Ministry of State for Environmental Affairs
Egyptian Environmental Affairs Agency (EEAA)
Egyptian Pollution Abatement Project (EPAP)

Self Monitoring Manual
Wastewater Management

2003

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LIST OF ACRONYMS

°C	Degree Celsius
API	American Petroleum Institute
BOD	Biological Oxygen Demand
$CaCl_2$	Calcium Chloride
$CaSO_4$	Calcium Sulfate
Cd	Cadmium
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
CPI	Corrugated Plate Interceptors
Cr	Chromium
Cu	Copper
DAF	Dissolved Air Flotation
DO	Dissolved Oxygen
EEAA	Egyptian Environmental Affairs Agency
EPAP	Environmental Pollution Abatement Project
Fe	Iron
$FeSO_4$	Iron Sulfate
ft	Feet
GOS	Gravity Oil Separator
H_2S	Hydrogen Sulfite
H_2SO_4	Sulfuric acid
Hg	Mercury
IAF	Induced Air Flotation
IWWTP	Industrial Waste Water Treatment Plant
kg	Kilogram
kN/m^2	Kilo Newton per meter square
lbf/in^2	Pound feet per inch square
m	Meter
mg/l	Milligram per liter
MHUUC	Ministry of Housing, Utilities and Urban Communities
ml/l	Milliliter per liter
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
mm	Millimeter
Mn	Manganese
MOHP	Ministry of Health & Population
Na_2CO_3	Sodium Carbonate
NaOH	Sodium Hydroxide
NH_3	Ammonia
NH_4-N	Ammonium nitrate
Ni	Nickel
NO_3-N	Nitrate
O & G	Oil and Grease
OUR	Oxygen Uptake Rate
Pb	Lead
pH	Concentration of Hydrogen Ion
RAS	Return Activated Sludge

RO	Reverse Osmosis
SBR	Sequential Batch Reactor
SBR	Sludge Blanket Depth
SM	Self-Monitoring
SO_2	Sulfur dioxide
SO_2	Sulfur Dioxide
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TOD	Total Oxygen Demand
TPI	Tilted Plate Interceptors
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
VSS	Volatile Suspended Solids
Zn	Zinc

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I. I. INTRODUCTION

1.1 PREFACE

The Egyptian Environmental Affairs Agency (EEAA) has developed General Inspection and Self – Monitoring Manuals and several industrial specific manuals for inspection and self-monitoring.

Meanwhile, other manuals are being designed and produced for inspection and monitoring of industrial wastewater treatment plants, hazardous waste management, and industrial energy production.

This manual is concerned with self-monitoring guidelines for the industrial wastewater treatment facilities, which may be present or will be installed in various industrial sectors and sub-sectors.

The manual is designed to be used by the industrial community together with the sector specific manual to check the performance and efficiency of the industrial wastewater treatment plants.

In order to do so, self-monitoring personnel should be familiar with the different types of the wastewater treatment operations and processes commonly applied for their industries.

Based on above, this manual has been developed for the industrial wastewater treatment plants with the following objectives:

- To familiarize the industrial community with the Nature and Characteristics of the industrial wastewaters discharged from their industries as well as corresponding parameters used for measuring pollution levels.
- To be familiar with various treatment packages and their suitability to treat different waste streams.
- To appreciate the sections of the Egyptian legislation relevant to wastewater emissions and sludge treatment and disposal and the compliance of industry with such regulations.
- To present the industrial community with the general principles to be followed for self-monitoring.
- To enable self-monitoring personnel to evaluate and monitor the operation and efficiency of wastewater treatment plants.
- To design and establish a basic self-monitoring system for the treatment plant which can be considered as a minimum requirement to monitor compliance with the Egyptian laws.

Using this manual side by side with the specific sector manual will help in evaluating the performance of the treatment facilities that may be used by the industry to treat wastewater effluents in order to comply with environmental laws.

The General Self Monitoring Guidebook has been used as a reference to provide the general guidelines required to prepare a specific chapter on self monitoring principles and procedures for wastewater treatment plants.

1.2 DEFINITION, OBJECTIVES & MOTIVATION FOR SELF-MONITORING

Self-monitoring is an essential tool for companies to collect the necessary information on their existing IWWTP and record its performance and efficiency. This data can then be recorded and added to the environmental register.

The main objectives of a self-monitoring system are summed up in the following:

- To collect reliable and relevant data about the operation of the IWWTP and it's environmental performance.
- To analyze and use the data collected
- To improve efficiency of treatment plant if needed
- To monitor compliance with legal requirements
- To achieve continuous improvement of the operation and environmental performance.

In case of self-monitoring for IWWTP, environmental considerations in the work environment and surrounding ambient air are narrowed under odor, noise and hazardous chemical emissions which have direct impact on the environment in addition to monitoring of treated effluent characteristics and handling of sludge and hazardous substances. Self-monitoring also comprises monitoring of process parameters (operations control) that may affect the process performance and hence affect the environmental impact of the facility.

1.3 BENEFITS OF SM TO IWWTP OPERATORS

Self-monitoring can offer benefits to the competent authorities through:

- Utilizing the operator's knowledge and experience of this process in planning and carrying out a monitoring program that can lead to improved control over performance and efficiency of IWWTP.
- Self-monitoring will normally provide more information than may be obtained by periodic inspection by competent authorities.

If mandated, self-monitoring can provide more benefits to the competent authorities by providing a mechanism for educating the operator about the requirements for complying with relevant laws, regulations and permits and for increasing management responsibility for compliance. The benefits of self-monitoring results to the operators include:

- Ensuring compliance with environmental regulations thus saving on fine payments.
- Raising and assessing the awareness about efficiency of the wastewater treatment plant during operation and following up on it's performance.
- Providing industrial community with more reliable data to verify the single unrepresentative samples and/or measurements.
- Protecting company personnel from civil and criminal liabilities.
- Implementing corrective actions if non-compliance occurs.
- Self-Monitoring System (SMS) is necessary if the facility would like to comply with environmental management systems (e.g. ISO 14000) and gain a competitive edge.
- Identifying trends in IWWTP performance and setting alarms.
- Deciding on chemicals, additives, fuel and investment strategies linked to the WWTP.

- Helping reduce financial problems in the company thus improving the economic viability of the industry.
- Facilitating better decision-making.

1.4 DESIGN OF SELF MONITORING MANUAL

The Self-Monitoring Manual for industrial wastewater treatment plants contains five main chapters following a table of contents, list of figures and list of tables included in the manual.

The first chapter gives an introduction to the whole project then focuses on demonstrating the main idea describing the main objectives and benefits of the self monitoring and hoe to use the manual in parallel with self monitoring guidebook and sector specific manual.

The second chapter of the manual provides a comprehensive introduction to industrial wastewater treatment plants, which includes nature and characteristics of wastewater with a description in simple terms of the meaning of BOD_5, COD, TDS….etc and the environmental impacts related to these parameters.

In this chapter the need for industrial wastewater treatment plants is explained in relation to the compliance with regulatory limits for discharging effluents to the Nile, sea, canals, municipal sewer and reuse of effluent…etc. Also in this chapter, the common types of wastewater treatment plants are briefly described.

Chapter 3 describes thoroughly the main treatment technologies commonly applied in Egypt including mechanical, physical, chemical and biological processes.

Combinations of these technologies are also provided, mainly: physiochemical, chemical-biological and anaerobic-aerobic treatment systems. Both schematics and flow diagrams are used for demonstration.

The advantages and disadvantages of each process are explained. Key operation parameters and parameters for measuring performance are also compared.

Sludge treatment and disposal techniques are also covered in chapter 3 including preliminary operation, sludge thickening, stabilization, dewatering, drying beds, sludge disposal and utilization. Auxiliary operation, mainly disinfection and reuse of treated effluent, are also described in chapter 3 as related to real applications in the Egyptian industries.

Chapter 4 provides the Egyptian legislation related to industrial wastewater discharge to different receiving bodies, treatment and disposal of solid waste and sludge.

Environmental impacts in work environment (e.g. noise and odor) and regulations dealing with hazardous materials and hazardous waste are also covered in this chapter.

Preparing the self-monitoring register for wastewater treatment plant as per Egyptian law requirement is also demonstrated.

Chapter 5 was designed to provide the industrial community with the principles of self-monitoring with reference to General Self Monitoring Guidebook. This chapter also indicates the self-monitoring targets including monitoring of emissions, aspects of occupational safety and operation parameters.

The main procedures to be conducted during the self monitoring activities are also outlined in Chapter 5 starting by assessment the existing monitoring capacity, gathering information, samples collection for analysis and parameters to be monitored.

Typical cases of troubleshooting are presented in Chapter 5 as examples such as checking the normalities or abnormalities in operation, detection of malfunctioning in the treatment process, and detection of dubious analysis results provided by the chemical lab.

Comparing operation values with design values are also included. In addition, chapter 5 provides simple techniques for evaluation of IWWTP performance and for preparation of final self - monitoring report.

Some guidance are also included in chapter 5 to give the company management some recommendations on issues related to best management practice which are not directly related to compliance management.

At the end of the manual two annexes are attached, Annex 1 provides a set of definitions and terminology related to industrial wastewater treatment while, Annex 2 is the contents of the Environmental Register as required by law, Annex 3 provides item considered in a sampling program and Annex 4 provides information on data collection and processing.

A list of references used in preparing the manual is also included.

2. PRINCIPLES OF INDUSTRIAL WASTEWATER TREATMENT PLANTS

2.1 NATURE & CHARACTERISTICS OF INDUSTRIAL WASTEWATER

It is only natural for industry to presume that its wastewater can best be disposed of in the domestic sewer system. However, city authorities should not accept any wastewater discharges into the domestic sewer system without first learning the facts about the characteristics of the wastewater, the sewage system's ability to handle them, and the effects of the wastewater upon all components of the city disposal system. Institution of a sewer ordinance, restricting the types or concentrations of wastewater admitted in the sewer leading to a treatment plant, is one means of protecting the system. The following table gives a comparison between the typical range of BOD and S.S. load for industrial and municipal domestic wastewater. While table (2-2) gives a comparison in concentration values.

Table (2-1): Typical range of BOD and S.S. load for industrial and municipal wastewater *

Origin of waste	Biochemical oxygen demand "BOD" (kg/ton product)	Total Suspended solids "TSS" (kg/ton product)
Domestic sewage	0.025 (kg/day/person)	0.022 (kg/day/person)
Dairy industry	5.3	2.2
Yeast industry	125	18.7
Starch & glucose industry	13.4	9.7
Fruits & vegetable canning industry	12.5	4.3
Textile industry	30 - 314	55 - 196
Pulp & paper industry	4 - 130	11.5 - 26
Beverage industry	2.5 - 220	1.3 - 257
Tannery industry	48 - 86	85 - 155

* Rapid assessment for industrial pollution

Table (2-2): Typical range of concentration values for industrial and municipal wastewater **

Origin of waste	pH	T.S.S, mg/l	BOD, mg/l	COD, mg/l	TDS, mg/l	O&G, mg/l
– Domestic Sewage	7	220	250	500	500	-
– Dairy Industry	4	12150	14000	21100	19000	320
– Yeast Industry	5.3	540	2100	3400	3500	9
– Fruits & Vegetable Canning	5.5	2200	800	1400	1270	94
– Textile Industry	6.5	1800	840	1500	17000	155
Pulp & Paper Industry	8	1640	360	2300	1980	-
– Beverage Industry	9	760	620	1150	1290	-
– Tannery Industry	10	2600	2370	4950	8500	115
– Fish Canning	11	565	890	2350	8218	290

** Previous analysis conducting in several companies.

The important contaminants of concern in wastewater treatment are listed in the table 2-3. Secondary treatment standards for wastewater are concerned with the removal of biodegradable organics, suspended solids, and pathogens. Many of the more stringent standards that have been developed recently deal with the removal of nutrients and priority pollutants. When wastewater is to be reused, standards normally include requirements for the removal of refractory organics, heavy metals, and in some cases dissolved inorganic salts.

Table (2-3) Important contaminants of concern in industrial wastewater treatment

Contaminants	Reason for importance
Suspended solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment.
Nutrients	Both nitrogen and phosphate, along with carbon, are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater.
Priority pollutants	Organic and inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity. Many of these compounds are found in wastewater.
Refractory organics	These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides.
Heavy metals	Heavy metals are usually discharged to wastewater from commercial and industrial activities and have to be removed if the wastewater is to be reused.
Dissolved inorganics	Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused.

2.1.1 Physical Characteristics

The most important physical characteristic of wastewater is its total solids content, which is composed of floating matter, settleable matter, colloidal matter, and matter in solution. Other important physical characteristics include odor, temperature, color, and turbidity.

a) Total Solids

Analytically the total solids content of a wastewater is defined as all the matter that remains as residue upon evaporation at 103 to 105 °C. Matter that has a significant vapor pressure at this temperature is lost during evaporation & is not defined as a solid. Settable solids are those solids that will settle to the bottom of a cone-shaped container (called an Imhoff cone) in a 60-minute period.

Settable solids, expressed as mL/L, are an approximate measure of the quantity of sludge that will be removed by primary sedimentation. Total solids, or residue upon evaporation, can be further classified as non-filterable (suspended) or filterable by passing a known volume of liquid through a filter.

The filterable-solids fraction consists of colloidal and dissolved solids. The colloidal fraction consists of the particulate matter with an approximate size range of from 0.001 to 1 μm. The dissolved solids consist of both organic & inorganic molecules and ions that are present in true solution in water. The colloidal fraction cannot be removed by settling. Generally, biological oxidation or coagulation, followed by sedimentation, is required to remove these particles from suspension.

The suspended solids are found in considerable quantity in many industrial wastewater, such as cannery and paper-mill effluents. They are screened and/or settled out at the treatment plant. Solids removed by settling and separated from wash water are called *sludge*, which may then be pumped to drying beds or filtered for extraction of additional water (dewatering).

Each of the categories of solids may be further classified on the basis of their volatility at 550 ± 50 °C. The organic fraction will oxidize and will be driven off as gas at this temperature, and the inorganic fraction remains behind as ash. Thus the terms "Volatile suspended solids" and "Fixed suspended solids" refer, respectively, to the organic and inorganic (or mineral) content of the suspended solids. The volatile-solids analysis is applied most commonly to wastewater sludge to measure their biological stability.

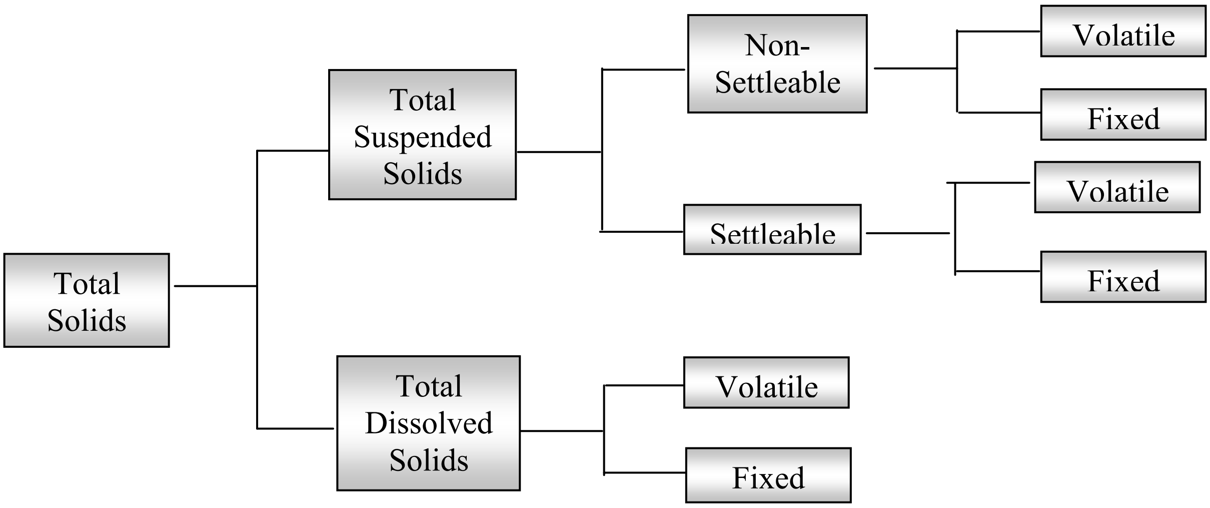


Fig. (2-1) Classification of Total Solids

b) Odors

Odors are usually caused by gases produced by the decomposition of organic matter or by substances added to the wastewater. Industrial wastewater may contain either odorous compounds or compounds that produce odor during the process of wastewater treatment.

c) Temperature

The temperature of water is a very important parameter because of its effect on chemical reactions and reaction rates, aquatic life, and the suitability of the water for beneficial uses. Increased temperature, for example, can cause a change in the species of fish that can exist in the receiving water body. Industrial establishments that use surface water for cooling-water purposes are particularly concerned with the temperature of the intake water.

In addition, oxygen is less soluble in warm water than in cold water. The increase in the rate of biochemical reactions that accompanies an increase in temperature, combined with the decrease in the quantity of oxygen present in surface waters, can often cause serious depletions in dissolved oxygen concentration in the summer months. When significantly large quantities of heated water are discharged to natural receiving water, these effects are magnified. It should also be realized that a sudden change in temperature can result in a high rate of mortality of aquatic life. Moreover, abnormally high temperatures can foster the growth of undesirable water plants and wastewater fungus.

d) Color

Color of industrial wastewater varies according to the type of industry. Knowledge of the character and measurement of color is essential. Since most colored matter is in a dissolved state, it is not altered by conventional primary devices, although secondary treatment units, such as activated sludge and trickling filters, remove a certain percentage of some types of colored matter. Sometimes color matters needs chemical oxidation procedures for removal.

e) Turbidity

Turbidity, a measure of the light-transmitting properties of water, is another test used to indicate the quality of wastewater discharges and natural waters with respect to colloidal and residual suspended matter. In general, there is no relationship between turbidity and the concentration of suspended solids in untreated wastewater. There is, however, a reasonable relationship between turbidity and suspended solids for the settled secondary effluent from the activated sludge process.

2.1.2 Chemical Characteristics

a) Organic Matter

Organic compounds are normally composed of a combination of carbon, hydrogen, and oxygen, together with nitrogen in some cases. Other important elements, such as sulfur, phosphorus, and iron, may also be present. Also, industrial wastewater may contain small quantities of a large number of different synthetic organic molecules ranging from simple to extremely complex in structure. Typical examples include surfactants, organic priority pollutants, volatile organic compounds and agricultural pesticides as shown in table (2-3). The presence of these substances has complicated industrial wastewater treatment because many of them either cannot be or are very slowly decomposed biologically.

- **Fats, Oils, and Grease.** Fats are among the more stable of organic compounds and are not easily decomposed by bacteria. Kerosene, lubricating oils reach the sewer from workshops and garages, for the most part they float on the wastewater, although a portion is carried into the sludge on settling solids. To an even greater extent than fats, oils, and soaps, the mineral oils tend to coat surfaces causing maintenance problems. If grease is not removed before discharge of the wastewater, it can interfere with the biological life in the surface waters and create unsightly floating matter and films. The oil and grease (O & G) is a very important test used to determine the hydrocarbon content of industrial wastewaters. O&G tests include free O&G and emulsified O&G measures. These tests will determine the type of treatment required. Free O&G can be removed by flotation & skimming using gravity oil separator (GOS). However, emulsified oil is removed by Dissolved Air Flotation system after chemical de-emulsification of oil. In any case, O&G have to be removed prior biological treatment as they will clog the flow distributing devices and air nozzles.

- **Surfactants.** Surfactants are large organic molecules that are slightly soluble in water and cause foaming in wastewater treatment plants and in surface waters into which the wastewater effluent is discharged. Surfactants tend to collect at the air-water interface. During aeration of wastewater, these compounds collect on the surface of the air bubbles and thus create a very stable foam.

- **Phenols.** Phenols and other organic compounds are also important constituents of water. Phenols cause taste problems in drinking water, particularly when the water is chlorinated. They are produced primarily by industrial operations and find their way to surface waters via industrial wastewater discharges. Phenols can be biologically oxidized at concentrations up to 500 mg/liter.

- **Volatile Organic Compounds (VOCs).** Organic compounds that have a boiling point less than < 100 ^{o}C and/or a vapor pressure > 1 mm Hg at 25 ^{o}C are generally considered to be volatile organic compounds (VOCs). The release of these compounds in sewers and at treatment plants is of particular concern with respect to the health of collection system and treatment plant workers.

- **Pesticides & Agricultural Chemicals.** Trace organic compounds, such as pesticides, herbicides, and other agricultural chemicals, are toxic to most life forms and therefore can be significant contaminants of surface waters.

Parameters of Organic Content

➢ ***Biochemical Oxygen Demand (BOD_5)***

The most widely used parameter of organic pollution applied to wastewater is the 5-day BOD (BOD_5). The BOD_5 is usually exerted by dissolved and colloidal organic matter and imposes a load on the biological units of the treatment plant. Oxygen must be provided so that bacteria can grow and oxidize the organic matter. An added BOD_5 load, caused by an increase in organic waste, requires more bacterial activity, more oxygen, and greater biological-unit capacity for its treatment.

Figure (2-2) illustrates one possible effect of a given industrial wastewater on a sewage plant. In this instance the industrial wastewater, with its constant rate of degradation, tends to smooth out the rate of decomposition of the sewage so that the result shows less upsurge due to nitrogenation. Also, the rate of decomposition of the industrial wastewater tends to slow down the initial rapid rate of domestic sewage.

The determination of the BOD_5 involves the measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. Several dilutions of the wastewater are put into standard BOD_5 bottles with water that has been saturated with oxygen, and contains bacteria. A control bottle is also prepared with only water and bacteria. The bottles are put into a standard incubator for five days, hence this is called the “Five-Day BOD Test (BOD_5).” The difference in oxygen levels between the control bottle and the bottles with oxygen remaining is used to calculate the BOD_5 in mg/L.

The BOD_5 test results are used to:

* Determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present.
* Determine the size of wastewater treatment facilities.
* Measure the efficiency of some treatment process.
* Determine compliance with wastewater discharge permits.

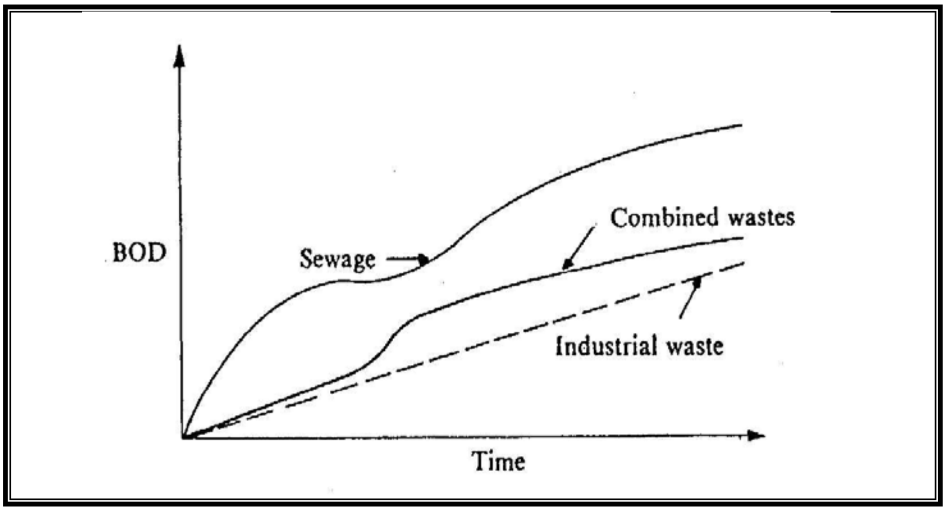


Fig. (2-2) Deoxygenation rates of sewage, a certain industrial wastewater and a combination of the two.

The limitations of the BOD_5 test are as follows:

* A high concentration of active, acclimated seed bacteria is required.
* Pretreatment is needed when dealing with toxic wastes, and the effects of nitrifying organisms must be reduced.
* Only the biodegradable organics are measured.
* The test does not have stoichiometric validity after the soluble organic matter present in solution has been used.
* An arbitrary, long period of time is required to obtain results.

➢ ***Chemical Oxygen Demand (COD)***

The COD test is used to measure the organic matter in industrial wastewater that contains compounds that are toxic to biological life. It oxidizes the reduced compounds in wastewater through a reaction with a mixture of chromic and sulfuric acid at high temperatures. There is another COD test using permanganate as the oxidizing agent but this test will give lower values and is not directly relatable to the standard COD test.

The COD of wastewater is, in general, higher than that of the BOD_5 because more compounds can be chemically oxidized than can be biologically oxidized. For many types of wastewater, it is possible to correlate COD with BOD_5. This can be very useful because COD can be determined in 3 hours, compared with 5 days for the BOD_5. Once the correlation has been established, COD measurements can be used to good advantage for treatment-plant control and operation.

The ratio of COD to BOD_5 is usually 1.5: 2 for industrial wastewater containing biodegradable material (e.g. Food Industry). For wastewaters with ratios higher than 3, it is assumed that some oxidizable material in the sample is not biodegradable. Nonbiodegradable material sometimes is called refractory and found mainly in wastewater from chemical and pulp & paper industries.

b) Inorganic Matter

Several inorganic components of wastewater are important in establishing and controlling wastewater quality. Industrial wastewater has to be treated for removal of the inorganic constituents that are added in the use cycle. Concentrations of inorganic constituents also are increased by the natural evaporation process, which removes some of surface water and leaves the inorganic substance in the wastewater.

- **pH**. The hydrogen-ion concentration is an important quality parameter of wastewater. The concentration range suitable for the existence of most biological life is quite narrow and critical. Wastewater with an adverse concentration of hydrogen ion is difficult to treat by biological means, and if the concentration is not altered before discharge, the wastewater effluent may alter the concentration in the natural waters.

- **Alkalinity**. Alkalinity in wastewater results from the presence of the hydroxides, carbonates, and bicarbonates of elements such as calcium, magnesium, sodium, potassium, or ammonia. Of these, calcium and magnesium bicarbonates are most common. Borates, silicates, phosphates, and similar compounds can also contribute to the alkalinity. The alkalinity in wastewater helps to resist changes in pH caused by the addition of acids. The concentration of alkalinity in wastewater is important where chemical treatment is to be used, in biological nutrient removal, and where ammonia is to be removed by air stripping.

- **Nitrogen**. Because nitrogen is an essential building block in the synthesis of protein, nitrogen data will be required to evaluate the treatability of wastewater by biological processes. Insufficient nitrogen can necessitate the addition of nitrogen to make the wastewater treatable. Where control of algal growth in the receiving water is necessary to protect beneficial uses, removal or reduction of nitrogen in wastewaters prior to discharge may be desirable. The total nitrogen, as a commonly used parameter, consists of many numerous compounds such as; NH_3, NH_4-N, NO_3-N, NO_2-N, urea, organic-N (amines, amino acids, ...etc).

- **Phosphorus.** Phosphorus is also essential to the growth of algae and other biological organisms. The organically bound phosphorus is an important constituent of industrial wastewater and sludge.

- **Sulfur.** Sulfate is reduced biologically under anaerobic conditions to sulfide, which in turn can combine with hydrogen to form hydrogen sulfide (H_2S). Hydrogen sulfide released to the atmosphere above the wastewater in sewers that are not flowing full tends to accumulate at the crown of the pipe. The accumulated H_2S can then be oxidized biologically to sulfuric acid, which is corrosive to steel pipes and equipment.

- **Toxic Inorganic Compounds.** Because of their toxicity, certain cations are of great importance in the treatment and disposal of wastewater. Many of these compounds are classified as priority pollutants. Copper, lead, silver, chromium, arsenic, and boron are toxic in varying degrees to microorganisms and therefore must be taken into consideration in the design of a biological treatment plant. Many plants have been upset by the introduction of these ions to the extent that the microorganisms were killed and treatment ceased. Other toxic cations include potassium and ammonium at 4000 mg/L. Some toxic anions, including cyanides and chromates, are also present in industrial wastewater. These are found particularly in metal-plating wastewater and should be removed by pretreatment at the site of the industry rather than be mixed with the municipal wastewater. Fluoride, another toxic anion, is found commonly in wastewater from electronics manufacturing facilities. Organic compounds present in some industrial wastewater are also toxic.

- **Heavy Metals.** Trace quantities of Many metals, such as nickel (Ni), manganese (Mn), lead (Pb), chromium (Cr), cadmium (Cd), zinc (Zn), copper (Cu), iron (Fe), and mercury (Hg) are important constituents of some industrial wastewaters. The presence of any of these metals in excessive quantities will interfere with many beneficial uses of the water because of their toxicity; therefore, it is frequently desirable to measure and control the concentration of these substances**.**

2.1.3 Biological Characteristics

Some industries have certain pathogenic organisms like slaughter houses others have molds and fungi as starch and yeast factories. Biological tests on wastewater determine whether pathogenic organisms are present by testing for certain indicator organisms. Biological information is needed to assess the degree of treatment of the wastewater before its discharge to the environment. The parameters setting the standards for the discharge of different industrial wastewater effluents are outlined in table (2-4). Total nitrogen is a commonly used parameter that includes a number of parameters , NH3, NH4-N, NO3-N, NO2-N, urea, organic N such as amines, amino acids, proteins, etc.) and process chemicals. The presence of these compounds depends on the production.

