have been identified as a potential problem – e.g. for tanneries); other analytes specified by law.

During the set-up period it is advisable to monitor some parameters more regularly, such as BOD which should be monitored weekly and metals which should be monitored monthly.

3.2 What Tests Should be Conducted?

Some assays are very easy and very cheap and can be done frequently with little cost: others are inconvenient and expensive and so are in practice done less frequently. Full descriptions of those that can be performed in the factory are provided in Chapter 4 but a simple explanation of each is given here.

If a pH electrode and meter are used **pH** can be monitored continuously, but it should be measured at least daily. Continuous pH monitoring and control to a set point (in the range 6 to 8) are very important as deviations from this range are very likely to result in death or inhibition of the microorganisms in the biological ETP, and its subsequent failure – resulting in increased pollution. The use of occasional measurements using pH papers (even narrow range papers) is not recommended. These papers are not accurate – especially when used with coloured effluents like textile waste waters. Furthermore, it is very difficult to use them for monitoring pH correction since measurement is not continuous and therefore considerable fluctuations will occur, which may influence performance of the biological and physico-chemical ETP.

Half hour settled solids is an easy test and for ASPs should be done daily to give an idea of the amount of sludge present.

SVI/MLSS should be measured at least once a week to show the weight of sludge biomass in the ASP and how well it settles.

BOD is a time consuming method and is generally best done in a specialist laboratory. Under normal running conditions it should be assayed at least once a month, but may be needed more often when the ETP is being set up or after factory closure periods.

COD is easier to do and with some initial setting up it should be possible to do this test in the laboratory of any textile factory, although factories may prefer to send samples for analysis. Again it should be assayed at least monthly but more frequently in the setting up period and during times of operational difficulties.

TSS is a simple test with little equipment needed and can easily be done on site on at least a monthly basis.

TDS is again a simple assay which could be done locally.

Colour assay can also be done locally without much expenditure.

3.3 Where should Samples be Taken from?

For normal monitoring it is sufficient to monitor the final effluent only. However certainly when the ETP is being set up and occasionally thereafter it is important to take samples at several stages throughout the ETP to try to establish how much contribution the different stages of the treatment process make to the overall purification of the effluent. How many samples and where they are taken depends on the exact design of the whole plant but the following suggestions would be suitable for many plants:

- Outflow from the equalization tank;
- After physico-chemical treatment (overflow from the clarifier);
- After biological treatment (overflow from settling tank); and
- Final effluent.

4 Methods for Sampling and Testing

Many of the parameters already discussed can be measured on site and descriptions of how to undertake these analyses are given more fully here. Some of the parameters however require specialist equipment or knowledge and cannot be tested at most factories. Where this is the case samples must be taken and sent to an accredited laboratory for analysis. If the analysis is unlikely to be performed in the factory the description of the analysis is not given in detail but more information on these analyses can be found in Standard Methods For The Examination of Water & Wastewater, 20th edition, APHA-AWWA-WEF (1998) or Methods for Chemical Analysis of Water and Wastes (MCAWW), Revised Version (March 1983).

4.1 Sample Collection

Collection of samples is the first step of monitoring and must be performed in an appropriate way. The sample may have to be handled and stored differently depending on the nature of the sample and the parameters that will be analyzed for. Samples which are improperly collected and/or preserved may yield inaccurate and unreliable results.

Where to Collect the Sample from

For proper sampling the sample must truly represent the existing conditions. The procedure of collection depends on the specific analyses to be made from the sample, the expected results from the analyses, and the type of operation being sampled. For example to test the pH in a neutralization tank the sample should be taken from the point where the acid or alkaline is properly mixed with the wastewater; not from the point where the acid or alkaline is added. Proposed locations for sample collection are given in Table 3.

