Technical Guidance Document Series Number-DOE-IETS-9

GUIDANCE DOCUMENT ON THE DESIGN AND OPERATION OF INDUSTRIAL EFFLUENT TREATMENT SYSTEMS

Specified in Regulation 5, Environmental Quality (Industrial Effluent) Regulations 2009

DOE Malaysia
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FOR THE USE OF THE INDUSTRIES AND CONSULTANTS

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CONTENTS

FOREWORD

The design procedure, considerations, requirements, criteria, standards and specifications of industrial effluent treatment system (IETS) described in this Guidance Document (to be referred to as "criteria") represent the minimum criteria that an owner of an industrial facility shall comply with. These criteria shall be met in order to comply with Regulations 5 of the Industrial Effluent Regulations, 2009 (to be referred to as IERs).. The owner shall take additional measures either in the form of providing redundancies, installation of additional equipment, providing higher safety factor, etc if these additional measures are deemed appropriate to further ensure compliance with the effluent discharge standards stipulated in the IERs all the time. The Guidance Document will be reviewed and updated from time to time.

DATO' HAJAH ROSNANI IBARAHIM
Director General
Department of Environment, Malaysia
2009

CHAPTER 1: INTRODUCTION

The purpose of this Guidance Document is to stipulate:

- The minimum design criteria for common unit operations and unit processes to be complied with by the engineer when undertaking an exercise in the design of an industrial effluent treatment system (IETS) at the design stage.

- The operating conditions to be maintained for various unit operations and unit processes by the IETS operator at the operational stage.

The preparation of this document takes cognizance of the contributing factors that would result in a success story of industrial effluent treatment, namely an acceptable design of the IETS and later, its optimal operation. A well trained and experienced engineer will ensure that the IETS is adequately designed and a competent operator will ensure that the IETS is optimally operated. As a consequence, the final result is a success story of regulatory compliance on a continuous basis or improvement in regulatory compliance and mitigation of adverse environmental impact.

1.1. Deviation from Design Criteria

Deviations from the design criteria stipulated in this Guidance Document shall be allowed only if documented evidence can be substantiated to justify the use of lower criteria or standard without compromising the desired quality or outcome. The evidence shall be documented and submitted to the DOE.

It is to be noted that for some IETS components, numerical design criteria are not specified because of the nature of the design process and the design variables involved are application – specific and largely dependent on the desired quality of the product or outcome and on the management decision on the technology to be used. In these cases, wide flexibility is given to the design engineer in consultation with the client, to decide on the design variables and operating conditions. However, these variables and operating conditions shall be documented and submitted to the Department of Environment (DOE).

1.2 Design of Unit Operations and Unit Processes not Discussed in Guidance Document

The types of unit operations and unit processes of IETS discussed in this Guidance Document are not exhaustive. The design engineer shall design such IETS components according to established design criteria which shall be submitted to the DOE with the notification form.

1.3 Notification Requirement

Regulation 4, IERs requires a new source or an altered source of effluent discharge to notify the DOE via the use of the notification form specified in the Second Schedule. Details of the design of the IETS shall also be furnished along with notification form.

CHAPTER 2: GENERAL CONSIDERATIONS AND PRINCIPLES

This chapter describes the general principles that the design engineers need to adhere to and the considerations needed to be taken into account when designing an industrial effluent treatment system (IETS).

2.1 Design Engineers

Engineers who have undergone university training and obtained a degree in certain discipline are better equipped and hence are more appropriate to handle certain aspects of environmental problems. Nevertheless, it should be noted that engineers from one discipline, through additional training such as post graduate courses and relevant on the job training may develop sufficient working knowledge and expertise in other closely related disciplines. Professional ethics will dictate that one would not be willing to undertake an engineering assignment which is not within one's expertise.

From the perspective of the Industrial Effluents Regulations, 2009, in performing an IETS design task, the following shall be adhered to.

Physico – Chemical Treatment Processes

The process and functional design of the physico – chemical treatment processes shall be carried out by:

- A chemical or an environmental engineer, or
- A civil engineer who has taken courses in the design of physico – chemical treatment processes at the undergraduate level or has undergone a postgraduate course in environmental engineering or water pollution control engineering, or
- An engineer in other relevant discipline who has undergone a postgraduate course in environmental engineering or water pollution control engineering.

Biological Treatment Processes

The process and functional design of the biological processes shall be carried out by:

- An environmental engineer, or
- A chemical engineer who has taken courses in the design of biological treatment processes at the undergraduate level or has undergone a postgraduate course in environmental engineering or water pollution control engineering, or
- An engineer in other relevant discipline who has undergone a post graduate course in environmental engineering or water pollution control engineering.

The design of mechanical, electrical, or electronics components as well as the structural design shall be carried out by relevant engineers in conformance to the applicable legislations which are currently in force. All the engineers shall maintain current registration with the Board of Engineers Malaysia (BEM).

2.2 Effluent Flowrate

2.2.1 Effluent Flowrate Estimation

Determination of the flowrate of industrial effluent is a fundamental step in the design of effluent collection and treatment systems. Reliable data on existing and projected flows must be available if the industrial effluent treatment system (IETS) is to designed properly. For existing industrial manufacturing industries, effluent flowrate estimate shall be developed from water consumption record or from the analysis of flowrate data or from actual measurements such as those conducted in industrial effluent characterization studies (IECSs). For new manufacturing industries, estimate shall be made using data from existing industries operating elsewhere utilizing similar manufacturing processes or from published data.

2.2.2 Flowrate for Design

For the design of IETS, it is recommended that the peak flow (i.e the maximum daily flow, Q_{peak}) is used. The maximum daily flow is important particularly in the design of facilities involving detention time such as equalization basins.

Q_{peak} is computed from the relationship:

$$Q_{peak} = Q_{average} \times \text{ peaking factor}$$

where the peaking factor is recommended to be approximately 2.5.

2.3 Significant Pollution Parameters

Based on literature data or experience with similar industries or raw materials and manufacturing processes employed, the engineer shall identify the significant pollution parameters in the effluent streams. Table 2.1 below gives a guide on significant pollution parameters for some common industry categories/types.

Table 2.1: Priority effluent parameters for different industries (list not exhaustive)

Industry Type	**Typical Priority Effluent Parameters**
Chlor-Alkali (Mercury Cell)	T, pH, SS, Mercury, Chlorides
Chlor-Alkali (Diaphragm Cell)	T, pH, SS, Chlorides T, pH, SS, O&G, Arsenic, Cadmium, Chromium (trivalent), Chromium (hexavalent), Lead, Nickel, Mercury, Silver, Zinc, Fluoride, Cyanides-depending on the metals involved
Fertilizer (Nitrogenous)	T, pH, SS, Ammoniacal nitrogen, COD
Fertilizer (Phosphate)	T, pH, COD, SS, Ammoniacal nitrogen, Fluoride
Pulp and Paper	T, pH, BOD5. COD, SS, Sulfides,
Petroleum Refining	T, pH, COD, SS, BOD_5, O&G, Phenolic compounds
Steel Industry	T, pH, COD, SS, Chromium (trivalent), Iron, Cadmium, Copper, O&G
Synthetic Fiber	T, pH, BOD_5, COD, SS, Sulfides, O&G
Tanning and Leather Finishing	T, pH, BOD_5, COD, SS, Sulfide, Chromium (trivalent), Chromium (hexavalent), Phenolic compounds, O&G,
Textile Processing	T, pH, BOD_5, COD, SS, Chromium, Copper,
Pigments and Dyes	T, pH, COD, Lead, Copper, Zinc
Thermal Power Plants	T, pH, SS, O&G
Rubber Products	BOD_5, COD, SS, Zinc, Chromium,
Paints, Varnishes & Lacquers	pH, COD, SS, Lead, Chromium, Cadmium, Zinc, Barium
Pesticides	COD, Mercury
Printing	COD, Lead, Color
Industrial Chemicals	pH, BOD_5, COD, SS Phenolic Compounds, Cyanide, Ammoniacal Nitrogen, Cadmium, Lead, Chromium, Mercury, Nickel, Zinc, Arsenic
Oil & Gas Production	T, pH, BOD_5, COD, SS, O&G, Chloride, Phenolic Compounds
Petrochemicals	T, pH, BOD_5, COD, SS, O&G, Phenolic Compounds
Dairy Industry	T, pH, BOD_5, COD, SS, O&G