2.2 NEED FOR INDUSTRIAL WASTEWATER TREATMENT PLANTS

Industry views wastewater treatment as an imposed necessity which it employs when it is compelled to, especially when wastewater's effect on the receiving watercourse is readily visible or when public approval and claim will be gained for the expenditure and effort.

Industry should attempt to treat its wastewater at the lowest cost that will yield a satisfactory effluent for the particular receiving stream, which may necessitate considerable study, research, and pilot investigations. Planning ahead will provide time to make appropriate decisions. Conversely, lack of planning on minimizing wastewater treatment costs may mean that a sudden demand for an immediate solution will cause industry to decide to cease production.

The public attitude toward pollution control, which bordered on apathy during the first half of the twentieth century, has undergone drastic change in the early 1970s as part of the surge in public concern for the quality of the environment. Sincere public concern will be required over a long period of time to make the necessary changes in society to bring about significant improvements in our environment. Major changes in our political, social, legal, and economic approaches to pollution control will be required and therefore much more than clever technological advances will be needed.

To prevent any health hazards caused by discharging wastewater to water streams, the wastewater must be treated before discharge. Such treatment should comply with the terms of the legislation defining the characteristics of the effluent discharging in water streams. The concept of planing and development should be based on the criteria to protect land, water resources, aquatic life in streams and rivers and marine life from pollution and to safeguard public health as a high priority. Egyptian standards for quality of wastewater to be discharged in water streams have been updated in 1994 by law 4 and by decree 44/ 2000 of law 93, 1962 for discharging effluent to public sewer and by Law 48, 1982 for discharging to fresh water bodies including River Nile.

The environmental inspection on wastewater treatment plants aims to support and strengthen the Protection of both the environment and the public health, since the pollution generated from the industrial establishments has a negative impact not only on the environment, but also on the health of the individuals. Therefore, it is noted that most of the procedures that could be implemented by industrial establishments to reduce the negative environmental impacts, will also lead to reducing the effects that present a threat to the health of workers within the plants and the public living in regions affected by the various emissions from the plants.
In this respect, the effectiveness of the inspection on industrial wastewater treatment plants will lead to the protection of the environment and the protection of workers and public health.

Table (2-4) Parameters setting the standards for the discharge of industrial wastewater

Parameter	Industry													
	Automobile	Beverage	Canning	Fertilizer	Inorganic chemicals	organic chemicals	Meat products	Metal finishing	Plastics & synthetics	Pulp & paper	Petroleum refining	Steel	Textiles	Dairy
BOD_5	x	x	x		x	x	x		x	x	x		x	x
COD	x		x	x	x	x		x	x	x	x		x	x
TOC			x			x				x	x			x
TOD					x									
pH		x	x	x	x	x	x		x	x	x	x	x	x
Total solids	x				x									
Suspended solids	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Settable solids		x					x							
Total dissolved solids		x	x	x	x	x	x		x	x	x		x	
Volatile suspended solids											x			
Oil & grease	x	x		x		x	x	x	x	x	x	x	x	
Heavy metals, general						x		x		x			x	
Chromium	x			x	x						x	x	x	
Copper											x			
Nickel	x													
Iron	x			x	x						x	x		
Zinc	x			x					x		x	x		
Arsenic					x									
Mercury				x	x									
Lead	x				x						x			
Tin	x											x		
Cadmium	x													
Calcium				x										
Fluoride				x	x									
Cyanide					x	x		x	x		x	x		
Chloride	x			x	x	x					x	x		x
Sulfate	x			x	x				x		x	x		
Ammonia	x			x		x	x		x	x	x	x		
Sodium				x										
Silicates					x									
Sulfite										x				
Nitrate	x			x		x			x	x	x			x
Phosphorus			x	x	x	x	x		x	x	x			x
Urea or organic nitrogen				x										
Color		x	x				x			x	x		x	x
Total coliforms		x					x			x				
Fecal coliforms			x							x				
Toxic materials		x					x		x	x	x		x	x
Temperature		x	x	x	x						x	x	x	x
Turbidity		x					x			x	x			x
Foam	x													
Odor											x			
Phenols	x				x	x			x	x	x	x	x	
Chlorinated benezoids & polynuclear aromatics					x				x					
Mercaptans / sulfide									x		x		x	

2.3 COMMON TYPES OF WASTEWATER TREATMENT METHODS

After treatment objectives have been established for a specific project and the applicable regulations have been reviewed, the degree of treatment can be determined by comparing the influent wastewater characteristics to the required effluent wastewater characteristics. A number of different treatment and disposal or reuse alternatives are then developed and evaluated, and the best alternative is selected.

The contaminants in wastewater are removed by physical, chemical, and biological means. The individual methods usually are classified as physical unit operations, chemical unit processes, and biological unit processes.

2.3.1 Physical Unit Operations

Treatment methods in which the application of physical forces predominates are known as physical unit operations. Because most of these methods evolved directly from man's first observations of nature, they were the first to be used for wastewater treatment. Screening, mixing, flocculation, sedimentation, flotation, filtration, and gas transfer are typical unit operations.

2.3.2 Chemical Unit Processes

Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions are known as chemical unit processes. Precipitation, adsorption, and disinfection are the most common examples used in wastewater treatment. In chemical precipitation, treatment is accomplished by producing a chemical precipitate that will settle. In most cases, the settled precipitate will contain both the constituents that may have reacted with the added chemicals and the constituents that were swept out of the wastewater as the precipitate settled. Adsorption involves the removal of specific compounds from the wastewater on solid surfaces using the forces of attraction between bodies.

2.3.3 Biological Unit Processes

Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes. Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) from wastewater. Basically, these substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling. Biological treatment is also used to remove nutrients (nitrogen & phosphorus) from wastewater. With proper environmental control, wastewater can be treated biologically in most cases.

III. DESCRIPTION OF MAIN TREATMENT TECHNOLOGIES

The treatment processes and technologies described in this text are those most commonly applied in Egypt for the industrial wastewater treatment.

3.1 MECHANICAL PROCESSES

3.1.1 Screening

The first unit operation encountered in wastewater-treatment plants is screening. A screen is a device with openings, generally of uniform size that is used to retain the coarse solids found in wastewater.

The screening element may consist of parallel bars, rods or wires, grating, wire mesh, or perforated plate, and the openings may be of any shape but generally are circular or rectangular slots. A screen composed of parallel bars or rods is called a rack. Although a rack is a screening device, the term ”screen” should be limited to the type with wire cloth or perforated plate. However, the function performed by a rack is called screening and the materials removed by it are known as screening or raking. Bar racks normally have clear openings between bars of 15 mm.

According to the method of cleaning, racks and screens are designated as hand cleaned or mechanically cleaned. According to the size of openings, screens are designated as coarse or fine. Coarse screens have openings of ¼ inch or more, and fine screens have openings of less than ¼ inch. The principle types of screening devices in use are described in table (3-1) and illustrated in figures (3-1 & 3-2).

The aquarake is a self cleaning filter system, which can be installed directly into an open channel. While, the vibrating curved screen uses a motor, which vibrates the screen. This vibrator ensures a clog free screen and quicker removal of solids from the screen. The vibrating curved screen can also be equipped with a spray-cleaning device.

In the rotary screen the water flows from the top through a rotating drum and leaves the drum from the inside to the outside at the bottom. The rotary screen can be equipped with a scraper blade, which intermittently cleans the drum and a spray-cleaning device if deemed necessary.

3.1.2 Oil Separation

Floatables, namely non-emulsified oil and organics, are usually the main consideration in designing industrial primary treatment devices, rather than settleables. For this reason, most refineries, many chemical plants, and other industrial facilities use oil-water separation devices instead of primary clarifiers.

➢ **API Separators**

An API separator is an oil-water separator that is designed to American Petroleum Institute “API” standards, and is used extensively in refineries and many other industrial plants. There are standards for both rectangular and circular units, however, one rarely finds circular units in the field as the size of most units is more compatible with the rectangular configuration. These units frequently handle storm flows and storm flows can impose a very high flow rate, relative to process flows, on the unit, requiring a large unit. In general, this separator can handle very large flow. However, its disadvantage is the long retention time required for efficient oil separation.

Table (3-1) Types of Mechanical Screens

Screening Surface				
Type of screen	**Size classification**	**Size range (in[a])**	**Screen material**	**Application**
Bar rack	Coarse	0.6 – 1.5	Steel, Stainless steel	Pretreatment
Inclined:				
Fixed	Medium	0.01 – 0.1	Stainless-steel wedge-wire screen	Primary treatment
Rotary	Coarse	0.03×0.09×2	Milled bronze or copper plates	Pretreatment
Drum (rotary)	Coarse	0.1 - 0.2	Stainless-steel wedge wire cloth	Pretreatment
	Medium	0.01 – 0.1	Stainless-steel wedge-wire screen	Primary treatment
	Fine	6-35 µm	Stainless-steel and polyester screen cloths	Removal of residual secondary suspended solids
Rotary disk	Medium	0.01 – 0.4	Stainless-steel	Primary treatment
	Fine	0.001 – 0.02	Stainless-steel	Primary treatment
Centrifugal	Fine	0.002 – 0.02	Stainless-steel, polyester and various other fabric screen cloths.	Primary treatment, secondary treatment with settling tank and the removal of residual secondary suspended solids

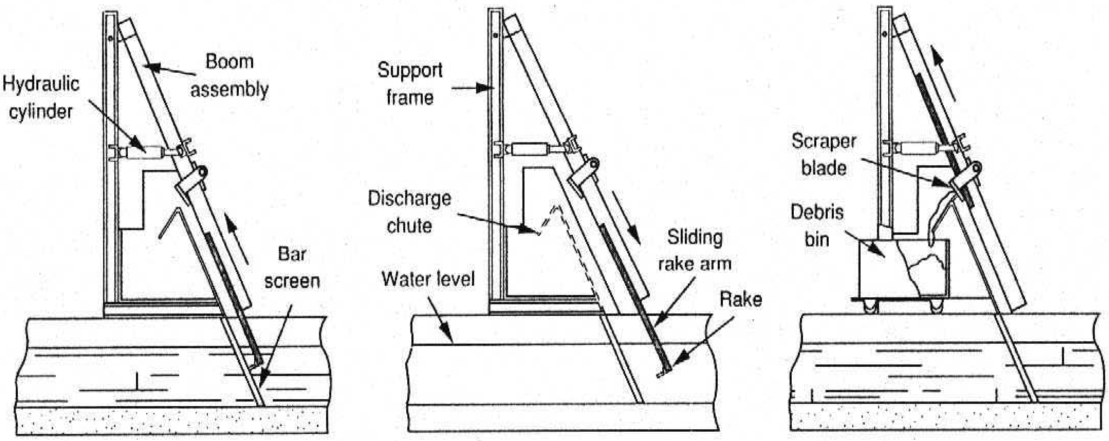


Figure (3-1): Typical mechanically cleaned bar rack.

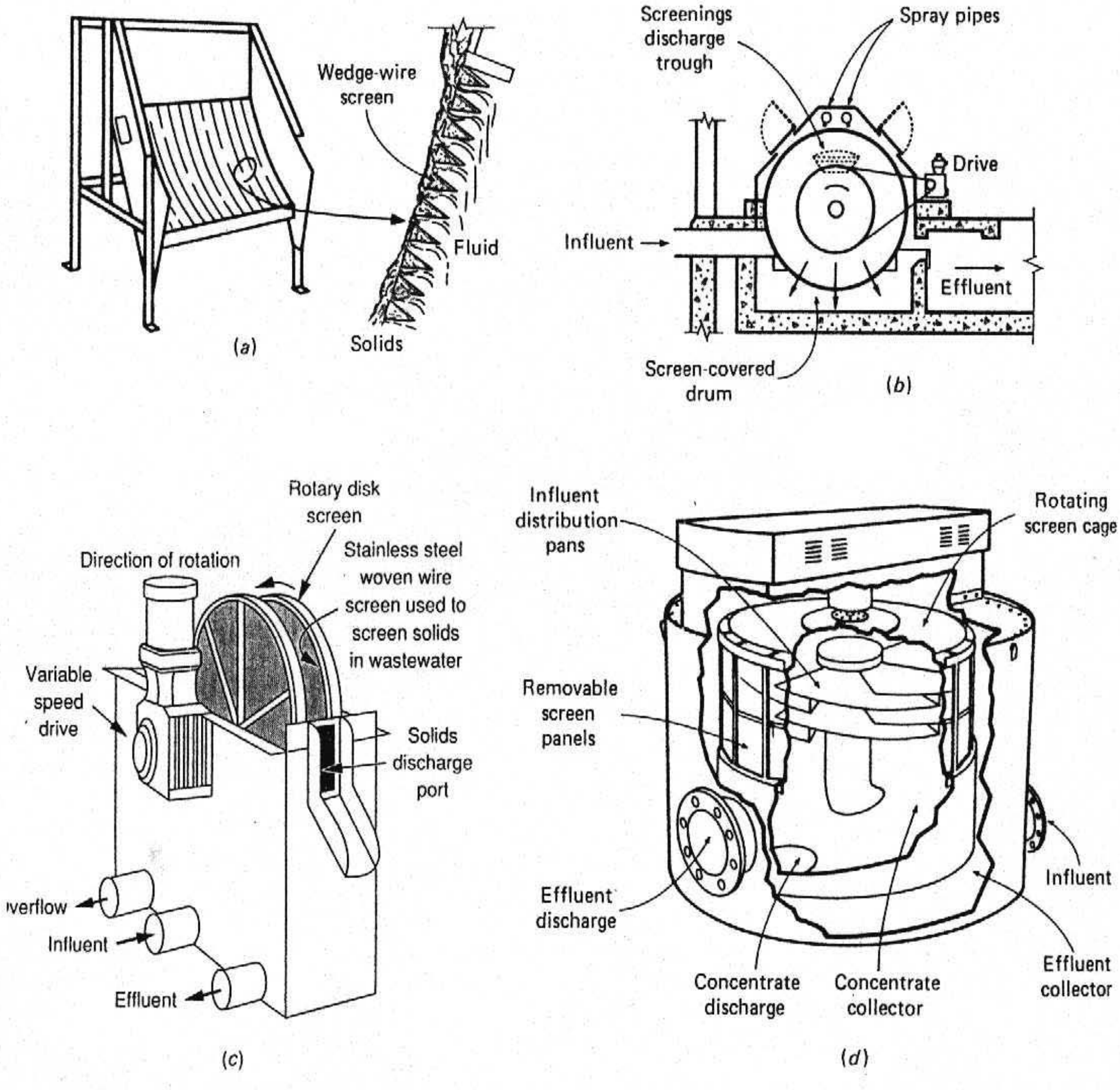


Figure (3-2): Typical screening devices used for wastewater treatment:
(a) inclined fixed screen (shown with cover removed), (b) rotary drum screen,
(c) rotary disk screen, and (d) centrifugal screen

- **CPI Units**

Corrugated Plate Interceptors (CPI), sometimes called Tilted Plate Interceptors (TPI), are replacements for API separators and primary clarifiers. They consist of stacks of plates or bundles of slanted tubes, usually at 60 degrees, in a vessel or tank. It has been found that if the plates are tilted at 60 degrees, the solids will slide down the plates and be collected at the bottom. A cross section in a typical down flow of CPI units is shown in figure (3-3).

The projected horizontal area of the plates form the settling surface, thus a CPI surface area can be placed in a small space.

CPIs are widely used for oil-water separation in many industries, but have found only limited acceptance in refineries. The reason is the units cannot take shock loads and high flows as well as a conservatively designed API separator, and oil in refinery wastewater usually separates quite well not requiring the large surface or coalescing area. They have some advantages over API separators. They are usually more efficient than API separators and primary clarifiers in removing oil and solids, as more surface area can be provided.

3.1.3 Flow Equalization

Flow equalization is used to overcome the operational problems caused by flow variations, to improve the performance of the downstream processes, and is also used as an emergency tank to equalize wastewater effluent in case of any process failure in the treatment process.

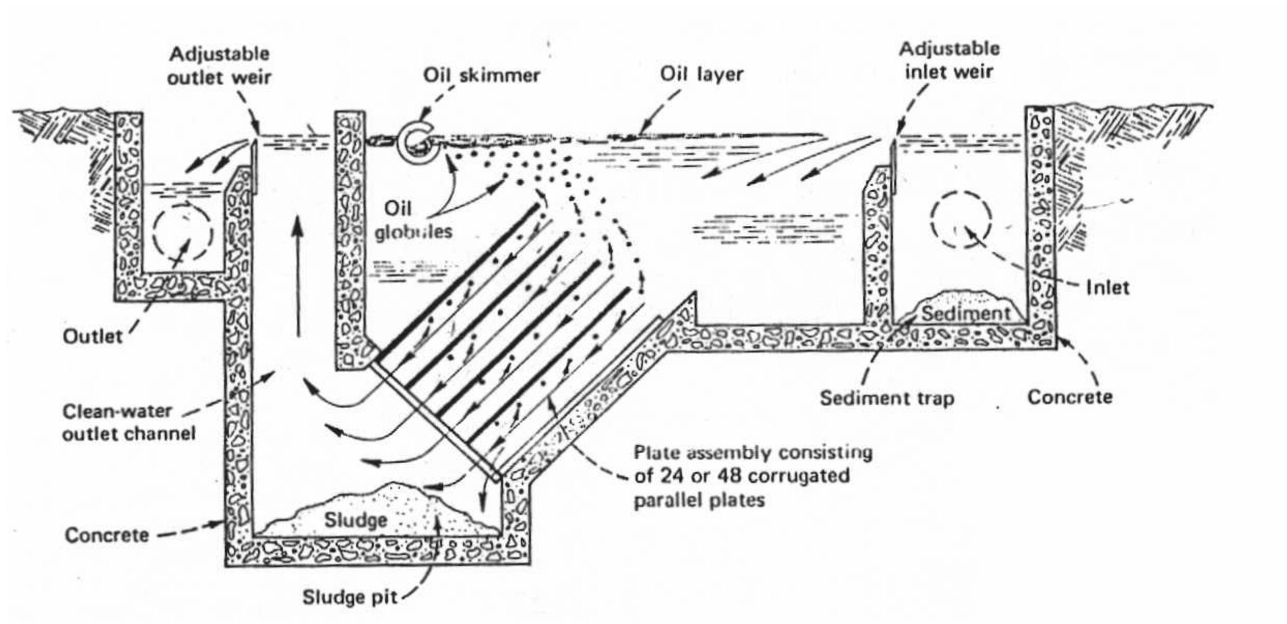
Flow equalization is simply the damping of flow rate variations so that a constant or nearly constant flow rate is achieved. This technique can be applied in a number of different situations, depending on the characteristics of the collection system.

The principal benefits that are cited as deriving from the application of flow equalization are as follows:

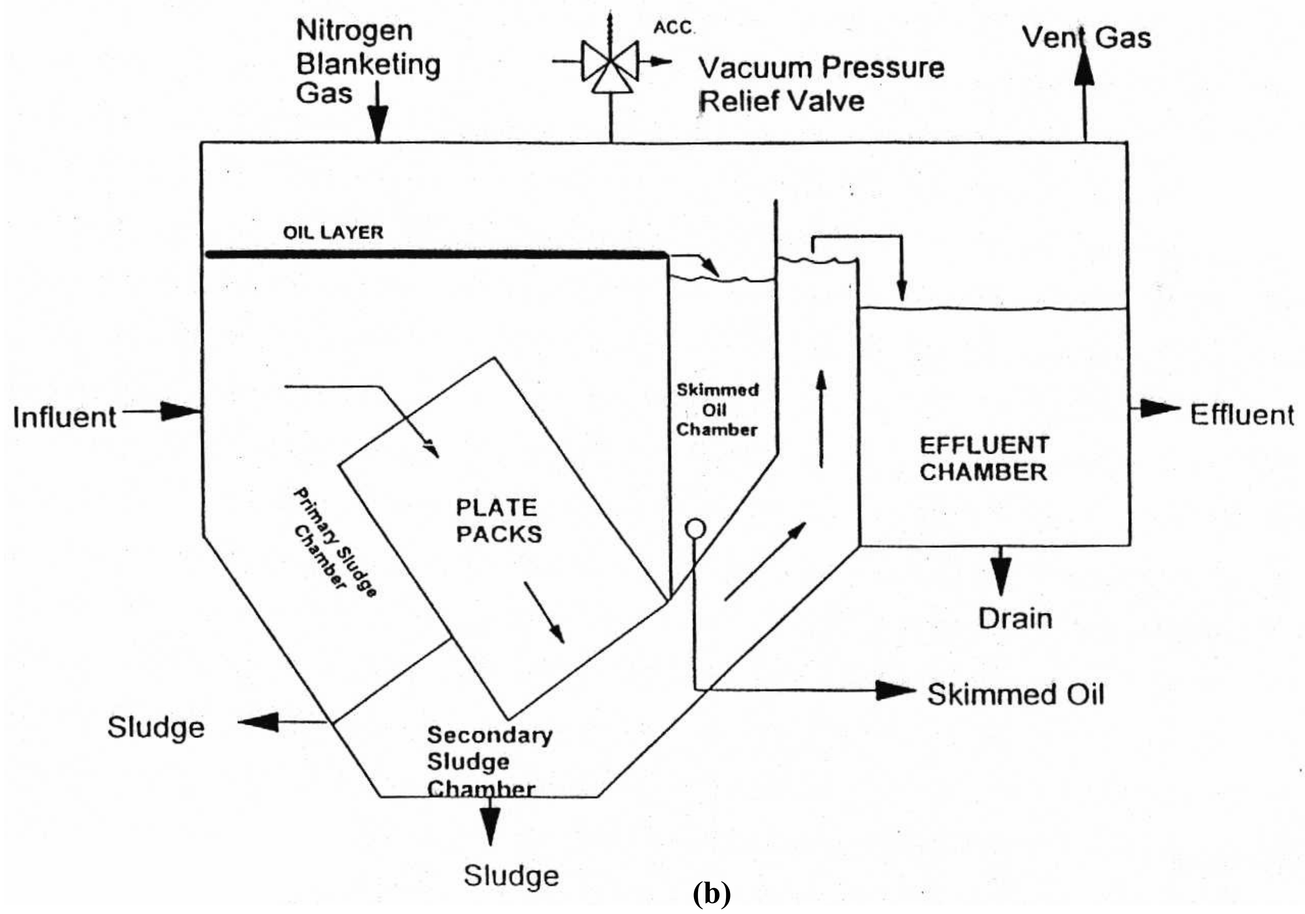
- Wastewater treatability is enhanced after equalization.
- Biological treatment is enhanced, because shock loading is eliminated or can be minimized, inhibiting substances can be diluted, and pH can be stabilized.
- The effluent quality and thickening performance of secondary sedimentation tanks following biological treatment is improved through constant solids loading.
- Filter performance is improved and more uniform filter backwash cycles are possible.
- In chemical treatment, damping of mass loading improves chemical feed control and process reliability.

Flow equalization is an attractive option for upgrading the performance of overloaded treatment plants because of the relatively low costs involved.

The best location for equalization facilities to be at existing and proposed treatment plant sites. In some cases, equalization after primary treatment and before biological treatment may be appropriate but the design must provide for sufficient mixing to prevent solids deposition and concentration variations and also to provide aeration to prevent odor problems.



(a)



(b)

Figure (3-3): (a) Corrugated-Plate Interceptor (CPI) for refinery wastewater
(b) Cross-section of a typical down flow CPI

3.2 PHYSICAL TREATMENT

3.2.1 Sedimentation

Sedimentation is the separation from water, by gravitational settling, of suspended particles that are heavier than water. It is one of the most widely used unit operations in wastewater treatment. The terms sedimentation and settling are used interchangeably. A sedimentation basin may also be referred to as a sedimentation tank, settling basin, or settling tank.

Sedimentation is used for separation of grit and particulate matter in the primary settling basin, separation of biological-floc in the activated-sludge settling basin, and separation of chemical-floc when the chemical coagulation process is used. It is also used for solids concentration in sludge thickeners.

Sedimentation basins are often referred to as either clarifiers or thickeners. If the main purpose of the operation is to produce an effluent stream with low suspended solids, the vessel is usually called a clarifier. If the major concern is the production of a concentrated suspension, the vessel is normally called a thickener. The terms clarifier and thickener are often used interchangeably in describing settling tanks for effluent streams from activated sludge reactors since both clarification and thickening occur in any sedimentation basin.

In wastewater treatment plants, sedimentation is applied to separate a variety of organic and inorganic solids from raw or treated wastewaters. Primary settling tanks are used to remove solids from the waste stream entering the plant. Secondary settling tanks handle the solids in the effluent from a biological reactor. The settling characteristics of suspended particles depend upon the nature of the particles, their concentration and the conditions in the settling device

- **Ideal settling basins**

An ideal settling basin is defined as a tank in which settling occurs in the same manner as in a quiescent settling container of the same depth. A schematic diagram of a rectangular horizontal flow settling basin is shown in figure (3-4).

This basin is comprised of four zones according to function. The inlet zone is a region where the incoming suspension is distributed uniformly over the cross-section of the tank. Thus, the concentration of suspended particles of each size is the same at all points in the vertical cross-section at the inlet end.

In the settling zone, the particles settle at the same rate as they would in a quiescent. At the outlet zone, the clarified liquid is collected uniformly over the cross-section of the basin. The solids collect in a sludge zone at the bottom of the tank. All particles reaching the sludge zone are permanently removed from suspension.

- **Tube settlers**

If the tubes are horizontal or slightly inclined, the solids will accumulate on the bottom and must be removed by periodical draining. If the tubes are inclined at a steep angle, the solids will slide down the tubes countercurrent to the liquid flow and can be collected at the bottom.

- **Thickeners**

A thickener is a sedimentation basin that is used to concentrate a suspension. The particles in a thickener generally settle collectively in the zone-settling regime. As shown in figure (3-5), the bottom part of a thickener is filled with a bed of suspended solids, which increases in

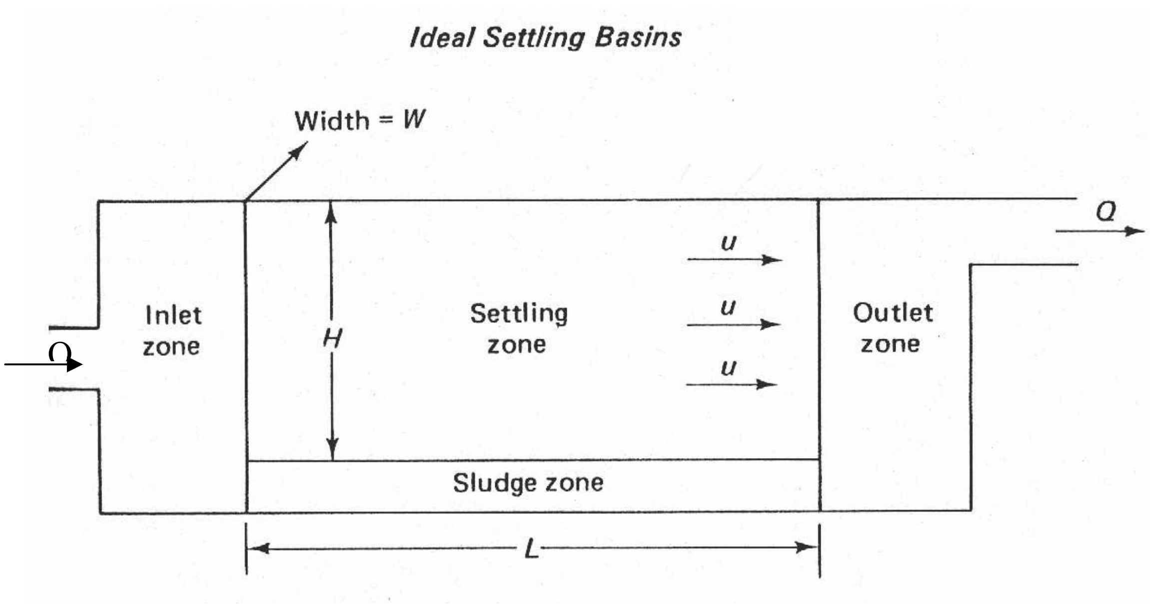


Figure (3-4): Schematic diagram of a rectangular horizontal flow-settling basin.

concentration with greater depths. A clarified liquid separates from the suspended solids at the interface and the clear liquid is removed at the top. A thickener thus fulfills the dual function of providing a concentrated underflow and a clarified liquid overflow.