Table 3: List of Parameters to be Checked at Different Sampling Points

Unit	Parameters to test for	Sampling point
Equalization tank	pH, TDS, TSS, BOD, COD, temperature	Outflow
Neutralization tank	pH	Outlet, to ensure that the acid or alkali has been properly mixed
Coagulation	pH	Outlet
Flocculation		
Primary Clarifier	TSS, TDS, COD, pH, BOD	Outflow
Biological Reactor	DO, pH, samples of AS for microscopic examination, temperature	In aeration basin
Secondary Clarifier	BOD, COD, TSS	Outflow
Treated Water	pH, TDS, TSS, BOD, COD	Outlet

Type of Container to be Used

For sample collection either laboratory grade plastic or glass bottles are appropriate. If an external laboratory is undertaking the tests ensure that they have approved the sample bottles used.

Whatever the material is, the bottle should have a cap to make it air tight. The sample bottle should be totally filled so that no free air is available in the bottle, as the oxygen content of the free air may oxidize the organic and inorganic substances present in the sample, and thus can alter the value of BOD_5 and COD. Sampling bottles should be clean and dry when the sample is taken. They can also be rinsed with the sample before filling to ensure that they are not contaminated. Care should be taken when collecting the sample not to contaminate it, for example the cap should not be placed on any surface but should be held around the outside and replaced as soon as the sample is collected.

All sample bottles should be clearly labeled and the labelling codes recorded. It is good practice to take some duplicates (two samples from the same point) and to label them differently to monitor the performance of the laboratory that is conducting the analyses or the analytical equipment being used.

Gloves and safety glasses should always be worn when taking samples.

Amount of Sample to be Collected

Different quantities of sample are needed for different tests. The number of parameters to be tested determines the amount of sample to be collected. For monitoring 20 parameters including BOD_5, COD (both filtered and unfiltered) 2 liters of sample is probably sufficient. If an external laboratory is undertaking the tests check how many replicates they perform and ask how much sample they require.

4.2 Sample Preservation and Transportation

Preservation and transportation of samples is as important as their proper collection. The whole procedure of sample collection, transportation to the laboratory and testing takes a significant amount of time throughout which spontaneous chemical reactions and microbial activity are going on in the sample, which will affect the results. It is necessary to prevent such reactions taking place. To do this it is recommended to lower the sample temperature to between 0^0C and 4^0C as soon as possible after the sample has been collected. The temperature can be lowered by placing tightly sealed samples in an insulated cold box containing ice.

For heavy metal tests it is recommended to preserve the sample in acidic conditions. Generally adding 2-3 drops of concentrated nitric acid to 1 litre of sample is sufficient to preserve the sample (pH 3-4). Concentrated nitric acid is highly reactive and thus hazardous for bare skin; so proper care should be taken while using it. However it is recommended to take advice on acidifying sample from the laboratory that will analyse the samples. If other parameters are to be tested it is best not to acidify the whole sample as that might affect other analyses; instead a sub-sample of appropriate volume should be put into a small labeled container and acidified.

The sample should be transported to the laboratory as quickly as possible in the preserved condition. Any delay in transportation may influence the result. For example, BOD_5 is a measure of the quantity of dissolved oxygen used by microorganisms in the biochemical oxidation of the organic matter in the wastewater over a 5-day period at 20^0C. So experts generally recommend starting the BOD_5 test within a couple of hours of collection.

It is advisable to ask the laboratory personnel how they would like the samples to be preserved. It is also essential to ensure that they are prepared for the samples to be delivered so that testing of perishable samples can begin on arrival without delay. For a test that takes several hours or days it is essential to check that the laboratory personnel will be available to complete the test.

4.3 Tests Performed at the Factory

Certain tests can be performed at the factory. Simple measurements of pH, conductivity (TDS), temperature and DO can all be performed on site using hand held probes. The advantage of this is that samples do not need to be collected and taken away and results can be obtained immediately. However it is essential that the correct equipment is used as cheap, simple equipment such as "pen style" pH meters, is not adequate. Furthermore the personnel using the equipment must be well trained so that they can detect faults with the equipment. Equipment must be regularly calibrated and it is good practice to check these results by sending some samples to an external laboratory.

pH Test

This test can be done very easily on site. A calibrated pH meter probe is submerged in a sample of the effluent and after stirring gently for a few moments the pH meter should give a stable pH reading. A good quality, temperature compensating pH meter may be reasonably costly (the cost of a pH meter is around Tk 50,000 and a spare electrode is approximately Tk 10,000) but it is likely to be a good investment as many of the units of the ETP require pH measurement including the equalization tank, the biological unit and the final effluent.

