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GUIDANCE DOCUMENT ON PERFORMANCE MONITORING OF INDUSTRIAL EFFLUENT TREATMENT SYSTEMS

Specified in Regulation 9 (A), Environmental Quality (Industrial Effluent) Regulations 2009

DOE Headquarters
April 2017

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FOREWORD

Performance monitoring of an industrial effluent treatment system (IETS) is a **proactive and preventive procedure** aimed at ensuring the IETS is optimally operated thus producing **quality effluent** at all times. If practiced vigorously by the regulated sectors, performance monitoring will enhance their **environmental image**, improve **regulatory compliance** and as a consequence, result in enhancement of the **water quality** of our rivers.

The implementation of the activities specified in this **Technical Guidance Document** fulfills the requirement on **performance monitoring** as stipulated in Regulation 9 (a) of the Industrial Effluent Regulations, 2009 (commonly referred to as the IER). The procedure and specifications on performance monitoring of IETSs described in this Guidance Document represent the **minimum requirements** that an owner of an industrial premise shall comply with. The owner of the industrial premise shall conduct monitoring of additional **process parameters (**commonly referred to as **performance monitoring parameters)** wherever deemed appropriate to further assure all **unit operations** and **unit processes** of their IETS are optimally operated and maintained, in order to produce **compliant effluent** on a continuous basis. The Guidance Document will be reviewed and updated from time to time.

This Guidance Document can be cited as **IETS PERFORMANCE MONITORING GUIDANCE DOCUMENT.**

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Director General
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April, 2017

CHAPTER 1- INTRODUCTION

Industrial effluents vary significantly in **pollution characteristics** hence effluents from different industries require different **unit processes** and **unit operations** to treat them. It is in everyone's interest that the unit processes and unit operations in an industrial effluent treatment system (IETS) function in an optimal manner in order for the IETS to produce an **effluent quality** that continuously complies with the **discharge standards**. However, how does one monitor, maintain and ensure that the unit processes and unit operations of the IETS are occurring in an optimal fashion? **Performance monitoring** of IETS is the answer to the above question. Performance monitoring is the practical implementation of the "**maintenance culture**" that would assure that any facility that has been constructed or installed (i.e. in this case, the IETS) will always function effectively and efficiently. Consequently, the performance of the IETS on a **sustained basis** is ensured resulting in **improvement in regulatory compliance, enhancement in corporate image** of the industries, and **amelioration of water quality**. IETS performance monitoring is a systematic, scheduled set of activities carried out with the aim of obtaining information on **key parameters** controlling the processes occurring in the IETS treatment components. Since it was first introduced by the Department of Environment in 2006, industries which have implemented IETS performance monitoring have found it to be an effective tool for ensuring **optimal performance** of the IETS hence maintaining **regulatory compliance** on a continuous basis.

This Document presents general considerations and procedure on IETS performance monitoring so that effective monitoring program can be established for the varied types of unit processes and operations found in an IETS.

CHAPTER 2 -PURPOSE OF GUIDANCE DOCUMENT

In general, the Guidance Document on IETS Performance Monitoring is intended to provide a guidance on the practice of **performance monitoring** as a routine activity and an integral part of the operation of an industrial effluent treatment system (IETS).

Specifically, the purpose of this Guidance Document is to stipulate:

- The **performance monitoring parameters** for major categories of IETS unit operations and unit processes commonly being employed to treat industrial effluents in Malaysia.
- The **sampling location, frequency of sampling and analysis** of the performance monitoring parameters.
- The **recommended optimal range of values** for typical performance monitoring parameters to be maintained for various unit operations and unit processes by the IETS operator or supervisor to ensure optimal operation of the IETS.
- The **record keeping requirements.**

Monitoring and recording of the IETS performance is required to demonstrate that the IETS is **functioning optimally** and the **effluent standards** are being **complied** with. Additionally, the Guidance Document also recommends useful practical procedure for performing **data analysis** and IETS **performance reporting format** that can be used by the IETS operator/supervisor to communicate with the factory management on IETS performance status. There is an urgent need to **mainstream** the environmental and regulatory compliance concerns into the **industry's management** and **decision-making process**. **Environmental mainstreaming** (EM) has been adopted by the Department of Environment as a strategic management approach to developing **self-regulation culture** within the regulated sectors.

The procedure and specifications mentioned in this Guidance Documents represent the minimum that an industry shall comply with. In a particular situation, if deemed appropriate, the industry may expand their performance monitoring activities or monitor **additional parameters** in order to ensure closer monitoring of the IETS processes to achieve the desired effluent quality on a sustained basis.

CHAPTER 3 -WHAT IS PERFORMANCE MONITORING?

Performance monitoring of an IETS can be understood to mean the **proactive and preventive monitoring** of all the major **IETS components** to ensure that each component is working properly and optimally operated as designed. This requires one to monitor certain **key process parameters** characteristic of the unit process or unit operation of the IETS (commonly referred to as the **performance monitoring parameters**) on a **scheduled basis** to provide a diagnostic indication of the **"health status"** of the treatment processes occurring in those treatment components.

Eventhough some industries are routinely conducting various tests to monitor the performance of the unit operations and unit processes which make up the effluent treatment system in their premises, by en large, the practice of performance monitoring of the IETS in many industries is an exception rather than the norm. For the most part, IETS performance monitoring has not fully been incorporated into the **standards operating procedure** (SOP) for IETS operation. IETS performance monitoring has not yet developed into a **culture**.

Over the years, experience gained in different parts of the world shows that treatment processes within the IETS can be optimally controlled by maintaining certain key parameters within the **recommended ranges**. **Performance monitoring** concentrates on the **processes** occurring within the IETS itself, while **compliance monitoring** concentrates on the **final effluent.** Performance monitoring can be viewed as an "**upstream activity**" while **compliance monitoring**, is viewed as a "**downstream activity**". Although performance monitoring activities can also include the monitoring of the final effluent, the focus is not on the monitoring of the final effluent as being misunderstood by some industries. Focusing only on the final effluent may lead to a "**too-late situation**" where things have gone out of hand and consequently difficult to control or get back on track.

In summary, IETS performance monitoring enforced through the Industrial Effluent Regulations 2009 (IER) is the "**maintenance culture in action**" in the field of industrial effluent treatment. It will develop **ownership** of the IETS among the IETS operating/supervising team as well as ability to have a **control over the processes** occurring within the IETS. As a result, IETS performance will be enhanced and effluent quality ensured on a sustained basis. Performance monitoring is also one of the **environmental mainstreaming (EM) tools** that will help to pave the way for the cultivation of **self-regulation culture** within the industrial premises in Malaysia.

CHAPTER 4 -REGULATORY REQUIREMENTS ON PERFORMANCE MONITORING

The requirement on performance monitoring is stipulated in regulation **9 (a)** of the Industrial Effluent Regulations 2009 (IER). The industries are required to adhere to the procedure and specifications on performance monitoring stipulated in this Guidance Document.

4.1 Deviation from specified procedure

Deviations from the procedure and specifications stipulated in this Guidance Document shall be allowed only if **documented evidence** can be substantiated to justify the use of **more relaxed procedure** without compromising the desired **degree of control** of the IETS unit operations or unit processes. The evidence shall be documented and kept for inspection by the DOE inspectors.

4.2 Performance monitoring of unit operations and unit processes not discussed in this Guidance Document

The types of unit operations and unit processes of IETS discussed in this Guidance Document are **not exhaustive**. For those unit operations and unit processes which are not discussed, the IETS engineer or consultant shall decide on the following: the **key performance monitoring parameters** for the IETS treatment processes in question; the **sampling and monitoring frequency** of the parameters; and the **acceptable range of values** for the parameters for optimal IETS operation. In deciding the above details, the owner and the IETS process consultant shall be guided by the **industry standard best practices** and **technical evidence** for the particular treatment process. The references used the IETS engineer or consultant shall be documented for the inspection by the DOE inspectors.

CHAPTER 5 – GENERAL CONSIDERATIONS ON PERFORMANCE MONITORING OF INDUSTRIAL EFFLUENT TREATMENT PROCESSES

A successful effluent treatment is dependent upon **all components** of the industrial effluent treatment system (IETS) being operational in optimal condition. Problems with any part of the system components will affect the overall efficiency of the IETS resulting in **poor effluent quality**. To ensure successful treatment and regulatory compliance, each of the treatment components (i.e. **unit processes** and **unit operations**) and must be **closely monitored** on a **regular basis**. The following are the general considerations and activities associated with the conduct of performance monitoring of an IETS.

5.1 Influent monitoring

For successful operation of an IETS, routine **influent monitoring** is usually performed. At a minimum, the incoming raw effluent (i.e. the influent to the IETS) must be monitored for its **flow and quality**. Additionally, raw effluents from **major effluent streams** from different production floors may also be monitored at several points within the factory. Influents are preferably sampled at points of highly **turbulent flow** in order to ensure good mixing.

5.2 Effluent monitoring

The net result of the effective operation of the all the unit operations and unit processes within the IETS is reflected in the quality of the **final effluent**. For performance monitoring, **flow measurement** must be made and **effluent samples** at the **final discharge point** (FDP) must be collected for analysis. The quality of the final effluent must comply with the **discharge standards** all the time. The requirements on final effluent monitoring are discussed in detail in chapter 8.

On-line monitoring of certain parameters at the final discharge point (FDP) such as pH, COD, TOC, ammonia, fluoride, and suspended solids may also be performed to obtain **discharge compliance** on a **real time basis**.