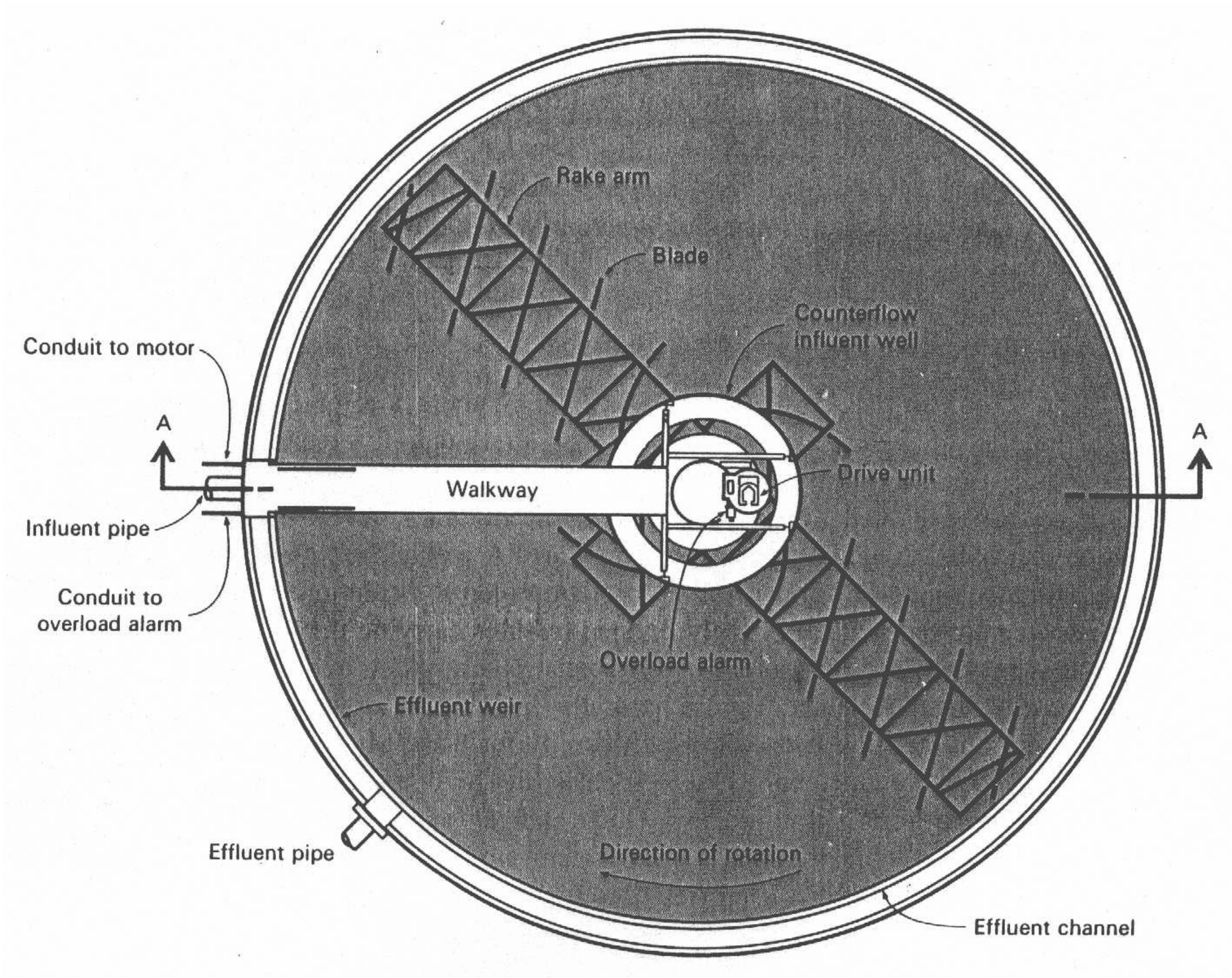
A thickener is often used to concentrate the solids in the effluent stream of an activated sludge reactor. Part of the concentrated underflow is generally recycled to the reactor to maintain a high concentration of biological solids in the reactor.

Sedimentation basins are constructed in a variety of shapes and sizes, circular tanks or rectangular tanks. Solids are removed either by mechanical devices, which move the solids to a central collection point, or by hydraulic collectors, which remove the solids near the point of deposit.

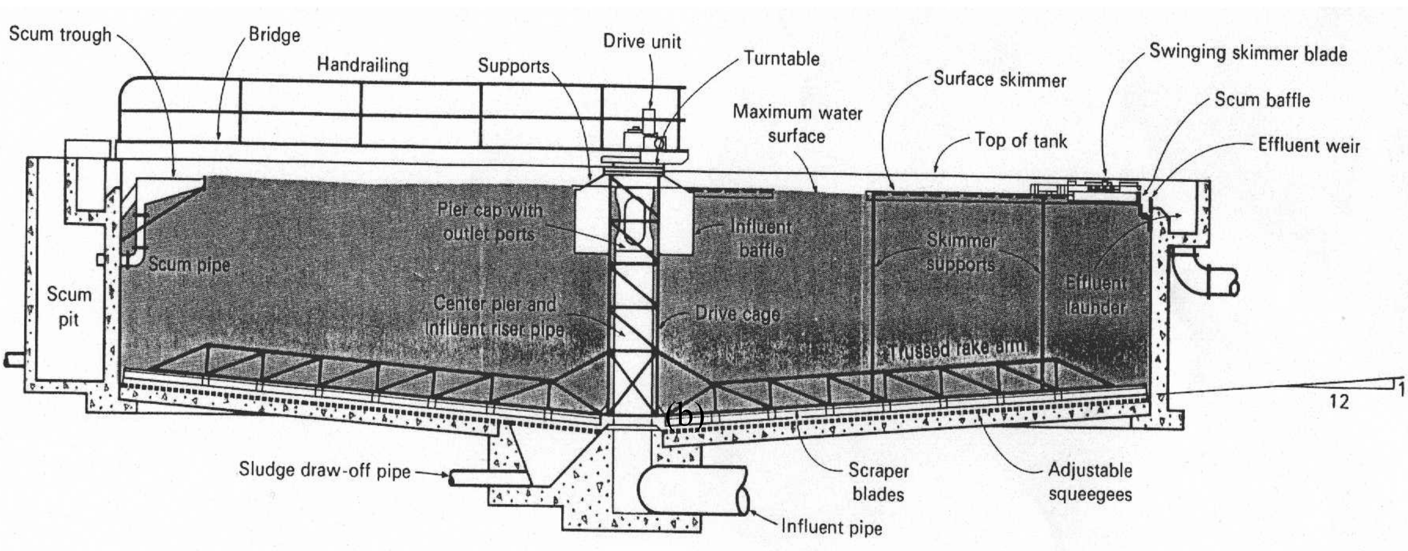
Primary sedimentation basins generally remove 40 to 65% of suspended solids along with 25 to 50% of BOD_5. Settled solids concentration usually range from 4 to 10% for primary sedimentation basins and from 0.5 to 2% for thickeners handling effluent from activated sludge reactors.

3.2.2 Flotation

Flotation is a unit operation used to separate solid or liquid particles from a liquid phase. Separation is brought by introducing fine gas (usually air bubbles) into the liquid phase. The bubbles attach to the particulate matter, and the buoyant force of the combined particle and gas bubble is great enough to cause the particle to rise to the surface. Particles that have a higher density than the liquid can thus be made to rise.



(a) PLAN



(b) Section

Figure (3-5): Schematic of gravity thickener (a) plan and (b) section A-A.

Flotation is used to remove suspended matter and to concentrate biological sludge. Principal advantage of flotation over sedimentation is that very small or light particles that settle slowly can be removed more completely and in a shorter time. Once the particles have been floated to the surface, they can be collected by a skimming operation.

Types of flotation systems:

- ***Air Flotation:*** In this system, as shown in figure (3-6), air bubbles are formed by introducing the gas phase directly into the liquid phase through a revolving impeller through diffusers. Aeration alone for a short period is not particularly effective in bringing about the flotation of solids, although some success with these units has been experienced on certain scum-forming wastes.

- ***Vacuum Flotation:*** This process consists of saturating the wastewater with air either directly in an aeration tank or by permitting air to enter on the suction side of a sewage pump. The bubbles and the attached solid particles rise to the surface to form a scum blanket, which is removed by a skimming mechanism. Grit and other heavy solids that settle to the bottom are raked to a central sludge for removal.

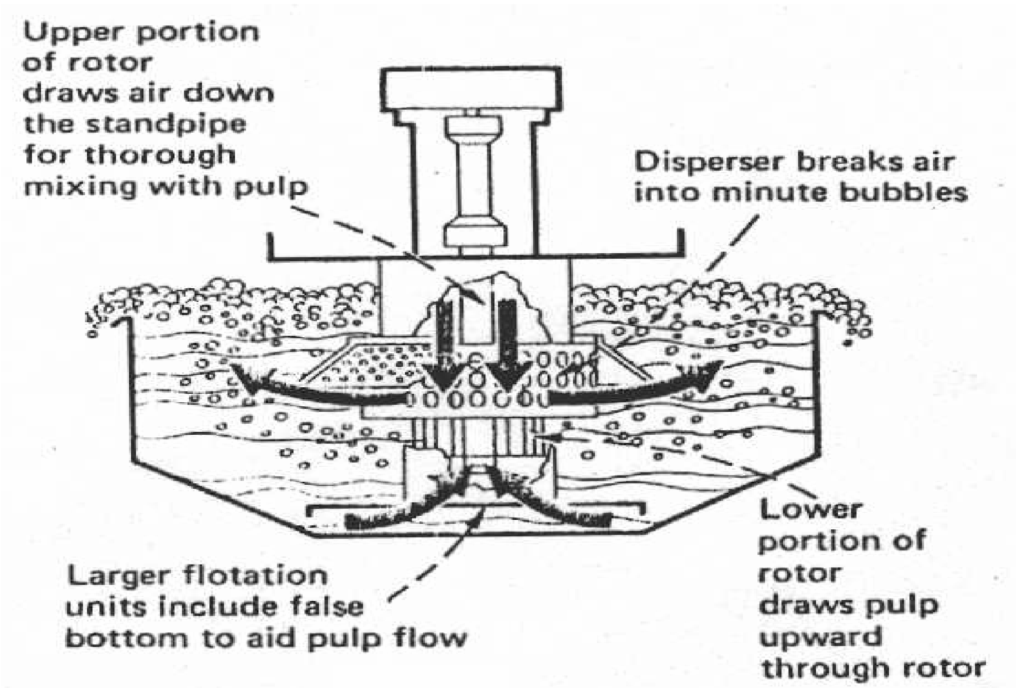


Figure (3-6): Induced Air Flotation for Oily Wastes & Suspended Solids.

3.2.3 Coalescence

Coalescence are also used for removal of low concentrations of free and emulsified oil, and are used as a single unit process or are used to polish effluents from other types of oil-water separators. Coalescence, as shown in figure (3-7), is merely composed of beds of oleophilic material such as shells, resins, straw or plastic in shredded, ball, or packing ring form. The oleophilic material attracts small free oil droplets and can also attract some types of emulsified oils. The oil coalesces on the material into larger drops and rises to the surface.

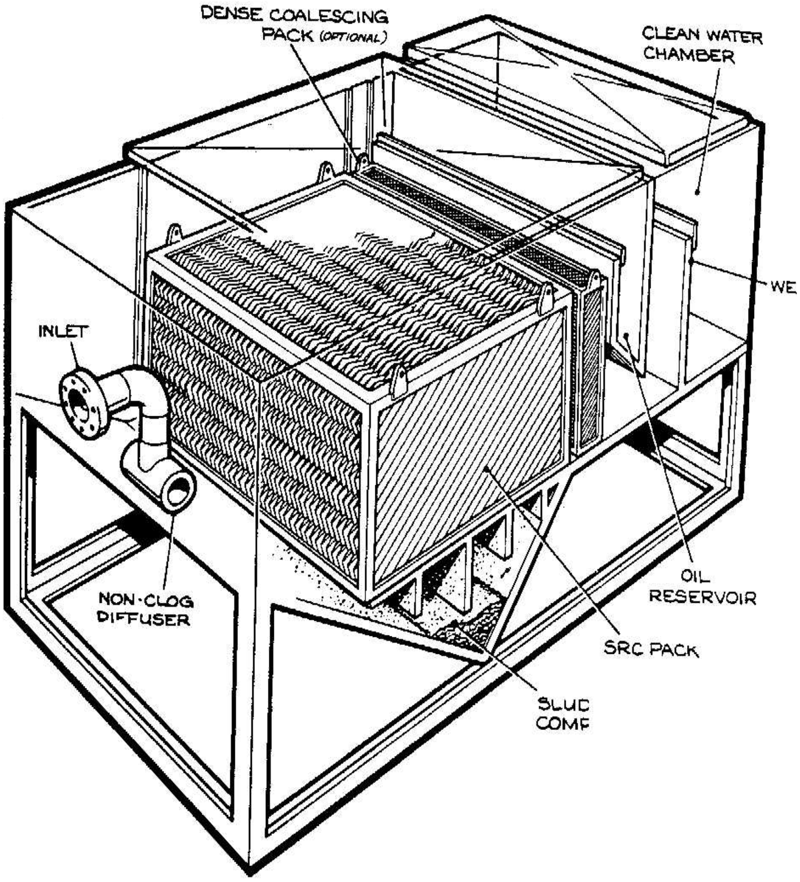


Figure (3-7): The Slant Rib Coalescing Separator is a highly effective gravity separator for the removal of dispersed oil and solids from water

3.3 CHEMICAL TREATMENT

3.3.1 Chemical Pre-Treatment

- **Neutralization**

Industrial wastes often contain acidic or alkaline components which require neutralization before discharge or treatment. For wastes that are discharged to receiving waters, a pH between 6 and 9 is frequently specified by regulatory agencies. For wastes entering biological treatment processes, the pH should be maintained between 6.5 and 8.0 for optimum growth of the microorganisms. Aerobic biological processes generate CO_2, which also affects the pH of the system. Spent acid, especially sulfuric acid, constitutes the majority of plant wastes requiring neutralization. Lime is the most widely used alkaline material for neutralization acid wastes because of its low cost. The solid lime, however, may be slow to react and may form insoluble precipitates such as $CaSO_4$.

Sodium carbonate (soda ash), sodium hydroxide, and ammonia react faster with acids than lime but they are more expensive. Alkaline wastes are usually neutralized with sulfuric acid or with waste acids from other operations. A flue gas can also be used to neutralize alkaline wastes since the CO_2 in flue gas forms carbonic acid when contacted with water.

Neutralization is probably the oldest and most frequent of chemical methods of acidic and alkaline waste streams to keep the pH of the effluent in the range of 6 to 8 required by many regulatory agencies. Many chemical waste streams exceed these limits and fluctuate sharply with time.

Acidic wastes are commonly neutralized with waste alkaline streams, lime, dolomite, ammonia, caustic soda, or soda ash. The choice of the alkaline reagent used depends on the volume of the waste stream, the variability of pH, and the price of the neutralizing alkali. Lime is most often used, despite the frequent formation of precipitates or suspended solids, which must be separated by sedimentation or filtration before the waste is discharged to the receiving waters because of its low cost.

Highly alkaline wastes usually require treatment with a waste acidic stream, sulfuric acid, hydrochloric acid, or flue gas containing carbon dioxide.

Neutralization is usually accomplished in two steps since pH varies in concentration increments of 10: rough neutralization with waste streams or with cheap chemicals, followed by final polishing, often with instrumented controls, using caustic soda solutions or sulfuric acid.

When large volumes of wastes are involved, recovery may be more economical than neutralization, where an acid of commercial purity is produced, eliminating a waste disposal problem.

- **Oxidation/Reduction**

Oxidants are used in wastewater treatment as a first step in the removal of heavy metals to oxidize organics or as a last step in a treatment process, to oxidize odiferous compounds such as hydrogen sulphide or to oxidize inorganics such as cyanide and for disinfection.

Air is the least expensive and most common oxidant. Ferrous iron is readily oxidized to the ferric state by contact with air. This is usually accomplished with oxidation towers that are similar in construction to cooling towers. Other chemical oxidants are chlorine and its variant hypochlorite in both sodium and calcium versions. Another widely used oxidant is potassium permanganate. Chlorine and its variants have been alleged to form carcinogenic compounds when used to oxidize organics. Before using chlorine in a process, even a non-wastewater process, it would be well to check to see if any carcinogens could be formed. Potassium permanganate is used to oxidize odiferous compounds and for organics reduction. Hydrogen peroxide is effective in reducing organics such as COD, and is worth considering when faced a COD, organic or odor reduction problem.

- **Coagulation**

It takes place in rapid mix, or flash mix basins which are very rapid. The primary function of rapid mix basin is to disperse the coagulant so that it contacts all of the wastewater.

Two theories have been advanced to explain basic mechanisms involved in the stability and instability of colloid systems:

- Chemical theory assumes that colloids are aggregates of definite chemical structural units – it occurs because of specific chemical reactions between colloidal particles and the chemical coagulant added.
- Physical theory proposes that reduction of forces tending to keep colloids apart occurs through the reduction of electrostatic forces, such as the zeta potential. Good coagulation, flocculation and sedimentation is difficult to obtain in wastewater treatment.

- **Flocculation**

The purpose of flocculation is to form aggregates or flocs from the finely divided matter. The flocculation of wastewater by mechanical or air agitation may be worthy of consideration when it is desired to:

- Increase the removal of suspended solids and BOD_5 in primary settling facilities.
- Condition wastewater containing certain industrial wastes.
- Improve the performance of secondary settling tanks, especially the activated sludge process. Also, to increase the collisions of coagulated solids, they agglomerate to form settleable or filterable solids. It is accomplished by prolonged agitation of coagulated particles in order to promote an increase in size and density.

Flocculation can be carried out in a separate basin of an integral part of the clarifier structure. When air flocculation is employed, the air supply system should be adjusted so that the flocculation energy level can be varied throughout the tank. In both mechanical and air agitation flocculation systems, it is common practice to taper the energy input so that the flocs initially formed will not be broken as they leave the flocculation facilities.

3.3.2 Chemical Precipitation

Chemical precipitation in wastewater treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids and facilitate their removal by sedimentation. In some cases the alteration is slight, and removal is affected by entrapment within a voluminous precipitate consisting primarily of the coagulant itself. Another result of chemical addition is a net increase in the dissolved constituents in the wastewater.

In the past, chemical precipitation was used to enhance the degree of suspended solids and BOD_5 removal (1) where there were seasonal variations in the concentration of the wastewater (such as in cannery wastewater), (2) where an intermediate degree of treatment was required, and (3) as an aid to the sedimentation process. The need to provide more complete removal of the organic compounds and nutrients (nitrogen and phosphorus) contained in wastewater has brought about renewed interest in chemical precipitation. Chemical processes in conjunction with various chemical operations have been developed for the complete secondary treatment of under treatment wastewater, including the removal of either nitrogen or phosphorus or both. Other chemical processes have also been developed to remove phosphorus by chemical precipitation and are designed to be used in conjunction with biological treatment.

Chemical Precipitation for Improving Plant Performance
Over the years a number of different substances have been used as precipitants. The most common ones are listed in table (3-2). The degree of clarification obtained depends on the quantity of chemicals used and the care with which the process is controlled. By chemical precipitation, it is possible to obtain a clear effluent, substantially free from matter in suspension or in the colloidal state.

From 80 to 90 percent of total suspended matter, 50 to 80 percent of BOD_5 and 80 to 90 percent of bacteria can be removed by chemical precipitation. In comparison, when plain sedimentation is used, only 50 to 70 percent of total suspended matter, 25 to 40 percent of BOD_5 and 25 to 75 percent of bacteria can be removed. The chemicals added to wastewater interact with substances that are either normally present in the wastewater or added for this purpose.

Table (3-2): Chemicals used in industrial wastewater treatment

Chemical	Formula	Molecular Weight
Alum	$Al_2(SO_4)_3.18H_2O$	666.7
Ferrous Sulfate	$FeSO_4.7H_2O$	278.0
Lime	$Ca(OH)_2$	56 as CaO
Ferric Chloride	$FeCl_3$	162.1
Ferric Sulfate	$Fe_2(SO_4)_3$	400

3.3.3 Physio-Chemical Treatment

➢ **Dissolved Air Flotation (DAF) System**
In dissolved air flotation (DAF), air is intimately contacted with an aqueous stream at high pressure, dissolving the air. The pressure on the liquid is reduced through a back pressure valve, thereby releasing micron-sized bubbles that sweep suspended solids and oil from the polluted stream to the surface of the air-flotation unit.

Applications include treating effluents from refinery API separators, metal finishing, pulp and paper industry, cold-rolling mill, poultry processing, grease recovery in meat-packing plants, cooking-oil separation from French-fry processing and some dairy industries. An increasingly important application is the thickening of sludge.

DAF units usually remove oil down to 5 ppm or less, and the released air may have to be treated in a control unit.

DAF units are generally sized with an overflow rate of 1500 to 3000 gal./day/sq.ft. and a retention time of 30 to 40 minutes.

A variant of the DAF unit that is commonly used in oil fields and for ballast water treatment is the Induced Air Floatation (IAF) unit. In the past it was rarely used in chemical plants and refineries but interest in it is increasing because the unit is totally enclosed and can use recycled gases for floatation. The unit utilizes polymer feed and usually has four eggbeater type frothing units for floatation. The unit has high power consumption, but uses much less space than a DAF unit. It is as efficient or more efficient than a DAF unit depending on oil and emulsion characteristics.

Attachment of gas bubbles to suspended-solids/gas mixture is carried to the vessel surface after precipitation of air on the particle, collision of a rising bubble with a suspended particle, trapping of gas bubbles as they rise under a floc particle and adsorption of the gas by a floc formed or precipitated around the air bubble.

To dissolve air for flotation, three types of pressurized systems are used. Full-flow or total pressurization is used when the wastewater contains large amounts of oily material. The intense mixing occurring in the pressurization system does not affect the treatment results. Partial-flow pressurization is used where moderate to low concentrations of oily material is present. Again, intense mixing by passage through the pressurization systems does not affect treatment efficiency significantly. The recycle-flow pressurization system is for treatment of solids or oily materials that would degrade by the intense mixing in the other pressurization systems. This approach is used following chemical treatment of oil emulsions, or for clarification and thickening of flocculent suspensions.

A schematic drawing of dissolved-air flotation system is shown in figure (3-8). The solids-laden or oily-water influent mixture enters the flotation vessel, and the air-solids mixture rises to the liquid surface. The air-solids mixture has a specific gravity less than water. Solids having a specific gravity greater than water tend to settle to the bottom and are removed by a rotating scraper arm. Attached to the same shaft is a rotating skimmer blade that removes the floating matter from the surface of the vessel into a skimming hopper. Clean water passes underneath a skirt and then must leave the vessel through a launder, which is located in the peripheral region.

A portion of the effluent water is recycled for pressurization. Compressed air is introduced into the discharge of the recycle pump, and intimate contact with the water is achieved in the aeration tank. Maximum solubilization efficiency is important at this point. The aerated recycle water is then returned through a back-pressure valve, where the pressurized air is released, and mixed with the influent for flotation.

Flocculents such as synthetic polymers may be used to improve the effectiveness of dissolved air flotation. Also coagulants such as filter alum may be used to break emulsified oils and to coagulate materials for improved flotation recovery. DAF unit is equipped sometimes with a Lamella plate as shown in figure (3-9) which increases the separation area, and to ensure that even the smallest flocs are removed from the wastewater.

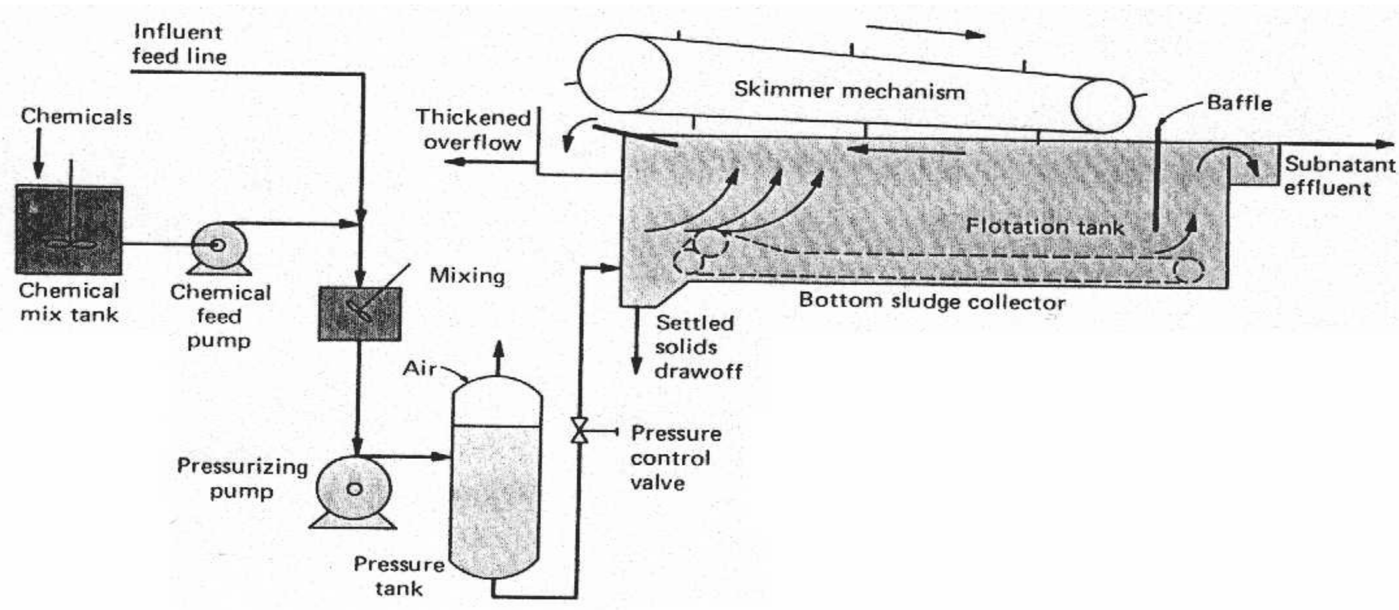


Figure (3-8): Schematic diagram for DAF system without recycling

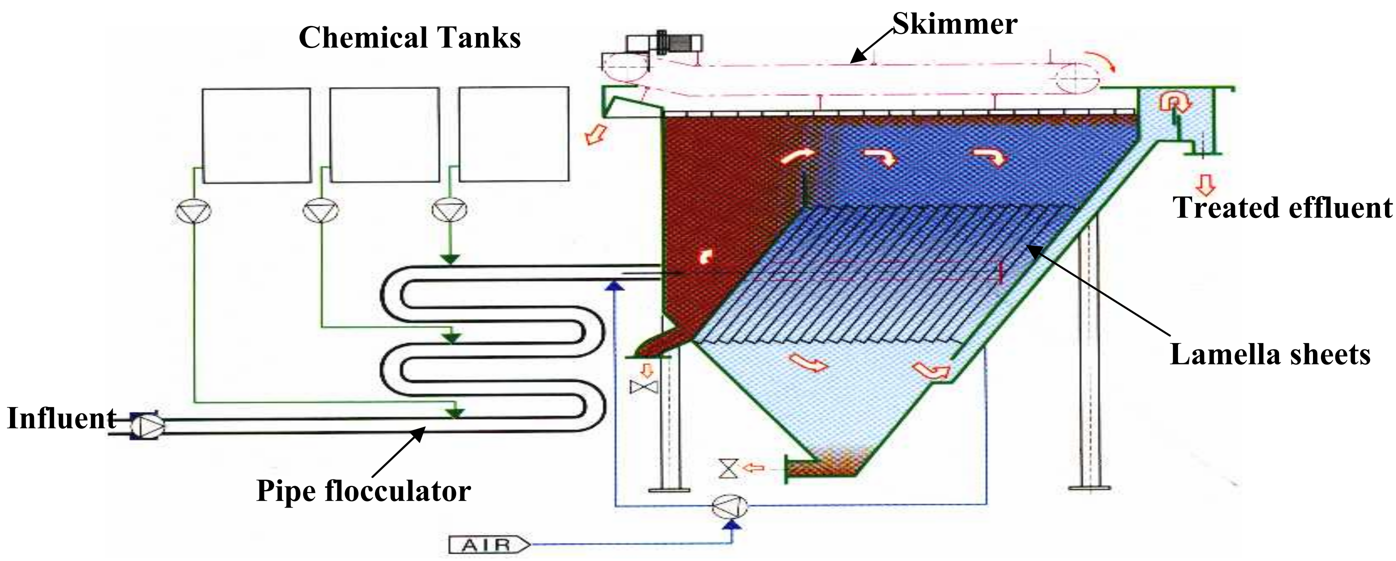


Figure (3-9): DAF system with lamella separator & type flocculator.

3.4. BIOLOGICAL TREATMENT

The major biological processes used for wastewater treatment are five major groups: aerobic processes, anoxic process, anaerobic process, combined aerobic anoxic and anaerobic/aerobic processes.