Table 2.1 countinued

Fruit and Vegetable Processing	T, pH, BOD_5, COD, SS
Food and Beverage	T, pH, BOD_5, COD, SS, O&G
Glass Manufacturing	T, pH, COD, SS, Barium, O&G
Sugar	T, pH, BOD_5, COD, SS, O&G
Detergent	pH, COD, O&G, Anionic Detergent
Photographic	pH, COD, Silver, Cyanide, Fluoride
Glue Manufacture	pH, BOD_5, COD, Phenolic compounds; Formaldehyde
Oil & Gas Exploration	T, pH, BOD_5, COD, SS, O&G, Chloride, Phenolic compounds
Vegetable Oil Mills	T, pH, BOD_5, COD, SS, O&G
Plastic Materials and Products	SS
Wood Products	pH, SS, COD, Phenolic compounds
Pharmaceutical	T, pH, BOD_5, COD, SS

Note: BOD = biochemical oxygen demand; COD = chemical oxygen demand, SS= suspended solids; O&G = oil and grease

2.4 Mass Balance

A mass balance is a set of calculations used to account for the mass flows of various parameters among the different unit processes and unit operations that make up the entire IETS. A mass balance model shall be developed to track major pollutants such as BOD, COD, SS and metals in the liquid and solid streams in the IETS. Mass balances shall be developed to assess equipment performance based on existing data or to project future loading when a manufacturing facility is intending to adopt manufacturing process changes or to increase production capacity. To represent steady state plant operations, annual or monthly data, wherever relevant, shall be used for the development of mass balance.

2.5 Primary or Preliminary Treatment

Effective removal of grit, debris, excessive oil and grease, metals and other contaminants that could affect the biological process shall be accomplished prior to subjecting the effluent to the biological treatment processes.

2.6 Segregation of Effluent Streams

Separate drainage system for storm water shall be provided with no possibility for the storm water to be mixed with process effluent streams. Preferably, the effluent streams are conveyed through a piping system properly colored and labeled.

Incompatible effluent streams, for example cyanide – bearing effluent stream shall be segregated from acidic effluent streams to prevent the evolution of toxic hydrogen cyanide gas. Similarly, highly concentrated batch dumps shall be treated separately and shall not be mixed with the rest of the effluent streams.

2.7 Redundancies

The principle of redundancy to be adhered to in the design process is that the design of major components of the IETS whether they are related to the unit processes such as the aeration tanks or unit operations such as the precipitation tanks, shall provide sufficient units to ensure that the IETS is fully operational even during maintenance period. If this redundancy principle has not been complied with in the design, the manufacturing activity generating the effluent streams needs to be shut down whenever there is an equipment malfunction or the IETS is scheduled for maintenance.

2.8 Batch Discharges

If an IETS is designed to discharge its final effluent an a batch basis, any discharge of effluent shall be preceded by sampling of the effluent and analysis of the relevant parameters which can be made in a short time frame. Such parameters include COD and metals which are amenable to rapid measurement using portable equipment. Compliance with the discharge standards shall be assured before the discharge is allowed. A record of the discharge details including the time, the discharge quality, the person authorizing the discharge etc. shall be maintained by the industry for the inspection by the DOE officers.

2.9 Submittal of Design Calculations

Detailed engineering calculations shall be submitted to justify the basis of design for the all the unit processes and unit operations of the entire IETS. The calculations shall show the basis for sizing the aeration tanks, aeration equipment, clarifiers, return sludge equipment, waste sludge equipment, dissolved air flotation (DAF) unit, precipitation tank, coagulation tank, flocculation tank, ion-exchange column, adsorption column, chemical dosing system nutrient requirements, equipment involving membrane processes, transfer pumps, metering pumps, equalization tanks, screens etc. The quantities of chemicals to be used shall also be computed.

2.10 Flow Charts and Process and Instrumentation Diagram (PID)

The following flowcharts and diagrams shall be prepared and submitted to the DOE.

- Flow chart of the manufacturing process indicating the points of generation of effluent streams
- Flow chart of the IETS
- Process and instrumentation diagram (PID) of the IETS

2.11 All Effluent Streams to Undergo Treatment

Effluent streams generated from all processes and activities occurring within the manufacturing facility shall be collected and channeled to the IETS for treatment. This includes shop floor cleaning, spills, valve leaks etc, Discharge of treated effluent from the premise shall take place only through the designated discharge point downstream of the IETS.

2.12 Compliance with Discharge Standards

The specifications stipulated in this Guidance Document represent the minimum requirements and criteria to be complied with in the design and operation of an IETS. However, the overall responsibility still rests on the owner of the industry to ensure the final effluent quality meets the applicable discharge standards. The design engineers and the owner shall take additional measures deemed appropriate to ensure discharge compliance is met at all time. The discharge standards stipulated in Fifth, Seventh and Eighth Schedules are reproduced below for ease of reference.

Table 2.2: Fifth Schedule to the Industrial Effluent Regulations, 2009

[Paragraph 11(1)(a)]

ACCEPTABLE CONDITIONS FOR DISCHARGE OF INDUSTRIAL EFFLUENT OR MIXED EFFLUENT OF STANDARDS A AND B

	Parameter	Unit	Standard	
			B	A
	(1)	(2)	(4)	(3)
(i)	Temperature	°C	40	40
(ii)	pH Value	–	5.5-9.0	6.0-9.0
(iii)	BOD_5 at 20oC	mg/L	50	20
(iv)	Suspended Solids	mg/L	100	50
(v)	Mercury	mg/L	0.05	0.005
(vi)	Cadmium	mg/L	0.02	0.01
(vii)	Chromium, Hexavalent	mg/L	0.05	0.05
(viii)	Chromium, Trivalent	mg/L	1.0	0.20
(ix)	Arsenic	mg/L	0.10	0.05
(x)	Cyanide	mg/L	0.10	0.05
(xi)	Lead	mg/L	0.5	0.10
(xii)	Copper	mg/L	1.0	0.20
(xiii)	Manganese	mg/L	1.0	0.20
(xiv)	Nickel	mg/L	1.0	0.20
(xv)	Tin	mg/L	1.0	0.20
(xvi)	Zinc	mg/L	2.0	2.0
(xvii)	Boron	mg/L	4.0	1.0
(xviii)	Iron (Fe)	mg/L	5.0	1.0
(xix)	Silver	mg/L	1.0	0.1
(xx)	Aluminum	mg/L	15	10
(xxi)	Selenium	mg/L	0.5	0.02
(xxii)	Barium	mg/L	2.0	1.0
(xxiii)	Fluoride	mg/L	5.0	2.0
(xxiv)	Formaldehyde	mg/L	2.0	1.0
(xxv)	Phenol	mg/L	1.0	0.001
(xxvi)	Free Chlorine	mg/L	2.0	1.0
(xxvii)	Sulphide	mg/L	0.50	0.50
(xxviii)	Oil and Grease	mg/L	10.0	1.0
(xxix)	Ammoniacal Nitrogen	mg/L	20.0	10
(xxx)	Colour	ADMI*	200	100

*ADMI- American Dye Manufacturers Institute

Table 2.3: Seventh Schedule to the Industrial Effluent Regulations, 2009

(Regulation 12)

ACCEPTABLE CONDITIONS FOR DISCHARGE OF INDUSTRIAL EFFLUENT CONTAINING CHEMICAL OXYGEN DEMAND (COD) FOR SPECIFIC TRADE OR INDUSTRY SECTOR