5.3 Sampling criteria

To assure smooth operation of an IETS, a **sampling and analysis plan** must be established and implemented. Among the criteria to be considered in effluent sampling are:

(i) Samples taken must be **representative**

(ii) Location of sampling points must be **safe and easily accessible**

(iii) Whenever possible and where it is not burdensome economically, **on-line continuous measurement** should be implemented.

For some parameters such as biochemical oxygen demand (BOD) and suspended solids (SS), instead of grab sampling, composite sampling may be used. A **grab sample** may be defined as an individual discrete sampling over a period of time not exceeding 15 minutes. It can be taken manually using a pump, scoop, pail, or automatically by using an automatic sampler. **Composite samples** from ponds with long detention times may not be representative. Convenience, accessibility and practicability are important factors but they must not be compromised with the need for **representativeness** of sampling. Preferably samples shall be analyzed as soon as possible. If necessary, **preservation protocols** recommended in the **Standard Methods** must be adhered to. Parameters such as pH, D.O. and temperature shall be measured **in-situ**.

5.4 Analytical requirements

For the purpose of IETS performance monitoring, analysis of the effluent can be accomplished **by in-situ measurements** using **portable equipment** widely available in the market. Equivalent methods modified from the Standard Methods are totally acceptable. Under Regulation 9 (b) of the Industrial Effluent Regulations 2009 (IER) the industries are also required to provide facilities, relevant equipment, or instruments for the purpose of conducting performance monitoring. An **on-site laboratory** equipped with basic facilities to conduct routine measurements and equipment calibration is required to facilitate the conduct of IETS performance monitoring in a technically conducive environment. Eventhough for the purpose of IETS performance monitoring, measurements of parameters using portable analytical equipment/equivalent methods are acceptable, the analytical requirements for the **final effluent samples** (compliance monitoring) need to follow the **Standard**

Methods as the results are required to be reported to the Department of Environment. The industries are required to maintain and submit monthly discharge monitoring reports (MDMR) to the DOE to demonstrate **compliance** with the **discharge standards** as stipulated in regulation 7 (3) of the IER. The on-line reporting of discharge information applicable to all types of effluent discharges is commonly known as the **On-line Environmental Reporting** (OER).

5.5 Flow measuring devices

Flowrate measurements of the **influent** and **effluent** shall be made by the use of **flow meters** which are available in various types. This requirement has been mentioned in sections 5.1 and 5.2. The use of digital flow meters is generally preferred but alternatively, in limited cases, other flow measuring devices such as orifice plate, weirs, or V notches can also be used. The type of flow meter chosen shall be **appropriate** for its application.

CHAPTER 6 - PERFORMANCE MONITORING OF BIOLOGICAL TREATMENT PROCESSES (BPs)

Biological treatment processes (BPs) employ the service of **microorganisms** to accomplish the job of converting the **organics** which are present in dissolved and colloidal forms into **biological cells** and **gaseous by products**. The biodegradation process can occur either in the presence or absence of **dissolved oxygen**. BPs are generally categorized based on the **oxygen requirements** and they fall into **three categories**, namely: **Aerobic** processes (in the presence of molecular oxygen), **anaerobic** processes (in the absence of molecular oxygen or combined oxygen), and **anoxic process** (in the presence of combined oxygen). Different groups of microorganisms are responsible for the different processes.

To operate an industrial effluent treatment system (biological processes) (IETS-BP) efficiently several **tests** have to be conducted **periodically** to monitor the performance of the various processes. The "**health**" and **performance** of the treatment system can be monitored by monitoring the relevant parameters. Three different types of **parameters** can be distinguished for monitoring biological treatment processes (BPs):

- Parameters that are essential to ensure the biological process are **functioning** optimally such as pH, dissolved oxygen (DO), and nutrients.

- Parameters that provide **diagnostic check** on the "**health**" status of the various unit operations and unit processes such as mixed liquor volatile suspended solids (MLVSS), sludge volume index (SVI) and specific oxygen uptake rate (SOUR) for an activated sludge process.

- Parameters that indicate the **efficiency** of the treatment system in removing the organics such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

The importance of the various **performance monitoring parameters** for different categories of BPs is discussed briefly below. The sources subject to the Industrial

Effluent Regulations are required to adhere to the requirements stipulated in the following paragraphs.

6.1 Performance monitoring (PM) parameters of the biological reactor

6.1.1 Dissolved Oxygen (DO)

Aerobic biological unit processes require a **sufficient** amount of dissolved molecular oxygen (DO) for growth and metabolism of aerobic microorganisms. Various technical sources quote that, preferably, for an aerobic system designed for the removal of **carbonaceous organic matter**, a minimum **bulk DO concentration** of 2.0 mg/L must be maintained in all areas of the **aerobic reactor**. For a system which requires **nitrification**, a higher DO concentration of more than 2.0 is required. Typically 2.5 to 3.5 mg/L of DO is maintained. Oxygen limited growth environments may promote the predominance of **filamentous organisms** affecting the **settleability** of sludge. Low DO also promotes **sulfide precipitation** of iron and other metals. On the other hand, **denitrification** process requires an absence of DO or a very low DO level. **Anaerobic** processes occur in the **absence** of DO.

DO shall be measured **in-situ** at **several points** in the aeration tank. Typically, in practice three locations in the aeration tank are identified. DO can be measured by using a **portable** hand-held DO meter or measured continuously by **on-line** DO probe and transmitter equipped with a recording device.

Table 6.1 summarizes the **dissolved oxygen** levels that need to be maintained in the reactors for different BP systems.

Table 6.1: DO level to be maintained for different BP systems

BP system	DO, mg/L
Aerobic: carbonaceous removal	1.5 (minimum) to 2.0
Nitrification	2.5 to 3.5
Denitrification	Zero or very low
Anaerobic	Zero

6.1.2 pH

Monitoring of pH is important from several standpoints. The **optimum biological activity** of the aerobic microorganisms for the treatment process is in the pH range from 6.5 to 8.5. Low pH is a cause of **filamentous** growth resulting in sludge **settleability** problems. Besides that, extreme pH values will be detrimental to concrete structures of the IETS and its components. For an **anaerobic** process, the pH in the reactor should preferably be maintained in the range of 6.7 to 7.4. When pH falls below 6.7, the **methanogenisis** reaction will be seriously affected. The **nitrification** process prefers a pH range of 8.0 to 9.0 while the **denitrification** process, 7.0 to 7.5.

For an **aerobic** process such as an activated sludge system, pH must be monitored, preferably on a continuous basis, at a minimum at one location at the **influent end** of the aeration tank. For an anaerobic reactor in the form of a tank, pH must be monitored at **several depths** of the digester tank.

Table 6.2 summarizes the **pH** levels that need to be maintained in the reactors for different BP systems.

Table 6.2: pH value to be maintained for different BP systems

BP system	pH value
Aerobic: carbonaceous removal	6.5 to 8.5
Nitrification	8.0 to 9.0
Denitrification	7.0 to 7.5
Anaerobic: Methanogenesis	7.0 to 7.4; Never < 6.7

6.1.3 Mixed liquor suspended Solids (MLSS) and mixed liquor volatile suspended solids (MLVSS)

The mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) are commonly used to represent the **microorganisms** in biological treatment processes, especially the activated sludge process. MLVSS is the **volatile fraction** of the MLSS. Solids analysis is important in the control of biological effluent treatment processes where the solids information is used in the calculation of **food to microorganism ratio** (F/M ratio), **sludge volume index** (SVI), **recirculation ratio (R)**, **wasting rate (Qw),** etc. In a long and narrow tank, samples for MLSS and MLVSS measurements shall be taken from **three points**, namely close to the inlet (i.e. influent end) to the tank, in the middle and at the outlet (i.e. effluent end) of the tank. MLSS sampling for sequencing batch reactors (SBRs) shall be performed during idle stage of its operation cycle.

Typically, the MLSS concentration shall be maintained within the range of 1,500 to 3,000 mg/L for a **conventional activated sludge (CAS)** process and 3,000 to 6,000 mg /L for an **extended aeration activated sludge (EAAS)** process respectively. **Membrane bioreactors (MBRs)** employ a combination of the activated sludge process (i.e. a suspended growth process) and the **membrane filtration system** to replace the secondary clarifier. A higher MLSS concentration can be supported where up to 20,000 mg/L has been reported. For upflow anaerobic sludge blankets (UASBs), typical MLVSS is 3,000 mg/L.

Table 6.3 summarizes typical MLSS levels that are maintained in the reactors for different BP systems.

Table 6.3: MLSS level to be maintained for different BP systems

BP system	**MLSS, mg/L**
Conventional activated sludge	1,500 to 3,000
Extended aeration activated sludge	3,000 to 6,000
Membrane bioreactor	10,000 to 20,000
Upflow anaerobic sludge blanket	3,000

6.1.4 Sludge volume index (SVI)

The sludge volume index (SVI) is used as an indicator for the **settling characteristics** of the sludge in the secondary clarifier. The SVI values which show a trend towards poor settling can be an indictor for the onset of IETS (BP) experiencing upset conditions. SVI measurements also yield information which is used to establish the proper **recirculation ratio** for optimum process efficiency and maximum solids concentration in the waste sludge.

Poor settling sludge will result in low concentration of solids in the return-activated sludge (RAS) hence a drop in MLSS and MLVSS concentration in the aeration tank. Consequently, the F/M ratio in the aeration tank increases which results in a reduced BOD and COD removal efficiency. Sludges exhibiting poor settling characteristics are indicated by high SVI values.