It is essential that pH electrodes are treated carefully and in accordance with manufacturer's guidelines to ensure optimal results from the equipment. They must be regularly calibrating with standard pH solutions. Normally two different standard buffers are used pH 7 and either pH 4 or 9. As textile waste tends to be alkaline, it is best to use a second standard of pH 9. The electrodes will need to be replaced regularly (probably every six months). Electrodes must be well cared for and are easily breakable so spares must be kept 'in-house'.

Colour

Pure water is colorless but when it is contaminated with soluble impurities or a suspension of insoluble impurities various colours may be observed. For discharge effluent many of the ETP suppliers advised the color standard below 60 Pt-Co (Platinum-Cobalt) units[a], though there is nothing specifically mentioned about it in Bangladesh legislation. The platinum-cobalt method of measuring color is the standard method, the unit of color being that produced by 1mg platinum/L in the form of chloroplatinate ion. Colour can be measured on the ETP premises either by the Visual Comparison Method or Spectrophotometric Method. In the first method the colour of water is

[a]Personal comment from ETP suppliers and textile buyers.

compared with different coloured glass disks held at the end of metallic tubes. The glass disks give results in substantial agreement with those obtained by the platinum-cobalt method and their use is recognized as a standard field procedure (APHA-AWWA-WEF, 1998)[6]. This can be done using a Lovibond Comparator which is manually operated.

For the spectrophotometric method any spectrophotometer can be used. Although their accuracy and performance can vary.

Total Dissolved Solid

Many types of TDS meters are available, however, as with pH meters, it is advisable to use a good quality bench type meter. Measurement of TDS using a meter is based on a measurement of conductivity which can be correlated with dissolved solids. After taking a small amount of representative sample a calibrated TDS meter probe has to be completely submerged in the sample. After stirring gently for sometime the TDS meter should give a stable TDS reading in mg/L unit.

Similarly to pH meters, TDS meters need to be regularly calibrated with standard calibrating solutions.

TDS can also be measured by filtration to remove suspended solids and then evaporation of the filtrate (remaining liquid portion) (usually done at 105°C) to leave a solid residue which can be weighed. This requires weighing scales accurate to at least two decimal places.

Mixed Liquor Suspended Solids Test

The mixture of solids resulting from combining recycled sludge with influent wastewater in the bioreactor (ASP aeration tank) is termed the Mixed Liquor Suspended Solids (MLSS). For the MLSS test a piece of dry filter paper is weighed and the weight recorded. The filter paper is placed in a filter holder. A specific volume (preferably less than 50mL) of homogenized sample is poured onto the filter paper and a vacuum is applied until all the liquid has been drawn through the paper. The filtered sludge is then washed with distilled water. The solid and the filter paper are transferred onto a watch glass and dried in an oven for at least 1 hour at 105ºC – the sample is dried until a constant weight is achieved. After cooling the filter paper with the solid is weighed again and the weight recorded. The weight of the filter paper is subtracted from the weight of the solid and filter paper, to give the weight of the suspended solids removed from the sample. The MLSS is the weight of the solid divided by the volume of sample.

$$\text{MLSS (g/L)} = \frac{\text{Wt. of the filter paper with solid, (g)} - \text{Initial wt. of filter paper, (g)}}{\text{Volume of sample, (L)}}$$

In practice MLSS of less that 1g/l is rather low while MLSS of over 5g/l if high for most effluents – but it really does depend on local conditions and ETP manufacturers should be consulted about this. It is probably however more important to retain a fairly steady value that to aim for a specific value.

Sludge Volume Index Test

The Sludge Volume Index (SVI) test is helpful to identify the performance of the biological unit, by quantifying the biomass in the reactor and the biomass in the clarifier as well as the coagulation unit, flocculation unit and sedimentation unit. The lower the SVI value the better the settling quality of these units. Also, high SVI values indicate poor settling qualities and possible bulking problems in the secondary clarifier.