	(1)	(2)	(3)	(4)
	Trade/Industry	Unit	Standard	Standard
			A	B
(a)	Pulp and paper industry			
	(i) pulp mill	mg/L	80	350
	(ii) paper mill (recycled)	mg/L	80	250
	(iii) pulp and paper mill	mg/L	80	300
(b)	Textile industry	mg/L	80	250
(c)	Fermentation and distillery industry	mg/L	400	400
(d)	Other industries	mg/L	80	200

Table 2.4: Eighth Schedule to the Industrial Effluent Regulations, 2009

(Regulation 13)

ACCEPTABLE CONDITIONS FOR DISCHARGE OF MIXED EFFLUENT CONTAINING CHEMICAL OXYGEN DEMAND (COD)

(1)	(2)	(3)
	Standard	Standard
Unit	A	B
mg/L	80	200

2.13 On Site Lab Facilities

To ensure optimal performance of the IETS constant monitoring of the processes occurring in the IETS is essential. This warrants the establishment of a laboratory equipped with basic facilities within the industry premise to enable the IETS personnel to conduct routine performance monitoring activities such as sampling, sample preservation, equipment calibration, sample analysis etc. Performance monitoring measurement of flow, pH, ORP, dissolved oxygen, suspended solids, oxygen uptake and jar tests, etc. are part and parcel of IETS operation which can be made by using in-situ portable instruments without having to wait for "very accurate results" from the accredited labs. The measurement of these parameters which is done on a routine basis is facilitated by having a simple lab provided in close proximity to the IETS site. Appropriate adjustments to the IETS operation can immediately be made based on the results of this routine monitoring.

CHAPTER III: DESIGN OF BIOLOGICAL TREATMENT PROCESS

This chapter describes the general design considerations that shall be reviewed and the criteria followed when designing any biological treatment system.

3.1 Process Selection

Dissolved organic matter found in the industrial effluents is removed by employing biological treatment processes. These include suspended growth systems such as the activated sludge processes and attached growth systems (or fixed film systems) such as the trickling filters or rotating biological contactors. In the Malaysian setting, attached growth processes are seldom used to treat industrial effluents. Biological treatment processes are also categorized as aerobic process, anaerobic process or anoxic process. Most biological treatment processes employed for the treatment of industrial effluents in Malaysia are typically of the aerobic process type.

The engineer shall justify the choice of the biological treatment process for the industrial effluent. Calculations and documentation shall be submitted to the Department of Environment to justify the basis of design for all the components of the biological treatment system including/be the following items:

a. process efficiency
b. dimension of the reaction tanks
c. sizing of the mechanical equipment
d. operational rationale (including maintenance)
e. performance monitoring

The design for the related unit processes such as clarifiers and sludge processing, shall also comply with the requirements stipulated in the other chapters of this Guidance Document.

3.2 Type of Activated Sludge Process and its Variants

The activated sludge process and its various modifications have been widely employed successful to treat industrial effluents from a wide range of industrial manufacturing for the removal sources of biodegradable organics. The choice of the process most applicable to a particular situation will be dictated by several factors such as the size of the industry, effluent characteristics, degree and consistency of treatment required and stipulated discharged standards imposed by the regulatory agency. All designs shall incorporate for flexibility of different modes of operation of the IETS.

There exist several major types of activated sludge process which are commonly used to treat industrial effluents in Malaysia. These are: conventional activated sludge, extended aeration activated sludge and sequencing batch reactors (SBR). These are briefly described below:

- Conventional activated sludge is characterized by introduction of influent stream and return activated sludge at one end of the aeration tank, a plug-flow aeration tank and different types of aeration system.
- Extended aeration activated sludge is characterized by a low F/M ratio, long sludge age and long aeration tank detention time (typically, greater than 18 hours).
- Sequencing batch reactors (SBR) is a fill-and-draw, non steady state activated sludge process in which one or more reactor basins are filled with effluent during a discrete time period and then operated in a batch treatment mode. SBRs accomplish equalization, aeration and clarification in a timed sequence.

Other variants of activated sludge process are: complete mix, step aeration, tapered aeration, contact stabilization, high-rate aeration and high purify oxygen. These are not common in Malaysia, hence will not discussed in this Guidance Document.

3.3 Equalization Basin

Equalization basins serve the objective of minimizing the fluctuation in the flow and concentration of the influent. Whenever necessary, equalization basins shall be provided to serve any of the following purposes.

(i) elimination of organic shock load
(ii) stabilization of pH, hence minimizing chemical treatment
(iii) minimization of flow surges to physico-chemical treatment systems
(iv) prevention of high concentration of toxic materials entering the biological systems.

3.3.1 Design of Equalization Basins

Equalization shall be provided when there is considerable fluctuation in flow and pollutant concentrations. The size of the equalization basin shall be adequate to absorb pollutant fluctuations and dampen concentrated batches. Adequate mixing shall be provided through the use mechanical mixers or other method of mixing.

For an existing industry, if an equalization basin is to be provided, the actual size of the basin shall be determined by performing a series of calculations involving time versus flowrate data (reference can be made to Metcalf and Eddy, 1994). For a new industry to be established, the size of the equalization basin shall be determined on the basis of acceptable detention time, ranging from 2 to 3 hours. The volume (V) of the basin is computed from the relationship.

$$V = Q_{peak} \times \text{detention time}$$

Where Q_{peak} is the maximum daily flow.

3.4 Aeration Tanks

3.4.1 Required Volume

The volume of the aeration tank shall be calculated using the F/M ratio or the sludge age approach based on the kinetic relationships. The relevant formulae are given in Appendix I.

Table 3.1 shows the typical range of F/M ratio, sludge age, mixed liquor suspended solids, aeration requirement, HRT, etc. for design of a conventional activated sludge process. All design parameters shall be checked to determine if they fall within the typical range for the selected F/M ratio or sludge age and the aeration tank volume. Diurnal load variation and peak loading shall be considered when checking critical parameters.

Table 3.1: Summary of typical design parameters for a conventional activated sludge system

Description	Unit	Design Criteria Range
Minimum number of aeration tank	-	2
F/M ratio	d^{-1}	0.25 – 0.50
HRT	h	6 - 16
O_2 requirement	kgO_2per kg BOD_5 removed	1.5
MLSS	mgL^{-1}	1500 - 3000
DO in aeration tank	mgL^{-1}	2.0 – 4.0
Sludge yield, Y*	kg sludge produced per kg BOD_5 removed	0.8 – 1.0
Decay coefficient, k_d*	d^{-1}	0.03 – 0.07

Table 3.1 continued

Sludge, θ_c	d	5 – 10
Organic loading	kgm^3 d^{-1}	0.3 – 0.7

* The values of kinetic coefficients depend on the characteristics of the effluent, hence must be determined for each effluent from bench or pilot plant studies. Values given here are typical for sewage.

Appendix I also lists other formulae which are commonly used in the design of activated sludge systems. These formulae shall be used to design the associated components of the activated sludge system.

3.5 Oxygen Requirements

Oxygen requirements for carbonaceous BOD removal include oxygen to satisfy the BOD of the effluent plus the endogenous respiration of the microorganisms. Additional oxygen is required if nitrification occurs.

Oxygen requirements depend on the influent loading to the aeration tank as well as the process design and should be determined using rational calculations. Calculations should be based on the peak hourly BOD loading to the aeration tanks. Recycle flows from solid processing operations shall be considered since these streams often have high BOD concentrations.

The oxygen requirements for an activated sludge system shall be estimated using the formulae reproduced in Appendix II.