3.4.1 Aerobic Biological Treatment

The aerobic biological processes are further subdivided depending on whether treatment is accomplished in suspended-growth systems, attached-growth systems, or combinations thereof. All the biological processes used for the treatment of wastewater are derived from processes occurring in nature.

a) Aerobic suspended growth:

- Activated sludge processes
- Plug flow with recycle
- Aerated lagoons
- SBR

b) Aerobic attached growth:

- Trickling filter
- Roughing filter
- Rotating biological contractor
- Fixed film nitrification reactor

Details of these processes are described below.

a) Aerobic suspended growth

- **Activated-Sludge Process**

Activated sludge is a secondary treatment process in which wastewater that has normally received primary sedimentation is allowed to flow through the aeration tank or "reactor" where aerobic bacterial culture is maintained in suspension. The reactor contents are referred to as the "mixed liquor".

The aerobic environment in the reactor is achieved by the use of diffused or mechanical aeration, which also serves to maintain the mixed liquor in a completely mixed regime. After a specified period of time, the mixture of new cells and old cells is passed into a settling tank, where the cells are separated from the treated wastewater. A portion of the settled cells is recycled to maintain the desired concentration of organisms in the reactor, and a portion is wasted. The portion wasted corresponds to the new growth of cell tissue, associated with a particular wastewater.

The major types of activated sludge treatment processes used for secondary treatment are:

- Conventional Activated Sludge and variation of the conventional systems, and
- Extended Aeration.

- **Conventional Activated Sludge**

The conventional activated sludge system contains a tank for wastewater aeration followed by a settler and a solids recycle line. The wastewater flows through under constant aeration in the presence of activated sludge and exits at the end of the tank after 4-8 hours of residence time. As the flow passes through the tank, the high oxygen demand gradually will decrease. The oxygen concentration in the reactor should be 0.5-2 mg/l throughout, where values over 2 mg/l are considered lost energy. Most conventional plants use tapered aeration to adjust the air rate along the reactor length to satisfy the local oxygen demand. A process flow diagram for different conventional treatment systems are shown in figure (3-10).

- **Extended Aeration**

This is the modified form of a conventional activated sludge process in which the production of excess sludge is minimized by oxidation and an increase in residence time, i.e. through the larger size of the aeration tank. The retention time is extended to 1-2 days, which results in a very low net yield of sludge due to its consumption of endogenous respiration. The main advantage of the extended aeration system is in having the minimum of sludge handling facilities as compared with other conventional activated sludge processes. The sludge in extended aeration effluents is very light, of non-degradable nature, and settles with difficulty. Therefore, settling tanks are provided with a longer retention time of approximately 4 hours versus 2 hours for the conventional treatment process.

- **Plug Flow With Recycle**

The plug-flow system with cellular recycle can be used to model certain forms of the activated-sludge process. In a true plug-flow model, all the particles entering the reactor stay in the reactor an equal amount of time. Some particles may make more passes through the reactor because of recycle, but, while they are in the tank, they all pass through in the same amount of time. The true plug-flow-recycle system is theoretically more efficient in the stabilization of most soluble wastes than the complete-mix recycle system. The fact that the plug-flow system cannot handle shock loads as well as the complete-mix system is the main disadvantage.

- **Aerated Lagoons**

Aerated lagoons (sometimes called ”aerated ponds”) evolved from facultative stabilization ponds when surface aerators were installed to overcome the odors from organically overloaded ponds. The aerated-lagoon process is essentially the same as the conventional extended-aeration activated-sludge process, except that an earthen basin is used for the reactor, and the oxygen required by the process is supplied by surface or diffused aerator. In aerobic lagoon, all the solids are maintained in suspension. In the past, aerated lagoons were operated as flow-through activated-sludge systems without recycle, usually followed by large settling ponds. Many aerated lagoons are now used in conjunction with settling facilities and incorporate the recycle of biological solids.

- **Sequential Batch Reactor “SBR”**

Sequential Batch Reactor (SBR) is a fill-and-draw activated-sludge treatment system. The unit processes involved in the SBR and conventional activated-sludge systems are identical. Aeration and sedimentation/clarification are carried out in both systems. However, there is one important difference. In conventional plants, the processes are carried out simultaneously in separate tanks, whereas in SBR operation the processes are carried out sequentially in the same tank.

As currently used, all SBR systems have five steps as illustrated in figure (3-11) and shown in table (3-3) and are commonly carried out in sequence as follows: (1) fill, (2) react (aeration), (3) settle (sedimentation/clarification), (4) draw (decant), and (5) idle. Sludge wasting is another important step in the SBR operation that greatly affects performance. In an SBR operation, sludge wasting usually occurs during the settle or idle phases. A unique feature of the SBR system is that there is no need for a return activated-sludge (RAS) system. Because both aeration and settling occur in the same chamber, no sludge is lost in the react step, and none has to be returned from the clarifier to maintain the sludge content in the aeration chamber. All wastewaters commonly treated by conventional activated-sludge plants can be treated with SBRs.

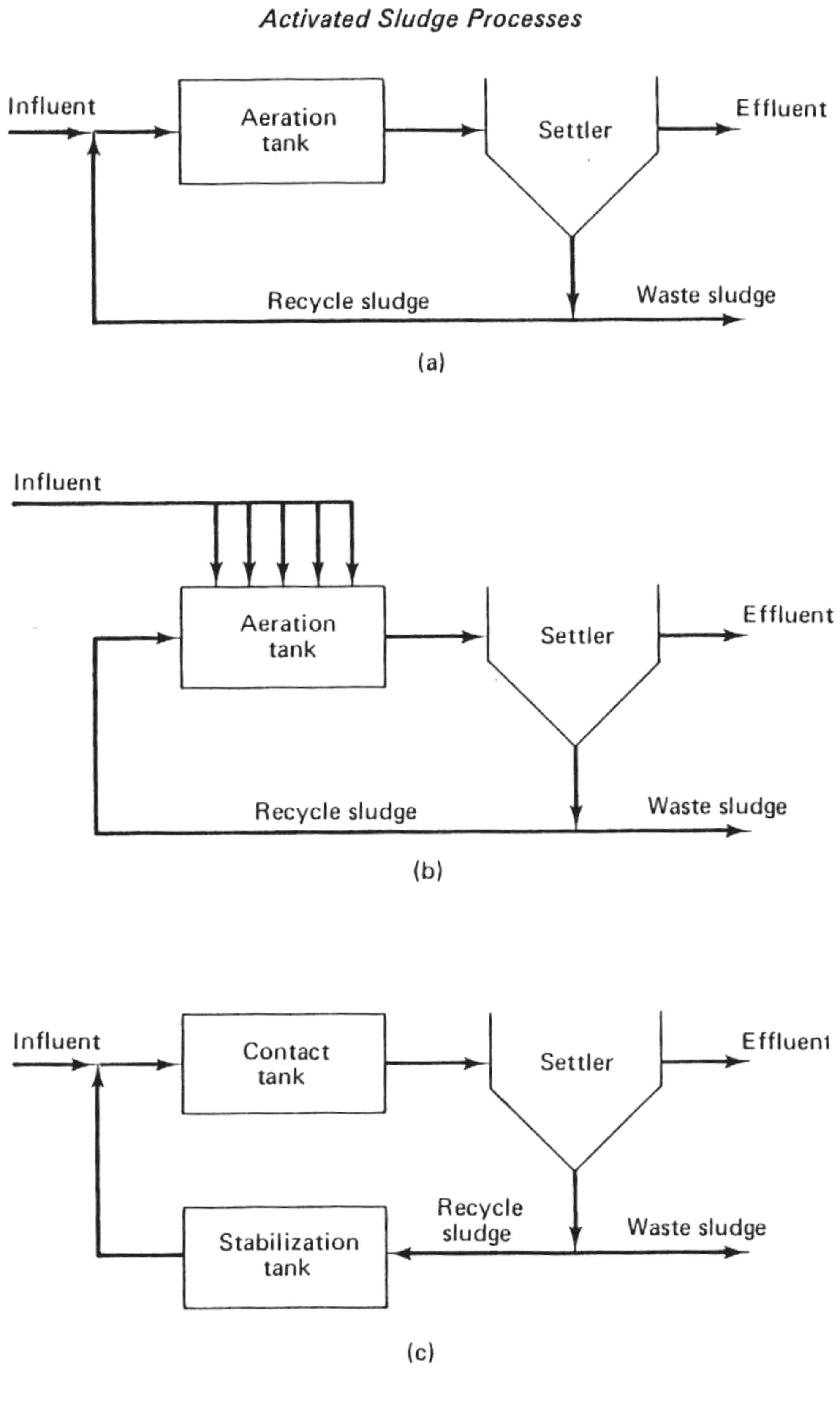


Figure (3-10): Activated Sludge variations:
(a) conventional; (b) step aeration; (c) contact stabilization

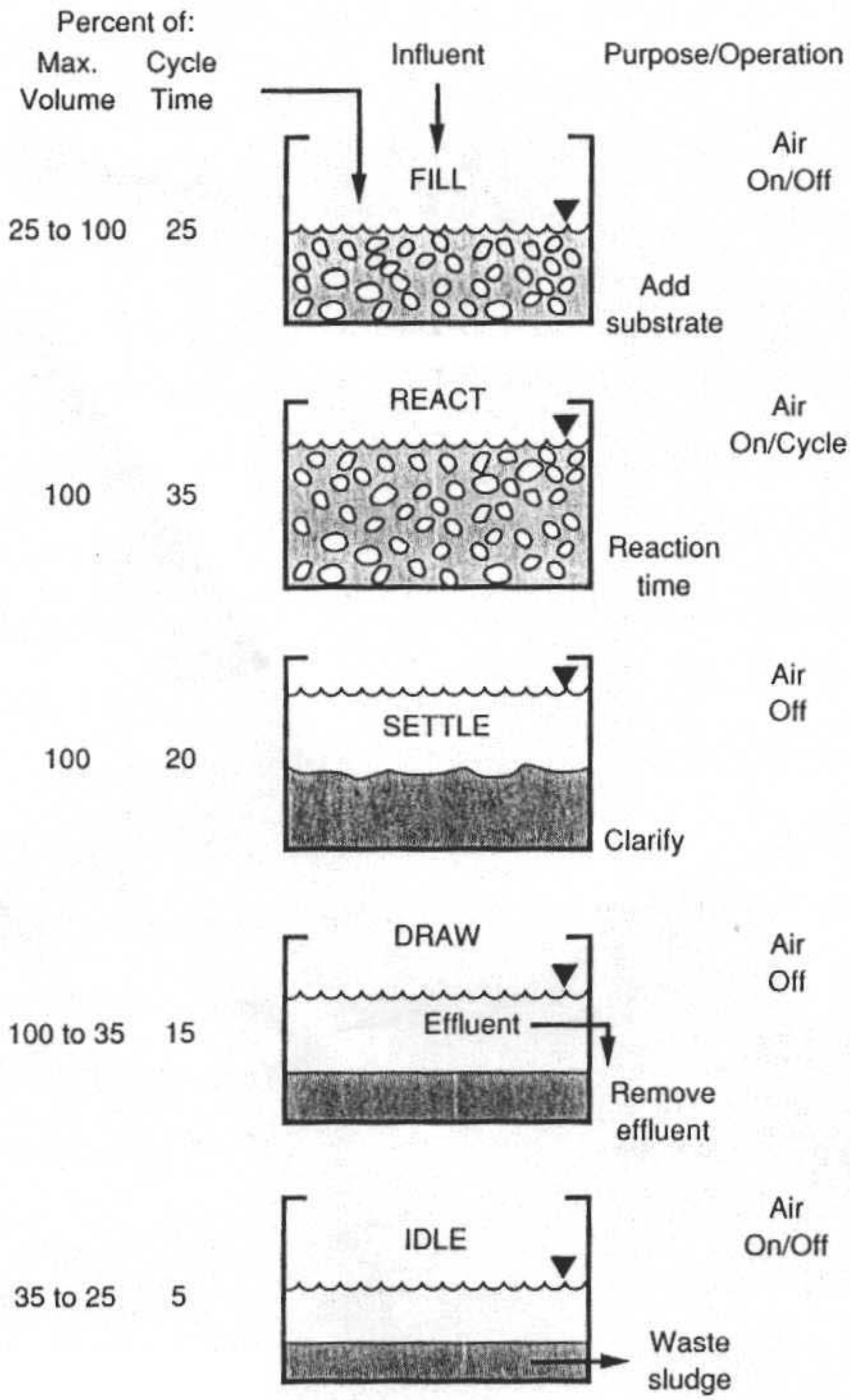


Figure (3-11): Typical operation sequence for a sequencing batch reactor.

Table (3-3) Description of the operation steps for the sequencing batch reactor

Operational Step	Description
Fill	The purpose of the fill operation is to add substrate (raw wastewater or primary effluent) to the reactor. The fill process typically allows the liquid level in the reactor to rise from 25 percent of capacity (at the end of idle) to 100 percent. If controlled by time, the fill process normally lasts approximately 25 percent of the full cycle time.
React	The purpose of react step is to complete the reactions that were initiated during fill. Typically, react takes up 35 percent of the total cycle time.
Settle	The purpose of settle is to allow solids separation to occur, providing a clarified supernatant to be discharged as effluent. In an SBR, this process is normally much more efficient than in a continuous flow system because in the settle mode the reactor contents are completely quiescent.
Draw	The purpose of draw is to remove clarified treated water from the reactor. Many types of decant mechanisms are in current use, with the most popular being floating or adjustable weirs. The time dedicated to draw can range from 5 to 30 percent of the total cycle time (15 minutes to 2 hours), with 45 minutes being a typical draw period.
Idle	The purpose of idle in a multi tank system is to provide time for one reactor to complete its fill cycle before switching to another unit. Because idle is not a necessary phase, it is sometimes omitted.

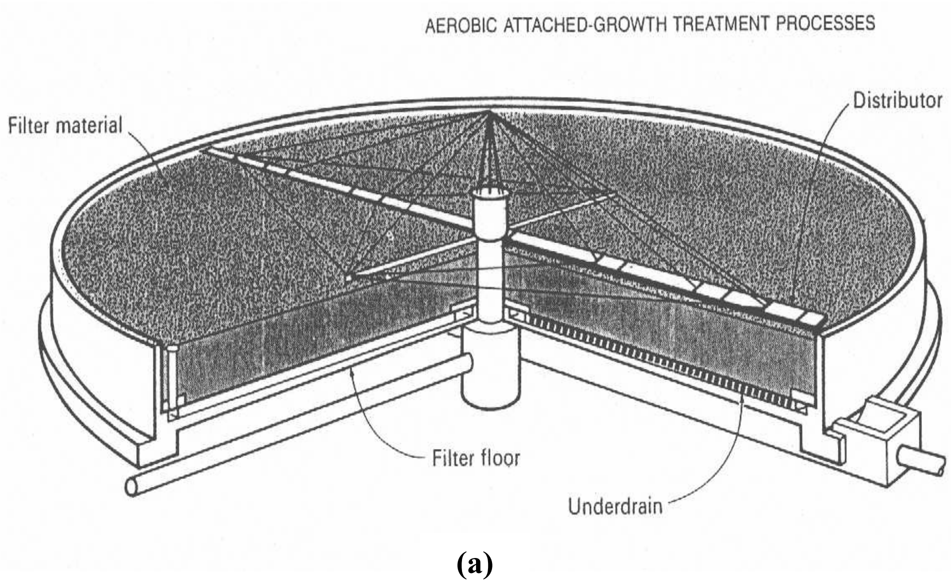
b) Aerobic Attached-Growth Treatment Processes

Aerobic attached-growth biological treatment processes are usually used to remove organic matter found in wastewater. They are also used to achieve nitrification. The attached – growth processes include the trickling filter, the roughing filter, rotating biological contactor, and fixed-film nitrification reactor.

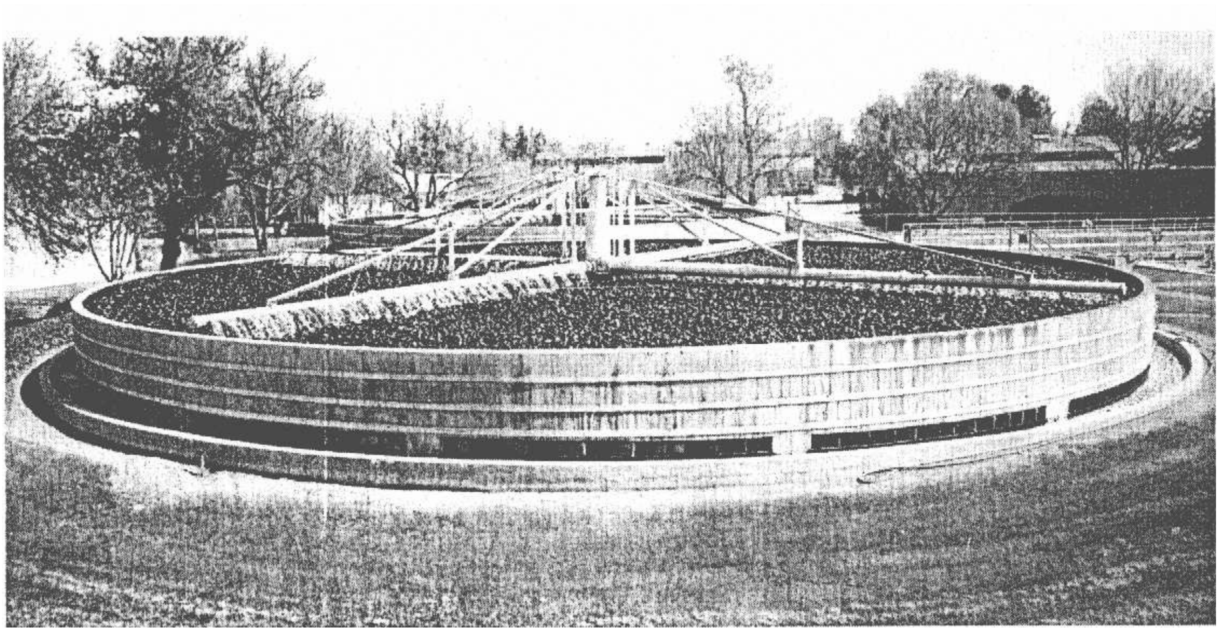
- **Trickling Filter " Biological Air Filters"**

The concept of a trickling filter grew from the use of contact filters, which were watertight basins filled with broken stones. In operation, the contact bed was filled with wastewater from the top, and the wastewater was allowed to contact the media for a short time. The bed was then drained and allowed to rest before the cycle was repeated. A typical cycle required 12 hours (6 hours for operation and 6 hours of resting). The limitations of the contact filter included a relatively high incidence of clogging, the long rest period required, and the relatively low loading that could be used.

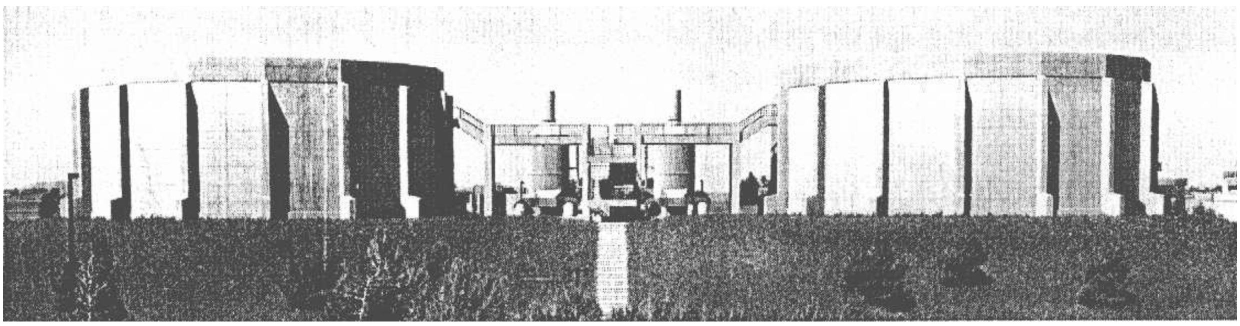
The modern trickling filter shown in figure (3-12) consists of a bed of a highly permeable medium to which microorganisms are attached and through which wastewater is percolated or trickled. The filter media usually consist of either rock (slag is also used) or a variety of plastic packing materials. In rock-filled trickling filters, the size of the rock typically varies from 1 to 4 in. (25 to 100 mm) in diameter. The depth of the rock varies with each particular design but usually ranges from 3 to 8 ft. (0.9 to 2.5 m) and average 6 ft. (1.8 m). Rock filter beds are usually circular and the liquid wastewater is distributed over the top of the bed by a rotary distributor.



(a)



(b)



(c)

Figure (3-12): Typical trickling filters:
(a) Cutaway view of a trickling filter
(b) Conventional rock-filled type
(c) Tower trickling filters

Trickling filters that use plastic media have been built in round, square, and other shapes with depths varying from 14 to 40 ft (4 to 12 m). Three types of plastic media are commonly used: vertical-flow packing, cross-flow packing, and a variety of random packing.

The collected liquid is passed to a settling tank where the solids are separated from the treated wastewater. In practice, portion of the liquid collected in the under-drain system or the settled effluent is recycled, usually to dilute the strength of the incoming wastewater and to maintain the biological slime layer in a moist condition.

➢ **Roughing Filters**

Roughing filters are specially designed trickling filters operated at high hydraulic loading rates. Roughing filters are used principally to reduce the organic loading on downstream processes and in seasonal nitrification applications where the purpose is to reduce the organic load so that a downstream biological process will dependably nitrify the wastewater during the summer months.

Although the earliest roughing filters were shallow stone media systems, the present trend is toward use of synthetic media or redwood at depths of 12 to 40 ft.

➢ **Packed-Bed Reactors**

Still another attached-growth process is the packed-bed reactor, used for both the removal of carbonaceous BOD_5 and nitrification. Typically, a packed-bed reactor consists of a container (reactor) that is packed with a medium to which the microorganisms can become attached. Wastewater is introduced from the bottom of the container through an appropriate under drain system or inlet chamber. Air or pure oxygen necessary for the process is also introduced with the wastewater.

In the past ten years a number of different anaerobic processes have been developed for the treatment of sludge and high-strength organic wastes. The most common anaerobic suspended-growth process used for the treatment of wastewater is complete-mix anaerobic digestion process.

3.4.2 Anaerobic Biological Treatment

The anaerobic process has been developed for the treatment of sludge and high strength organic load.

The disadvantage of the anaerobic treatment as compared to aerobic treatment is that the slow growth rates require a relatively long detention time in the digester for adequate waste stabilization to occur. On the other hand, most of the organic waste is converted to methane gas, which is combustible and therefore a useful end product. The high temperature necessary to achieve adequate treatment are often listed as disadvantages of the anaerobic treatment process; however, high temperatures are necessary only when sufficiently long mean cell-residence time cannot be obtained at nominal temperatures.

- **Anaerobic Contact Process**

Some industrial wastes that are high in BOD_5 can be stabilized very efficiently by anaerobic treatment. In the anaerobic contact process, untreated wastes are mixed with recycled sludge and then digested in a reactor sealed off from the entry of air. After digestion, the mixture is separated in a clarifier or vacuum flotation unit, and the supernatant is discharged as effluent, usually for further treatment. Settled anaerobic sludge is then recycled to seed the incoming wastewater.

3.4.3 Pond Treatment Processes

Ponds systems can be classified as (1) aerobic, (2) maturation, (3) facultative and (4) anaerobic with respect to the presence of oxygen. Among those, the most commonly process used in the Egyptian industry is the aerobic stabilization pond.

- **Aerobic Stabilization Ponds**

In their simplest form, aerobic stabilization ponds are large, shallow earthen basins that are used for the treatment of wastewater by natural processes involving the use of both algae and bacteria.

Tables (3-4) and (3-5) illustrate the main treatment technologies in Egypt, their advantages, typical risks and problems for each type and applicability in different industries in Egypt.

Table (3-4): Main Treatment Technologies: Advantages and Disadvantages

Treatment Method	Advantages	Typical Risks & Problems
Screening	Removes large suspended particles and consequently partially reduces pollution load. Flow homogenization	Blockage, overflows or odor problems could arise due to infrequent cleaning.
API & CPI separators	Simple design Handles larger capacity Minimum mechanical and electrical equipment requirements Low operation and maintenance cost	Large area requirement Limited to removal of free O&G
Flow Equalization	Reduced size and cost of downstream treatment facilities	Requires large area in case of high flow rate. Anaerobic condition if not aerated
Settling Basins	Easy to operate Steadiness of treatment operations (Reduced shock loads)	Improper control over sedimentation tanks may cause solids and BOD overloading problems. Fouling Large area requirement
Lamella separator	Higher separation efficiency Easy discharge of settled sludge Less area required	Cleaning problems
Coalescence	Small & compact Easy operation & maintenance Low cost	Limited capacity Partial removal of emulsified oil
DAF System	Removal of both free and emulsified oil Removal of both floating and settable solids Very small and light particles can be removed completely in short time.	High chemical consumption Relatively high sludge formation
Conventional Activated Sludge	Low land required No problems of flies	High-energy consumption Sludge bulking Requires very highly skilled professionals to operate

Treatment Method	Advantages	Typical Risks & Problems
Extended Aeration System	Sludge is partially digested within air tank. More resistance to incoming shock load	Retention time in final clarifier twice that of conventional system. Higher consumption of oxygen
Aerated Pounds	Good BOD removal	Higher sludge production High suspended solids in effluent
SBR	Higher efficiency Save on area as no separate clarifier is required Less sludge formation	High power consumption Failure if any problem occurs in the automatic control system
Trickling Filter	Low equipment and power cost Shock loading can be absorbed. Minimum sludge produce	Fly and odor nuisance Limited capacity pounding and clogging of filters
Bio tower	Minimum sludge formation Vertical design, less area required	Fly and odor nuisance Limited capacity Pounding and clogging of filters
Anaerobic Treatment	High organic pollution load Less sludge production	Biogas production Temperature required (30^oC) Very sensitive to shock load

Table (3-5): Main Treatment Technologies: Applicability in Egypt

Treatment Method	Applicability in Egypt
Screening	Food Industries (Edfina for Preserved Food Company) Textiles Industries (El-Nasr Wool and Selected Textile Company – STIA)
API & CPI separators	Amria Oil Refineries Suez Oil Refineries Sumed
Flow Equalization	Dairy Industries (Siclam for Dairy Products)
Settling Basins	Textile Industries (UNIRAB)
Lamella separator	Pharmaceutical Industries (The Nile Pharmaceutical Company)
Coalescence	In several Gas Stations
DAF System	Oil & Soap Industries (Tanta Oil & Soap Company). Food Industries (Edfina for Preserved Food Company)
Conventional Activated Sludge	Pharmaceutical Industries (Amreya Pharmaceutical Company)
Extended Aeration System	Pharmaceutical Industries (The Nile Pharmaceutical Company)
Aerated Pounds	Centralized unit for Borg-El-Arab Industrial estate
SBR	El-Misreyeen Dairy
Trickling Filter	Misr Rayon, Kafr-El-Dawar El-Nasr Spinning & Weaving, Mehalla
Bio tower	Carbon Black
Anaerobic Treatment	Starch & Yeast Industries

3.5 COMBINATIONS OF TECHNOLOGIES COMMONLY APPLIED IN EGYPT

3.5.1 Physical / Chemical Treatment

Due to the presence of high levels of suspended particles and high levels of oil & grease, preliminary physical treatment is carried out to reduce the pollution load prior to chemical treatment. The first treatment procedure is frequently a physical separation of insoluble or immiscible materials from the wastewater.

The industrial waste effluent is passed first through a suitable screen for debris removing and then transferred to the oil trap unit to remove free oil. Clarification may be used for removing turbidity, sediment and floating material and is usually the first step in treatment since these impurities are objectionable and interfere with any subsequent treatment. This step occurs before the balancing tank. The function of the balancing tank is to control fluctuation in wastewater characteristics.

In the chemical treatment, coagulant and flocculent chemicals are dosed and mechanically mixed to enhance solid coagulation flocks formation, to be separated in the primary clarifier tank.

DAF unit can be used as a physical /chemical treatment method to remove suspended matter and oil and grease. Organic pollution load can also be substantially reduced.

3.5.2 Chemical / Biological Treatment

Due to the high level of TDS or TSS and to minimize the load on the biological treatment plant, chemical treatment will be carried out to reduce the pollution load.

Sand, oil and grease and other toxic materials are not allowed to enter the biological treatment plant. Otherwise, they will poison and kill the useful microorganisms. Hence, reliable pretreatment shall promote sound performance for longer time.

From the point of view of industrial wastewater treatment, the preliminary & primary treatments are imported to allow biological treatment under steady conditions. The following measures are important prior to the biological step:

* Prevention of the introduction of toxic or inhibiting substances.
* Equalization of the wastewater inlet by buffering hydraulic or pollutant fluctuations possibly combined with aeration of the equalization basin.
* Previous separation of inorganic and organic sediments.
* Neutralization and buffering of pH fluctuations.

3.5.3 Anaerobic/aerobic Treatment

Anaerobic / aerobic treatment is used when:

- Organic load reaches a very high limit
- Organic load contains a large fraction of complex organic matter

In the anaerobic stage the removal efficiency reaches 75-80 % then the anaerobic effluent will flow to the aerobic treatment stage for consumption of the remaining organic matter. Excess aerobic biosolids are pumped to the aerobic sludge storage whereas excess anaerobic biosolids are pumped to the anaerobic sludge storage and then to the dewatering unit.