SVI can be computed from the 30 minutes settling test by using the following formula:

$$\text{SVI} = \frac{\text{SV}_{30} \times 1{,}000}{\text{MLSS}} \qquad \ldots(6.1)$$

Where :

SVI = sludge volume index, mL/g

SV_{30} = settled sludge volume in 30 minutes, mL/L

MLSS = mixed liquor suspended solids, mg/L

(Note: 1,000 is the conversion factor from mg/g)

The settled sludge volume is taken from the 30 minutes **sludge settling test** on the mixed liquor sample.

SVI must be measured routinely to monitor **sludge settleability**. A as a guide, typical SVI values indicating the settling characteristics of the sludge are given in Table 6.4 below.

Table 6.4: SVI values and sludge settling characteristics

SVI , mL/g	**Sludge settling characteristics**
<50	Excellent
50-100	Good
100-150	Satisfactory
>150	poor-bulking of sludge

6.1.5 Nutrients

Many industrial effluents are **deficient in nutrients** hence, to ensure adequate amounts of nutrients are supplied to the aeration tanks, **nutrient balance** must be periodically checked. The primary nutrients, which are commonly found lacking in many industrial effluents are Nitrogen (N) and Phosphorus (P). For aerobic processes, the rule of thumb for the weight ratio of BOD_5: N: P to be maintained in the **influent** to the aeration tank should be approximately 100BOD: 5N: 1P. For anaerobic processes, a lower ratio of 250BOD: 5N: 1P is used. Calculation of **nutrient availability** and **dosage** required shall be based only on **total inorganic nitrogen** (TIN = ammonia + nitrite + nitrate) and **ortho-phosphorus**. A practical method of checking for nutrient deficiency is to assure that at least 1.0 mg/L TIN and 0.5 to 1.0 mg/L ortho-phosphate remains in the **aeration tank effluent** at all times. Typical signs of nutrient deficiency are **filamentous growth** and **bulking** of activated sludge in activated sludge systems.

The nutrient requirements are summarized in Table 6.5.

Table 6.5: Nutrient ratios for different BP systems

BP system	Nutrient ratio required in tank influent	Residual nutrient in tank effluent, mg/L
Activated sludge	100BOD: 5N: 1P	TIN > 1.0; Ortho-P: 0.5 to 1.0 mg/L
Anaerobic	250BOD: 5N: 1P	

6.1.6 Oxygen Uptake Rate (OUR)

Respirometry measures the **oxygen uptake** by the aerobic microorganisms. The utilization of oxygen by the microorganisms indicates the **biological activity** occurring in the aeration tank and is interpreted to mean that the effluent is being biodegraded aerobically. **Specific oxygen uptake rate** (SOUR) is the amount of oxygen per unit mass of the mixed liquor volatile suspended solids. A sudden rise in SOUR indicates an upsurge of **organic load** while a sudden decrease indicates a **toxic or pH shock**. SOUR must be measured on a scheduled basis to monitor the biological activity in the aerobic reactor such as the aeration tank of an activated sludge system. SOUR can be computed from OUR by the following relationship:

$$SOUR = \frac{OUR}{MLVSS} \quad \ldots.(6.2)$$

Where:

SOUR = specific oxygen uptake rate, mg of O_2 /(L h) per g of MLVSS

OUR = oxygen uptake rate, mg of O_2/L per h

MLVSS = X_V = mixed liquor volatile suspended solids, mg/L

Table 6.6 summarizes **typical SOUR values** and the corresponding **floc settling characteristics.**

Table 6.6: Typical range of SOUR values and corresponding floc properties.

SOUR, mg O_2/h g MLVSS	Floc description; Settling characteristic
> 20	Dispersed floc; Settling Slow
8-20	Flocs forming; Settling normal
< 8	Pin Floc; Settling too fast

6.1.7 Food to microorganism (F/M) Ratio

Food to microorganism (F/M) ratio expresses the **amount of food** available to the **microorganisms** in the aeration tank. Insufficient amount of food or overdose of it will lead to **settling problems** in the clarifier and poor **organics removal efficiency**. Food is represented by the **BOD** while the microorganisms are represented by the **MLVSS**. Either BOD or COD can be used to calculate the F/M ratio, but once one of them is chosen, it should be used throughout for comparative purposes. F/M ratio must be determined on a regular basis for monitoring the activated sludge process.

F/M ratio is calculated by using the following formula:

$$F/M = \frac{BOD_{in}\ (Q)/1{,}000}{V_r\ (X_V)} \quad \ldots\ldots(6.3)$$

Where:

F/M = food to microorganism ratio, $\frac{\text{kg BOD per d}}{\text{kg MLVSS under aeration}}$

BOD = biochemical oxygen demand of influent to the aeration tank, mg/L

Q = influent flowrate, m^3/d

V_r = aeration tank volume, m^3

X_V = MLVSS = mixed liquor volatile suspended solids, mg/L

(Note: 1,000 is the factor to convert g to kg)

Typical F/M ratios for different activated sludge system are given in Table 6.7.

Table 6.7: Typical F/M ratios for different types of activated sludge system

Type of activated sludge System	**F/M ratio, kg BOD per d / kg MLVSS under aeration**
Conventional activated Sludge	0.2 to 0.5
Extended aeration activated Sludge	0.05 to 0.15

6.1.8 Sludge age (θ_c)

Sludge age is a design and an operational parameter which is related to food to microorganism (F/M) ratio. Sludge Age (θ_c) is calculated using the following formula:

$$\theta_c = \frac{V_r\ (X)}{Q_{WAS}\ (X_{WAS})} \quad \ldots\ldots(6.6)$$

Where:

θ_c = sludge age, d

V_r = aeration tank volume, m^3

X = MLSS= mixed liquor suspended solids concentration, mg/L

Q_{WAS} = sludge wasting rate, m^3/d

X_{WAS} = wasted sludge suspended solids concentration, mg/L

Typical sludge age range for different processes is given in Table 6.7.

Table 6.7: Typical sludge age for different biological processes

Type of process	Sludge age, d
CAS	5 to 10
EAAS	12 to 30
UASB	Low strength (COD up to 750 mg/L): 20 Medium strength (COD from 750 to 1,000 mg/L): 30 High strength: (COD from 1,000 to 10,000 mg/L): 50

Notes:

CAS: Conventional activated sludge

EAAS: Extended aeration activated sludge

UASB: Upflow anaerobic sludge blanket

6.1.9 Oxygen reduction potential (ORP)

At the biochemical level, the processes occuring in biological treatment reactors treating organic effluents involve oxidation-reduction (commonly known as **redox**) reactions. Oxidation-reduction (ORP) measurements can be made easily using a Redox meter. Important redox reactions in biological treatment involving **aerobic processes** include the removal of **organic matter** (C-BOD), **nitrification** (NH_3 to NO_2^- and NO_3^-), and **phosphorus** removal. **Denitrification** (NO_3^- to N_2) is an **anoxic process** while acidification and methane production are **anaerobic processes**. Each of the above processes occurs within its own range of ORP values which are summarized in Table 6.8.

Table 6.8: Biochemical reactions in biological treatment processes and their ORP ranges

Biochemical reactions	ORP, mV
C-BOD	+ 50 to + 250
Nitrification	+ 100 to + 350
Denitrification	+ 50 to - 50
Biological phosphorus removal	+ 25 to + 50
Acidogenesis	- 40 to - 250
Methanogenesis	-175 to - 400

6.1.10 Volatile fatty acids (VFAs) and alkalinity

For an anaerobic treatment process designed to occur in a tank, apart from the tank liquor pH, two additional parameters to assess whether the anaerobic process is performing in an optimal fashion are the **volatile fatty acids (VFA) and total alkalinity**. Typically, the VFA concentration should range from 50 to 300 mg/L while total alkalinity from 2,000 to 5,000 mg $CaCO_3$/L. Combining the information on VFA and alkalinity, the **VFA/total alkalinity ratio** must also be monitored where the recommended ratio to be maintained is in the range of 0.05 to 0.25. However, a value < 0.1 is preferred because it indicates the presence of a good buffering capacity.

6.1.11 Organic loading rates (OLR)

Organic loading rate (OLR) is applicable to ponding systems as well as anaerobic digesters (AD), upflow anaerobic sludge blankets (UASBs) and expanded granular sludge bed (EGSB). OLR is defined as the amount of **BOD or COD** applied per unit volume of the pond or digester. OLR is usually expressed in kg BOD or COD/m^3.d. As a part of performance monitoring activity, OLR is monitored on a scheduled basis, by monitoring the **influent BOD or COD** and **flowrate**. For UASBs and EGSBs, OLR depends on the characteristics of the raw effluent where typical OLR ranges from 5 to 15 kg COD/(m^3.d) to 10 to 40 kg COD/(m^3.d) respectively.

6.1.12 Sludge depth

Sludge depth monitoring is relevant to **ponding systems**, **anaerobic digesters** and **activated sludge system**. Various instruments are available for measuring the sludge depth in ponds and tanks which include **sludge judge** and **electronic devices**. For ponding systems, sludge depth management may translate into **desludging** requirement. Sludge depth monitoring in clarifiers of ASTSs is discussed in section 6.1.14.

6.1.13 Microscopic examination

There are different groups of **microorganisms** found in the biological treatment systems such as the **ponding** system, the **suspended growth** system (activated sludge process), or the **attached growth** system (trickling filters and rotating biological contactors). Because each of these groups **thrives best** under certain conditions, their presence or absence can be related to the degree of treatment, hence the **efficiency** of an IETS utilizing biological processes.