The SVI is the volume of 1 g of sludge after 30 minutes of settling time, and is measured in ml/g. The SVI can be determined by placing a mixed-liquor (a mixture of microbial solids and waste water) sample in a 1 or 2 liter cylinder and measuring the settled volume after 30 minutes and dividing it by the corresponding sample's MLSS concentration[3]. Mathematically SVI can be expressed as:

$$\text{SVI (mL / g)} = \frac{\text{Settled volume of sludge, mL}}{\text{Volume of sample, L}} \times \frac{1}{\text{MLSS (g / L)}}$$

For example, a mixed-liquor sample with a 3000 mg/l TSS concentration that settles to a volume of 300 ml in 30 min in a 1 liter cylinder. So the MLSS value of this sample is 3 g/l and the SVI value of this sample is 100 ml/g.

An SVI value of 100 ml/g or less is considered a good settling sludge. SVI values above 150 mg/l are typically associated with filamentous growth - a condition called bulking in which filaments prevent good settling of sludge, leading to high BOD and TSS in the effluent. Ideally an SVI value that ranges from 50 to 75 mg/l is good for most conventional activated sludge plants.

Stirred Sludge Volume Index Test

The Stirred Sludge Volume Index (SSVI) test is another indicator of the settling qualities of the mixed-liquor of the AS unit. The test is virtually identical to the SVI test except that stirring with a specially designed stirrer at very low speed is considered to give a more accurate measurement of settled sludge volume. To perform the test the AS sample has to be mixed thoroughly, and poured into the settling tube (of specific volume) and stirred for 30 minutes at 1 rpm. At the end of the stirring time, the volume of the sludge layer can be calculated as ml/g.

SSVI is more accurate than SVI but the starring apparatus is not always available.

4.4 Heavy Metal Test

Some heavy metals may be present in the effluent, usually arising from: impurities in the dyes or other chemicals; pesticides used on the cotton; or from the machinery. As the Environmental Conservation Act, 1995 and Rules, 1997 specify effluent quality standards that factories must comply with that include metals it is necessary for these to be analyzed for in accordance with the legislation (usually annually when the Environmental Clearance Certificate is renewed) or when required by buyers. For most textile effluents they should be present in very low concentrations or not at all and will not impact significantly on the functioning of the ETP, but monitoring is still advisable and required.

To analyze wastewater for metals samples should be taken following the guidelines given previously. They should be sent to an accredited laboratory and analyzed within 24 hours. The procedure for preparing the samples may vary but most will be analyzed using atomic adsorption spectroscopy. More information about metal analysis can be found in Standard Methods for the Examination of Water & Wastewater, 20^{th} edition, APHA-AWWA-WEF, 1998.

4.5 List of Equipment

To establish a laboratory on the factory premises requires some basic equipment. Table 4 lists some of the apparatus that are required for the most common tests that can be performed on site. Additional equipment can be purchased if the management wishes to establish a more sophisticated laboratory and perform many of the tests on-site. These include an automatic spectrophotometer with all the necessary accessories, a COD reactor (heating block), DO meter and conductivity meter. There are a number of reputable companies in Bangladesh that will supply such equipment.