3.5.1 Aeration System

There are several factors which would determine the oxygen requirements for an IETS. These are namely BOD loading, degree of treatment and concentration of mixed liquor suspended solids to be maintained. Aeration system shall be designed to supply sufficient oxygen to maintain a minimum dissolved oxygen concentration of 2 mg/L at average design load and 1.0 mg/L at peak design loads throughout the mixed liquor. In the absence of experimentally determined values, a rule of thumb which can be used is to design for an oxygen requirement of 1.1 kg oxygen for 1 kg peak BOD_5 applied to the aeration tank for all activated sludge processes, with the exception of the extended aeration, for which the value is 2.35. Aeration system shall be designed to maintain velocities greater than 15 cm/s at all points in the aeration tank.

Oxygen requirements for carbonaceous BOD removal are dependent on the sludge age. For preliminary design before process design is initiated, a rough guide or rule of thumb on oxygen requirements for carbonaceous BOD removal is to provide 1.5 kg of oxygen per kg of BOD removed. Where ever relevant, provisions for nitrogenous oxygen demand shall be considered separately and are typically 4.6 kg of O_2 per kg of total kjedahl nitrogen (TKN) applied.

3.5.2 Diffused Aeration System

Air requirements for diffused aeration systems shall be determined based on the oxygen requirements using the industry-accepted equations given in Appendix III. The engineer shall state clearly the type of diffusers, or course bubble diffusers or combination systems selected in the design.

As a general guide for carbonaceous BOD removal, the minimum oxygen requirements are given in Table 3.2 below.

Table 3.2: Guide on minimum oxygen requirements

Process	**Cubic meter of air required per kg of BOD applied to aeration tank**
Conventional	90
Step aeration	90
Contact stabilization	90
Modified or 'high rate'	25 to 90 depending on BOD removal expected
Extended aeration	130

Air required for channels, pump or other air-use demand shall be added to the air volume requirements.

Manufacture's specifications shall be corrected to account for actual operational conditions (use the worst case scenario).

3.5.3 Mechanical Aeration System

Power input from mechanical aeration system shall range from 1.3 kw to 3.4 kw per 100m^3 of aeration tank.

Another guide for rough estimate of the oxygen requirement for mechanical aeration system is to provide 1.5 kg of O_2 per 1 kg of overall BOD removed for conventional activated sludge process. For extended aeration process, a value of 2.0 is often used. Another commonly used rule of thumb is to provide 50 m^3 of air per kg of BOD removed for conventional process and 125 m^3 for extended aeration.

Multiple mechanical aeration unit installations shall be designed to meet the maximum oxygen demand with the largest unit out of service. Additionally, if deemed appropriate, the design shall also provide for varying the amount of oxygen transferred in proportion to the load demand on the IETS.

A spare aeration mechanism shall be made available for single unit installations. Access to the aerators shall be provided for routine maintenance.

3.6 Sequencing Batch Reactors (SBRs)

SBRs are an attractive option for small and medium effluent flows. One of the advantages of the SBR is that it eliminates the need for the clarifier, hence affords substantial savings in capital cost.

SBRs shall be designed to meet all the requirements stipulated in the proceeding sections on activated sludge. Special conditions shall be given to the following:

- A pre-aeration, flow equalization basin shall be provided for when the SBR is in the settle and/or draw phases. If multiple SBR basins are provided a pre-aeration basin will not be needed if each SBR basin is capable of handling all the influent peak flow while another basin is in the settle and/or draw phase.
- When discharging from the SBR means shall be provided to avoid surges to the succeeding treatment units.
- The effluent from the SBRs shall be removed from just below the water surface (below the scum level) or a device which excludes scum shall be used. All decanters shall be balanced so that the effluent will be drawn equally from the effluent end of the reactor.

CHAPTER IV: NUTRIENT REQUIREMENTS

Many industrial effluents do not contain sufficient amounts of nutrients particularly nitrogen (N) and phosphorus (P) for optimal microbial growth: These nutrient – deficient industrial effluents need to be supplemented with nutrient addition. Based on experience, the design engineer shall identify the need for nutrient addition and compute the amount required. Typically, the BOD:N:P ratio to be maintained is 100:5:1. The associated equipment and instrumentation to ensure adequate supply of nutrient to the biological treatment process shall be designed accordingly. This includes the nutrient tank, agitation system, dosing and metering system and nutrient storage requirement. As a guide, Table 4.1 shows industrial effluents which have been found to be nutrient deficient.

Table 4.1 Nutrient deficient industrial effluents (Broderick and Sherrard, 1985)

Waste Type	Deficient nutrient
Bakery	N
Bottling plant	N, P
Brewery	N
Citrus	N
Chemical plant	P
Coffee, soluble	N
Coke oven	P
Corn	N
Cotton keiring	N
Dairy	N, P
Food processing	N, P
Formaldehyde	N, P
Fruits and vegetables	N, P
Paper and pulp	N, P
Pear	N, P
Pharmaceutical	P
Phenols	N
Pineapple	N, P
Rag and rope	N, P
Sugar beets	N

Table 4.1 continued

Soybean	N
Textile	N
Vinegar	N, P
Winery	N, P

CHAPTER V: DESIGN OF CLARIFIERS

Sometimes in the treatment of industrial effluents, pretreatment for the removal of suspended solids is required before the effluent is sent to a biological treatment process to remove dissolved organics. If the concentration of suspended solids in the raw effluent is low, primary sedimentation is not required. If the solids present are organic in nature, a certain fraction of the biochemical oxygen demand is also removed through the sedimentation process which is normally achieved by gravity sedimentation. Clarifiers are also required after the industrial effluent has undergone biological treatment in the aeration tank to separate the biological solids from the supernatant. In chemical treatment processes too, for example in the removal of metals via precipitation process, the metal precipitates need to be separated from the solution by clarification process. This chapter describes the design considerations to be taken into account by the engineer when designing clarifiers.

5.1 Design Criteria for Primary Clarifiers

Information on settling characteristics of the solids is important in the design of clarifiers. For new industries, the relevant information on settling characteristics from similar operation elsewhere is extremely useful. If information is not available, design of sedimentation tank/clarifier is normally based on "acceptable design criteria" generally found to work in practice. Typical design criteria for primary clarifiers are given in Table 5.1 below. The criteria are based on peak flowrate i.e peaking factor x average flowrate. Based on the stipulated design criteria for surface overflow rate and detention time the engineer shall determine the clarifier dimensions. The length to width ratio for rectangular tanks is typically 3:1.

If a new clarifier is to be designed for an existing industry effluent sampling and laboratory testing is conducted to investigate the settling characteristics of the effluent prior to design work. The settling data are analyzed to generate a plot of percent suspended solids removal versus surface over flowrate from which the clarifier dimensions can be computed.

Table 5.1: Typical design criteria for primary clarifiers

Description	**Unit**	**Design Criteria**	
		Average flow	**Peak flow**
Surface over flowrate (SOR)	$m^3m^{-2}d^{-1}$	30	70
Solids loading rate (maximum)	$kgm^{-2}d^{-1}$	-	30
Weir overflow rate (WOR)	$m3m^{-1}d^{-1}$	100	200
Detention time (minimum)	h	-	2

5.2 Design Criteria for Secondary Clarifiers

Design of secondary clarifiers is influenced by the high incoming suspended solids concentrations which are typically in the range of 2500 mg/L to 5000 mg/L. Under this situation, interactions between particles result in hindered settling. For an existing industry the design of secondary clarifiers shall follow the solids flux method following the analysis of data from settling tests.

In the absence of solids settling data, based on design peak hourly flow, the criteria in Table 5.2 shall be used for the design of secondary clarifiers.

Table 5.2: Design criteria for secondary clarifiers

Treatment process	**SOR $m^3m^{-1}d^{-2}$**	**Solids loading rate, $kgd^{-1}m^{-2}$**	**WOR, $m^3d^{-1}m^{-1}$**	**Detention time, h**
Conventional complete mix	50	100	200	2
Extended aeration	40	150	300	2

Note: SOR= Surface overflow rate; WOR= Weir overflow rate

5.3 Clarifier Monitoring

A method of measuring and monitoring the sludge depth in the clarifier shall be identified. If deemed appropriate, a sludge level sensor may be selected and installed by the design engineer to continuously monitor the sludge level and to facilitate the necessary operational actions.