In activated sludge systems, the **bacteria** are responsible for stabilization of most of the **organic matter** contained in the effluent and also for **floc formation** which helps in **sludge settling**. **Protozoa** can be used as an **indicator** of the efficiency the treatment process. Although protozoa themselves do not stabilize the organic matter in the effluent, they **feed on the bacteria** and this helps **clarify the effluent**. The presence of ciliated protozoa in a biological treatment process such as an activated sludge process is indicative of an **efficient treatment process**. The presence of **rotifers**, a metazoan, is indicative of a condition of very **low F/M ratio** or **high sludge age (old sludge)**.

Filamentous organisms when present in abundance in an activated sludge can result in **sludge bulking** which may lead to **sludge carryover** in the clarifier effluent and discharge noncompliance. The predominance of filamentous organisms which can be either bacteria or fungi, is usually the result of **low pH, low DO, low nutrient levels, septicity, high oil and grease, and high sulfide.**

Weekly or preferably, **daily microscopic examinations** of the microorganisms in the mixed liquor sample from the biological reactor (such as the aeration tank of an activated sludge system) are recommended to observe:

- The bacterial floc size and shape
- The presence of filamentous bacteria
- The changes in the number of protozoans (flagellates, ciliates)
- The presence of rotifers

Typically, a microscope with **a magnification power** of 100 x to 200 x is adequate for the above purpose.

The above discussion is most relevant to a suspended growth system such as the activated sludge system. However, for the most part, the discussion is also applicable to other biological treatment systems such as the ponding system, trickling filter and rotating biological contactors.

6.1.14 Performance monitoring of secondary Clarifiers

Success of a biological treatment process (BP) for removing **dissolved and colloidal organic matter** depends on efficient **biochemical oxidation** of organic matter in the reactors and subsequent **sludge separation** in the **clarifier**. This is particularly true for an activated sludge treatment system (ASTS). Monitoring and controlling clarifier performance is critical for the successful operation of a (BP). Minimum **clarifier performance monitoring** includes the following:

- Monitoring the **flowrate**.
  Calculate and compare the detention time (DT), surface overflow rate (SOR), and weir overflow rate (WOR) with the design values.
- Monitoring the **suspended solids** concentration of the clarifier influent and effluent.
  Calculate the solids loading rate (SLR) and solids capture and compare with the design value.
- Monitoring the **pH** of the clarifier influent and effluent.
  A drop in pH indicates septic sludge in the clarifier. Observe for gassing and ashing.
- Monitoring the **DO** of the clarifier influent and effluent (inside of effluent weir).
  A large drop in DO indicates biological activity still occurs in the clarifier.
- Monitoring the **sludge level** (also referred to **as sludge depth**) in the clarifier.
  The recommended sludge depth to be maintained is not more than a third of clarifier depth. Sludge depth can be measured by using a core sampler, sludge judge, an automatic sludge depth meter or sludge gun.
- **Weir cleaning** can be afforded by using water spraying or automatic weir cleaner.
- Performing **preventive and corrective maintenance** of the clarifier weir to keep it in clean and level condition.

The frequency required for the above performance monitoring activities must be determined on a case to case basis. Clarifier monitoring is **not applicable** to sequencing batch reactors (SBRs) and membrane bioreactors (MBRs).

Most of the PM activities discussed above are also applicable to **primary clarifiers.**

6.1.15 Jar test

Jar testing to determine the **coagulant dosage** may be required in the operation of a biological treatment system if coagulants are added to aid in the settling of activated sludge in the clarifiers.

6.1.16 Monitoring the overall performance of a biological treatment process

The **overall performance** of a biological treatment process (BP) in treating an organic effluent can best be monitored on the basis of either biological oxygen demand (BOD) or chemical oxygen demand (COD) or both. BOD test measures the amount of **biodegradable organic matter** in the effluent while COD measures all components which can be **oxidized** by potassium dichromate, the oxidizing agent used in the test. COD is a better IETS **operational performance monitoring parameter** because the test results can be obtained within 3-4 hours, compared to BOD_5 which requires 5 days. If necessary, changes to the operational characteristics of the IETS can then be made promptly, based on the COD test results. However, BOD values can be computed from **correlation relationship** between COD and BOD which can be established for a particular effluent. To monitor the overall organic removal, the BOD of the raw effluent and the final discharge must be measured and BOD removal efficiency computed. Another parameter, which is also commonly monitored is total suspended solids (TSS). TSS of the raw effluent and treated effluent is monitored and its removal efficiency computed.

If the BP is also designed to remove **nutrients**, particularly **ammoniacal nitrogen**, the concentration of ammoniacal nitrogen in the raw effluent and treated effluent must be measured. The ammonia removal efficiency can then be calculated. Other forms of nitrogen such as nitrite and nitrates should be monitored whenever relevant.

6.1.17 Summary of performance monitoring requirements for biological treatment processes

6.1.17.1 Activated sludge treatment system (ASTS)

Table 6.9 summarizes the **sampling requirements** to monitor the performance of the activated sludge system (ASTS). The requirements include the **parameters** which shall be monitored, the **sampling locations** and the **sampling frequency**. Figure 6.1 illustrates a schematic diagram of a typical activated sludge system while Fig. 6.2 to 6.4 show the recommended sampling locations for the equalization tank, the aeration tank and the secondary clarifier, respectively. The sampling requirements summarized in Table 6.9 are also applicable to all versions of the activated sludge systems such a conventional activated sludge (CAS) systems, extended aeration activated sludge (EAAS) systems, sequencing batch reactors (SBRs) and oxidation ditches (ODs).

Table 6.9: Recommended sampling requirements for an activated sludge system

Parameter	Sampling location description	Sampling station in Figs 6.2 to 6.4	Sample type	Sampling frequency
Equalization tank *				
Flow	EQ outlet	P1	Totalizer	Daily
BOD	EQ outlet	P1	Preferably composite	Weekly
COD	EQ outlet	P1	Preferably composite	Daily
pH	EQ outlet	P1	In-situ	Daily
TIN	EQ outlet	P1	Grab	Monthly
Aeration tank				
DO	In the aeration tank, preferably at three locations	P2, P3, P4	In-situ	Daily
MLSS	In the aeration tank	P3	Grab	Daily
MLVSS (from MLSS analysis)	-	-	-	Weekly
SVI	Aeration tank outlet or close to outlet**	Around P4 or P5	Grab	Daily
pH	In the aeration tank	Around P2	In situ	Daily
SS of RAS	RAS line	P6	Grab	Daily
SS of WAS	WAS line	P7	Grab	Daily
Q_{RAS}	RAS line	P6	Totalizer	Daily
Q_{WAS}	WAS line	P7	Totalizer	Daily
F/M ratio ***	-	-	-	Weekly
SOUR	In the aeration tank at the effluent end	Around P4	Grab	Weekly
Microscopic examination	In the aeration tank	Around P3	Grab	Weekly

Secondary clarifier** **				
Sludge level/blanket and solids level	Middle of clarifier	P8	Grab	Daily or several times daily
BOD	Clarifier effluent	P9	Preferably composite	Weekly
COD	Clarifier effluent	P9	Preferably composite	Daily
SS	Clarifier effluent	P9	Preferably composite	Daily
pH	Clarifier effluent	P9	In-situ	Daily
TIN	Clarifier effluent	P9	Grab	Monthly

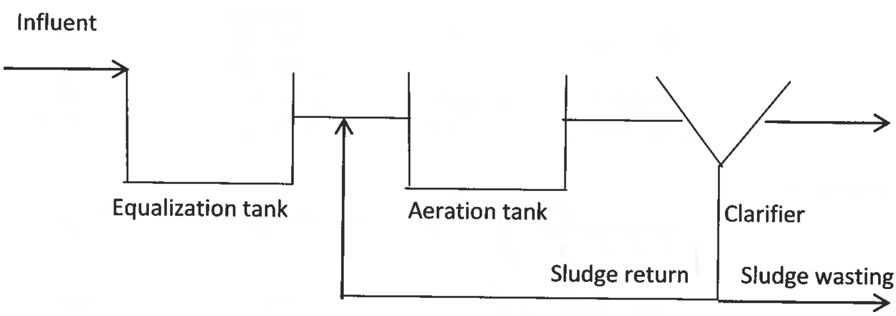
Note: * If there is no equalization tank, take the samples of the influent (i.e. raw effluent)

** More than one sample and sampling from the aeration tank itself may be required if the aeration tank is long and narrow.