Anaerobic / aerobic treatment methods are very limited with regards to experience and know-how in Egypt but are very often found in Europe or America to treat industrial wastewater with a very good performance and with the high process stability which only a two step process can guarantee. The cycle operation of the anaerobic/aerobic system is shown in figure (3-13).

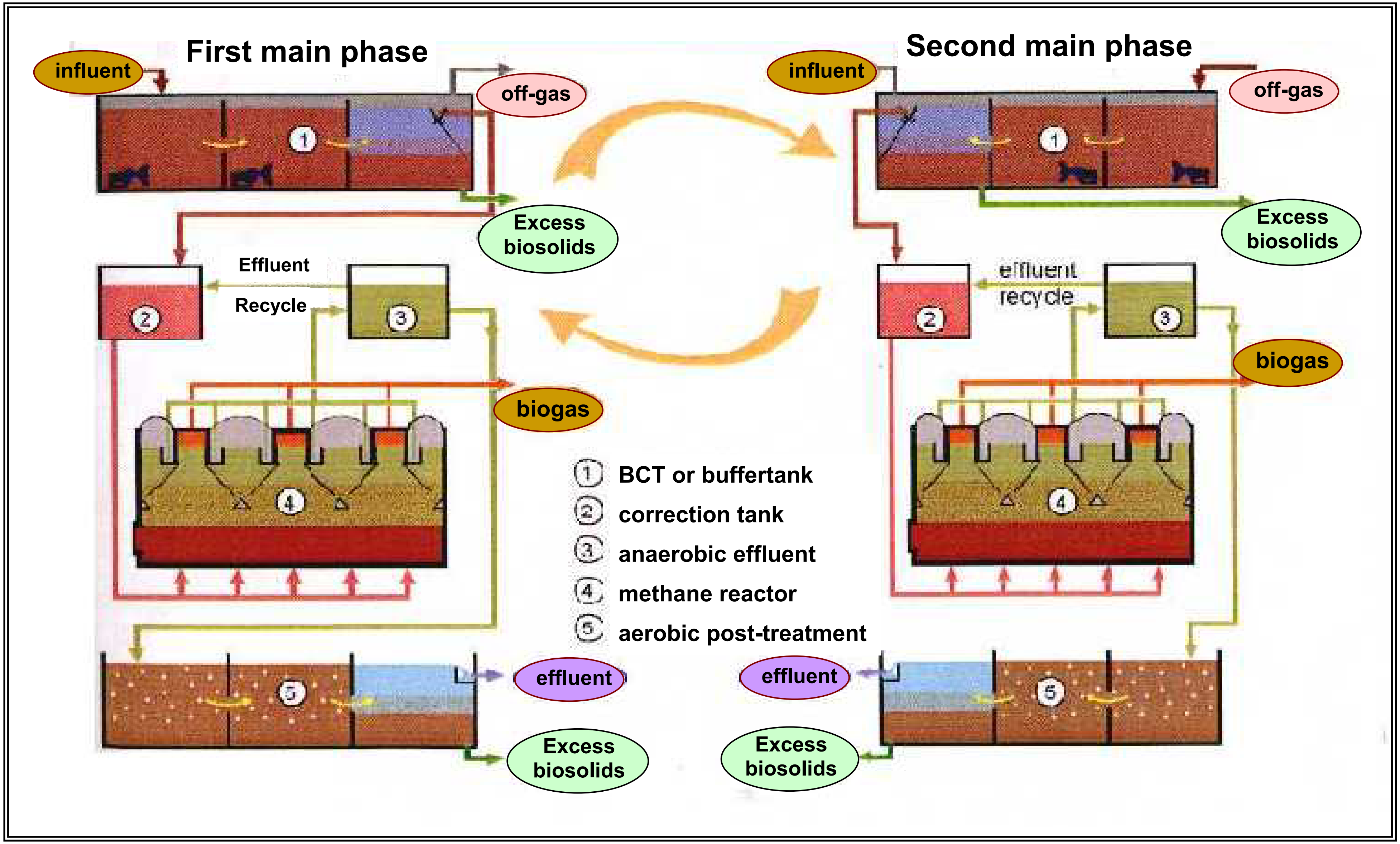


Figure (3-13): Two stage anaerobic/aerobic cyclic operation

3.6 SLUDGE TREAMENT AND DISPOSAL

The constituents removed in wastewater treatment plants include screenings, grit, scum, and sludge. The sludge resulting from wastewater treatment operations and processes is usually in the form of a liquid or semisolid liquid that typically contains from 0.25 to 12 percent solids by weight, depending on the operations and processes used. Sludge is by far the largest in volume, and its processing and disposal is perhaps the most complex problem facing the engineer in the filed of wastewater treatment.

The problems of dealing with sludge are complex because it is composed largely of the substances responsible for the offensive character of untreated wastewater. The portion of sludge produced from biological treatment requiring disposal is composed of the organic matter contained in the wastewater but in another form which can also decompose and become offensive; and only a small part of the sludge is solid matter.

Thickening (concentration), conditioning, dewatering, and drying are used primarily to remove moisture from sludge; digestion, composting, incineration, wet-air oxidation, and vertical tube reactors are used primarily to treat or stabilize the organic material in the sludge.

3.6.1 Preliminary Operations

Sludge grinding, degritting, blending, and storage are necessary to provide a relatively constant, homogenous feed to sludge-processing facilities. Blending and storage can be accomplished either in a single unit designed to do both or separately in other plant components.

a) Sludge Grinding
Sludge grinding is a process in which large and string material contained in sludge is cut or sheared into small particles to prevent the clogging of or wrapping around rotating equipment.

b) Sludge Degritting
In some plants where separate grit removal facilities are not used ahead of the primary sedimentation tanks or where the grit removal facilities are not adequate to handle peak flows and peak grit loads, it may be necessary to remove the grit before further processing of the sludge. Where further thickening of the primary sludge is desired, a practical consideration is sludge degritting. The most effective method of degritting sludge is through the application of centrifugal forces in a flowing system to achieve separation of the grit particles from the organic sludge. Such separation is achieved through the use of cyclone degritters, which have no moving parts.

c) Sludge Blending
Sludge is blended to produce a uniform mixture to downstream operations and processes. Uniform mixture is most important in short detention time systems, such as sludge dewatering, heat treatment, and incineration. Provision of a well-blended sludge with consistent characteristics to these treatment units will greatly enhance plant operability and performance.
Sludge from primary, secondary, and advanced processes can be blended in several ways:

- In primary settling tanks
- In pipes
- In sludge processing facilities with long detention times
- In a separate blending tank

Blending tanks are usually equipped with mechanical mixers and baffles to ensure good mixing.

d) Sludge Storage

Sludge storage must be provided to smooth out fluctuations in the rate of sludge production and to allow sludge to accumulate during periods when subsequent sludge processing facilities are not operating. Sludge storage is particularly important in providing a uniform feed rate ahead of the following processes: lime stabilization, heat treatment, mechanical dewatering, drying, and thermal reduction.

In small installations, sludge is usually stored in the settling tanks and digesters. In large installations that do not use aerobic and anaerobic digestion, sludge is often stored in separate blending and storage tanks. Such tanks may be sized to retain the sludge for a period of several hours to a few days. If sludge is stored longer than two or three days, it will deteriorate and will be more difficult to dewater.

3.6.2 Sludge Thickening

Thickening is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction. Thickening is generally accomplished by physical means, including gravity and flotation thickening. The gravity thickening is extensively used while the flotation method is not commonly used.

- **Gravity Thickening**

Gravity thickening is accomplished in a tank similar in design to a conventional sedimentation tank. Normally, a circular tank is used. The supernatant flow that results is returned to the primary settling tank or to the head works of the treatment plant. The thickened sludge that collects on the bottom of the tank is pumped to the digesters or dewatering equipment as required. Gravity thickening is most effective on primary sludge.

3.6.3 Sludge Stabilization

Sludge is stabilized to (1) reduce pathogens, (2) eliminate offensive odors, and (3) inhibit, reduce, or eliminate the potential for putrefaction.

The technologies for sludge stabilization are (1) lime stabilization (2) heat treatment (3) anaerobic digestion, and (4) aerobic digestion. Lime stabilization is used in Egypt while the other methods are not commonly used.

- **Lime Stabilization**

In the lime stabilization process, lime is added to untreated sludge in sufficient quantity to raise the pH to 12 or higher. Two methods for lime stabilization used are addition of lime to sludge prior to dewatering, termed “lime pre-treatment” and the addition of lime to sludge after dewatering, or “lime post-treatment”. Either hydrated lime, $Ca(OH)_2$, or quicklime, CaO, may be used for lime stabilization. Fly ash, cement kiln dust, and carbide lime have also been used as a substitute for lime in some cases.

Post-lime stabilization has several significant advantages when compared to pre-lime stabilization: (1) dry lime can be used: therefore, no additional water is added to the dewatered sludge; (2) there are no special requirements for dewatering; and (3) scaling problems and associated maintenance problems of lime sludge dewatering equipment are eliminated.

3.6.4 Sludge Dewatering

Dewatering is a physical (mechanical) unit operation used to reduce the moisture content of sludge. Sludge dewatering is commonly combined with a chemical treatment step (sludge conditioning) to improve its characteristics.

- **Chemical Conditioning**

The use of chemicals to condition sludge for dewatering is economical because of the increased yields and greater flexibility obtained. Chemical conditioning can reduce the 90 to 99 percent incoming sludge moisture content to 65 to 85 percent, depending on the nature of the solids to be treated. Conditioning is used in advance of mechanical dewatering systems such as vacuum filtration, centrifugation, belt filter presses, and pressure filter presses. Chemicals used include ferric chloride, lime, alum, and organic polymers.

Adding conditioning chemicals to sludge may increase the amount of dry solids. Polymers do not increase the dry solids content significantly, whereas iron salts and lime can increase the dry solids content by 20 to 30 percent.

Chemicals are most easily applied and metered in the liquid form. Dissolving tanks are needed if the chemicals are received as powder. In most plants, these tanks should be large enough for at least one day's supply of chemicals and should be furnished in duplicate. The tanks must be fabricated or lined with corrosion resistant material. Polyvinyl chloride, polyethylene, and rubber are suitable materials for tank and pipe lining for acid solutions. Metering pumps must be corrosion resistant. These pumps are generally of the positive displacement type with variable-speed or variable-stroke drives to control the flow rate.

Polymers are used commonly in centrifuge and belt press dewatering but are used less frequently for vacuum and pressure filtration.

Ferric chloride and lime are two of the chemicals used most commonly to condition sludge for vacuum filter dewatering.

Intimate admixing of sludge and coagulant is essential for proper conditioning. The mixing must not break the floc after it has formed, and detention should be kept to a minimum so that sludge reaches the dewatering unit as soon after conditioning as possible.

- **Mechanical Dewatering**

Available dewatering processes include centrifuges, belt filter presses, recessed plate filter presses, drying beds, and lagoons.

– **Centrifugation**

For separating liquids of different density, thickening slurries, or removing solids, the centrifugation process is widely used in industry. The centrifugal devices used for thickening sludge are solid bowl and imperforated basket centrifuges.

- **Solid Bowl Centrifuge**

In the solid bowl machine, sludge is fed at a constant flow rate into the rotating bowl, where it separates into a dense cake containing the solids and a dilute stream called "centrate". The centrate contains fine, low-density solids and is returned to the wastewater treatment system. The sludge cake, which contains approximately 70 to 80 percent moisture, is discharged from the bowl by a screw feeder into a hopper or onto a conveyor belt.

Solid bowl centrifuges are suitable generally for a variety of sludge dewatering applications. The units can be used to dewater sludge with no prior chemical conditioning, but the solids capture and centrate quality are improved considerably when solids are conditioned with polymers.

▪ **Imperforated Basket Centrifuge**

Imperforated basket centrifuges are particularly suitable for small plants. Basket centrifuges can be used to concentrate and dewater waste activated sludge, with no chemical conditioning at solids capture rates up to 90 percent.

After the centrifuge is filled with solids, the unit starts to decelerate. In the dewatering mode, a "skimming" step takes place before the initiation of plowing. Skimming is the removal of soft sludge from the inner wall of sludge in the basket. The Skimming volume is normally 5 to 15 percent of the bowl volume. The skimming stream is returned to the wastewater treatment system.

– **Belt Press**

Belt filter presses are continuous-feed sludge-dewatering devices that involve the application of chemical conditioning, gravity drainage, and mechanically applied pressure to dewater sludge. In most belt filter presses, conditioned sludge is first introduced on a gravity drainage section where it is allowed to thicken. In this section, a majority of the free water is removed from the sludge by gravity. On some units, this section is provided with a vacuum assist, which enhance drainage and may help to reduce odors. Following gravity drainage, pressure is applied in a low-pressure section and followed by a high-pressure section, where the sludge is subjected to shearing forces as the belts pass through a series of rollers. The squeezing and shearing forces thus induce the release of additional quantities of water from the sludge. The final dewatered sludge cake is removed from the belts by scraper blades as shown in figure (3-14).

A typical belt filter press system consists of sludge-feed pumps, polymer-feed equipment, a sludge-conditioning tank (flocculator), a belt filter press, a sludge cake conveyor, and support systems (sludge-feed pumps, wash water pumps, and compressed air).

– **Filter Press**

In a filter press, dewatering is achieved by forcing the water from the sludge under high pressure, as shown in figure (3-15). Advantages cited for the filter press include high concentrations of cake solids, filtrate clarity, and high solids capture. Disadvantages include mechanical complexity, high chemical costs, high labor costs, and limitation on filter cloth life. Various types of filter presses have been used to dewater sludge. The two types used most commonly are the fixed-volume and variable-volume recessed plate filter presses.

▪ **Fixed-Volume, Recessed Plate Filter Press**

The fixed-volume, recessed plate filter press consists of a series of rectangular plates, recessed on both sides, that are supported face to face in a vertical position on a frame with a fixed and movable head. A filter cloth is hung or fitted over each plate. The plates are held together with sufficient force to seal them so as withstand pressure applied during the filtration process.

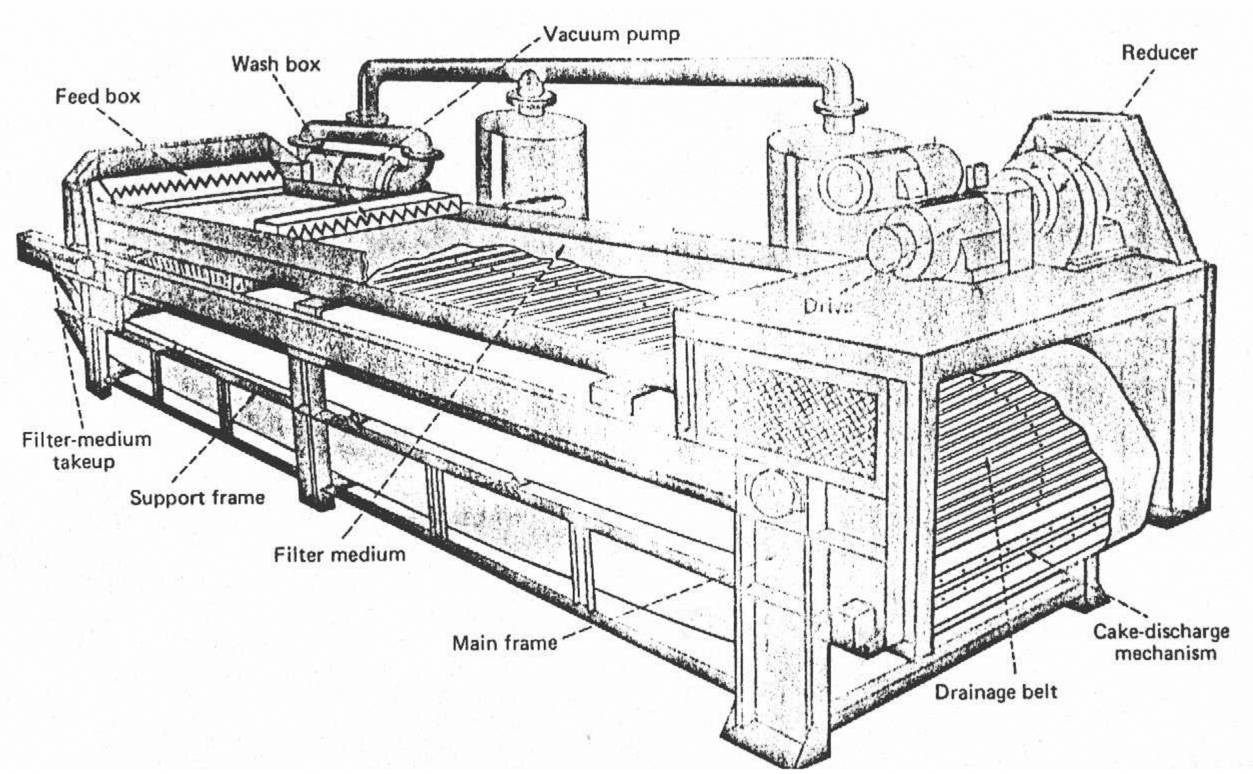


Figure (3-14): Horizontal-belt filter press

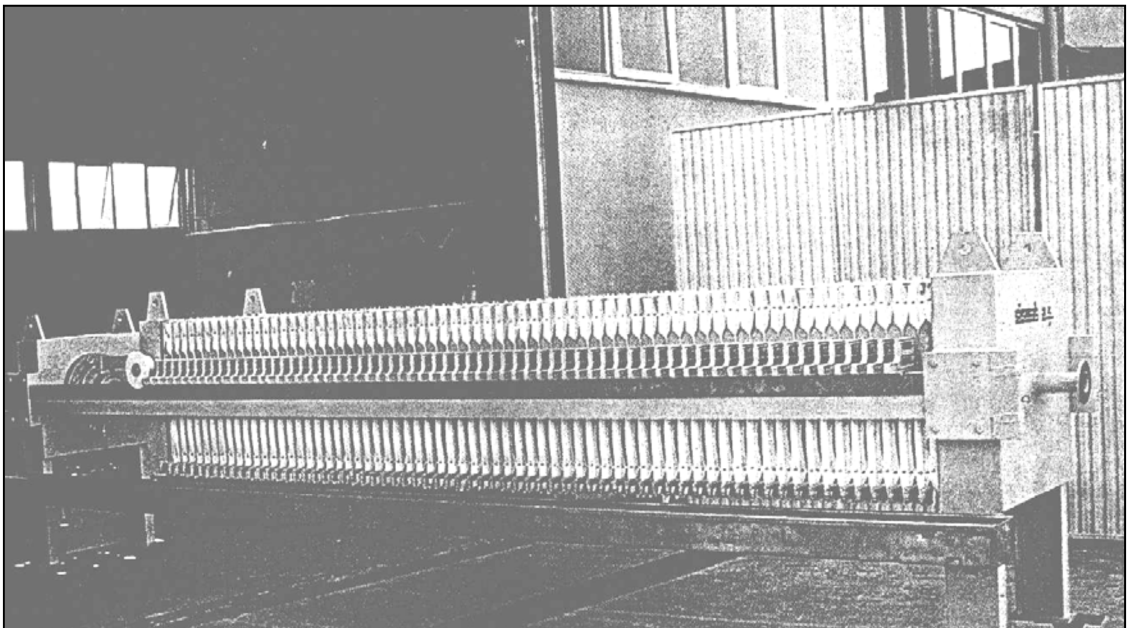


Figure (3-15): Filter press

In operation, chemically conditioned sludge is pumped into the space between the plates, and pressure of 100 to 225 1bf/in^2 (690 to 150 kN/m^2) is applied and maintained for 1 to 3 hrs, forcing the liquid through the filter cloth and plate outlet ports. The plates are then separated and the sludge is removed. The filtrate is normally returned to the head works of the treatment plant. The sludge cake thickness varies from about 1 to 1.5 in (25 to 38 mm), and the moisture content varies from 48 to 70 percent. The filtration cycle time varies from 2 to 5 hrs and includes the time required to (1) fill the press, (2) maintain the press under pressure, (3) open the press, (4) wash and discharge the cake, and (5) close the press.

- **Variable-Volume, Recessed Plate Filter Press**

Another type of filter press used for wastewater sludge dewatering is the variable-volume recessed plate filter press, commonly called the “diaphragm press”. This type of filter press is similar to the fixed-volume press except that a rubber diaphragm is placed behind the filter media. The rubber diaphragm expands to achieve the final squeeze pressure, thus reducing the cake volume during the compression step.

– **Sludge Drying Beds**

Sludge drying beds are typically used to dewater digested sludge. After drying, the sludge is removed and either disposed of in a landfill or used as a soil conditioner.

The principal advantages of drying beds are low cost, infrequent attention required, and high solids content in the dried product. Four types of drying beds are used: (1) conventional sand, (2) paved, (3) artificial media, and (4) vacuum-assisted. Conventional sand drying beds are most extensively used.

- **Conventional Sand Drying Beds**

Conventional sand drying beds are generally used for small and medium-sized industries. In a typical sand drying bed, sludge is placed on the bed in a 8 to 12 in (200 to 300 mm) layer and allowed to dry. Sludge is dewatered by drainage through the sludge mass and supporting sand and by evaporation from the surface exposed to the air. Most of the water leaves the sludge by drainage; thus the provision of an adequate under drainage system is essential. Drying beds are equipped with lateral drainage lines.

The drainage lines should be adequately supported and covered with coarse gravel or crushed stone. The sand layer should be from 9 to 12 in (230 to 300 mm) deep with an allowance for some loss from cleaning operations.

The moisture content is approximately 60 percent after 10 to 15 days under favorable conditions. Sludge removal is accomplished by manual shoveling into wheelbarrows or trucks or by a scraper or front-end loader. Provisions should be made for driving a truck onto or alongside of the bed to facilitate loading.

Open beds are used where adequate area is available and is sufficiently isolated to avoid complaints caused by occasional odors. Open sludge beds should be located at least 300 ft (about 100m) from dwellings to avoid odor nuisance. Covered beds with greenhouse types of enclosures are used where it is necessary to dewater sludge continuously throughout the year regardless of the weather and where sufficient isolation does not exist for the installation of open beds.

– **Lagoons**

Drying lagoons may be used as a substitute for drying beds for the dewatering of digested sludge. Lagoons are not suitable for dewatering untreated sludge, limed sludge, or sludge with a high-strength supernatant because of their odor and nuisance potential.

Dewatering by subsurface drainage and percolation is limited by increasingly stringent environmental and groundwater regulations. If a groundwater aquifer used for a potable water supply underlies the lagoon site, it may be necessary to line the lagoon or otherwise restrict significant percolation. Sludge depths usually range from 2.5 to 4 ft (0.75 to 1.25 m). Evaporation is the prime mechanism for dewatering. Facilities for the decanting of supernatant are usually provided, and the liquid is recycled to the treatment facility. Sludge is removed mechanically, usually at a solids content of 25 to 30 percent. The cycle time for lagoons varies from several months to several years. A minimum of two cells is essential, even in very small plants, to ensure availability of storage space during cleaning, maintenance or emergency conditions.

3.6.5 Sludge Disposal and Uitilization

a) Beneficial Uses of Sludge

The fertilizer value of biological sludge, which should be evaluated where the sludge is to be used as a soil conditioner, is based primary on the content of nitrogen, phosphorus, and potassium.

Trace elements in sludge are those inorganic chemical elements that, in very small quantities, can be essential or detrimental to plants and animals. The term "heavy metals" is used to denote several of the trace elements present in sludge. For land application of sludge, concentrations of heavy metals may limit the sludge application rate and the useful life of the application site.

Sludge may also be treated chemically. Chemical fixation/solidification has been applied to the treatment of industrial sludge and hazardous wastes to immobilize the undesirable constituents for use of sludge as landfill cover and for land reclamation projects. Stabilized sludge may also be disposed of in landfills. The chemical fixation process consists of mixing untreated or treated liquid or dewatered sludge with stabilizing agents such as cement, sodium silicate, pozzolan and lime so as to chemically react with or encapsulate the sludge. For many chemical treatment processes, the product is similar in consistency to natural clay.

b) Sludge Disposal

Final disposal for the sludge and solids that are not beneficially used usually involves some form of land disposal. In addition to spreading sludge on land, other methods of final disposal include landfilling and lagooning.

➢ **Landfilling**

There are two types of landfills for industrial sludge: those which accept non-hazardous wastes and those that accept hazardous wastes.

Landfills are designed to prevent the contamination of ground water and to prevent the migration of the wastes from the landfill. For this reason, landfills usually have thick, 3 to 10 feet covers of clean impermeable clay or dirt on top. The cover is designed to shed water from the landfill and to prevent penetration of the landfill contents by rainwater. In some cases, plastic barriers are embedded in the cover for this purpose also.

Landfill bottom and sides are also made of impermeable clays or dirt. The sump collects leachate from the landfill and is pumped to a wastewater treatment plant.

Hazardous landfills must meet very stringent requirements. The bottoms and sides must be double contained, which is usually accomplished by installing two liquid barriers, usually plastic. Liquid is collected from the space between the barriers in a leachate collection system and is properly disposed of. The top of a hazardous waste landfill must be impermeable, which is usually accomplished by installing a plastic water barrier in the dirt cover.

Landfills have been known to catch fire; fires in landfills can be very difficult to control and contain. Therefore, landfills are filled in sections (cells) isolated by dirt barriers to prevent fire.

Landfill operations must control blowing materials, and this is usually done with fences. Proper records must be kept to ensure no hazardous material are put into non -hazardous landfills, and there are numerous legal requirements for record keeping for hazardous landfills. Landfills should be surrounded by a strong industrial-type fence to keep people and animals out. Landfills can be dangerous places for those not aware of the dangers. Storm water runoff from landfill requires control measures.

- **Lagooning**

A lagoon is an earth basin into which untreated or digested sludge is deposited. In untreated sludge lagoons, the organic solids are stabilized by anaerobic and aerobic decomposition, which may give rise to objectionable odors. The stabilized solids settle to the bottom of the lagoon and accumulate. Excess liquid from the lagoon, if any, is returned to the plant for treatment. Lagoons should be located away from highways and dwellings to minimize possible nuisance conditions and should be fenced to keep out unauthorized persons.

3.7 AUXILIARY OPERATIONS

3.7.1 Disinfection

Disinfection refers to the selective destruction of disease-causing organisms. All the organisms are not destroyed during the process. This differentiates disinfection from sterilization, which is the destruction of all organisms. Disinfection is most commonly accomplished by the use of the following agents:

1. Chemical Agents
2. Physical Agents
3. Radiation

a) Chemical Agents

Chemical agents that have been used as disinfectants include chlorine and its compounds, bromine, iodine, ozone, phenol and phenolic compounds, alcohols, heavy metals and related compounds, dyes, soaps and synthetic detergents, quaternary ammonium compounds, hydrogen peroxide and various alkalies and acids. Of these, the most common disinfectants are the oxidizing chemicals where chlorine is the one most universally used. Bromine and iodine occasionally are used for swimming pool water but have not been used for treated wastewater. Ozone is a highly effective disinfectant, and its use is increasing even though it leaves no residual. Highly acid or alkaline water can also be used to destroy pathogenic bacteria, because water with a pH greater than 11 or less than 3 is relatively toxic to most bacteria.

b) Physical Agents
Physical disinfectants that can be used are heat and light. Heating water to the boiling point, for example, will destroy the major disease-producing non-spore forming bacteria. Heat is commonly used in the beverage and dairy industry, but it is not a feasible means of disinfecting large quantities of wastewater because of the high cost. However, pasteurization of sludge is used extensively in Europe.

Sunlight is also a good disinfectant. In particular, ultraviolet radiation can be used. Special lamps that emit ultraviolet rays have been used successfully to sterilize small quantities of water. The efficiency of the process depends on the penetration of the rays into water. The contact geometry between the ultraviolet-light source and the water is extremely important, because suspended matter, dissolved organic molecules, and water itself will absorb the radiation, in addition to the microorganisms. It is therefore difficult to use ultraviolet radiation in aqueous systems, especially when particulate matter is present.

c) Radiation
The major types of radiation are electromagnetic, acoustic, and particle. Gamma rays are emitted from radioisotopes, such as cobalt 60. Because of their penetration power, gamma rays have been used to disinfect (sterilize) both water and wastewater.

Mechanisms of Disinfectants
These are four mechanisms that have been proposed to explain the action of disinfectants: (1) damage to the cell wall, (2) alteration of cell permeability, (3) alteration after colloidal nature of the protoplasm, and (4) inhibition of enzyme activity. Damage or destruction of the cell wall will result in cell lysis or death. Same agents, such as penicillin, inhibit the synthesis of the bacterial cell wall. Agents such as phenolic compounds and detergents alter the permeability of the cytoplasmic membrane. These substances destroy the selective permeability of the membrane and allow vital nutrients, such as nitrogen and phosphorus.