5.4 Design Criteria for Plate Clarifiers/Plate Settlers

A very common type of clarifier used in the industry for small flows, especially for clarifying metal precipitates is the lamella clarifier. Lamellas are a special case of a tube clarifier.

The engineer shall compute and submit the following information

- Type of clarifier
- Angle of inclination and clarifier dimensions
- Total effective settling area
- Surface overflow rate

- Flowrate
- Ratio of clarification to thickening area
- Plate spacing
- Sludge storage compartment
- Use of coagulants and flocculants

The ratio of clarification to thickening area shall be determined from laboratory settling tests of representative effluent samples for existing industries or from past experience with similar applications for new industries. For metal hydroxides, typical design criteria are given below:

Table 5.3: Typical design criteria for lamella clarifiers

Surface over flowrate (SOR)	0.01m^3 per min per m^2 of horizontal projected area
Angle inclination	55° - 60°

An inlet plenum shall be provided to uniformly distribute the influent to the inclined plate compartments. The outlet area shall be designed to force uniform flow from all plate compartments and also over the entire with of the plates.

The design shall incorporate features to inhibit channeling. A sufficient sludge compartment to store the accumulate solids shall also be provided in the design.

CHAPTER VI: DESIGN OF NEUTRALIZATION TANK

If the influent to the biological treatment process is expected to exhibit pH outside the optimal range for biological treatment, pH neutralization shall be provided. Neutralization is typically accomplished by using acidic or alkaline chemical treatment.

6.1 Design Criteria for Neutralization Tank

The sizing of the neutralization tank shall be based on the average flow and the acceptable retention time commonly used in practice. The general equation used to be to compute the tank volume (V) is:

$$V = Q_{avg} \times \text{retention time}$$

Where Q_{avg} is the average flow rate.

The minimum retention time shall be 10.0 min.

The engineer shall indicate the characteristics of neutralization chemicals to be used and shall design the capacity of metering pumps and associated dosing equipment accordingly.

The design of the neutralization system shall be an automatic system that includes mixer and level controls, automatic chemical addition, automatic pH monitoring, automatic filter feed pump and control panel.

CHAPTER VII: DESIGN OF CHEMICAL PRECIPITATION SYSTEMS

Chemical precipitation is the most common technique used for removing dissolved metals from metal bearing industrial effluents. The ionic metals are converted to an insoluble form by the chemical reaction between the soluble metal compound and the precipitating agent. The unit operations typically involved in this technique include neutralization, precipitation, coagulation and flocculation, solid-liquid separation and dewatering.

The most widely used chemical precipitation is hydroxide precipitation where dissolved metals are converted to an insoluble form by the use of sodium hydroxide as the precipitant. Some metals can also be precipitated as sulfides, carbonates or phosphates.

7.1 The Design pH

The working pH for precipitating the metals shall be decided primarily based on the information obtained from the graph of metals solubility versus pH. As a result of the presence of other constituents in the effluent stream, the pH of minimum solubility may change slightly. The situation may be further complicated by the presence of other metals in the raw effluent stream. This is common for effluents generated from electroplating processes involving plating of more than one metal. If more than one metal is to be precipitated, a pH value that is applicable to all metals shall be identified. Alternatively, each metal shall be separately precipitated in different stages.

The design engineer shall explain how the pH range has been selected for the precipitation system to effectively precipitate all the metals regulated by the Industrial Effluents Regulations, 2009 (IERs). Jar Test experiments to refine the actual pH range applicable to the effluent stream is recommended.

7.2 Chemical Coagulation and Flocculation

To promote aggregation of the suspended solids into larger particles and enhance subsequent settling, chemical coagulants and flocculants are added. The design engineer shall describe the chemicals to be used and their characteristics and details of application as recommended by the manufacturer. Results of jar test experiments to investigate the optimum application conditions such as pH, dosage and removal efficiency shall be presented.

The design engineer shall design high-energy rapid-mix condition to provide sufficient mixing of the coagulants. The contact time required in the rapid- mix chamber shall be typically 1 to 3 minutes. However, it is recognized that the optimum retention time is dependent on the velocity gradient and coagulant dosage applied. The design engineer shall provide a root mean square velocity gradient (G) of the order 300s^{-1} for back mix reactors and 400s^{-1} to 1000s^{-1} for plug-flow in-line reactors.

Flocculation is a slow mixing process to promote agglomeration of coagulated solids. It is accomplished by equipping the flocculators with slowly rotating paddles or other moving devices. The design engineer shall ensure the design meets the criteria stated in Table 7.1 for the average G.

Table 7.1: Average G for different types of flocs

Type of Floocs	**G, S^{-1}**
Fragile flocs such as biological flocs	10 - 30
Medium strength (turbidity flocs)	20 - 50
Chemical precipitation floc	40 - 100

Note: G is the root mean square velocity gradient.

In the flocculation chamber, the design engineer shall ensure a design contact time range from 20 minutes to an hour or more.

7.3 Instrumentation for process control

The efficiency of treatment process to precipitate the metals is highly depended on pH, hence continuous and accurate pH monitoring is imperative. The design engineer shall incorporate instrumentation system to monitor pH which is linked to the chemical dosage system. If the treated effluent is to be further treated in a biological treatment process, pH readjustment shall be required. Hence the engineer shall ensure the requirement for another pH meter is catered for in the design.

7.4 Clarifier Design

The design of clarifier shall follow the specifications stipulated in Chapter V on the Design of Clarifiers.

CHAPTER VIII: DESIGN OF OXIDATION REDUCTION SYSTEMS

The oxidation reduction systems are used in the treatment of chromates and cyanides where chromates undergo reduction while cyanides undergo oxidation. For the removal of hexavalent chromium, sodium bisulfite or sulfur dioxide is added while chromium is reduced to trivalent chromium. In the case of cyanide, chlorine or sodium hypochorite is used to oxidize the cyanide, followed by the hydrolysis of cyanogen chloride to form cyanide. This chapter is dedicated to the discussion of the treatment of chromates using oxidation-reduction technique.

8.1 Removal of Chromium

Industrial effluents containing hexavalent chromium such as chromates and dichromates are commonly treated by a two-step process where in the first step, hexavalent chromium (Cr^{6+}) is reduced to trivalent chromium (Cr^{6+}) and in the second step, the trivalent chromium is precipitated as chromium hydroxide.

As the oxidation – reduction potential (ORP) and the speed of the reduction reaction is intimately affected by the pH of the solution, the monitoring of pH and ORP is essential to ensure proper control of the reduction process. Typical reducing agents used in the first stage of the process are sodium bisulfite or sulfur dioxide.

In the second stage, hydroxide precipitation is accomplished by the addition of alkaline solution such as ammonia or sodium hydroxide.

8.2 Design Criteria and Instrumentation for Two Stage Chromium Removal System

For a typical two stage chromium removal system, two pH control systems and one ORP system are recommended. All three controllers should be the on/off type that have a control relay with adjustable dead band. It is also recommended that the controllers also have alarm relays to alert the operator of conditions outside the normal range. For a two stage oxidation-reduction system, a typical design and control system shall consist of the following features:

- A pH meter shall be installed in the first tank where with the addition of acid, the pH shall be maintained at a value in the range of 2 – 3.
- An ORP meter shall be also installed in the first tank where after the addition of reducing agent the ORP shall be maintained at a value of approximately 250 – 300 mV range.
- The reaction time in the first stage shall be typically 10 to 15 mins. The reaction time increases if pH is controlled at higher levels. Variations in pH

also affect the measured ORP. Therefore pH shall be held constant to achieve consistent ORP control.

- A pH meter is installed in the second tank where through the addition of alkaline solution, the pH shall be maintained at a pH of 8 - 9.