*** F/M ratio is computed from BOD or COD of influent and MLVSS data

****If there is no advanced treatment process, the clarifier effluent is the final effluent.

DO = dissolved oxygen; BOD = biochemical oxygen demand; COD = chemical oxygen demand; MLSS = mixed liquor suspended solids; MLVSS = mixed liquor volatile suspended solids; SVI = sludge volume index; RAS = return activated sludge; WAS = waste activated sludge, F/M ratio = food to microorganism ratio; TSS = total suspended solids; TIN = AN + nitrite + nitrate



(Note: assume no primary clarifier and advanced treatment)

Fig 6.1: Schematic diagram of a typical activated sludge process

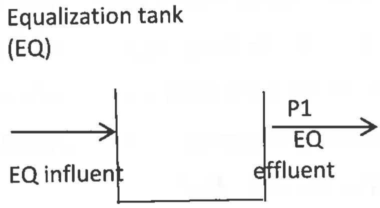


Fig 6.2: Sampling location for equalization tank

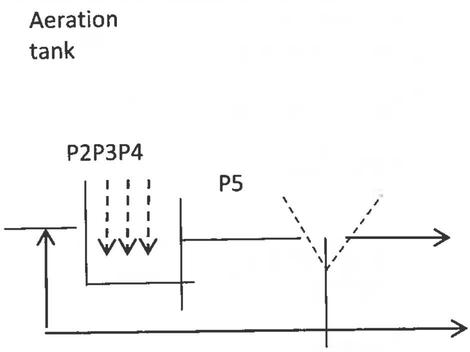


Fig 6.3: Sampling location for aeration tank

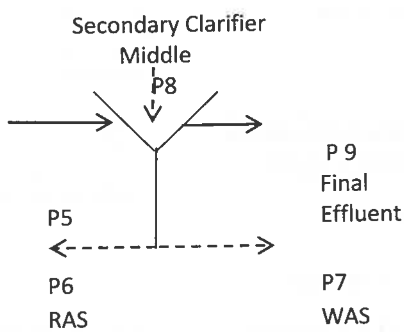


Fig 6.4: Sampling location for secondary clarifier
(RAS: return sludge; WAS: Waste activated sludge)

6.1.17.2 Membrane bioreactors (MBRs)

Membrane bioreactors (MBRs) combine activated sludge process (suspended growth) with a **membrane filtration system**. The latter replaces the secondary conventional gravity clarifier. Table 6.10 summarizes the parameters which shall be monitored, the sampling locations and the sampling frequency to be complied with, to monitor the performance of the membrane bioreactors (MBR).

Table 6.10: Recommended performance monitoring specifications for membrane bioreactor (MBR) system

Parameter	Monitoring Frequency	Sampling Location
Permeate flux	Continuous	MBR
HRT	Daily calculation (less frequent, if flow variation is low)	Influent
Sludge age	Daily calculation	Reactor
F/M	Daily calculation	Reactor
Transmembrane pressure (TMP)	continuous	Reactor
MLSS, MLVSS	Daily or weekly	Reactor
Temperature	Continuous	Influent and MBR tanks
Flow	Continuous	Influent
Dissolved Oxygen	Continuous	EQ and Reactor
COD (or alternatively BOD)	Continuous (for large systems) or weekly if variation is low	Influent & Permeate
Microbiology	Weekly	Reactor
N&P	Monthly (less frequent if variation in influent characteristics is low)	EQ
pH	Continuous	Influent and EQ

6.1.17.3 Moving bed biofilm reactors (MBBRs)

Moving Bed Biofilm Bioreactor (MBBR) is a combination of activated sludge process (suspended growth) and biofilter (attached growth). MBBR system utilizes the entire tank volume for biomass growth. Biofilms grow on **floating media** which are kept in motion by the agitation of **air bubbles**. The sampling requirements as described for the activated sludge system are also applicable to the MBBRs.

6.1.17.4 Trickling filters (TFs)

Table 6.11 summarizes the performance monitoring requirements for conducting performance monitoring of trickling filters (TFs).

Table 6.11: Recommended performance monitoring specifications for trickling filters (TFs)

Sample type	Parameter	Monitoring *Frequency
TF influent	DO pH Temperature	Daily
	SS Settleable solids BOD	Weekly or monthly
Recirculated flow	DO pH Temperature	Daily
TF effluent	DO pH Jar test	Daily
TF system final effluent**	DO pH SS	Daily
	Settleable solids BOD	Weekly

*Note: Monitoring frequency may be reduced during normal operations and increased during abnormal conditions.
** DO and settleable solids are additional parameters to the list of significant parameters for compliance purpose

6.1.17.5 Rotating biological contactors (RBCs)

Table 6.12 summarizes the sampling requirements for conducting performance monitoring of rotating biological contactors (RBCs).

Table 6.12: Recommended sampling requirements for rotating biological contactors (RBCs)

Sample type	Parameter	Monitoring *Frequency
RBC influent	DO pH Temperature	Daily

	SS Settleable solids BOD	Weekly or monthly
RBC drum	Rotation speed	Weekly
RBC effluent	DO pH Jar test	Daily
RBC system final effluent**	DO pH SS	Daily
	Settleable solids BOD	Weekly

*Note: Monitoring frequency may be reduced during normal operations and increased during abnormal conditions.
** DO and settleable solids are additional parameters to the list of significant parameters for compliance purpose

6.1.17.6 Upflow anaerobic sludge blanket (UASB)

Upflow anaerobic sludge blanket (UASB) is a form of **anaerobic** process which is commonly employed for the treatment of **high strength organic effluents**. Table 6.13 summarizes the sampling requirements for conducting performance monitoring of upflow anaerobic sludge blankets (UASBs).

6.13 Recommended sampling requirements of upflow anaerobic sludge blanket (UASB)

Parameter	**Sampling frequency**
Flowrate	Daily
BOD	Once in two weeks
COD	Alternate days
pH	Daily or continuous
Temperature	Daily or continuous
VFA	Daily
VFA/Alkalinity	Daily
ORP	Daily or continuous
Nutrients (N)	Once in two weeks
OLR	Daily
* Biogas (pressure and analysis)	Daily, if the objective is biogas capture

* Typically the following gases are monitored: O_2, CO_2, CH_4, H_2S.

6.1.17.7 Ponding systems

Table 6.14 summarizes the sampling requirements for conducting performance monitoring of ponding systems which include stabilization ponds, facultative ponds, maturation ponds, etc. the parameters are applicable to **aerobic systems**.

Table 6.14: Recommended sampling requirements for ponding systems

Parameter	Sampling location	Sample type	Sampling frequency
Flow	Inlet, outlet	Totalizer	Daily
BOD	Inlet, outlet	Preferably composite	Monthly
COD	Inlet, outlet	Preferably composite	Once in two weeks
DO	Preferably at three locations*	In situ	Daily or weekly
pH	Preferably at three locations*	In situ	Daily or weekly
Nutrients	Inlet	Grab	Monthly
Sludge depth	Entire pond	-Daily	Once in two to three years

Note: * Close to inlet and outlet and middle of the pond

For **anaerobic ponds**, volatile fatty acids (**VFAs**) and **total alkalinity** should be monitored, at a minimum, on a weekly basis.

6.1.17.8 Other Types of biological treatment processes

For other types of biological treatment systems, which are not discussed in this Guidance Document, the industry personnel shall determine the details of the sampling requirements based on experience obtained at other premises and information in the literature. The sampling procedure shall be **documented** for the inspection by the DOE inspectors.

CHAPTER 7 - PERFORMANCE MONITORING OF PHYSICAL CHEMICAL PROCESSES

Although some physical chemical treatment processes (PCPs) have **well-defined** performance monitoring parameters, several PCPs do not have distinct process parameters due to the nature of physical/chemical processes involved. This fact is particularly true in the case of **physical processes**. In such cases, performance monitoring takes more of the form of **operation and maintenance** (O&M) rather than performance /process monitoring per se. This is a major difference between the nature of performance monitoring of biological treatment processes compared to the monitoring of physical chemical treatment processes. In many physical treatment processes, monitoring activities are more focused on the maintenance of the hardware (i.e. the **"hardware"** aspect) of the IETS operation rather than on the process monitoring (i.e. the **"software"** aspect) of the IETS operation.

The control of physical chemical treatment processes is for the most part accomplished by the use of **automatic instrumentation systems** or **portable measuring instruments** providing **in-situ readings**. As a general requirement, **maintenance** of the instrumentation systems and portable instruments including the calibration of the sensors, probes, dosing pumps and ensuring sufficient supply of relevant chemicals, etc. typically forms an integral part of the IETS (PCP) performance monitoring routine.

The paragraphs below discuss how performance monitoring is carried out for some physical processes, which do not lend themselves to process monitoring, and for chemical processes which have distinct and well defined process monitoring parameters.

7.1 Equalization

Equalization is commonly practiced to **dampen** variations in flow and pollution concentrations. Apart from flowrate, some effluent quality parameters are identified and **maximum** limits are placed on them to ensure optimum treatment occurs in the subsequent treatment processes. These parameters typically include pH, SS, BOD, COD, and metal concentration. Monitoring frequency of the parameters depends on the degree of fluctuation of the parameters and may range from once a day to once a week.

7.2 Cooling

An effluent generated at elevated temperatures is often cooled using a **cooling pond** or **tower**. Apart from flowrate, temperature is monitored on a daily or weekly basis, depending on temperature variability of the raw effluent.

7.3 Dissolved air flotation (DAF)

Dissolved air flotation system (DAF) is considered to be one of the most cost-effective technologies for removing **total suspended solids** (TSS) from a wide range of industries such as pulp and paper mills, recycled fibre, drink, food processing, dairies, textile mills, bakeries, meat processing and animal by-products industry.

Sometimes the DAF process is preceded by **screening**, **equalization**, **pH adjustment**, and **chemical coagulation**.

One of the most important design and operational parameters of a DAF system is the **Air to Solids (A/S) ratio**. At the operational stage, DAF performance monitoring aims to ensure the A/S ratio is maintained as in the design stage. This can be accomplished by changing the **recycle flow rate**, the **operating pressure**, or both. To enable this operation to be made, information on the suspended solids concentration is required hence it must be routinely monitored. The monitoring frequency depends on the degree of fluctuation of the raw effluent's TSS concentration. A/S ratio should be monitored and maintained within the range of 0.005 to 0.06 mL air/ mg SS (or 0.0065 to 0.078 mg air/mg SS). The entire influent flow or only the recycle flow may be **pressurized** by the pressurizing pump or compressor to 250 to 450 kPa gage. Higher pressures up to 725 kPa have been reported. Other items to be monitored include the influent and recycle flow rate, operating pressure, influent and effluent SS concentration, skimmer speed, and coagulant and flocculant dose (if coagulant and flocculant addition is practiced).