Heat radiation, and highly acid or alkaline agents alter the colloidal nature of the protoplasm. Heat will coagulate the cell protein and acids or bases will produce a lethal effect.

3.7.2 Reuse of Treated Effluent

Reuse of treated wastewater in various industries is becoming very popular being a cheaper source of water supply where the industrial plant can reuse its own wastewater through recycling or after treatment or it can be used for irrigation. There are many possibilities that some of hazardous and toxic chemicals may pass to the treated effluents. In order to eliminate health hazards several advanced methods of tertiary treatment for industrial effluents with disinfection are available world wide to meet the standards for effluent reuse for several purposes. However, the following techniques are the ones commonly applied for water reuse in Egypt.

Advanced Treatment Techniques "Tertiary Treatment"

a) Filtration
Filtration devices include cartridge filters, diatomaceous earth filters, and granular-media filters. Cartridge filters are rarely used in wastewater treatment for economic reasons.

- **Granular Media Filters**

Granular media filters are widely used in wastewater treatment for the removal of both organic and inorganic suspended solids. Granular media filters can operate either by gravity flow (gravity filters) or by pressure (pressure filters). Both down flow and up flow filters are used by industry.

The most common types of filters are two and three media filters. A common design for a two media filter would have a bed of 0.5 mm sand layer below a 0.9 mm anthracite layer. A common design for a three-media filter would have a 30 to 40 mesh garnet layer below the sand layer. Specialty filters could use different media with different effective sizes.

Solids are captured by the bed and eventually have to be removed by scouring and backwashing.

- **Carbon Adsorption**

Carbon adsorption is used to remove certain types of organic contaminants that are resistant to primary and secondary treatment when such removal is required. These include contaminants that are toxic, and contaminants that are resistant to biological treatment, but require a higher degree of removal. There are some cases where an organic stream contains contaminants that are valuable enough to recover with carbon adsorption.

Another use of carbon columns is to remove Volatile Organic Compounds (VOCs) from wastewater. All VOCs can be adsorbed onto activated carbon to a greater or lesser extent. Some companies provide carbon columns and remove them when spent and recharge them in their own facility. This is cost effective for small streams, but not for large streams. Spent carbon from the columns may be disposed of; however it is usually classified as a hazardous waste that makes disposal expensive. Carbon can be regenerated by passing a stream of steam through it or by removing it and heating in a furnace. In both, a stream of VOC containing steam or off-gas is produced which must be properly disposed of. Condensing the steam and either burning the condensate in a furnace or sending it to a hazardous waste disposal company (if hazardous) would be the usual methods of disposal.

Activated carbon can be regenerated with steam, heat, solvent wash, acid or caustic wash, or using a wet oxidation regenerator.

Adsorbability can be described by the following general list, which shows the most adsorbable type of compound on top and least adsorbable:

* Organic Acids
* Aldehydes
* Esters
* Ketones
* Alcohols
* Glycols

Filtration system “granular media and carbon adsorption” followed by desinfection are in use in some industries in Egypt for water reuse in irrigation.

b) Membrane Separation

Membrane separation techniques are used to remove very fine particles from water, to desalinate water, and recently, membranes have been developed to remove organics from water, such as oil and other organics that have clogged and degraded membranes in the past. Membranes are made of various materials but all have a consistent pore size that will permit particles or molecules of a given size to pass through the membrane and will prevent molecules or particles of a size larger then the pore size from passing through. Basically, membranes are filters that present a physical barrier of a definite and specific pore size.

- **Ultrafiltration**

Ultrafiltration utilizes membranes that are sized to remove a given particle size and larger, as required. The particles removed usually have a molecular weight in the ranger of 500 to 1000. The feed is the wastewater stream, the permeate is the filtered wastewater, and the bleed would contain the concentrated solids. Ultrafiltration is generally preceded by conventional filters or cartridge filters to prevent blinding of the membranes. The membranes must be cleaned and back flushed periodically. A gel layer can form on the membrane that further increases resistance to flow.

There are three manufacturing processes for membranes, namely the phase inversion process, the track-etched membrane, and the anopore inorganic (anodized aluminum) membrane.

An interesting variant of ultrafiltration is a system that uses a backwash preceded by an air wash. This system is less likely to clog and is used as tertiary treatment for wastewater and to replace clarifiers in water treatment where clarifiers cannot remove sufficient turbidity. Microfilters normally have a reject rate of 10%, but the 10% can be further filtered so that only 1% of the water is lost as reject.

- **Reverse Osmosis (RO) System**

A great deal of technology has been developed to minimize the flow resistance of the membrane by making it as thin as possible.

Industrially, valuable products can be recovered from a wastewater stream by using membranes of different pore sizes. For example, in cheese production the liquid whey fraction, which is left when the milk is coagulated to produce the cheese, is 93% water. Since the whey has a BOD_5 of > 30,000 mg/l, municipal sewage treatment systems have difficulty handling this waste. However, if the whey is passed over a RO unit, the proteins are concentrated while the lactose and other components and most of water pass through the membrane. The permeate is passed to a second membrane where the water is removed as permeate with BOD_5 below 1000 mg/l and the concentrate is an enriched lactose solution.

There are three types of membrane systems in the market today:

* Tubular Membrane System
* Spiral Wound Membrane Systems
* Hollow Fine Fiber Membrane System

Reverse Osmosis systems can be used to concentrate heavy metals or other salts, and to recover diluted solutions of chemicals. It is also used as a pretreatment step prior to ion exchange to improve the efficiency of the ion exchange process by concentrating the wastewater stream.

3.8 INTEGRATED MODEL FOR INDUSTRIAL WASTEWATER TREATMENT

All treatment technologies described earlier under sections 3.1 – 3.7 can be used to develop a model for sequential treatment of industrial wastewater which can be described as follows and shown in figure (3-16).

3.8.1 Primary Treatment

As industrial wastewater enters a plant for treatment, it flows through a screen, which removes large objects such as rags and sticks that might clog pipes or damage equipment. After screening, it passes into a grit chamber, where cinders, sand and small stones settle to the bottom.

Sedimentation is currently the most widely used primary treatment operation. In a sedimentation unit, solid particles are allowed to settle to the bottom of a tank under quiescent conditions. Chemicals may be added in primary treatment to neutralize the stream or to improve the removal of small-suspended solid particles. Primary reduction of solids reduces oxygen requirements in a subsequent biological step and also reduces the solids loading to the secondary sedimentation tank. After screening is completed and grit has been removed, sewage still contains organic and inorganic matter along with other suspended solids. These solids are minute particles that can be removed from wastewater in a sedimentation tank.

Primary treatment alone has proved to meet some industries demands for higher water quality in order to comply with environmental regulations for effluent discharge to various water bodies.

3.8.2 Secondary Treatment

Secondary treatment generally involves a biological process to remove organic matter through biochemical oxidation. The particular biological process selected depends upon such factors as quantity of wastewater, biodegradability of waste and availability of land. The principal secondary treatment techniques used are the activated sludge process and the trickling filter.

In the activated sludge process, wastewater is fed to an aerated tank where microorganisms consume organic wastes for maintenance and for generation of new cells. The resulting microbial floc (activated sludge) is settled in a sedimentation vessel called a clarifier or thickener. A portion of the thickened biomass is usually recycled to the reactor to improve performance through higher cell concentrations.

Trickling filters (bio-filters) are beds packed with rocks, plastic structures, or other media. Microbial films grow on the surface of the packing and remove soluble organics from the wastewater flowing over the packing. Excess biological growth washes off the packing and is removed in a clarifier.

The trend today is towards the use of the activated sludge process instead of trickling filters. The activated sludge process speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with wastewater. After the wastewater leaves the settling tank in the primary stage, it is pumped into an aeration tank, where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, bacteria break down organic matter into harmless by-products. The sludge, now activated with additional billions of bacteria and other tiny organisms, can be used again by returning it to the aeration tank for mixing with air and new wastewater. From the aeration tank, the partially treated wastewater flows to another sedimentation tank for removal of excess bacteria.

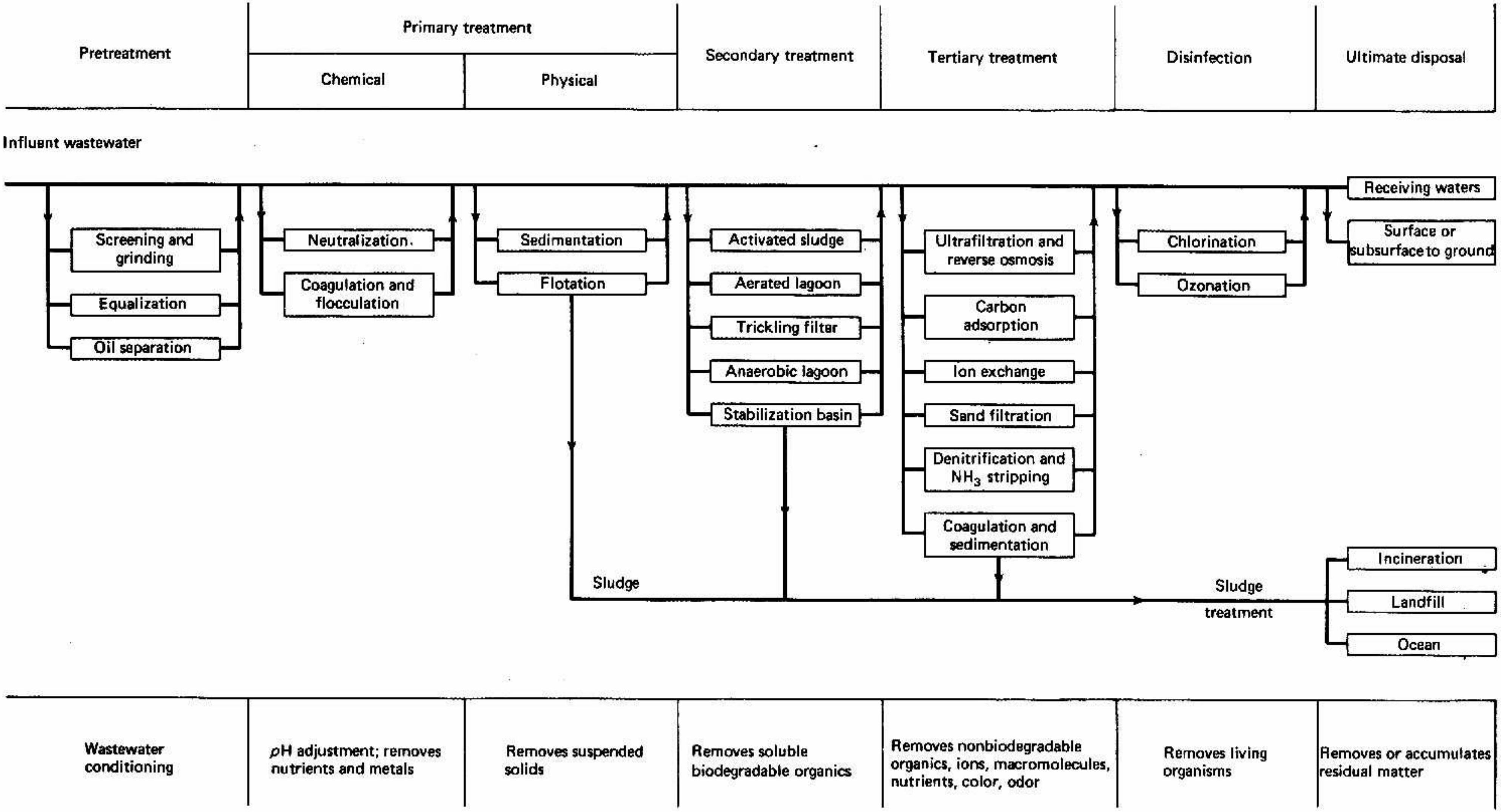


Figure (3-16): Possible Choices for Wastewater Treatment Technologies and their Sequences

3.8.3 Tertiary Treatment

Many industrial effluent standards require tertiary or advanced wastewater treatment to remove particular contaminants or to prepare the water for reuse. Some common tertiary operations are removal of phosphorus compounds by coagulation with chemicals, removal of nitrogen compounds by ammonia stripping with air or by nitrification - denitrification in biological reactors, removal of residual organic and color compounds by adsorption on activated carbon and removal of dissolved solids by membrane processes (reverse osmosis and electrodialysis). The effluent water is often treated with chlorine or ozone to destroy pathogenic organisms before discharge into the receiving waters.

Tertiary treatment is intended primarily for upgrading the quality or polishing of effluent and to remove further the suspended solids, BOD_5 and excess nutrients. The various processes of tertiary treatment applied to industrial effluents are as follows:

* Coagulation and sedimentation
* Activated carbon adsorption
* Electrodialysis
* Biological nitrification
* Ion exchange
* Ultrafiltration.

In general, tertiary treatment requires considerable sophistication in design, construction and operation.

3.8.4 Sludge Treatment

Selection of a treatment sequence for sludge depends upon the nature of the sludge, environmental factors and ultimate disposal options. Wastewater treatment processes generate significant quantities of sludge from suspended solids in the feed biomass generated by biological operations and precipitates from added chemicals.

Sludge conditioning by chemicals or heat improves rates of dewatering. In dewatering operations, the water content of sludge is reduced to a level where they can be handled as damp solids. Vacuum filtration, centrifugation and sand beds are the most common dewatering methods. Thermal processes, such as heat drying and incineration are used to either dry the sludge or to oxidize its organic content. Residual sludge and ash from sludge treatment processes must be disposed of in the ocean or on land. Some of the options for ultimate disposal on land are landfill, land reclamation and crop fertilization.

3.9 SUMMARY OF INDUSTRIAL WASTE: CHARACTER AND TREATMENT METHODS

Industries producing wastes	Major characteristics	Major treatment and disposal methods
Textiles	Highly alkaline, colored, COD & temperature, high suspended solids	Neutralization, chemical precipitation, biological treatment, aeration and/or trickling filtration.
Leather goods	High total solids, hardness, salt sulfides, chromium, pH, precipitated lime, and BOD_5	Equalization, sedimentation, and biological treatment
Laundry trades	High turbidity, alkalinity, and organic solids	Screening, chemical precipitation, flotation, and adsorption
Canned goods	High in suspended solids, colloidal and dissolved organic matter	Screening, lagooning, soil absorption or spray irrigation
Dairy products	High in dissolved organic matter, mainly protein, fat and lactose	Acidification, flotation Biological treatment, aeration trickling filtration, activated sludge
Brewed and distilled beverages	High in dissolved organic solids, containing nitrogen and fermented starches or their products	Recovery, concentration by centrifugation and evaporation, trickling filtration; use in feeds; digestion of slops
Meat and poultry products	High in dissolved and suspended organic matter, blood, other proteins, and fats	Screening, setting and/or flotation, trickling filtration
Beet sugar	High in dissolved and suspended organic matter, containing sugar and protein	Reuse of wastes, coagulation, and lagooning
Pharmaceutical products	High in suspended and dissolved organic matter	Activated sludge
Yeast	High in solids (mainly organic) and BOD_5	Anaerobic digestion, trickling filtration
Pickles	Variable pH, high suspended solids, color, and organic matter	Good housekeeping, screening, equalization
Coffee	High BOD_5 & S.S.	Screening, settling, and trickling filtration
Fish	Very high BOD_5, total organic solids, O&G and odor	Oil removal, biological treatment
Soft drinks	High pH, suspended solids and BOD_5	Screening, neutralization
Bakeries	High BOD_5, grease, floor washings, sugars, flour, detergents	Amenable to biological oxidation
Water production	Minerals and suspended solids	Screening then
Sugar cane	Variable pH, should organic matter with relatively high BOD_5 of carbonaceous nature.	Neutralization, recalculation, chemical treatment, some selected aerobic oxidation
Palm oil	High BOD_5, COD, solids and total fats and low pH	Neutralization, coagulation, flotation, filtration

Industries producing wastes	Major characteristics	Major treatment and disposal methods
Pulp & paper	High or low pH, color, high suspended, colloidal, and dissolved solids, inorganic filters	Settling, lagooning, biological treatment, aeration, recovery of by-products using flotation
Photographic	Alkaline, containing various organic and inorganic reducing agents	Recovery of silver; discharge
Steel	Low pH, acids, cyanogen, phenol, ore, coke, limestone, alkali, oils, mill scale, and fine suspended solids	Neutralization, recovery and reuse, chemical coagulation
Metal-plating	Acid, metals, toxic, low volume, mainly mineral matter	Alkaline chlorination of cyanide, reduction and precipitation of chromium, lime precipitation on other metals
Oil fields and refineries	High dissolved salts from field; high BOD_5, odor, phenol, and sulfur compounds from refinery	Recovery of salts; acidification burning of alkaline sludge
Fuel oil use	High in emulsified and dissolved oils	Leak and spill prevention, flotation
Rubber	High BOD_5 and odor, high suspended solid, variable pH, high chlorides	Aeration chlorination, sulfonation, biological treatment
Glass	Red color, alkaline nonsettleable suspended solids	Calcium-chloride precipitation
Glue manufacturing	High COD, BOD_5, pH, chromium, periodic strong mineral acids	Aerobic biological treatment, flotation, chemical precipitation
Candle manufacturing	Organic (fatty) acids.	Anaerobic digestion
Metal containers	Metal fines, lube oils, variable pH, surfactants, dissolved metals.	Oil separation, chemical precipitation, collection and reuse, lagoon storage. Final carbon absorption
Petrochemicals	High COD, T.D.S., metals, COD/BOD_5 ratio.	Recovery and reuse, equalization and neutralization, chemical coagulation, settling or flotation, biological oxidation
Cement	Heated cooling water, suspended solids, some inorganic salts	Segregation of dust-contact streams, neutralization and sedimentation
Asbestos	Suspended asbestos and mineral solids	Detention in ponds, neutralization and land filling
Paints and inks	Contain organic solids from dyes, resins, oils, solvents, etc	Settling ponds for detention of paints, lime coagulation of printing inks.
Acids	Low pH, low organic content	Neutralization, burning when some organic matter is present
Detergents	High in BOD_5 and saponified soaps	Flotation and skimming, precipitation with $CaCl_2$

Industries producing wastes	Major characteristics	Major treatment and disposal methods
Corn starch	High BOD_5 and dissolved organic matter; mainly starch and related material	Equalization, biological filtration, anaerobic digestion
Pesticides	High organic matter, benzenering structure, toxic to bacteria and fish, acid	Activated-carbon adsorption, alkaline chlorination
Formaldehyde	Normally high BOD_5 and HCHO, toxic to bacteria in high concentrations	Trickling filtration, adsorption on activated charcoal
Mortuary	Blood salt, formaldehydes, high BOD_5	Chlorination
Hospital-Res.	Bacteria, various chemical radioactive	Holding and biological aeration
Organic	Varied types of organic chemicals	Biological degradation plant control, process modification
Steam power	Hot, high volume, high inorganic and dissolved solids.	Cooling by aeration, storage of ashes, neutralization of excess acid wastes
Scrubber power plant wastes	Particulate, SO_2, impure absorbents or NH_3, NaOH	Solids removal usually by settling, pH adjustment and reuse
Coal	High-suspended solids mainly coal, low pH, high H_2SO_4 and $FeSO_4$.	Settling flotation

IV. EGYPTIAN LEGISLATION ON INDUSTRIAL WASTEWATER

4.1 BACKGROUND

Three primary laws regulate the discharge of wastewater according to the government of Egypt environmental regulations. These laws are:

- Law 4 of 1994 regulates discharge in coastal environments.
- Law 93 of 1962 and amended executive decree No. 44 for year 2000 regulates discharge to sewer systems.
- Law 48 of 1982 regulates discharge into underground reservoirs and branches or canals of the Nile, to the main stream of the Nile, and to municipal and industrial drains.

The regulations implementing these laws are independent of each other in terms of regulated streams, inspection, and enforcement entities. However, all these laws refer to the laboratories of the Ministry of Health and Population (MOHP) as the analytical body for measurements of wastewater parameters, which are shown in table (4-1).

The most important regulatory connection between these laws, as well as other environmental laws, is the environmental register required by law 4/1994. The register includes all information concerning a facility's discharges over a 1-year period. Historical information must be kept for 10 years. EEAA is mandated to do inspection and independent analysis of these registers.

These laws aim to:

- Protect the environment, seashores, and ports of the Arab Republic of Egypt from pollution hazards in all their forms and shapes.
- Protect the natural resources in the economic zone.
- Compensate any natural or juridical person for any damage caused due to the pollution of the water.
- Protect the employees who are working to maintain the sewerage system from harmful industrial waste.
- Protect the structures, equipment, and biological treatment operations from harmful industrial waste.

Table (4-1) Comparison of Egyptian Laws Related to Wastewater

Law	Subject of Law (related to wastewater)	Issues Regulated by the Law and Methods of Regulation	Responsible Entity
4/1994	Discharge of Liquid Wastes to Marine Waters	• Prohibition of untreated (in violation of this law) wastewater discharge to marine waters, either directly or indirectly, intentionally or unintentionally. • Banned discharge of wastewater containing non-degradable polluting substances.	Egyptian General Authority for Shore Protection, in coordination with EEAA.

Law	Subject of Law (related to wastewater)	Issues Regulated by the Law and Methods of Regulation	Responsible Entity
		• Perform periodic analysis for samples of the treated wastewater, from establishments permitted to discharge to marine waters, and in case of violations, it gives 1 month for compliance. If not completed, disposal will be stopped, license will be revoked without prejudice, and/or penalties as mentioned in this law imposed.	MOHP Laboratories. In case of violation, EEAA is notified and begins administrative procedures.
48/1982	Discharge of Liquid Wastes to the Nile and Waterways	• Prohibition of wastewater discharge to the Nile and waterways, even if in compliance with the specifications of this law, unless a license is acquired	Ministry of Irrigation in coordination with the MOHP
		• Perform periodic analysis for samples of the treated wastewater from establishments licensed to discharge into waterways, in case of violations without immediate danger, 3 months to comply are allowed. If renovations are not completed, discharge will be stopped, and/or license will be withdrawn without prejudice to the penalties given in the law. In case of violations with immediate danger, the establishment will be notified to remove the causes of harm immediately. If they are not removed, the license will be withdrawn and discharge stopped **or** the Ministry of Irrigation will undertake this at his expense.	MOHP Laboratories. In case of violation, the Ministry of Irrigation is notified to begin administrative procedures.
93/1962 (and amend-ments)	Discharge of Wastewater to the Public Sewer System	• Prohibition of wastewater discharge to the public sewer system, which is in compliance with the specifications of this law, unless a license is acquired. Otherwise, the discharge is stopped by administrative procedures.	Ministry of Housing, in cooperation with the sanitary drainage authorities.
		• Perform periodic analyses for samples of the treated wastewater from establishments licensed to discharge to public sewer systems, and in case of violation, 6-months are give to bring the discharge into compliance. If the work is not completed, license will be withdrawn and/or the grace period may be extended. In case of immediate danger, the discharge is stopped.	MOHP Laboratories. In case of violation, the Ministry of Housing and the sanitary drainage authorities are to be notified to take administrative procedures.

4.2 LAWS CONCERNING WASTEWATER EFFLUENTS TO DIFFERENT RECEIVING BODIES

Limits for pollutants in wastewater vary depending on the type of receiving water body. The parameters that should be monitored are BOD_5, COD, pH, temperature, residual chlorine, TSS, TDS, and oil & grease. Table (4-2) presents the permissible limits for discharges to the different recipients (sea, Nile, canals, agriculture drains, and public sewer) according to the different relevant laws. Spent lube oil has a negative impact on water and soil and therefore its disposal should be monitored. A record should be kept for this purpose.

4.3 LAWS CONCERNING SOLID WASTE AND SLUDGE

A number of laws address solid waste management. The following laws apply to scrap and sludge from the wastewater treatment plant.

- Law 38/1967 which addresses public cleanliness, regulates the collection and disposal of solid wastes from houses, public places, commercial, and industrial establishments.
- Ministry of Housing, Utilities and Urban Communities (MHUUC) decree No. 134 of 1968, which provides guideline from domestic and industrial sources, including specifications for collection, transportation, composting, incineration and land disposal.
- Law 31/1976, which amended law 38/1967.
- Law 43/1979, the law of local administration, which provided that City Councils are responsible for "physical and social infrastructure", effectively delegating responsibility for infrastructure functions.
- Law 4/1994 regulates incineration of solid waste:

  - **Article 37.** It is prohibited to burn, throw away or treat garbage and solid waste except in areas designated for such purpose that are far from housing or industrial or agriculture areas as well as from waterways. The Executive Regulations of this law shall determine the requisites and specifications and the minimal distances between areas designated for such purposes. Local units shall be obliged to designate, in agreement with EEAA, special areas for burning, throwing away or treating garbage and solid wastes according to the provisions of this article.
  Articles 38 & 39 of the Executive Regulations.

Table (4-2): Egyptian Environmental Requirements

Parameter (mg/l unless otherwise noted)	Law 4/94 Discharge in Coastal Environment	Law 93/62 Discharge to Sewer System (as modified by Decree 44/2000)	Law 48/82 Discharge into			
			Underground Reservoir & Nile Branches/Canals	Nile (Main Stream)	Non potable surface water	
					Municipal	Industrial
BOD_5 (5 day, 20^{o}C)	60	600	20	30	60	60
COD (Permanganate)	-	-	10	15	40	50
COD (Dichromate)	100	1100	30	40	80	100
pH (units)	6-9	6-9.5	6-9	6-9	6-9	6-9
Oil & Grease	15	100	5	5	10	10
Temperature (^{o}C)	10^{o}C > avg. temperature of receiving body	43	35	35	35	35
Total Suspended Solids	60	800	30	30	50	60
Settleable Solids (ml/l)	-	After 10 min: 8 cm After 30 min: 15 cm^3	-	-	-	-
Total Dissolved Solids	2000	-	800	1200	2000	2000
PO_4	5	25	1	1	-	10
NH_3-N (Ammonia)	3	-	-	-	-	-
NO_3-N (Nitrate)	40	100	30	30	50	40
Total Recoverable Phenol	1	0.05	0.001	0.002	-	0.005
Fluoride	1	-	0.5	0.5	-	0.5
Sulfide	1	10	1	1	1	1
Chlorine	-	-	1	1	-	-
Surfactants	-	-	0.05	0.05		-
Probable counting for the colon group in 100 cm^3	5000	-	2500	2500	5000	5000

Parameter (mg/l unless otherwise noted)	Law 4/94 Discharge in Coastal Environment	Law 93/62 Discharge to Sewer System (as modified by Decree 44/2000)	Law 48/82 Discharge into			
			Underground Reservoir & Nile Branches/Canals	Nile (Main Stream)	Non potable surface water	
					Municipal	Industrial
Aluminum	3	-	-	-	-	-
Arsenic	0.05	2	0.05	0.05	-	-
Barium	2	-	-	-	-	-
Beryllium	-	-	-	-	-	--
Boron	-	1	-	-	-	-
Cadmium	0.05	0.2	0.01	0.01	-	-
Chromium	1	-	-	-	Total concentration for these metals should be: 1 for all flow streams	
Chromium Hexavalent	-	0.5	0.05	0.05		
Copper	1.5	1.5	1	1		
Iron	1.5	-	1	1		
Lead	0.5	1	0.05	0.05		
Manganese	1	-	0.5	0.5		
Mercury	0.005	0.2	0.001	0.001	-	-
Nickel	0.1	1	0.1	0.1		-
Silver	0.1	0.5	0.05	0.05	-	-
Tin	-	2	-	-	-	-
Zinc	5	-	1	1		-
Cyanide	0.1	0.2	-	-	-	0.1
Total Metals	-	5	1	1	1	1
Pesticides	0.2	Should be absent	Should be absent	Should be absent	Should be absent	Should be absent
Color	Should be absent	-	Should be absent	Should be absent	Should be absent	Should be absent

4.4 LAW CONCERNING WORK ENVIRONMENT

The following are the laws regulating violations of work environment:

- **Near heavy machinery: noise is regulated by article 42 of law 4/1994:**
  - **Article 42.** All agencies and individuals, while performing production, service or other activities, particularly when using tools, equipment, horns or loudspeakers, shall abide by the permissible limits of sound intensity. Authorities issuing licenses shall ensure that the total sound produced from fixed sources within one area shall be within the permissible limits, and shall ensure that establishments select appropriate tools and equipment to guarantee this. The Executive Regulations of this law shall define the permissible limits of sound intensity and the permissible time limits for exposure to loud noise.
    Article 44 of the Executive Regulations and Table 1, Annex 7.

- **Ventilation is regulated by article 45 of law 4/1994:**
  - **Article 45.** Closed and semi-closed public places must have adequate ventilation facilities relative to their size and capacity as well as the type of activity performed therein, to ensure renewal and purity of the air and a suitable temperature.
    Article 47 of the Executive Regulations.