Table 4: List of the Apparatus and Accessories for In-house Laboratory

Test	Apparatus	Reagents
TDS, TSS, SVI, MLSS	Beaker-150mL (2pcs), Measuring Cylinder - 1000mL and 100ml (1pc each), Funnel (1pc), Dropping pipette (1pc), Filter paper (2pcs), TDS meter-Pocket type or Bench type (1pc), Oven (1pc)	Standard solution for TDS meter calibration
Hardness	Beaker-150mL (1pc), Measuring Cylinder (1pc), Dropper (1pc), Stirrer (1pc), HACH Auto-titration device (1pc)	EDTA (Ethylene Diamine Tetra Acetic Acid), Eriochrome Black T, Buffer Solution of pH 10
BOD_5	DO meter and electrodes	Dilution water, Seed (Mixed micro-organisms solution; usually 2ml for per litre of diluted water), A 2-point calibration is done at 0 and 100%. Calibration requires a freshly made saturated solution of sodium sulphite (Na_2SO_3) to set zero, 100% is set as the concentration in air just above the surface of clean water.
COD	Beaker-250mL (1pc), Dropping pipette (1pc), Stirrer (1pc)	Conc. Sulfuric Acid, Standard Potassium Di-chromate, Mercuric Sulfate, Silver Sulfate, Standard - Potassium Hydrogen Phthalate (KHP)
pH	pH meter (Bench or Pocket type, preferably with extra electrode)	Standard buffer solutions for calibration, pH 4, 7, 9 or10
Color	Loviband Comparator, or Spectrophotometer, e.g. HACH DR4000 or other similar absorbance spectrophotometer	Accessory chemicals
Turbidity	DR LANGE Turbidimeter, or Spectrophotometer, e.g. HACH-DR4000 or other similar absorbance spectrophotometer	Accessory chemicals
Chemical Coagulation	Coagulation (stirring) device, pH meter (1pc), Turbidity meter (1pc), Glass Beakers-1000 mL (6pcs)	Standard Alum Solution
General equipment	Balance for weighing chemicals and for dry weights. Reagent bottles for solutions. Volumetric flasks for making up solutions.	

5 Summary

At the very least, monitoring of the performance of ETPs is important to ensure that effluents are achieving the standards required by law. Textile manufacturers need to operate ETPs by law and must operate them effectively if they are to produce good effluents. International buyers also require dye houses to comply with the national laws and they are increasingly monitoring to ensure that this is the case.

Monitoring of ETPs also makes good business sense: if you have invested large amounts of capital in an ETP it is only sensible to monitor to check tht you are getting good performance from your ETP. If you do sufficient monitoring you should be able to get enough data to allow you to optimize performance and this may mean that you can reduce expenditure on energy and on chemicals. Although monitoring ETP performance may appear expensive it is essential and the suggestions made are feasible and not excessive when the effects of textile effluents on the environment and human health are considered.

Glossary

Absorption: Absorption is the assimilation of molecules or other substances into the physical structure of a liquid or solid without chemical reactions.

Algae: Algae are the simple plants containing chlorophyll. They are generally microscopic, but under conditions favorable for their growth they grow in colonies and produce mats and similar nuisance masses.

Assay: Assay is the qualitative or quantitative analysis of a substance to determine its components.

Bacteria: Bacteria are microscopic organisms with a very simple cellular structure; they are generally single-celled and, can reproduce by binary fission. They can be partly identified by their shapes: coccus, spherical; bacillus, rod-shaped; and spirillum, curved.

BOD_5: Biochemical Oxygen Demand is the most common chemical parameter of water quality measurement and is of the most important since it indicates the likely effects of pollution. When biodegradable organic matter in waste is released into a water body, microorganisms feed on the wastes, breaking it down to simpler organic and inorganic substances. In an aerobic environment it produces stable end products (carbon dioxide, sulfate, phosphate and nitrate) and in the process decreases the dissolved oxygen content of water.

$$\text{Organic matter} + O_2 + \text{Bacteria} \rightarrow CO_2 + H_2O + \text{New cells} + \text{Stable Products}$$

BOD_5 is therefore equal to the amount of dissolved oxygen which is consumed by a sample of effluent incubated for five days at 20°C. The BOD_5 test is done to determine the amount of oxygen required for biological treatment and also to determine the likely effect of an effluent on a receiving water body. Dissolved oxygen is measured before and after incubation, usually using a dissolved oxygen electrode. As the test requires a temperature controlled incubator (which may need to be refrigerated) it is unlikely to be performed at the factory.

Coagulant: A chemical used in coagulation. The coagulants used are metal salts with multiple positive charged cations. In waste water treatment processes the suspended solids that require removal are generally negatively charged, the high positive charge of the coagulants neutralizes their negative charge and allows them to come together into larger particles which can be separated more easily. The most popular coagulant in waste-treatment application is aluminum sulfate or alum [$Al_2(SO_4)_3.14H_2O$], which can be obtained in either solid or liquid form.