DAF systems are also used to remove **oil and grease** (O&G) from a wide spectrum of industrial sources. When the DAF system is used for O&G removal, the term S in the

(A/S) ratio refers to the O&G. Another version of the DAF system is the **dispersed or induced flotation** system, which uses a **revolving impeller** to form bubbles by introducing the gas phase directly into the liquid phase.

7.4 Removal of oil and grease

Depending on the size of oil particles, oil exists in industrial effluents in two basic forms:

- **Non-emulsified** where the oil floats on the surface of the water, hence it can be removed easily.
- **Emulsified** where oil is dispersed in water as emulsions after it has been subject to chemical or mechanical action. Oil in this form is more difficult to remove.

7.4.1 Removal of nonemulsified oil (Free oil)

Free, non-emulsified oil is typically removed from industrial effluents by using oil water separators, which work on **gravity forces**. The **gravity separators** come in various forms such as oil tank, American petroleum institute (API) separators and plate API separators. The floating oil is **skimmed off** over the weir of the separator tank.

Performance monitoring of the oil water separators includes the following:

- Monitoring the influent flowrate.
- Sampling and analysis for oil concentration of the influent and effluent.
- Physical inspection and maintenance of the separators for clogging, corrosions, and general equipment cleaning

Free oil and oil in a weakly emulsified state can also be removed in **coalescing devices** which include a variety of cartridge filters and coarse sand pressure filters.

7.4.2 Removal of emulsified oil

Many industries such as automotive and metal parts manufacturing plants, paint, surface coatings, and adhesives manufacturing industries, textile dyeing, oils, fats and waxes manufacturing and dyes and inks manufacturing industries generate emulsified oil. The **deemulsification techniques** for oil in water emulsions include chemical, electrolytic, or physical methods. **Chemical emulsion breaking** usually proceeds with acidification followed by chemical coagulation using inorganic or organic coagulants. **Physical methods** include **centrifuging** and **heating** while in **electrocoagulation** (EC), an electric current is passed through the effluent where electrolytic cell with an anode and a cathode is placed. The deesmulsified oil is then removed through conventional means such as dissolved air flotation (DAF) systems.

Sampling and performance monitoring of the deemulsifaction process depends on the emulsion breaking technique used. For chemical emulsion breaking, the performance monitoring activities include **flowrate** and **pH monitoring** and determining the **optimum dose** of the coagulants. For centrifugation, **Reynolds numbers** needs to be monitored to ensure moderate turbulence (Re between is 50,000 to 100,000) is maintained. For electrocoagulation, the process is monitored by monitoring the flowrate, **electrode current**, concentration of ferrous ion salt, and oil concentration.

7.5 Coagulation and flocculation

Total suspended solids (TSS) can either be present originally in the raw effluent or in the form of colloidal metal suspensions generated from chemical precipitation process. TSS is generally removed out of solution by coagulation and flocculation process. Coagulation and flocculation process are also applicable to oil and grease treatment as described previously. **pH adjustment** commonly precedes the coagulation process, hence pH needs to be monitored. **Jar testing** to determine the optimum pH and dose of the **coagulants** must be performed on a routine basis.

7.6 Removal of metals

A wide range of industries generates metals in their effluents. Metals are typically removed from solution by chemical precipitation or ion-exchange. **Chemical precipitation** techniques include hydroxide precipitation, sulfide precipitation, carbonate precipitation, chloride precipitation, and xanthate precipitation. Other less commonly used techniques for removing metals from industrial effluents include adsorption, evaporation, membrane filtration, electrodialysis, and photocatalysis.

7.6.1 Removal of metals by hydroxide precipitation

Removal of metals as metal hydroxides by **chemical precipitation** is heavily dependent on pH of the solution. The solubility of **metal hydroxides** is controlled by the solution pH where the point of **minimum solubility** dictates the **narrow pH range** within which the precipitation process needs to be maintained. The optimum pH range must be determined by conducting **metal solubility test** at different pH using the actual effluent. Once the pH range is determined, the pH of the solution in the precipitation tank needs to be monitored and recorded, preferably on a continuous basis.

Included in the hydroxide precipitation process is the removal of **fluoride**, which is a **non-metal**, sometimes with the addition of both calcium hydroxide and calcium chloride.

Generally, the performance monitoring requirements for a hydroxide precipitation process includes the metal **solubility testing** and **pH monitoring**.

7.6.2 Removal of metals by sulfide precipitation

Sulfide precipitation is commonly used to remove metals from metal-bearing effluents especially if **complexing agents** are present in the raw effluent. Performance monitoring of sulfide precipitation technology includes the monitoring of **flowrate**, **solution pH**, and **sulfide dosage.**

7.6.3 Removal of metals by other chemical precipitation technologies

These technologies include carbonate, sulfate, and chloride precipitation, which are employed for the removal of certain metals which may not be adequately removed by using the hydroxide precipitation. Typical performance monitoring requirements for these technologies include **pH monitoring** and **dosage of the precipitant**, wherever relevant.

7.6.4 Removal of metals by ion exchange

Ion exchange can be employed for removing **high strength** metal laden effluents or as a **polishing step** following conventional hydroxide precipitation technology to lower the metal concentration in the discharge. **pH adjustment** is performed to ensure the pH is within the operating range of the resin and **filtration** is carried out to remove suspended solids to prevent fouling of the resin. An important aspect of the operation of an ion exchange column is the monitoring of the column **breakthrough time,** which will determine the need for **column regeneration**. The onset of breakthrough is typically monitored via several ways, such as by monitoring:

- The **conductivity** or conductivity ratio
- The **metal concentration** in the outlet and inlet of the column
- The effluent **volume throughput**
- The column **usage time**

Another activity associated with the operation of ion exchange columns is the **regeneration** process and the handling of the concentrated **regenerant effluent stream**.

7.6.5 Removal of metals by electrowinning

An ion exchange process can be combined with an electrowinning process to handle the regenerant effluent stream, which is highly **concentrated** with the metal, removed from the effluent. Electrowinning is an **electrochemical process** that can be employed to remove metallic ions from concentrated rinse water, spent process solutions, and ion exchange regenerant. An advantage of electrowinning is that the metal removed from the effluent is plated out as a **solid metal**. Sometimes to enable automated system operation and ensure consistent environmental performance, the electrowinner is equipped with an **on-line metal sensor** to provide real-time monitoring of the concentration of the metal to be removed. To monitor the efficiency of the electrowinning process other parameters monitored may include **pH**, **current**, **voltage**, **temperature**, and **metal concentration**.

7.7 Removal of contaminants using redox process

Many of the chemical and the biochemical processes encountered in the treatment of industrial effluents can be described fundamentally as **oxidation-reduction** systems. Measuring and controlling **oxidation-reduction potential** (ORP) levels is especially relevant in the treatment of industrial effluents involving an oxidation-reduction reaction. Unit operations involving redox reactions are typically monitored by measuring the **ORP** level.

ORP is a measurement of the **status** of an oxidation-reduction reaction. Although it can be used to monitor the **degree of treatment** in the reaction tank, ORP values cannot be equated to a specific concentration of the metals such as chrome and therefore are not used as a **final discharge effluent standard**. Additionally, by monitoring pH/ORP, **chemical usage** can be optimized resulting in cost savings.

In the field of industrial effluent treatment using PCPs, ORP measurement has been be utilized successfully to monitor **chromate reduction** and **cyanide oxidation**. The **ORP** measurement can be made electrometrically using the millivolt mode of a pH meter.

7.7.1 Removal of chromium by two-stage process

In the treatment of effluents containing chromium, in the first stage, the **hexavalent chromium** is reduced to **trivalent chromium** by the addition of a **reducing agent** (sodium bisulfite or sulfur dioxide). In the second stage, the **trivalent chromium** is precipitated as **chromium (III) hydroxide**. The conditions to be maintained in both reaction tanks are given in Table 7.1. The **pH** and **ORP** in the reaction tanks must be maintained and their values recorded.

Table 7.1: Conditions to be maintained for two stage chromium removal

Parameter	First tank (Reduction)	Second tank (hydroxide precipitation)
pH	2 – 3	8 – 9
ORP	+ 250 mV to + 300 mV	-

7.7.2 Removal of cyanide by two-stage alkaline chlorination

Dilute cyanide effluent streams are typically treated by a two-stage process, commonly known as **alkaline chlorination**. In the first stage, the cyanide is oxidized to **cyanate** by the use of hypochlorite solution. In the second stage, through the addition of additional hypochlorite, the cyanate is oxidized to **carbon dioxide**. The conditions to be maintained in the reaction tanks are given in Table 7.2. The values of **pH** and **ORP** must be monitored and recorded.

Table 7.2: Conditions to be maintained for two stage alkaline chlorination of cyanide

	First Tank	Second Tank
pH	> 10, preferably, 11.0 to 11.5	~ 8.5
ORP	+ 325 mV to + 400 mV	+ 600 mV to + 800 mV

Other alternative technologies use **hydrogen peroxide** or **calcium hypochlorite** as the **oxidizing agents**.

7.8 Removal of various contaminants by carbon adsorption

Activated carbon adsorption is commonly used to remove a variety of contaminants from the effluents such as surfactants, dyes, pesticides, endocrine disruptors, gases, sulfides, metals, color, etc. A widely used application of activated carbon adsorption in effluent treatment is for the removal of **residual dissolved organics**. The presence of residual organics is reflected by the treated effluent COD, which may not still meet the regulatory discharge standard.