The design engineer shall describe the type of system to be used and identify the details of the chemicals and process conditions to be maintained including the following aspects:

- whether the process is a continuous or a batch process
- the reducing agents and the alkaline chemicals to be used
- whether coagulants and flocculants will be used and the types, chemical names, properties, application and recommended dosage
- pH and ORP to be maintained in the tank
- pH and ORP meters to be used and where the meters will be installed
- process and instrumentation diagram (PID) showing how pH and ORP measurements are linked to the chemical dosing system.

CHAPTER IX : TREATMENT OF CYANIDE EFFLUENT STREAMS

Electroplating shops usually generate dilute cyanide effluents streams which are typically treated via a two-stage process commonly known as alkaline chlorination. It has been reported in the literature that a properly designed, maintained and operated alkaline chlorination system will oxidize cyanides amenable to chlorination and produce good quality effluents. However, alkaline chlorination will not destroy stable cyanide complexes such as ferrocyanides or ferricyanides.

Additionally, copper, nickel and precious metal cyanide complexes require excess chlorine for effective cyanide destruction.

9.1 The Design Criteria for Alkaline Chlorination Process

The design for a two stage alkaline chlorination process shall incorporate separate tanks for each stage. Exception is allowed only for batch treatment system where one tank can be employed.

In the first stage where hypochlorite is used to oxidize cyanide to cyanate, the pH of the solution shall be maintained at pH 10 or higher, preferably in the range of 11.0 to 11.5. The minimum oxidation period shall be designed to be 10 min although longer retention times are commonly used in practice. The ORP set-point shall be controlled at approximately +325 millivolts with the maximum being +400 millivolts. During treatment, the engineer shall provide vigorous mixing of the solution to ensure uniform composition throughout the reaction tank and to prevent the production of solid cyanide precipitates that resist chlorination.

In the second stage, when additional hypochlorite is added, the pH shall be maintained at approximately 8.5. The ORP set point is between +600 millivolts to +800 millivolts to indicate a complete reaction. The engineer shall ensure a minimum retention time of 30 minutes, although retention times of 120 minutes are commonly employed in practice.

The engineer shall determine the following and design the alkaline chlorination system accordingly:

- working pH
- reaction time
- ORP set-points
- vessel size and geometry
- amount of chlorine required
- agitation requirements
- reagent delivery system
- solids removal system

9.2 Instrumentation for Process Control

In the continuous process the design engineer shall provide automatic instrumentation to control reagent dosing and to measure pH, ORP and temperature.

9.3 Treatment of Concentrated Cyanide Wastes

Concentrated cyanide wastes, such as spent plating or stripping solutions shall be treated separately either by electrolytic oxidation or thermal destruction or by other proven technologies. The concentrated cyanide waste streams shall not be reacted with hypochlorite to avoid the violet reaction which emits toxic chlorine gas.

9.4 Alternative Treatment for Cyanide Waste

There are several alternatives to alkaline chlorination process for treating cyanide effluent streams. These include the use of ozone, hydrogen peroxide, calcium hypochlorite, electrochemical oxidation, thermal oxidation and precipitation. If any of these alternative technologies is used, the design engineer shall ensure that proven and well established design criteria are used in the design process.

CHAPTER X: ION EXCHANGE

Ion exchange is a reversible chemical reaction where an ion from solution is substituted for a similarly charged ion attached to an immobile solid surface. Typically in industrial application to treat industrial effluent streams, synthetically produced organic resins are used as solid exchange surfaces. Ion exchange treatment has been widely used in the industry to remove various contaminants from industrial effluents, particularly metals.

10.1 Design Criteria for Ion Exchange Column

The engineer shall provide details of the following aspects/considerations and design the ion exchange column accordingly:

- type of resin
  - strong acid cation
  - weak acid cation
  - strong base anion
  - weak base anion
- segregation of effluent streams containing concentration of suspended solids (SS)
- pH adjustment
- resin capacity
- amount of resin required
- column dimensions
- mode of column operation
  - batch or column
  - co-current or countercurrent
- metals – selective chelating resins
  - selectivity coefficient
- handling of process residuals
  - backwash solution
  - regenerant
- electrowining
- breakthrough time

10.2 Handling of Process Residuals

Process residuals from ion exchange system are the regenerant waste stream and the backwash solution. Both effluent streams shall be treated to meet the stipulated discharge standards prior to discharge.

10.3 Instrumentation for Process Control

The engineer shall identify pertinent process parameters that require close monitoring to ensure optimal operation of the ion exchange system. Typically automatic controls are provided for the following:

- pH, if pH adjustment is required;
- level sensors to monitor the level in the dosing tank;
- no flow alarm and regenerant sensing.
- method of monitoring and detecting the breakthrough point.

The regenerant waste stream is highly concentrated and if the ion exchange system is removing metals, an electrowining process shall be considered, if deemed appropriate.

10.4 Off-site Regeneration

If off-site regeneration of ion exchange column is proposed, the engineer and the owner shall take the necessary actions to ensure compliance with other relevant regulations.

CHAPTER XI: DESIGN OF DISSOLVED AIR FLOTATION

Dissolved air flotation (DAF) is commonly used to remove suspended solids, oil and grease and other contaminants from effluent streams via the use of air bubble flotation. DAF systems work exceptionally well in effluent streams that include solids that tend to remain in suspension or float such as food, chemical and petroleum based effluents. Sometimes, chemical pretreatment is employed to help improve the performance of pollutant removal.

11.1 Design Criteria for Dissolved Air Flotation System

The design of DAF shall be based on the peak flowrate expected. Preferably, the design is preceded by treatability testing, (jar testing or bench scale batch tests or on-site pilot tests) of effluent samples to determine the design parameters such as air-solids ratio, chemical dosing, effluent quality, recycle rate and pressure, etc.

The design engineer shall identify or decide the following design parameters/ aspects:

- flowrate
- water temperature
- effluent characteristics
- pH adjustment
- coagulation and flocculation pretreatment
- solids loading
- surface loading
- hydraulic loading
- air to solids ratio
- solids handling system

Typical design criteria for sizing DAF for treating industrial effluents are given in Table 11.1.

Table 11.1: Criteria for design of dissolved air flotation (DAF)

Parameter	**Design Value**
Recycle pressure gage, kPa	100 – 300
Saturation efficiency, %	80
Recycle %	10 - 100
Pressurization tank detention time, min	3

Table 11.1 continued

Hydraulic loading rate, feed only, $Lm^{-2}s^{-1}$	0.3 – 0.7
Hydraulic loading rate, including recycle, Ls^{-1}/m^{-2}	0.7 – 1
Solids loading rate, $kgm^{-2}h^{-1}$	170
Air-solids ratio, kg air/kg solids	0.03 – 0.05
Detention time, min	15 - 60
Side water depth of the tanks	1.3 - 3

Deviations from the above design criteria can be allowed if they can be substantiated by literature data or data obtained from similar operations elsewhere.

For small flows and simple installations, hand operated controls and manual flow control may be allowed but for bigger installations, the DAF system shall be designed with programmable logic controllers (PLC), touch screen controls and automatic flow control. A fail-safe mode shall be provided to allow the DAF system to be operated manually in the event of a computer malfunction.

CHAPTER XII - DESIGN OF ACTIVATED CARBON COLUMN

Activated carbon adsorption has been widely as an advanced treatment technology to remove a variety of contaminants from industrial effluents. Activated carbon has an affinity for organics and its use for residual COD removal in Malaysian industries is not uncommon.

12.1 Design Criteria for Activated Carbon Adsorption Column

There are several approaches available for the design of adsorption columns. All established models are acceptable. However, in practice, simple models based on analysis of experimental data are commonly employed. This approach is also acceptable. The engineer shall determine the breakthrough time (breakpoint) of the carbon column by the use of adsorption isotherm model. A sample of breakthrough curve for the contaminant to be removed shall be provided, if available.