Chemical Oxygen Demand (COD): Chemical Oxygen Demand is another indication of the overall oxygen requirement, which a wastewater will impose on the receiving water. It is equal to the number of milligrams of oxygen that a liter of sample will absorb from a hot, acidic solution of potassium dichromate.

$$\text{Organic Matter} + Cr_2O_7^{2-} = 2\ Cr^{3+} + x\ CO_2 + y\ H_2O$$

Generally, more components of the wastewater sample can be chemically oxidized in this manner than in the standard BOD test. During the determination of COD, organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substance. Thus COD shows a greater value than BOD, especially when biologically resistant organic matter like lignin is present. The major advantage of the COD test is the short time required for evaluation. The determination can be made in about 3 hours rather than the 5-days required for the BOD test. COD is often used as a substitute for BOD. The assay requires a heating block but is not difficult to do, the determination of the amount of oxygen demand can be done by titration or using a spectrophotometer. It could be done on site or at a specialist laboratory.

Dissolved Oxygen (DO): Dissolved Oxygen. It is a necessary constituent required for most organisms living in water. If the concentration of dissolve oxygen reduces below 4-5 mg/L then forms of life that can survive begin to reduce. Organisms undergo stress at reduced DO concentrations that make them less competitive to sustain their species within the aquatic environment. Below 4mg/L DO concentrations have been shown to interfier with fish populations through delayed hatching of eggs, reduced size and vigor of embryos, production of monstrosities in young, interference with food digestion and acceleration of blood clotting decreased tolerance to certain toxicants reduced food efficiency and growth rate and maximum sustained swimming speed. In fish and other aquatic animals the ability to tolerate to low DO concentrations varies very much from species to species.

Oxygen is not very soluble at 20ºC a saturated solution contains about 9mg oxygen per liter. At higher temperature it is less soluble. Oxygen is very readily reduced by the action of microbes degrading organic matter. Oxygen can be measured by a titration or using an oxygen electrode, electrodes are preferable and give instant answers.

Flocculation: Flocculation is the process of agglomerating coagulated particles into settleable flocs.

Food–to-Mass (F/M) ratio: Food-to-mass or food-to-microorganism ratio used to predict the major microbial populations in a biological digestion process. F/M ratio is usually an important parameter in design of ETPs.

Fungi: Fungi are simple microorganisms without chlorophyll, sometimes one-celled but often filamentous – they are more complex in cellular structure than bacteria. Molds and yeasts are included in this category.

Hardness: Hardness is the concentration of calcium and magnesium salts in water. It is sometimes also taken to include iron and manganese.

Microorganism: This is the common term used to represent all bacterial and micro-sized living creatures. The main groups of microorganisms are bacteria, fungi, protozoa, algae and viruses. The number of microorganism is very important in biological treatment and the right kind of microorganisms have to be present in the treatment process.

Oxidation: Oxidation is the chemical reaction in which an element or ion loses electrons to an oxidizing agents and thus its positive valence increased.

pH: It is the measure of the acidic or alkaline condition of water. Mathematically pH is the negative logarithm of the hydrogen ion concentration. $pH = -\log [H^+]$. pHs below 7 are acidic while those above 7 are alkaline – 7 is neutral. Strong acids (like HCl) will have a pH around 1 while strong alkalis (like NaOH) will have pHs in the region of 13 to 14.
pH is a very important factor contolling biological life. Most organisms prefer neutral pH and at very low of high pHs only a limited range of specialist organisms can survive.

Polyelectrolyte: A polymeric material having a large number ion exchange sites. Generally polyelectrolytes are often used in ETPs as flocculants and on some occasions as coagulants. Flocculant polyelectrolytes can be classified in three types: cationic, anionic and nonionic polyelectrolytes. As a general rule, cationics are designed to work at lower pH values, anionics at higher. Nonionics are only slightly influenced by pH.

Protozoa: Large, microscopic single-cell organisms higher in the food chain than bacteria, which consume bacteria.

Zeta potential: The difference in voltage between the surface of the diffuse layer surrounding a colloidal particle and the bulk liquid beyond [4].

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