7.8.1 Carbon adsorption columns for continuous operation

For continuous operations, the activated carbon is used in **adsorption columns**. The adsorption process in a carbon column will continue until all the **adsorptive capacity** of the carbon has been used and the column's effluent reaches its set point. The time taken to reach this condition is referred as the **breakthrough time**. This time must be closely monitored to ensure that the carbon is **replaced** or **regenerated** before the stipulated time. The performance monitoring of the activated carbon column is focused on the monitoring of the **breakthrough time** of carbon beds, which can be determined via several ways such as:

- By sampling of effluent from the column and monitoring its **COD concentration**
- By consideration of the **hours of operation** of the column
- By using total **volume of throughput**.

The records of monitoring of the breakthrough time must be maintained for inspectional purposes.

7.8.2 Carbon adsorption in batch operation

If the activated carbon is used in a batch mode (one time application), the amount of activated carbon required for treating each batch of effluent must be estimated via a reliable bench scale **adsorption experiment**. The study results must be documented for the inspection by the DOE inspectors. Typical performance monitoring parameters in batch operations include **volume of effluent** to be treated and the **dosage (volume) of activated carbon** required.

The **spent carbon** in continuous operation mode must be handled properly, either for regeneration or for disposal as a scheduled waste according with the requirements of the Scheduled Waste Regulations, 2005. Similarly, in batch operations, the activated carbon with the **adsorbed contaminants** must also be managed as a scheduled waste.

7.9 Oxidation

Oxidation technologies are more commonly used for the removal of organics but some inorganics may also be treated by the technologies.

7.9.1 Chemical oxidation

Chemical oxidation includes the use of chlorine, hydrogen peroxide, and ozone as the **oxidizing agent** to oxidize the contaminants present in the effluent. Typical contaminants, which are destructed by the oxidation processes, are various **organic compounds** and **cyanide** (an inorganic compound). Performance monitoring parameters of chemical oxidation processes are typically pH and ORP.

Included in this category is the **bubbling of air** into an effluent to oxidize iron and manganese to improve the hydroxide precipitation of the metals.

7.9.2 Electrochemical oxidation

Electrochemical oxidation is also used to treat **concentrated cyanide** bearing effluents. Typically, the process is monitored by monitoring the voltage applied.

7.9.3 Wet air oxidation (WAO)

Wet Air Oxidation (WAO) is an oxidation process carried out at elevated temperatures (125 to 320° C) and pressures (30 to 200 bars) typically used for treating **highly concentrated effluents** such as spent caustic from oil and gas industry. The contaminants are **mineralized** to various organic and inorganic end products. The process is enhanced by using a **catalyst** and strong **oxidants** such as ozone and hydrogen peroxide. **Temperature** and **pressure** are the controlling parameters which are typically monitored on a continuos basis. Effluent quality parameters which are frequently monitored include **COD** and **ammonia**.

7.10 Advanced oxidation technologies (AOTs)

Advanced oxidation technologies (AOPs) are a group of treatment technologies, which employ **chemical oxidation-reduction processes** to remove toxic **soluble organics**, which are resistant to conventional biodegradation processes.

7.10.1 Advanced oxidation processes (AOPs)

AOPs refer to oxidation technologies using UV/O_3, O_3/H_2O_2, UV/ H_2O_2 or the photo Fenton reaction (UV/ H_2O_2/ Fe^{2+} or Fe^{3+}. The most commonly used technology is the **Fenton's process**. Since at acidic pH the direct attack by the free OH radicals generated by the Fenton's reaction is predominant, **pH monitoring** is essential. If the effluent from the Fenton's process will be further treated in a biological treatment process, the pH will be further adjusted hence pH monitoring is also required. The flowrate and pH monitoring records must be maintained.

7.13 Filtration

Effluent polishing with filtration technology is quite a common practice in many industries. The purpose of filtration is primarily to remove **residual suspended solids.** There are three major technologies which employ filtration mechanism to achieve the removal of the suspended solids: membrane filtration, media filtration, and filter bags.

7.13.1 Membrane filtration

In effluent treatment membrane processes are increasingly used for removal of residual **suspended solids**, **color** and **odor**. The membrane processes are categorized into the following categories: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). Typical performance monitoring activities include the monitoring of the **influent pH, transmembrane pressure (TMP)**, and **chemical cleaning of the membrane unit**.

7.13.2 Media filtration

Media filtration is commonly used to remove **fine residual suspended solids** from a treated effluent before it enters the carbon adsorption columns for removal of residual organics. Additionally, the purpose of media filtration is to **polish** the effluent to comply with stringent internal TSS discharge standard or for water recycling objective. Performance of the media filters is monitored by monitoring **differential pressure** and **effluent TSS** or **turbidity**.

7.13.3 Bag filtration and cartridge filtration

Filter bags are available in different specifications to meet different application requirements, largely dictated by the type and size of particles present in the effluent. As the liquid flows from the inside of the bag to the outside, particulates are **trapped** in the bag. Performance of the filter bags is monitored by monitoring the pressure drop and effluent TSS.

7.14 Removal of organics by stripping

7.14.1 Air stripping

Air or gas stripping is used to remove **volatile organic compounds** (VOCs) from an industrial effluent. Air stripping includes mechanical surface aeration, diffused aeration, spray fountains, spray or tray towers, and packed towers. There is a host of performance monitoring parameters which are generally relevant to air stripping processes. These include **effluent and gas flowrates**, **gas to liquid (G/L) ratio**, **temperature**, **pressur**e, and **VOC concentration**.

7.14.2 Steam Stripping

Steam stripping is a **distillation process** which makes use of **process heat** or **steam** to remove fairly soluble, non-volatile organics and inorganics from industrial effluents. Due to **high stripping temperatures**, heavier, more soluble organics can be stripped in stream stripping compared to air stripping. Steam stripping is carried out at temperatures between 90 and 120°C and pressures between 1 and 2 bar. Steam stripping is commonly employed in oil refineries, petrochemical, and chemical plants. Examples of **steam strippable organics** are benzene, alcohol (ethanol, propanol, IPA, butanol), MTBE, MEK, while ammonia is an example of inorganic compound. Typical performance monitoring parameters include **effluent and gas flowrates**, **temperature, pressure**, and **concentration of the organics** (or **ammonia**).

7.15 Removal of ammonia

Apart from biological treatment, ammonia can also be removed by using physical chemical treatment processes.

7.15.1 Ammonia removal by stripping

In ammonia stripping, **lime** or **caustic** is added to the effluent until the pH reaches 10.8 to 11.5. Ammonia which exists in solution as ammonium hydroxide ions is converted to **ammonia gas**. Ammonia stripping is typically accomplished in **ammonia stripping towers** which can be designed in a cross-flow or countercurrent mode. Ammonia stripping works well with effluents having ammonia concentrations in the range of 10 to 100 mg/L. Typical performance monitoring parameters are **effluent and air flowrates**, **effluent pH**, **temperature**, **pressure drop**, and **ammonia concentration** of the effluent.

7.15.2 Removal of ammonia by struvite precipitation

This is a **chemical precipitation** technology where ammonia is chemically precipitated as **magnesium ammonium phosphate (AMP)** at alkaline pH, typically about 9.0. This process removes both **ammonia** and **phosphate**. The optimum pH and dose of magnesium source such as magnesium chloride ($MgCl_2$) and magnesium sulfate ($MgSO_4$) must be established by experiment. Typical performance monitoring parameters include **effluent flowrate**, **pH**, and **dosage of the magnesium salt**.

7.16 Vacuum evaporation

Vacuum distillation technology is a unit operation that **concentrates** an effluent by eliminating the water by **boiling**. Since the evaporator is operated at a pressure lower than atmosphere (**vacuum**), the boiling temperature is lower than 100°C. There are several versions of the evaporators: heat pump vacuum evaporator, mechanical vacuum evaporators and multi-effect vacuum evaporators. Vacuum evaporation results in substantial reduction in effluent volume and possibility of reuse of water. Vacuum evaporators are used in electroplating industry, car and metals industry, printing industry, adhesives, paints, and inks manufacturing, and graphic arts. Since the vacuum evaporation system is typically operated in an **automatic mode**, there is minimal performance monitoring requirements. Typically, **effluent flowrate**, **temperature, pressure**, and **distillate quality** is monitored.

7.17 Monitoring of chemical solids clarifiers

Conventional gravity clarifiers or lamella plate clarifiers separate solids generated from physical chemical treatment processes (PCPs) from the aqueous phase. Performance monitoring activities of the clarifiers include **physical observation** of the **clarification efficiency** (clarity, SS carry over), monitoring of **TSS concentration** in the treated effluent, and ensuring **design criteria** are complied (SOR, SLR, WOR) with at the operational stage.

7.18 Monitoring of PCPs not discussed in this chapter

There exists a wide spectrum of physical-chemical treatment processes (PCPs), which is impossible to be covered in a single guidance document of this nature. If an industry uses a PCP, which is not discussed in this Guidance Document, the performance monitoring (PM) parameters for the PCP must be identified and monitored. An appropriate field log sheet (see the examples in the Appendices) must be developed and the record of performance monitoring activities maintained for inspectional purposes.

7.19 Summary of performance monitoring requirements for physical-chemical treatment processes

Table 7.3 presents a summary of the performance monitoring parameters which are typically monitored in the operation of common physical-chemical treatment processes (PCPs).