- **Work environment conditions are addressed in law 137/1981 for labor, Minister of Housing Decree 380/1983, Minister of Industry Decree 380/1982.**

4.5 LAWS CONCERNING HAZARDOUS MATERIAL AND WASTE

Law 4/1994 introduced the control of hazardous materials and waste. Articles 29 and 33 of the law make it mandatory for those who produce or handle dangerous materials in gaseous, liquid or solid form, to take precautions to ensure that no environmental damage shall occur. Articles 25, 31 and 32 of the executive regulations (Decree 338/1995) specify the necessary precautions for handling hazardous materials. There is no explicit article in law 4/1994 or in Decree 338/1995 (Executive Regulations) regarding maintaining a register for the hazardous materials; article 33 is concerned with hazardous wastes, such as sludge resulting from wastewater treatment. However, keeping the register for the hazardous materials is implicit in article 25 of the executive regulations regarding the application for a license.

Articles 29 – 33 of law 4/1994 regulate hazardous materials and wastes as follows:

- **Article 29.** It is forbidden, without a license from the component administrative authority, to handle hazardous substances and wastes. The Executive Regulations of this law shall determine the procedures and the conditions for granting such a license and the concerned authority. The Ministers, each in their field of competence, shall issue, in coordination with the Minister of Health and EEAA, a list of the hazardous substances and wastes as aforementioned in paragraph one of this article.

- **Article 30.** Management of hazardous wastes shall be subject to the procedures and regulations stated in the Executive Regulations of this law. The Executive Regulations shall designate the component authority, which, after consulting EEAA, will issue the tables of dangerous wastes to which the provisions of this law shall apply.

- **Article 31.** It is forbidden to construct any establishment for treating dangerous wastes without a permit from the competent administrative authority and before consulting EEAA. Disposal of dangerous wastes shall be according to the norms and conditions that will be stated in the Executive Regulations of this law. The Minister of Housing, Utilities and New Communities shall assign, after consulting with the Ministries of Health, Industry and EEAA, the disposal sites and the required conditions to authorize the disposal of dangerous wastes.

- **Article 32.** It is forbidden to import dangerous waste or to allow its entrance into or passage through Egyptian territories. It is forbidden, without a permit from the competent authority, to allow the passage of ships carrying hazardous wastes through territorial seas or the exclusive economic zone of the ARE.

- **Article 33.** It is mandatory for all those who produce or handle dangerous materials, either in gaseous, liquid or solid form, to take precautions to ensure that no environmental damage shall occur. The owner of an establishment whose activities may result in hazardous wastes shall, according to the provisions of this law, maintain a register of these wastes and the method of disposing thereof, as well as contracting concerned agencies for receipt of these wastes. The Executive Regulations shall state the data to be recorded in that register and EEAA shall be responsible for following up the register to ensure its conformity with the truth.

Articles 25-32 of the Executive Regulations.

4.6 SELF-MONITORING AND THE ENVIRONMENTAL REGISTER

Regarding the regulatory basis in Egypt of self-monitoring is not explicitly mandated by Egyptian environmental regulation. However, industrial facilities are required to keep a record of their inputs, outputs and releases in the environmental register as stated by Law 4/1994, which implicitly requires some sort of self-monitoring. EEAA is mandated to check the validity of the data in the environmental register and it is the responsibility of the operator to comply with laws and regulations.

Article 22 of law 4/1994 states that the owner of the establishment shall keep a register showing the impact of the establishment activity on the environment. Article 17 and Annex 3 of the executive regulations specify the type of the data recorded in the register (Annex 2 of this Manual). The emergency response plan and the hazardous materials register will also be part of the environment register as stated in part 5.4.

Environmental Register is regulated by article 22 of law 4/1994:

- **Article 22.** According to the provisions of this law, owners of establishments shall keep written records of the environmental impact of their establishment's activities. The Executive Regulations will determine the standard form of the required written document as well as its time table to assure the compliance of establishments with such a record. EEAA is designated to review the data of these written records to ensure that they are truthful, to take the required samples, to analyze them, and to measure the environmental impact of the norms established for the protection of the environment. In case of any violation, EEAA will notify the component administrative authority to mandate the owner of the establishment to rapidly correct these violations. If the owner does not comply within 60 days from the date of the notification, EEAA in agreement with the competent administrative authority, will take the required legal and legislative procedures to shut down the activities of the establishment and will request adequate compensation to treat the harm resulting from these violations.

Article 17 of the Executive Regulations and Annex 3.

V. SELF-MONITORING GUIDELINES

The self-monitoring system deals primarily with measurements of process inputs, releases and environmental pollution levels, as well as process conditions (operation controls) that may be related to the monitored emissions. The system also comprises reporting of the results to competent authorities. Monitoring procedures may be performed by the industrial establishment or through an external organization on behalf of and paid for by the industrial establishment. In any case, the information obtained from the sampling and monitoring system must be recorded and the results be reported to the appropriate internal and external decision-makers. The following sections will describe in further details the different aspects associated with self-monitoring planning and procedures.

5.1 SELF-MONITORING PLANNING PRINCIPLES

Planning for SM starts by setting the objectives. For the purpose of this manual, environmental self-monitoring concerning IWWTP will be considered. Compliance and efficiency assurance of the treatment plant requires measurements, analysis and data on end-of-pipe releases. The environmental manager with the help of various sector managers should carry out the planning activities. Fig (5-1) presents the various steps for the preparation and implementation of a self-monitoring plan.

According to the "Guidebook for Industrial Self-Monitoring", the main elements of the Self-Monitoring plan that describes the SMS include:

- Objectives and results required from the self-monitoring system
- Organization and share of responsibilities and tasks
- Planning activities and design of an implementation schedule
- Definition of the parameters and relevant monitored indicators to reach the objectives
- Design of an appropriate measurement and sampling program
- Data processing and reporting procedures
- System for follow-up decisions, actions and monitoring development
- Quality assurance and control

According to the above reference, the objective of the SMS can be limited to provide the data required for the Environmental Register which is mandated by the Environmental Law, e.g. Chemical inputs and emissions from the IWWTP and effluent quality. The established SMS should be gradually improved and upgraded, considering the plant financial and economic constrains. The self-monitoring plan may consist of two distinct parts:

- Self-monitoring plan for operation monitoring, including self-monitoring of raw materials, water, energy consumption, process conditions and incoming water quality according to the type of production.
- Self-monitoring plan for environmental aspects including solid wastes, discharges, air emissions, work environment, final discharge quality and noise.

5.1.1 Assessment of Existing Monitoring Capacity

Assessment of existing monitoring capacity includes the following aspects:

- Management system: presence of an existing system for data collection and reporting
- Human resources: available personnel, level of training, motivation
- Technical resources: monitoring equipment and laboratory, status of equipment
- Financial resources: available budget for self-monitoring activities

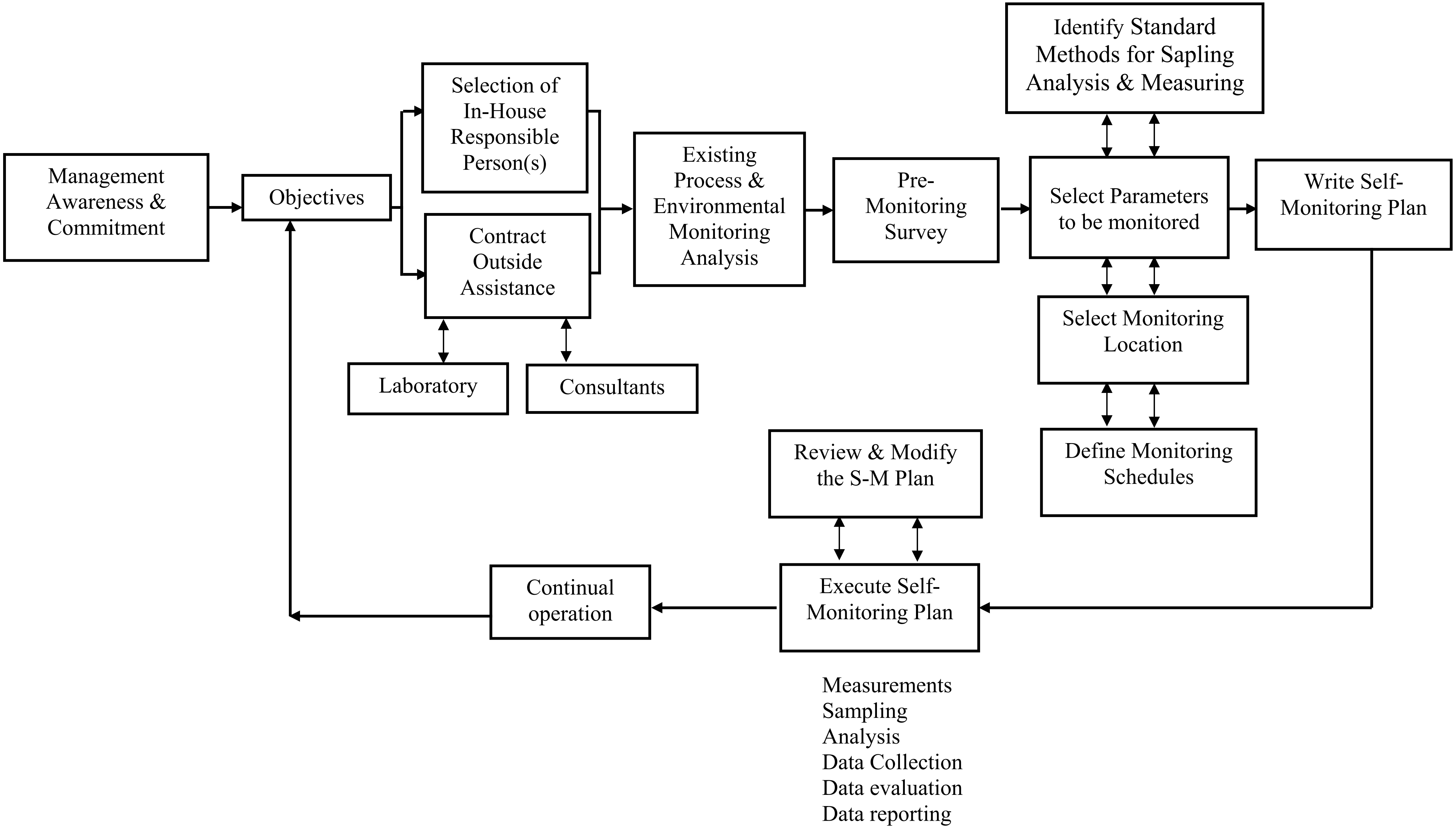


Figure (5-1): Preparation & Implementation Steps of Self-Monitoring

5.1.2 Identification of Key Parameters

The identification of key monitoring parameters requires an understanding of the treatment plant operation and various methods of wastewater treatment in general. Table (5-1) helps identify key operation parameters and monitoring parameters for different treatment technology cases. Priority should be given to parameters that determine compliance with Environmental Laws. The choice of the parameters is determined by the type of production, type of treatment, the legal requirements and the importance of the parameter for decision making. For each of the proposed parameters, the trends and variations should be monitored in addition to the value of the parameter at a given time. A pre-audit is necessary to determine sampling and measurements locations as well as schedules needed to design the self-monitoring plan.

5.1.3 General Data Required

When assessing the performance of the treatment plant and its impacts on the environment, some basic information is needed to put the monitoring data into context of interpretation. Such information includes:

- **Identification:** name, address, plant location, name of owner, manager and head of environmental department.
- **Inputs:** names, type and amount of chemicals, auxiliaries, fuels and electricity.
- **Technology:** description of treatment, applied technology, operating conditions (temp, pressure), maximum capacity, efficiency of treatment plant.
- **Abatement techniques:** solid waste management (sludge reuse and disposal), noise abatement.
- **Emissions and their sources:** mainly odor emissions and noise.
- Assessment of legislative and regulatory requirements.
- **Output :** Treated wastewater quality

5.1.4 Technical and Bench-Marking Data and Information

A facility should develop and maintain a system to collect and update information about technical development and typical IWWTP pollution and consumption figures (benchmarking). This system also includes the building of a framework for communication between the facility and various professional bodies or facilities having similar activities in order to facilitate information collection. Benchmarking and technical information are important because they help in finding problems and setting monitoring priorities. Benchmarking information is particularly important as it allows the facility to compare its performances to typical sector figures and find eventual problems.

5.1.5 Training and Awareness

Basic training about the general principles and objectives of the self-monitoring program should concern all the employees of the WWTP facility, including newcomers. Objectives of the training should be to achieve reliable monitoring and to increase awareness of all the employees about environmental matters and process optimization. Training should not be considered as a privilege for management but as a key element of the operator's work in order to obtain good data and improved process operation. Training should cover at least the items presented in table (5-2). Training sessions should be short and well-targeted. It should be verified that the knowledge and awareness of participants has effectively been increased as a result of training. Whenever changes occur in the organization or scope of the self-monitoring program, training should be updated according to the needs.

Table (5-1): Example of monitoring activity description table

Monitoring activity example	Location (example)	Parameter (example)	Associated tasks (example)	Person in charge (example)	Time schedule (example)	Starting date (example)
Wastewater	Discharge point	Flow rate	Recording the flow on the flow-meter	Operator X	Daily	Two weeks after communication & approval of the self monitoring plan, purchase & installation of the equipment
			Inspecting the flow meter	Flow meter supplier	Twice a year	
			Maintenance	Flow meter supplier	Twice a year & when failure has occurred	
			Calibration	Operator X	Monthly	
			Recording of data	Supervisors		
		COD	Grab-sampling	Laboratory staff	Weekly or monthly, on Thursday at 12.00	
			Preservation of sample	Laboratory staff	Within 2 hours	
			Transport of sample	Laboratory staff	Immediately after sampling	
			Analysis of sample	Laboratory staff	Within 24 hours	
			Reviewing & approving the analysis results	Chief of laboratory		
Gaseous emissions	Work Area	Odour, Noise	Measuring Odour, Noise	Operator Y	Once a year	Already existing
			Inspecting & calibrating measuring equipment	Operator W	Prior to use	Already existing but schedule changed from (date)

Table (5-2): Training items and targeted public

Subject of the Training Session	Contents	Targeted Audience
General presentation of the self-monitoring system	Organization and presentation of all the responsible persons. activities	All staff
Specific presentation of the self-monitoring activities		Various units, all staff
Technical training	sampling methods, quality and specific procedures sample preservation methods	Operators in charge of sampling Employees responsible for the quality assurance program and auditing of the self-monitoring
Technical training	Measurements and measuring instruments use, maintenance and calibration	Operators in charge
Technical training	Field testing and analysis	Operators in charge
Laboratory training	Analytical methods and quality control	Laboratory staff
Data analysis and reporting	Statistical analysis, reporting and information system	Supervisors and middle management

5.1.6 Data Collection, Manipulation and Reporting

Data collection and analysis should be carefully planned according to the following principles:

- Base the analysis on trends over both long periods (yearly) to take into consideration the shock loads that could take place in the plant and shorter periods (daily, monthly average) so as to keep track of treatment efficiency.
- Study the correlation between different parameters. The cause of variation for a highly variable parameter may be correlated to another parameter.
- Determine causes and degree of variation.

A considerable amount of data may be generated by the operator carrying out self-monitoring especially when continuous monitoring instrumentation are used. Data reduction is necessary to calculate time averaged means, percentile values and the like. The results obtained from self-monitoring should be represented in specific format. Proposed forms for record keeping of results to be maintained from the IWWTP during monitoring are shown in the following two forms:

- Form A: A-1 Record Keeping for end-of-pipe treated effluent (daily)
  A-2 End-of-pipe treated effluent (monthly average) [Annex]

- Form B: B-1 Record Keeping for end-of-pipe monitoring before & after treatment (monthly)
  B-2 End-of-pipe effluent and efficiency (yearly average) [Annex]

Form A-1: Record Keeping for End-of-Pipe Treated Effluent (Daily)

Parameters	Month of ……………																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
T (ºC)																														
pH																														
T.S.S (mg/l)																														
COD (mg/l)																														

Sample taken by: ………………… **Name:** ………………. **Signature:** ………….
Analyzed by: ……..………… **Date:** ………………

Form A-2: Record Keeping for End-of-Pipe Treated Effluent (Monthly Average)

PARAMETERS	Jan			Feb			Mar			Apr			May			Jun			Jul			Aug			Sept			Oct			Nov			Dec		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
T (ºC)																																				
pH																																				
T.S.S (mg/l)																																				
COD (mg/l)																																				

Sample taken by: ………………… **Name:** ………………. **Signature:** …………
Analyzed by: ……..………… **Date:** ………………

Form B-1: Record Keeping for End-of-Pipe Monitoring Before & After Treatment (Monthly)

Parameters	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept		Oct		Nov		Dec		Reg.
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	
Flow Rate																									
pH																									6-9.5
T.S.S. (mg/l)																									800
T.D.S. (mg/l)																									
COD (mg/l)																									1100
BOD (mg/l)																									600
O&G (mg/l)																									100
Phosphate (mg/l)																									25
THM (mg/l) Zn Ni Cu Cr Pb																									5 1 1.5 0.5 1

Note: * B: Before / A: After

Sample taken by: ………………… **Name:** ……..……….. **Signature:** …………
Analyzed by: ……..………… **Date:** ………………

Form B-2: Record Keeping for End-of-Pipe Effluent Monitoring Before & After Treatment & Efficiency (Yearly Average)

Parameters	YEAR 2001							Reg.
	Before Treatment			After Treatment			Efficiency %	
	Min	Max	Ave	Min	Max	Ave		
Flow Rate								
pH								6-9.5
T.S.S (mg/l)								800
T.D.S. (mg/l)								
COD (mg/l)								1100
BOD (mg/l)								600
O&G (mg/l)								100
Phosphate (mg/l)								25
THM (mg/l) **Zn** **Ni** **Cu** **Cr** **Pb**								5 1 1.5 0.5 1

Sample taken by: ………………… **Name:** ……..……….. **Signature:** ………….
Analyzed by: ……..………… **Date:** ……………

5.2 DEVELOPMENT OF SELF-MONITORING SYSTEM

5.2.1 Parameters to be Monitored

a. Compliance Monitoring Parameters

The regulations state the limits for the concentrations of some specific pollutants of wastewater when discharged into the recipient body.

Typical wastewater compliance parameters include:

- Total Suspended Solids (TSS), mg/l
- Total Dissolved Solids (TDS), mg/l
- Temperature, °C
- Chemical Oxygen Demand (COD Cr), mg O_2/l
- Biochemical Oxygen Demand (BOD_5), mg O_2/l
- Total Nitrogen (N), mg/l
- Total Phosphorus (P), mg/l
- pH
- Conductivity, mS/cm
- O&G, mg/l
- Chlorine
- Heavy Metals
- Phenols
- Cyanide

b. Process Operation Parameters

The discharge values for specific substances or parameters are mostly expressed as total amount per unit time. In some cases these values are given as specific amount per ton of product or as purification efficiencies.
The following basic consumption data are suggested as a start and can be expanded in the future to cover other parameters:

- Amount of chemicals used per m^3 of treated effluent and cost (L.E./m^3)
- Power consumed and cost (L.E.)
- Total Cost (L.E./m^3)
- Overall input/output data based on one month operation to be recorded quarterly.
- Consumption data per m^3 of treated effluent for the input/output recorded data.

- *Flow Measurement*

Measuring of the total wastewater flow is required for the operation of the wastewater treatment plant. There have been no provisions on the procedure or the accuracy of a flow measurement, but installation of automatic composite samplers (preferable flow dependant) can be used. Wastewater flow is usually measured with a venturi measurement equipment, but also magnetic and ultrasonic methods are used. Measurement equipment is maintained several times a year and the measurement system is calibrated regularly.

Regular maintenance, control and calibration are needed to obtain an acceptable measurement accuracy level. Structure of the measurement system, a possible mounting fault or false choice for

measurement area may cause errors. Other sources of error or factors disturbing the measurement are dirtying and temperature variations of the measuring equipment. Evaluation of the total error is extremely difficult, as it must include all these factors. Table (5-3) shows main treatment processes identifying operation and compliance control parameters for each.
Table (5-3)

Table (5-3): Main Treatment Technologies: Operation Control & Compliance Parameters

Treatment Process	Operation control parameters	Compliance parameters
Screening	Influent T.S.S level Fouling Pressure Drop Flow rate	T.S.S
API & CPI separators	Influent O&G level Flow rate	Free O&G
Flow Equalization	Retention time	Turbidity
Settling Basins	Retention time Inlet Flow	T.S.S
Lamella separator	Influent T.S.S level Flow Rate Fouling	T.S.S
DAF System	Influent O&G conc level Influent T.S.S level Chemical doses Input Flow rate Air pressure	T.S.S Total O & G COD
Conventional Activated Sludge	MLSS, MLVSS, DO levels Nutrient doses Air flow Settleability	BOD COD
Extended Aeration System	MLSS, MLVSS, DO levels Settleability	BOD COD
Aerated Ponds	DO levels	BOD
SBR	Retention Time Air flow Air bubbles distribution DO levels	COD T.S.S. BOD

Treatment Process	Operation control parameters	Compliance parameters
Trickling Filter.	Nutrient doses DO levels Air flow	BOD COD
Bio tower	D.O levels Nutrient doses Retention time Air Flow MLSS MLVSS	COD BOD
Anaerobic Treatment	Methane production H_2S level	BOD COD

MLSS – Mixed Liquor Suspended Solids
MLVSS – Mixed Liquor Volatile Suspended Solids

5.2.2 Sampling, Analytical Methods and Equipment Required

a. Sampling

Well realized sampling is essential for determination of wastewater discharges. The variety of conditions at different sampling locations requires that considerable judgment be exercised regarding the methodologies and procedures for the collection of representative samples of wastewater. There are, basic rules and precautions generally applicable to sample collection. Some important considerations for obtaining a representative wastewater sample include:

- The sample should be collected where the wastewater is well mixed. Therefore, the sample should be collected near the center of the flow channel, at approximately 40 to 60 percent of the water depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Skimming the water surface or dragging the channel bottom should be avoided. However, allowances should be made for fluctuations in water depth due to flow variations.
- In sampling from wide conduits, cross-sectional sampling should be considered.
- If composite sample is performed manually, the individual sample portions must be thoroughly mixed before pouring the individual aliquots into the composite container. For manual composite sampling, the individual sample aliquots should be preserved at the time of sample collection.
- When collecting samples or installing sampling equipment, field investigators should always wear a new pair of the appropriate protective gloves (disposal latex gloves, rubber gloves, etc.) to prevent contamination of the sample and reduce exposure to hazardous substances.

Since law 4/94 does not specify standards for the effluent from production lines but only for the effluent from the final disposal point, therefore, the EEAA inspectors will only be concerned with the end of pipe discharging points.

Samples are either **single grab samples**, **composite samples**, or **composite samples in proportion to the flow**. A single grab sample reveals the composition of the wastewater at the sampling time. With several single samples it is possible to follow the waste water load peaks, quality variation and the easily variable parameters. A composite sample reveals the average composition over a chosen period. A 24 hr composite sample is normally taken in proportion to the flow so that the sampler is controlled by a flow meter. The following items give further details.

- **Grab Samples**. Grab samples consist of either a single discreet sample or individual samples collected over a period of time not to exceed 15 minutes. The grab sample should be representative of the wastewater conditions at the time of sample collection. The sample volume depends on the type and number of analyses to be performed.

- **Composite Samples**. Composite samples are collected over time, either by continuos sampling or by mixing discrete samples. A composite sample represents the average wastewater characteristics during the compositing period. Various methods for compositing are available and are based on either time or flow proportioning. The choice of a flow proportional or time composite-sampling scheme depends on the permit requirements, variability of the wastewater flow or concentration of pollutants, equipment availability, and sampling location. The investigator must know each of these criteria before a sampling program can be initiated. If an investigator knows or suspects that there is significant variability in the wastewater flow or if the investigator knows nothing about the facility, a flow proportional sample is preferable. Otherwise, a time composite sample would be acceptable.

A time composite sample consists of equal volume discrete sample aliquots collected at constant time intervals into one container. A time composite sample can be collected either manually or with an automatic sampler.

A flow proportional composite sample can be collected using one of two methods. One method consists of collecting a constant sample volume at varying time intervals proportional to the wastewater flow. For the other method, the sample is collected by varying the volume of each individual aliquot proportional to the flow, while maintaining a constant time interval between the aliquots. Prior to collecting flow proportional samples, the facility's flow measuring system should be examined for proper installation and accuracy. If the facility's primary flow measuring device does not meet standard conditions, or is in an unsafe or inaccessible location, then the investigator may collect time composite samples. If the flow measurement system is acceptable, samples should be collected using the appropriate flow proportioning methods.

Flow proportional samples can be collected with an automatic sampler and a compatible flow-measuring device, semi-automatically with a flow chart and an automatic sampler capable of collecting discrete samples, or manually.

Sampling period and sample size are considered case-by-case depending on the analysis used and on the issues affecting the reliability of sampling and analysis. Samples for wastewater analysis are mostly taken over 24 hrs, 5-7 days a week. In some cases, samples are frozen and combined to cover a longer period. Samples for COD and suspended solids determination are taken daily or continuously and analyzed daily. Samples for BOD and nutrient determination are usually taken weekly. pH and conductivity are usually measured continuously.

-SAMPLE LOCATIONS

- General Considerations

Usually the objectives of the sampling program define the approximate locations for sampling. Since water quality varies from one place to another in almost all waste water systems, sampling locations should be appropriately selected to suit the particular programs information needs. Moreover, the nature and extent of spatial homogeneity can vary with time, and can also differ markedly between systems of the same type.

- Factors Considered in Selecting Sampling Locations

The selected sampling locations are representative sites. The term "representative point" is defined as a location at which specific conditions and parameters may be measured in such a manner as to characterize or approximate the quality or condition of the wastewater stream where specific conditions or parameters measured adequately reflect the actual conditions of those waters.

Factors influencing the selection of the sampling locations are:

1. Homogeneity of the wastewater: Turbulence and good mixing enhance the homogeneity or the uniform distribution of the constituents in the body of water.
2. Non-homogeneity of the wastewater: Poor mixing, for samples, in a waste discharge. Different densities constituents of, such as floating oils or settling

suspended solids. Chemicals or biological reactions, such as growth of algae in upper layers of the body of water, causing changes in pH…etc.

3. Other considerations such as pronounced degradation of water quality in specific areas, suitability for flow measurements, convenience and accessibility, ….etc.

- Selection of Sampling Locations in the Company

In selecting sampling locations the following factors were considered:

1. Homogeneity of wastewater: samples will be taken where good mixing and turbulence produces homogeneity and non-stratification.
2. General characteristics of wastewater: Samples of cooling water in fluent and effluent will be taken at representative sites in the cooling water streams.
3. Flow measurements: Flow measurements will be made at locations where corresponding discharges were known and estimated.
4. Convenience, accessibility, practicality and safety were certainly important, but were secondary to representatives of sampling.

- **Use of Automatic Samplers**

Automatic samplers may be used to collect composite or grab samples when several aliquots are to be collected at frequent intervals or when a continuous sample is required. For composite sampling applications, the automatic samplers may be used to collect time composite or flow proportional samples. In the flow proportional mode, the samplers are activated by a compatible flow meter. Flow proportional samples can also be collected using an automatic sampler equipped with multiple containers and manually compositing the individual sample portions proportional to the flow.

Automatic samplers must meet the following requirements:

* Sampling equipment must be properly cleaned to avoid cross-contamination which could result from prior use.
* No plastic or metal parts of the sampler shall come in contact with the water or wastewater stream when parameters to be analyzed could be impacted by these materials.
* The automatic sampler must be capable of providing adequate refrigeration during the sampling period. This can be accomplished in the field by using ice.
* The automatic sampler must be able to collect a large enough sample for all parameter analyses.
* The individual sample aliquot must be at least 100 mls.
* The automatic sampler should be capable of providing a lift of at least 20 feet and the sampler should be adjustable since the volume is a function of the pumping head.
* The pumping velocity must be at least 2 ft/sec to transport solids and not allow solids to settle.
* The intake line leading to the pump must be purged before each sample is collected.
* The minimum inside diameter of the intake line should be ¼ inch.
* An adequate power source should be available to operate the sampler for the time required to complete the project. Facility electrical outlets may be used if available.

- **Manual Sampling**

Manual sampling is normally used for collecting grab samples and/or for immediate in-situ field analyses. However, it can also be used in lieu of automatic equipment over extended periods of time for composite sampling, especially when it is necessary to evaluate unusual waste stream conditions.

The best method to manually collect a sample is to use the actual sample container, which will be used to transport the sample to the laboratory. This eliminates the possibility of contaminating the sample with intermediate collection containers. If the sampling personnel cannot physically reach the wastewater stream or it is not safe to reach for the sample, an intermediate collection container may be used, from which the sample can be redistributed to other containers. If this is done, however, the container used to collect the sample must be properly cleaned and must be made of a material that meets the requirements of the parameter(s) being investigated. Samples for oil and grease, bacteria, phenols, volatile organic compounds, and sulfides analyses must always be collected directly into the sample container.