The engineer shall determine the adsorber design details including the following:

- System operation whether:
  - fixed bed adsorber
  - downflow
  - gravity flow
- Granular or powdered activated carbon
- Surface loading rate (typically 0.00068 m s^{-1})
- Material of construction
- Sampling ports
- Quantity of activated carbon required
- Column dimensions
- Overall system pressure drop
- Pretreatment requirements
- Adsorbates competitive adsorption

12.2 Carbon regeneration

After the activated carbon has reached exhaustion and all the active sites are filled, it can be regenerated by chemical regeneration or heating. If the design of adsorption column incorporates adsorbent regeneration, the design engineer shall decide on the following:

- Chemical regeneration
  - chemical regeneration agents

- Thermal regeneration
    - regeneration temperature
- Regeneration
    - offsite or on-site

If the adsorber will be regenerated off site or the spent adsorbent disposed off, the relevant regulations on shipping and waste disposal requirements shall be complied with.

CHAPTER XIII: DESIGN OF SLUDGE DEWATERING FACILITIES

Sludge produced from various unit operations and unit processes of industrial effluent treatment systems (IETSs) can be categorized primarily as scheduled wastes (typically chemical sludges) or non-scheduled wastes (typically biological sludges and other sludges). These sludges are commonly being further treated through the use of a number of sl;udge dewatering techniques such as drying and filtration. The dewatering technologies commonly used in the industries in Malaysia are drying beds for biological sludges and filter presses for chemical sludges The purpose of these technologies is to reduce the volume and weight of the sludge which may contain appreciable amount of water.

13.1 Filter Presses

The most widely used technology for dewatering chemical sludges is the filter press. The design engineer shall design the filter press to handle the expected sludge quantity produced, exploring or taking into consideration the following aspects, wherever relevant:

- automatic operation of the filter press
- low pressure, high pressure operation
- equalization and feed tanks
- PLC control and automation
- cycle length
- use of conveyors, drip trays, piping and plate shifters (manual), semi-automatic, fully automatic)
- filtrate treatment
- method of cake disposal (hopper, drum, conveyor)
- cake storage

13.2 Dryers

Some industries generating small qualities of sludge utilize evaporation techniques for removing moisture from the sludge. Steam is typically used as the heat source. Principally, dryers shall be used only for drying sludges which have not beeb contaminated with volatile organic compounds (VOCs). If VOCs are present, the important consideration in the use of evaporation technique to dewater such sludges. is to ensure the temperature of operation does not exceed the volatilization temperature of the most volatile VOC contained in the sludge. When designing such a dryer system the engineer shall take into consideration or explore the following aspects:

- characteristics of the sludge including the volatile organic compound, if applicable
- quantity of sludge produced
- volatilization of the components found in the sludge
- installation of temperature measuring device to continuously monitor and record the temperature of the dryer
- installation of air pollution control, where applicable

13.3 Sludge Disposal

The design engineer shall state dearly the preferred option for final method of disposal of the sludge cake produced from the dewatering process.

CHAPTER XIV: DESIGN OF INSTRUMENTATION, CONTROL AND ELECTRICAL SYSTEM

An integral part of the design of an industrial effluent system (IETS) is the design of instrumentation, control and electrical system. The design of instrumentation, control and electrical systems shall conform to applicable Act, Codes and Regulations including:

Electricity Supply Act, 1990
National Electrical Safety Code 1994
Occupational Safety and Health Act, 1994

The design of the electrical or electronics components of the IETS shall be carried by an electrical engineer or electronic engineer, respectively.

The design engineers shall obtain the necessary approvals required in connection with the design, installation and operation of the equipment or systems regulated by the applicable Acts, Codes and Regulations.

In addition to the instrumentation requirement which has been specified in the individual chapters of this document, the engineer shall identify appropriate instruments and on-line sensors that would enhance the monitoring of key IETS process parameters and hence result in better operational control of the IETS. Whenever deemed appropriate, the engineer in consultation with the industry owner shall incorporate such instruments in the design of the IETS.

14.1 Instrumentation and Control Systems Requirements

14.1.1 Operational Reliability

An instrument and control system shall be designed with both operational reliability (accurate and repeatable results) and maintainability to ensure smooth and effective operation of the IETS.

14.1.2 Back-up Equipment

Instrumentation whose failure could result in effluent by passing or a violation of the effluent discharge standards shall be provided with an installed back up sensor and read out.

An automatic instrumentation system shall be backed up by an alternative manual system so that the IETS operation is not affected while the malfunctioned instrument is undergoing repair.

14.1.3 Calibrations

Vital instrumentation and control equipment shall be designed to permit alignment and calibration without requiring by passing of effluent or a violation of the effluent discharge standards. Automated systems shall have provisions for operator verification of performance and all necessary systems calibration devices.

14.1.4 Alarms and Annunciators

Alarms and annunciators shall be provided to monitor the condition of equipment failure where the failure could result in effluent by passing or a violation of the effluent discharge standards. Where ever appropriate, alarms and annunciators can also be provided to monitor violation of effluent standards at the final discharge point.

14.1.5 Spare Components

An adequate number of spare components shall be specified by the design engineer to permit in-plant repairs or modifications and adjustment. These include a variety of components such as starters, low voltage contactors, and components subject to wear and tear, such as motor brushes and switches. The design engineer shall also specify spare equipment components required for IETS performance monitoring such as pH meters and dissolved oxygen meters etc. and instruments necessary for the smooth operation of the IETS such as dosing equipment, aeration system, etc.

CHAPTER XV: DESIGN OF MECHANICAL COMPONENTS

Mechanical components in an IETS include pumps, piping system, valves, fittings, brackets supports, pressure gages etc. Preferably, the design of these IETS components shall be undertaken by a mechanical engineer, although a chemical engineer who has been involved in similar design exercises would be perfectly acceptable. The general design criteria to be used in designing the IETS mechanical components and choice of materials shall conform to sound engineering practices applicable to the field industrial effluent engineering practiced world-wide.

CHAPTER XVI: FINAL DISCHARGE POINT

There shall be only one discharge point from the entire premise. The discharge point shall be the point where the treated effluent is discharged after the last unit process or unit operation of the IETS. A flow meter and totalizer shall be installed at the final discharge point. Additionally, the engineer shall explore the need and practicality to monitor on a continuous basis, other important parameters which are amenable to on-line measurement such as pH and COD (or TOC, in place of COD). In certain cases, the suitability of incorporating a bioassay assessment facility to monitor the whole effluent toxicity (WET) shall also be considered.

For the purpose of completeness and ease of reference, the specifications on the final discharge point stipulated in the Eleventh Schedule of the Industrial Effluent Regulations, 2009 (IERs) are reproduced below. The specifications are relevant to the design of the IETS, hence shall be complied with.

Table 16.1: Eleventh Schedule to the Industrial Effluent Regulations, 2009
[Subregulation 17(1)]

SPECIFICATIONS OF POINT OF DISCHARGE OF INDUSTRIAL EFFLUENT OR MIXED EFFLUENT

1. The discharge point is located within the boundary of the premises, immediately after the final unit operation or unit process of the industrial effluent treatment system.

2. The location of the discharge point is easily accessible and does not pose any safety hazards to personnel performing site inspection or effluent sampling.

3. The industrial effluent or mixed effluent is discharged through a pipe, conduit or channel to facilitate effluent sampling.

4. The discharge point is physically identified by installing a metal identification sign which reads “Final Discharge Point”.

5. The discharge point and its surrounding is properly maintained to be free from any obstruction that may pose difficulty or hazards during site inspection or effluent sampling.

APPENDICES

Appendix I - List of formulae used for designing activated sludge systems.

(a) Aeration Volume

$$Vr = \frac{\theta_c QY (S_o - S_e)}{X (1 + k_d \theta_c)}$$

Where:

V_r = reactor volume, m^3

Q = influent wastewater flowrate, m^3 d-^{1}

$(S_o - S_e)$ = BOD removed, mgL^{-1}

θ_c = sludge age, d

k_d = endogenous decay coefficient, d^{-1}

Y = kinetic coefficient, d^{-1}

X = mixed liquor volatile suspended solids, mgL^{-1}

(b) Food To Microorganism Ratio

$$F/M = \frac{(S_o - S_e)}{\theta X}$$

Where:

F/M = food to microorganism ratio

$(S_o - S_e)$ = BOD removed, mgL^{-1}

θ = hydraulic detention time, d (V_r/Q)

X = mixed liquor volatile suspended solids, mgL^{-1}

(c) Sludge Wasting Rate

$$\theta_c = \frac{V_r X}{Q_w X_r + Q_e X_e}$$

Where:

Q_w = waste sludge flow rate, m^{3}d^{-1}

V_r = reactor volume, m^3

Q_e = treated effluent flowrate, m^{3}d^{-1}

θ_c = sludge age, d

X = mixed liquor volatile suspended solids, mgL^{-1}

X_r = volatile suspended solids in waste sludge, mgL^{-1}
= return activated sludge volatile suspended solids, mgL^{-1}
X_e = volatile suspended solids in treated effluent, mgL^{-1}

(d) Recirculation Ratio

$$Q_r = Q \frac{X}{X_r - X}$$

Where:
Q_r = return sludge flow, m^3d^{-1}
Q = treated effluent flowrate, m^3d^{-1}
X_r = return activated sludge volatile suspended solids, mgL^{-1}
X = mixed liquor volatile suspended solids, mgL^{-1}

(e) Sludge Production

$$Y_{obs} = \frac{Y}{1 + k_d\theta_c}$$

$$P_x = Y_{obs}\, Q\, (S_o - S_e)\, 10^{-3}$$

Where:
Y_{obs} = observed yield, gg^{-1}
P_x = net waste activated sludge produced, kg d^{-1}
Q = influent wastewater flowrate, m^3d^{-1}
$(S_o - S_e)$ = COD biodegradable, mgL^{-1}
θ_c = sludge age, d
k_d = endogenous decay coefficient, d^{-1}
Y = kinetic coefficient, d^{-1}

Appendix II - List of Formulae Used for Sizing Aeration System

(a) Oxygen Requirement

$$O_{2R} = Q\, (S_o - S_e)\, 10^{-3} - 1.42\, P_x$$

Where:
O_{2R} = oxygen requirement, kgd^{-1}
Q = influent wastewater flowrate, m^3d^{-1}

$(S_o - S_e)$ = COD biodegradable, mgL^{-1}

P_x = net waste activated sludge produced, kgd^{-1}

= $Y^{obs}\ Q\ (S_o - S_e)\ 10^{-3}$

(b) Standard Oxygen Transfer Required (SOTR)

$$\text{Standard Oxygen Transfer Required (SOTR)} = \frac{AOR * C_{s20}}{(\beta\ C_s - C_L) * \theta^{T-20}\ °C}$$

Where:

α = ratio of total O_2 transfer in effluent & clean water

β = ratio of oxygen saturation concentration in effluent & clean water

T = process temp. °C

C_{s20} = saturation conc. of O_2 at standard T

C_s = saturation of O_2 at process temperature

C_L = concentration in aeration tank, mgL^{-1}

= kg O_2d^{-1}, actual oxygen requirement

$$\text{Air flow rate;} = \frac{\text{SOTR}}{C_l\ \text{SOTE}}$$

Where:

C_l = Oxygen content of the air

SOTE = Standard oxygen transfer efficiency, %

Note: Certified oxygen transfer curve and certified diffuser headloss curve shall also be submitted

Appendix III - List of Formulae Used for Designing Adsorption Columns

a) Fruendlich Isotherm

The Fruendlich isotherm model is commonly used to represent the adsorption of contaminants on to adsorbents from aqueous solutions. It is used to determine the amount of adsorbent required to treat a certain flow of industrial effluent.

The Fruendlich isotherm is written as:

$$X/M = KC_f^{\ 1/n}$$

Where:

X = mass of contaminant adsorbed

= $(C_i - C_f) * (V)$

V = volume of solution , L

C_i = initial concentration of contaminant in solution, mgL^{-1}

C_f = final concentration of contaminant in solution , mgL^{-1}

M = weight of carbon mg

K,n = empirical constants

The Fruendlich model can also be written in its linearized form as:

$$\log \frac{x}{m} = \log k + \frac{1}{n} \log C_e$$

(b) Langmuir Adsorption - Isotherm

Sometimes, the Langmuir model fits the adsorption isotherms adequately. The model is written as:

$$X = \frac{X_m bC_e}{1 + bC_e}$$

Where:

X = x/m, the amount of solute adsorbed (x) per unit weight of adsorbent (m)

C_e = equilibrium concentration of the solute

X_m = amount of solute adsorbed per unit weight of adsorbent required for monolayer capacity .

b = a constant related to the heat of adsorption

The langmuir equation can also be written in its linearized form as:

$$C_e = \frac{1}{b X_m} + \frac{C_e}{X_m}$$

Appendix IV – List of Formulae Used for Designing of Mixing Device

(a) Velocity gradient (G), s-1:

$$G = \left(\frac{\rho}{V\mu}\right)^{0.5}$$

Where:

G = velocity gradient, s^{-1}:

ρ = power input, Ns^{-1}

V = Mixing chamber volume, m^3

μ = absolute .kinematic viscosity of fluid, Nsm^{-2}

ρ = QWh_L

Where:

Q = flowrate, m^3s^{-1}

W = weight of fluid, kgm^{-3}

h_L = head loss, m

The specifications in this guidance document represent the minimum requirements for the design and operation of Industrial Effluent Treatment Systems to be complied with by the industries. However, the Department of Environment assumes no responsibility for the accuracy, adequacy, or completeness of the concepts, methodologies, or protocols described in this document. The owner shall take additional measures where deemed appropriate, to further ensure compliance with the effluent discharge standards stipulated in the IERs.. Compliance with the regulatory requirements and standards is solely the responsibility of the industries.

References:

Bratly, S. 2006. Coagulation and Flocculation, 2nd Edition. IWA Publishing House, London

Bolto, B.A. and Pawlowski, L. 1987. Wastewater Treatment by Ion Exchange. E. & F. N. Spon. Ltd. London.

Broderick, T.A. and Sherrard, J.H. 1985. Treatment of Nutrient Deficient Wastewaters. J.Water Pollut. Control Fed., 57, 1178

Eckenfelder J.W. 2002. Industrial Water Pollution Control. McGraw-Hill Inc. Singapore

Lim D.O. and Liptak, B.G. 2005. Environmental Engineers Handbook. CRC Press. Boca Raton

Metcalf and Eddy Inc. 1991. Wastewater Engineering, Treatment, Disposal.and Reuse, 3rd Edn., McGraw- Hill Inc. New York

Noyes, R. 1994. Unit Operations n Environmental Engineering. Noyes Publications, New York

Orhon D. and Arton, N. 2004. Modeling of Activated Sludge Systems. Technomic Publishing Co. Inc. Lancaster.

Qasim S.R. 1994. Wastewater Treatment Plants – Planning, Design, and Operation, Technomic Publishing Co. Inc. Lancaster.

Russell, D.L. 2006. Practical Wastewater Treatment, Wiley Interscience, Canada

Shamsudin Ab Latif. 2002. Decolorization of Textile Wastewaters Using Peat-Activated Sludge Process. Doctoral Dissertation Submitted to Tulane University, New Orleans.

This Guidance Document was authored by Prof(Adj) Dr. Ir. Shamsudin Ab Latif, Deputy Director General (Development), Department of Environment, Malaysia.

Website: www.doe.gov.my

DEPARTMENT OF ENVIRONMENT
Ministry of Natural Resourses & Environment
Level 1-4, Podium Block 2 & 3, Lot 4G3, Presint 4,
Federal Government Administrative Centre
62574 Putrajaya, Malaysia
Tel: 603-8871 2000 Fax: 603-8888 9987