In some cases it may be best to use a pump, either power or hand operated, to withdraw a sample from the wastewater stream. If a pump is used, it is imperative that all components of the pump that come in contact with the sample are properly cleaned to ensure the integrity of the sample.

In general, samples are manually collected by first selecting a location in the wastewater that is well mixed then dipping the container in the wastewater stream so the mouth of the container faces upstream. The container should not be overfilled if preservatives are present in the container.

- **Analysis Parameters**

The selection of parameters for the analysis depends on the nature and characteristics of the influent which is directly related to the type of industry. The most common parameters require analysis for industrial wastewater effluents are:

pH,	NH_3 – N,
CL,	PO_4 – P,
T.S.S,	NO_3 – N,
TDS,	Heavy metals,
BOD_5,	Phenols,
COD,	Cyanide.
O&G,	

- **Special Process Control Samples and Tests**

During diagnostic evaluations, process control tests may be conducted to evaluate and troubleshoot the performance of the biological treatment processes of industrial wastewater treatment facility.

As an example the six basic activated sludge process control tests are:

* Sludge settleability (settlometer).
* Centrifuge spins.
* Aeration basin DO profiles.
* Oxygen uptake rate (OUR) measurements.
* Mixed liquor microscopic examinations.
* Sludge blanket depth (SBD) measurements.

b. Sampling Equipment

Sampling equipment should be appropriate and should not interfere with the results of the analysis (materials should be fluorocarbon resins, glass, stainless steel, high or low density polyethylene, polyethylene terephthalate, polystyrene or polypropylene and if unavoidable a short section of surgical grade silicone rubber tubing). The type of container should be adapted to the type of parameter analyzed.

c. Analytical Methods and Equipment Required

Standardized Methods of Sampling and Analysis issued by EEAA should be the basic reference for wastewater analysis procedures and techniques as shown below.

- pH Electrometry
- T.S.S. Gravimetry
- T.D.S. Gravimetry
- O&G Gravimetry
- BOD Electrometry
- COD Spectrophotometry
- Total Heavy Metals (THM) Atomic Absorption or Spectrophotometry
- Phosphate Spectrophotometry

Analysis of samples may be done on two different levels: Annex ( ) shows sampling procedures in details.

1- Qualitative and semi-quantitative determination (Testing): It is the easiest to use “on-site” and requires a battery of simple test equipment, such as pH paper. It may give precious information on the evolution of the concentration of various chemicals and parameters. Any detected change is leading to the laboratory analysis of the sample to confirm changes and assess the actual concentration of pollutant.

2- Laboratory analysis: It requires an owned laboratory or at least access to a competent laboratory. It may be very useful for a comprehensive assessment once a year at least or whenever problems have been detected. The competence of the chosen laboratory must be carefully checked, quality certification and/or official approval should be considered a basic prerequisite. An assessment of the different laboratories in terms of prices, availability and competence must be carried out well before the first sampling.

5.2.3 Calibration of Monitoring Equipment

Table (5-4) summarizes a plan for calibration of all equipment needed for the basic monitoring system for IWWTP.

Table (5-4): Equipment Calibration Plan

Equipment	Calibration Method	Calibration Site	Frequency
pH meter	Using buffer solution	At company lab	Before Use
Conductivity	EEAA method	At company lab	Once every three months
TDS	Using primary standard solution	At company lab	Once every three months
Hardness	Using primary standard solution	At company lab	Once every three months
Alkalinity	Using primary standard solution	At company lab	Once every three months
COD	Using primary standard solution	At company lab	At time of test
BOD	Using dissolved oxygen sample Winkler titration method	At company lab	Once every three months
S.S.	Using primary standard solution	At company lab	Once every three months
Noise Level Meter	Using standard noise source calibration	At company lab	Before Use

5.2.4 Typical Cases of Malfunctioning & Process Failure

The self-monitoring personnel can detect the most significant malfunctioning of the treatment process by the following observations:

- Bad odor release and gaseous emissions due to: a) the septic build up condition especially in sedimentation tanks or b) the accumulation of rags and other debris on the bar screen, and c) malfunctioning and poor maintenance of biological filters, clarifiers, sludge thickening and drying beds.
- Black color of raw wastewater with septic odor indicates that part of the wastewater is being retained because of slow flow due to a build up of sludge or grit.
- Thick, dark, greasy, scummy layers of deep tan to brown foam covering the entire surface of aeration tanks always indicates that the sludge is too old and may be over oxidized. .
- Excessive, billowing, white foam in aeration tanks may be due to young sludge. The sludge age should be increased by reducing the sludge waste rate.
- The presence of air bubbles on the surface of the aeration tank is an indication the proper activity of the biomass in activated sludge biological systems, SBR systems and extended aeration treatment.
- An extremely dark brown color with the odor of hydrogen sulphide in aeration tanks of activated sludge treatment indicates poor oxidation. A dark brown color with an earthy smell of oxidized wastewater in the aeration tank is an indication of proper functioning of the system.
- Surcharging around treatment units due to screens or grit chambers blockage, clogging of under drains biological filters as a result of the growth of algae and development of slime.
- Ponding of filters due to improper grading of the stone media and small size stones filled between larger size media.

- Flies around the biological filters. These may be present due to poor distribution of wastewater along the filter walls and insufficient hydraulic loading.
- High levels of noise due to improper maintenance of mechanical equipment.

The self-monitoring personnel should check the following points to insure that the operation of industrial process is normal:

- Quality of the influent water to the treatment plant (during peak processing time or during washing time).
- The entry pipeline to the treatment plant and compare with sewerage network map to identify the presence of any by-passing line which goes directly to the sewer line.

The self-monitoring personnel can detect dubious analysis results provided by the laboratory by checking the relationship between different parameters such as:

- COD value should be higher than the BOD_5 value.
- High levels of O&G value lead to the high levels of COD value.
- Total solid values should be higher than level of suspended solids.
- Total solids equal the level of suspended solids & dissolved solids.

The self-monitoring personnel should also check the relationship between the actual production capacity and the performance of wastewater plant in order to compare the operation values with design values (i.e. lower capacity means better performance, lower hydraulic load means higher quality of treated water due to the effect of water recycling).

Specific self monitoring issues for main treatment methods (physical, chemical and biological) are shown in table (5-5).

Table (5-5): Specific self monitoring issues for main treatment methods

Physical Treatment	Chemical Treatment	Biological Treatment
- Clogging /surcharging	- Type of chemicals used	- Bad odor
- Odor emission	- Amounts of Chemical Consumption	- Black Color
- Fouling	- Efficient sludge Separation, Turbidity of treated effluent	- Nutrients consumptions
- Flies	- pH level	- Air bubbling (as measure for Biomass activity)
- Noise	- Color	- Flies
		- Fouling of biological filters
		- Foaming indication of old sludge
		- MLSS for sludge stability
		- % solids of Dewatered sludge

5.2.5 Evaluation Of IWWTP Performance

The following factors may be useful to the self-monitoring personnel in the evaluating the performance of the IWWTP.

- **Odor**
  Odor problem is usually due to the excessive organic loading of industrial wastes or malfunctioning and poor maintenance of trickling filters, primary and secondary clarifiers and sludge thickening tanks.

- **Color**
  The black color of raw wastewater with septic odor may indicate that part of wastewater is being retained because of slow flow due to a build up of sludge or grit.

- **Surface foam and scum**
  Thick, dark, greasy, scummy layers of deep tan to brown foam covering the entire surface of aeration tanks always indicates that the sludge is too old and may be over oxidized.

- **Dissolved Oxygen**
  An extremely dark brown color with the odor of hydrogen sulphide in aeration tanks indicates poor oxidations. In conventional activated systems a DO level in the range of 1-3 mg/l with 2 mg/l is the desired minimum level.

- **Water quality testing**

  Testing the water quality can be further grouped into two groups, the first is testing the performance of individual units and the second group is testing the performance of the total treatment plant. Samples will be taken upstream and downstream every treatment units for testing the performance of individual units or samples will be taken at the entrance channel and exit point of the treatment plant for testing the integrated effects of the treatment units. The following parameters should be tested for inflow and outflow water; pH, COD, BOD_5, S.S, O&G.

- **Mixed Liquor Suspended Solids (MLSS)**

  MLSS in mg/l are composed of active microbial mass, non-active microbial mass, non-biodegradable organic and inorganic mass. The most economical ranges for maintaining MLSS in reactors are 2000 to 4000 mg/l.

- **Degree of Sludge Dewatering**

  By examining the performance of the dewatering system and the consistency of its output.

- **Survival of Fish Pond Tester.**

5.3 MONITORING OF WATER QUALITY, NOISE AND ODOR EMISSIONS

Environmental monitoring covers emissions to air, effluents and solid and hazardous waste. Self-monitoring concerning IWWTP requires emphasis on monitoring of water quality which is considered the key parameter when monitoring an IWWTP.

The regulations state the limits for the concentrations of some specific pollutants of wastewater when discharged to the recipient body. For monitoring purposes, the discharge values for specific substances or parameters are mostly expressed as total amount per unit time.

- Water quality testing can be grouped into two groups, the first is testing the performance of individual units and the second group is testing the performance of the total treatment plant. Samples are taken upstream and downstream for every treatment unit for testing performance of individual units. Samples are taken at the entrance channel and exit point of the treatment plant for testing the integrated effects of the treatment units. The following parameters should be tested for inflow and outflow water:

  - Wastewater Flow (Q), m^3/d
  - Total Suspended Solids (TSS), mg/l
  - Temperature, °C
  - Chemical Oxygen Demand (COD Cr), mgO_2/l
  - Biochemical Oxygen Demand (BOD_5), mgO_2/l
  - pH
  - Conductivity, mS/m
  - O&G, mg/l

Monitoring of such parameters greatly benefits the treatment plant if measured on a routine basis. Regular monitoring of influent water during peak processing time or during washing time prevents occurrence of sudden discharges of high COD and BOD loads to the plant. These shock loads can cause major malfunctions to the IWWTP.

Odor problems may occur when operating an IWWTP. Odor occurs as a result of excessive loading of industrial wastes or malfunctioning and poor maintenance of trickling filters, primary and secondary clarifiers and sludge thickening tanks. Extremely dark brown color and odor of hydrogen sulphide in aeration tanks indicates poor oxidations. In conventional activated systems a DO level in the range of 1-3 mg/l with 2 mg/l as average is the desired minimum.

The exposure of workers to noise levels higher than 90 decibel in the workplace can cause hearing problems. High levels of noise occur due to improper maintenance of mechanical equipment. Accordingly, the noise levels around the IWWTP area should be monitored, especially upon installing a new IWWTP plant or when new maintenance management is applied.

5.4 MONITORING ASPECTS OF OCCUPATIONAL SAFETY

Table (5-6) below shows examples of parameters and indicators for work environment and occupational health self-monitoring.

Table (5-6): Work environment and occupational health self-monitoring

Parameter / Indicator	Monitoring Method	Indication
Noise	Measurements	Compliance with legal requirements, quality of the work environment, safety, health
Hazardous chemical emissions ($Ca[OH]_2$ – sulphuric acid emissions – NaOH – HCl)	Gas analyses	Quality of the work environment, risk of professional disease
Hazardous chemical spills and handling (polymer)	Respiratory problems due to manual handling Observation of polymer dust – slippery floors	Quality of work environment, safety
H_2S and methane		
Exposure to pathogens	Medical checkup (skin, liver, eyes)	Quality of work environment, safety, health
Mist (pathogens / chemicals)		Quality of work environment, safety, health
Exposure to toxic / hazardous chemicals during cleaning of chemical sludge dewatering system		

5.5 MONITORING SLUDGE TREATMENT, SLUDGE QUALITY AND DISPOSAL

It is well documented that the proper handling and disposal of sludge is an extremely important component of wastewater treatment plants, otherwise huge operational and maintenance costs will be incurred.

If sufficient land is available then the cost of sludge treatment can be minimized by using ponds in which it is treated and removed after 3 – 10 year intervals. Sludge treatment problems can be minimized if extended aeration or oxidation ditches are used for wastewater treatment because the solids undergo endogenous respiration reducing the weight of dry solids to be treated.

Sludge should not be allowed to remain more than 24 hours in the thickening tank otherwise odor will develop due to septicity and this can be aggravated further with a rise in temperature.

The rate of return activated sludge (RAS) should be maintained according to the concentration after 2-3 hours of settlement. Return sludge should never be pumped so fast that it becomes thin, nor so slow that the sludge blanket builds up and disturbs the clarifier. Sludge pumping should be operated on a timer.

In the anaerobic digestion process, sludge must be added at a carefully controlled rate, it should be added in small quantities and slowly at frequent intervals or on a continuous basis.

In case of drying beds, applying wet sludge should not be applied over dry sludge until the preceding layer has been removed because the wet sludge will not drain. The sand lost from drying beds during every cleaning operation of dried sludge should be replaced and topped up to the designed depth.

Operating records such as depth of wet sludge, applied, pH, % of moisture contents, numbers of beds used, depth of dried sludge, time required for drying, weather and similar records of sludge dried, along with its disposal should be maintained. In many cases, solids concentration is an important factor in determining the efficiency of the dewatering units.

Typical solids concentration values for the sludge processing facilities

Operation	Solids concentration, %	
	Range	Typical
Gravity thickening		
Primary sludge	4-10	6
Primary sludge and waste activated sludge.	2-6	4
Floatation thickeners		
With chemicals	3-6	4
Without chemicals	3-6	4
Centrifuge thickeners		
With chemicals	4-8	5
Without chemicals	3-6	4
Vacuum filtration		
With chemicals	15-30	20
Belt filter press filtration		
With chemicals	15-30	22
Filter press		
With chemicals	20-50	36
Centrifuge dewatering		
With chemicals	10-35	22
Without chemicals	10-30	18

A daily settleability test is of vital importance to assist the operator in identifying problems and controlling the process. This test involves obtaining samples from the aeration tank and clarifier, settling them in a graduated jar within five minutes of their collection and allowing the samples to settle for a fixed period, usually 30 minutes. These results of sludge settling time versus volumes of settled sludge are plotted on a graph to prepare a settleability curve. If the actual curve of daily results rises above the ideal plant curve then it indicates that the sludge is too young. This needs adjustment of the return sludge rate in steps of a 20% increase at a time. This should also be accomplished by reducing the rate of sludge wasting and the aeration rate in the aeration tank. When the actual plant daily curve drops below the ideal plant curve then it indicates that the sludge is too old and it requires an increase in the sludge wasting rate. The common causes may be reduced organic loading, too high RAS rate from the clarifier, over aeration and retaining old sludge for long periods.

If the DO level is more than 4 mg/l then cut back the air during the night and if it is below 1 mg/l then increase it at night time and adjust it accordingly.

Parameter / Indicator	Monitoring Method	Indication
Amount of sludge from industrial water treatment plants (if decreasing, may for example indicate that clarifiers don't work well)	Weighing of treated sludge (pressed), book-keeping, recording of emptying and sludge treatment operations	Efficiency of wastewater treatment and clarification, possible impacts to receiving waters, changing in wastewater characteristics

5.6 MONITORING OF MAINTENANCE NEEDS

A proper preventive maintenance of wastewater treatment plants is extremely important for its trouble free operation. Operation and maintenance should be exercised in parallel and always go hand in hand. It is considered essential that at least the equivalent of one-third of the plant operation time should be spent in maintaining wastewater treatment plant equipment.

The treatment plant must be recognized as a highly specialized and complex manufacturing facility that must produce an acceptable product or effluent. It is the plant management's responsibility to produce this effluent at the lowest unit cost and at the highest quality possible. One important key to fulfilling this responsibility is a sound maintenance management program.

The person in charge of the treatment plant should be well educated, experienced and well versed to the nature of the job and of wastewater treatment technology. Training of wastewater treatment plant personnel is another important factor which should be well planned and tailored according to local requirements. It must be carried out regularly and on a continuous basis.

5.7 ENVIRONMENTAL REGISTER AND REPORTING

The general objective for the self-monitoring system is to deal with SM outputs which are representative, repeatable, reliable, compatible and comparable. These characteristics is dependent on the applied measures for quality control and quality assurance throughout that data production chain i.e. volume determination, sampling, sample pretreatment, treatment and analysis, data processing and reporting.

Environmental register
Only monitoring data related to compliance will be included in the environmental register. Description of the measuring and/or analytical techniques used should be reported as well as the location of sampling and measuring. EEAA/EPAP prepared a detailed description of the Environmental Register, based on the requirements of Law 4/1994 (see Annex 2). The competent authorities could request the inspection of the measuring devices to check their operability and the maintenance record for these devices. To assess compliance, a simple numerical or statistical comparison between the measurements, their uncertainty and the limit value may be performed. According to law 4/1994, compliance self-monitoring data should be recorded and kept for a minimum of 10 years.

Reporting
Description of the reporting scheme, its content recipient and purpose should be included in the self-monitoring plan. A monitoring report is a uniform presentation of data over a fixed period. An annual monitoring report that provides information of the past calendar year is always required.

Shorter period reports are required for significant polluters. The conditions of the process and equipment as well as location of monitoring points should be specified. Reporting can be:

- **Internal** to inform the Management and raise the environmental awareness of the facility personnel. It should include problems met during the implementation of the SM plan to be used in decision making.
- **External** for the competent authority. Based on the environmental register, establishments are required to report on environmental violations.

- Table (5-7) shows examples of various types of reports in a self-monitoring system.

Internal auditing and conclusion on result
The data obtained must be compared regularly with the objectives written down in the monitoring program to check they are being met.

Feedback and decision making
Feedback on the assessment of compliance based on the monitoring results should include all parties involved with the monitoring activities. The participants should make the necessary improvements and corrections to the next monitoring program.

In those parts of the monitoring program where compliance is met, possible reduction in frequency of monitoring can be considered and instead move resources to parts that need more accurate monitoring, e.g. borderline or non-compliance situations.

Feedback should include all parts of the monitoring program, process, product control, maintenance, environmental management and occupational safety. Detailed requirements should be set for the improvements needed and a data fixed for their implementation.

Table (5-7): Example of various types of reports in a self-monitoring system

Type of report and content	Source	Recipient	Schedule	Objectives
				INTERNAL REPORTING
First report - description of the monitoring system - scope and objectives - key persons and organization - self-monitoring plan	Person responsible for the self-monitoring system and the preparation of the plan	Upper management	When draft monitoring plan is ready	Inform and obtain commitment and approval of the monitoring system and plan
Following reports - data obtained - analysis of the data - problems met - conclusions - recommended specific actions and management decisions - proposed schedule for the actions - proposed investments	Person responsible for the self-monitoring system	Upper management	Monthly Quarterly Annually	Information and follow-up Information about trends-follow-up of the actions taken. Tool for decision making (decisions can lead to the development of the SMS) with 2 types of decision: correction of the system or its development. Budget and financial aspects-decision making (long term and middle term)
Activity reports Logbooks of results: measurements and analysis Problems met	Field staff and operators/laboratory	Persons responsible for self-monitoring issues	Weekly or monthly (depends on monitoring schedules)	

Table (5-7) cont'd: Example of various types of reports in a self-monitoring system

Type of report and content	Source	Recipient	Schedule	Objectives
EXTERNAL REPORTING				
First report Presentation of the proposed self-monitoring system (key persons, methods used to obtain data, schedules...)	Facility's management	EEAA / local authorities	Start up	EEAA clearance
Compliance report - summary of approved monitoring plan - data obtained - analysis of the data in terms of compliance	Facility's management	Authorities	Twice a year (Voluntary, only keeping the register is required)	Report on compliance status
Monitoring activities upgrading report Presentation of the self-monitoring system and upgrading plan Description of progress in implementation	Facility's management	EEAA / local authorities	With upgrading	Present developments in the monitoring activities and obtain EEAA clearance

Using outputs in public relations
Monitoring data is refined and distributed to the end users such as national and international reporting, research and statistical purposes, citizens, and the media. Citizens have the right to present complaints about the health or environmental impacts caused by the operation, these complaints are directed to the permitting and supervising authority.

Monitoring data is needed e.g. in national research and statistics, for planning and evaluation purposes, by national group organizations and the media.

5.8 RECOMMENDATIONS TO COMPANY MANAGEMENT

a) Good housekeeping

Good house keeping i.e. regular cleaning, tidying of site, buildings and pump houses, maintenance of green area, gardens and plantations will not only add to the life of the treatment plant but will provided psychological encouragement to the workers to work in an impressive atmosphere.

The site must be well-protected and barricaded and other safety regulations against fire, accidents and storage and handling of chemicals and equipment's should be observed strictly to avoid any mishaps.

b) Operational records and reports

A full record of the physical plant, performance operation, maintenance equipment and reports drawing should be maintained to calculate the efficiency of the treatment. Similarly all the operational manuals for each components of the plant and each item of equipment installed must be kept in a safe place for easy references in case of malfunctioning of the plant.

c) Maintenance of wastewater treatment plant

Operation and maintenance should be exercised in parallel and always go hand in hand. It is considered essential that at least the equivalent of one-third of the plant operation time should be spent in maintaining wastewater treatment plant equipment.

d) Training and development of staffing

A good management system will reduce breakdowns extend equipment life and provide for more efficient manpower utilization and performance. The person in charge of the treatment plant should be well educated, experienced and well versed to the nature of the job and of wastewater treatment technology.

Training of wastewater treatment plant personnel is another important factor, which should be well planned and tailored according to requirements as previously explained. It must be carried out regularly and on a continuous basis.

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DEFINITIONS AND TERMINOLOGY

- **Absorption.** The passage of one substance into or through another, e.g. an operation in which one or more soluble components of a gas mixture are dissolved in a liquid.
- **Activated Carbon.** A highly adsorbent form of carbon used to remove odorous and toxic substances from liquid or gaseous emissions. In waste treatment it is used to remove dissolved organic matter from wastewater.
- **Activated Sludge.** Sludge that results when primary effluent is mixed with bacteria-laden sludge and then agitated and aerated to promote biological treatment. This speeds breakdown of organic matter in raw sewage undergoing secondary waste treatment.
- **Adsorption.** An advanced method of treating waste in which activated carbon removes organic matter from wastewater.
- **Advanced Wastewater Treatment.** Any treatment of sewage that goes beyond the secondary or biological water treatment stage and includes the removal of nutrients such as phosphorus and nitrogen and a high percentage of suspended solids.
- **Aerobic Treatment.** Process by which microbes decompose organic compounds in the presence of oxygen and use liberated energy for reproduction and growth. Types of aerobic processes include extended aeration, trickling filtration, and rotating biological contractors.
- **Agglomeration.** The process by which precipitation particles grow larger by collision or contract with cloud particles or other precipitation particles.
- **Anaerobic.** A process that occurs in, or is not destroyed by, the absence of oxygen.
- **Bar Screen.** In wastewater treatment, a device used to remove large solids.
- **BOD (Biochemical Oxygen Demand).** A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water.
- **Biodegradable.** The ability to break down or decompose rapidly under natural conditions and processes.
- **Biological Treatment.** A treatment technology that uses bacteria to consume waste. This treatment breaks down organic materials.
- **COD (Chemical Oxygen Demand).** A measure of the oxygen required to oxidize all compounds in water, both organic and inorganic.
- **Chemical Treatment.** Any one of a variety of technologies that use chemicals or a variety of chemicals processes to treat waste.
- **Clarifier.** A tank in which solid is settled to the bottom and is subsequently removed as sludge.
- **Coagulation.** A clumping of particles in wastewater to settle out impurities. It is often induced by chemicals such as lime, alum, and iron salts.
- **Contaminant.** Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.
- **Dechlorination.** Removal of chlorine for a substance by chemically replacing it with hydrogen or hydroxide ions in order to detoxify the substances involved.
- **Decomposition.** The breakdown of matter by bacteria and fungi. It changes the chemical makeup and physical appearance of materials.
- **Denitrification.** The anaerobic biological reduction of nitrate nitrogen gas.

- **Diffused Air.** A type of aeration that force oxygen into sewage by pumping air through perforated pipes inside a holding tank and bubbling it through the sewage.
- **Digester.** In wastewater treatment, a unit process for degradation of sludge.
- **Disinfectant.** A chemical or physical process that kills pathogenic organisms in water. Chlorine is often used to disinfect sewage treatment effluent, water supplies, wells, and swimming pools.
- **DO (Dissolved Oxygen).** The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Secondary and advanced waste treatment are generally designed to protect DO in waste-receiving waters.
- **Dissolved Solids.** Disintegrated organic and inorganic material contained in water. Excessive amounts make water unfit to drink or to use in industrial processes.
- **Evaporation Ponds.** Areas where sewage sludge is dumped and allowed to dry out.
- **Filtration.** A treatment process for removing solid (particulate) matter from water by passing the water through porous media such as sand or a manmade filter. The process is often used to remove particles that contain pathogenic organisms.
- **Flocculation.** The process by which clumps of solids in water or sewage are made to increase in size by biological or chemical action so that they can be separated from the water.
- **Heavy Metals.** Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead. They can damage living things at low concentration and tend to accumulate in the food chain.
- **Ion Exchange Treatment.** A common water softening method often found on a large scale at water purification plants that remove some organisms and radium by adding calcium oxide or calcium hydroxide to increase the pH to a level where the metals will precipitate out.
- **Mechanical Aeration.** Use of mechanical energy to inject air into water to cause a waste stream to absorb oxygen.
- **Nutrient.** Any substance assimilated by living things that promote growth. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements.
- **Organic Matter.** Carbonaceous waste contained in plant or animal matter and originating from industrial sources.
- **Pathogens.** Microorganism that can cause disease in other organisms or in humans, animals and plants. They may be bacteria, viruses, or parasites and are found in sewage. Fish and shellfish contaminated by pathogens, or the contaminated water itself, can cause serious illnesses.
- **pH,** A measure of the acidity or alkalinity of a liquid or solid material.
- **Physical & Chemical Treatment.** Processes generally used in large-scale wastewater treatment facilities. Physical processes may involve air stripping or filtration. Chemical treatment includes coagulation, chlorination, or ozone addition.
- **Pretreatment.** Processes used to reduce, eliminate, or alter the nature of wastewater pollutants from non-domestic sources before they are discharged into publicly owned treatment works.
- **Primary Waste Treatment.** First steps in wastewater treatment; screens and sedimentation tanks are used to remove most materials that float or will settle. Primary treatment results in the removal of about 30 per cent of carbonaceous biochemical oxygen demand from domestic sewage.
- **Raw Sewage.** Untreated wastewater.

- **Residual.** Amount of pollutant remaining in the environment after a natural or technological process has taken place, e.g., the sludge remaining after initial wastewater treatment.

- **Reverse Osmosis.** A water treatment process used in small water systems by adding pressure to force water through a semi-permeable membrane.

- **Sand Filters.** Devices that remove some suspended solids from sewage. Air and bacteria decompose additional wastes filtering through the sand so that cleaner water drains from the bed.

- **Screening.** Use of screens to remove coarse floating and suspended solids from sewage.

- **Secondary Treatment.** The second step in most publicly owned waste treatment systems in which bacteria consume the organic parts of the waste. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settable solids and about 90 per cent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment.

- **Sedimentation.** Letting solids settle out wastewater by gravity during wastewater treatment.

- **Settlable Solids.** Materials heavy enough to sink to the bottom of a wastewater treatment tank.

- **Skimming.** Using a machine to remove oil or scum from the surface of the water.

- **Sludge.** A semi-solid residue from any number of air or water treatment processes.

- **Stabilization.** Conversion of the active organic matter in sludge into inert, harmless material.

- **Suspended Solids.** Small particles of solid pollutants that float on the surface of, or are suspended in sewage or other liquids. They resist removal by conventional means.

- **Tertiary Treatment.** Advanced cleaning of wastewater that goes beyond the secondary or biological stage. It removes nutrients such as phosphorus and nitrogen and most BOD and suspended solids.

- **TDS (Total Dissolved Solids).** The total amount of dissolved solid materials present in an aqueous solution.

- **TOC (Total Organic Carbon).** TOC is a measure of the amount of carbon in a sample originating from organic matter only. The test is run by burning the sample and measuring the CO_2 produced.

- **TOD (Total Oxygen Demand).** A measure of the oxygen demand of wastewater by injecting a small volume of the sample into oxygen containing carrier gas and passed through a catalyst bed at 900 ^{o}C. The carbon, nitrogen, and many minerals are converted to their oxides by consuming oxygen from the carrier gas, this amount of gaseous oxygen consumed is measured and given as the TOD of the sample in mg oxygen/liter of wastewater.

- **TSS (Total Suspended Solids).** A measure of the suspended solids in wastewater, effluent, or water bodies.

- **Trickling Filter.** A coarse, biological treatment system in which wastewater is trickled over a bed of stoned or other material covered with bacterial growth, leading to bacterial break down of the waste.

- **Turbidity.** A cloudy condition in water due to suspended silt or organic matter.

- **VSS (Volatile Suspended Solids).** The suspended organic fraction which will oxidize and will driven off as gas at temperature 550 ^{o}C $\pm$ 50 ^{o}C.

- **Wastewater Treatment Plant.** A facility containing a series of tanks, screens, filters, and other processes by which pollutants are removed from water.