Table 7.3: Performance monitoring requirements for physical chemical treatment processes

Process	Test/Check/Observation	Frequency (Preferred)	Remarks
Equalization	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	COD	Daily/weekly	Can be replaced by TOC. BOD can also be measured
	Metals	Daily/Weekly	If relevant
Cooling	Flowrate	Continuous/daily	-
	Temperature	Continuous/daily	-
Dissolved Air Flotation (DAF)	Flowrate; recirculation flow	Continuous/daily	To calculate A/S ratio
	SS or O&G, if relevant	Daily/weekly	
	Pressure	Daily	To calculate A/S ratio
Oil and Grease Removal (i) API	Flowrate	Continuous/daily	-
	O&G	Weekly/monthly	-
	Physical inspection of equipment	Monthly	-
(ii)Emulsion breaking - Chemical addition	pH	Continuous/daily	-
	Coagulant dose	Daily/weekly	-
- Centrifugation	Reynolds number	Daily/weekly	-
- Electrocoagulation	Flowrate	Continuous/daily	-
	Current	Continuous/daily	-

	Ferrous ions	Daily/weekly	-
	Oil and grease	Weekly/monthly	-
Coagulation and flocculation	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	Jar test	Weekly/monthly	
	Chemical dosing system	Daily/weekly	
Metals removal (i) Hydroxide			
	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	Chemical dosing system	Daily/weekly	
	Metal concentration	Decided on a case to case basis	-
(ii) Sulfide	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	Chemical dosing system	Daily/weekly	-
(iii) Ion exchange	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	Regenerant dosing system	Daily/weekly	-
	Metal concentration	Decided on a case to case basis	-
	Breakthrough time monitoring	-	Based on flowrate, usage time, and metal concentration
Electrowining	Flowrate	Continuous/daily	-
	Current	Continuous/daily	-
	Voltage	Continuous/daily	-
	Temperature	Continuous/daily	-
	Metal concentration	Daily/weekly	-
Redox process (i) Chromium removal	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	ORP	Continuous/daily	-
	Chromium	Decided on a case to case basis	-
(ii) Cyanide treatment	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	ORP	Continuous/daily	-
Carbon adsorption	Flowrate	Continuous/daily	-
	Pressure if relevant	Continuous/daily	
	COD	Decided on a case to case basis	-
	Breakthrough time monitoring	-	Based on flowrate, usage time, and COD
Oxidation (i) Chemical oxidation			
	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	ORP	Continuous/daily	-
(ii) Wet Air Oxidation	Flowrate	Continuous/daily	-

(WAO)	Temperature	Continuous/daily	-
	Pressure	Continuous/daily	-
(iii) Advanced Oxidation Processes (AOP)	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
Filtration			
(i) Membrane filtration	Flowrate	Continuous/daily	-
	pH	Continuous/daily	-
	TMP	Continuous/daily	-
	Chemical cleaning	When necessary	-
(ii) Media filtration	Flowrate	Continuous/daily	-
	Pressure drop	Continuous/daily	-
	SS	Daily/weekly	-
	Turbidity	Daily/weekly	Optional
(iii) Bag filtration	Flowrate	Continuous/daily	-
	Pressure drop	Continuous/daily	-
Stripping			
(i) Air stripping	Flowrate (Effluent, Air)	Continuous/daily	-
	Pressure	Continuous/daily	-
	Temperature	Continuous/daily	-
	VOC	Decided on a case to case basis	-
			-
(ii) Steam stripping	Flowrate (Effluent, Air)	Continuous/daily	-
	Pressure	Continuous/daily	-
	Temperature	Continuous/daily	-
	VOC	Decided on a case to case basis	-
iii) Ammonia stripping	Flowrate (Effluent, Air)	Continuous/daily	-
	Pressure	Continuous/daily	-
	Temperature	Continuous/daily	-
	Ammonia	Decided on a case to case basis	-
Vacuum evaporation	Flowrate	Continuous/daily	-
	Distillate quality	Decided on a case to case basis	-
	Temperature	Continuous/daily	-
	Pressure	Continuous/daily	-

Note:
Processes listed in the Table 7.3 are not exhaustive. This is a minimum sampling guide and is subject to modification depending on size of premise and IETS, complexity of operation, and problems encountered.

CHAPTER 8 -MONITORING OF FINAL EFLUENT

The fruit of rigorous implementation of IETS **performance monitoring** and **hardware maintenance** program is the excellent **quality** of the effluent produced at the **final discharge point (FDP)**. A success story of effluent treatment is demonstrated in the generation of **compliant effluent** on a sustained basis.

8.1 Compliance monitoring

Compliance monitoring is an integral part of the overall performance monitoring plan of any IETS. Compliance monitoring of the treated effluent at the final discharge point (FDP is dictated by regulation 7 of the IER which focuses only on **significant parameters**. Significant parameters may be determined by examining the **raw materials** and **auxiliary chemicals** used and the **manufacturing process** utilized by the industry. Experience from **similar industries** and information from the **literature** will also be useful in identifying the significant parameters.

Table 8.1 gives a guide on the significant parameters for different categories of industries while Table 8.2 summarizes the typical industrial sources discharging metals in their effluents.

8.1.1 Compliance monitoring of sources with continuous discharge

As understood from the Tenth Schedule of the IER (regulation 7), industries are required to perform **weekly sampling** of the final effluent, which must be analyzed by an accredited laboratory. Only **significant parameters** are required to be analyzed. Many industries are performing more frequent sampling and analysis of their final effluent, even on a daily basis. Additionally, the whole set of regulated parameters are also analyzed from time to time to provide assurance that the effluent is fully complaint.

8.1.2 Compliance monitoring of sources with batch discharge

The general requirement for final effluent monitoring, which is applicable to both continuous and batch discharges is **weekly** sampling and analysis. There are two scenarios for batch dischargers. The sampling requirements for each scenario are described below.

8.1.2.1 Discharge frequency of once or more than once in a particular week

Only **one representative sample** of the effluent discharged on any one of the days in the week is required to be taken for analysis to represent the sample for the particular week.

8.1.2.2 Discharge frequency of once a month or more frequent than once a month

Again in this case, only **one representative sample** of the effluent discharged is required to be sent for analysis to represent the sample for that particular week that the discharge was made. If the discharge was also made in another week within that month, another representative sample for that particular week will also be required to be taken for analysis.

Apart from the above minimum requirements, preferably, for batch discharges, the effluent to be discharged can be sampled for **each batch** to ensure **compliance** with the discharge standards before the discharge is allowed. Analysis can be performed on significant effluent parameters by using **rapid measurement techniques**. Such parameters typically include pH, COD and metals. The name of the CePIETSO authorizing the discharge, the time of discharge and the discharge quantity and quality must be recorded for the inspection by the inspectors of the Department of Environment.

For ease of reference, the **monthly discharge monitoring report (DMR)** as stipulated in the Tenth Schedule to the Industrial Effluent Regulations 2009 (IER) is reproduced in the Appendix. The requirement on submission of **monthly discharge data** stipulated in regulation 7 (3) of the IER is applicable to **continuous discharges** as well as **batch discharges**. As an additional requirement, batch dischargers are required to maintain discharge data every time a batch discharge is made as explained in the previous paragraph. The format for recording batch discharges is given in the Appendix.

Table 8.1: Significant effluent parameters for different industries

Industry Type	Typical Significant Effluent Parameters
Chlor-Alkali (Mercury Cell)	T, pH, TSS, chloride, chlorinated hydrocarbons
Chlor-Alkali (Diaphragm Cell)	T, pH, TSS, chloride, chlorinated hydrocarbons, arsenic, cadmium, chromium, mercury, lead, zinc, asbestos
Chlor-Alkali (Membrane Cell)	T, Sulfates, Chlorate, Bromate
Metal finishing and electroplating	T, pH, TSS, O&G, aluminum, arsenic, cadmium, chromium (trivalent), chromium (hexavalent), lead, nickel, mercury, silver, zinc, fluorides, cyanides
Fertilizer (Nitrogenous)	T, pH, TSS, AN, COD
Fertilizer (Phosphate)	T, pH, TSS, AN, COD, fluoride, aluminium, arsenic, cadmium, chromium, mercury, lead, zinc, nickel
Pulp and Paper	T, pH, BOD_5, COD, TSS, chromium, sulfides, copper, mercury, lead, nickel, zinc, chlorinated organic compounds, dioxin
Oil & Gas exploration and production	T, pH, BOD_5, COD, TSS, O&G, phenolic compounds, aluminum, arsenic, cadmium, chromium, copper, lead, nickel, zinc, boron, selenium, mercury, fluoride, ammonia, cyanide, formaldehyde, chlorides, sulfides, cyanide
Steel Industry	T, pH, COD, TSS, chromium (trivalent), iron, O&G, cadmium, copper, arsenic, fluoride, chromium, mercury, lead, nickel, manganese, cyanide
Synthetic Fiber	T, pH, BOD_5, COD, TSS, O&G, Sulfides
Tannery and Leather Finishing	T, pH, BOD_5, COD, phenolic compounds, TSS, sulfide, O&G, chromium (trivalent), chromium (hexavalent), boron, manganese, chloride
Textile Processing	T, pH, BOD_5, COD, TSS, O&G, chromium, copper
Pigments and Dyes	Temperature, pH, TSS, COD, Lead, Copper, Zinc
Thermal Power Plants	T, pH, TSS, O&G, chromium, zinc, biocides, chlorine
Rubber Products	BOD_5, COD, TSS, zinc, chromium
Paints, Varnishes & Lacquers	pH, TSS, COD, lead, chromium, cadmium, zinc, barium
Pesticides	pH, COD, mercuy, arsenic
Printing	pH, TSS, COD, O&G, lead, cadmium, chromium, copper, silver, zinc, color
Industrial chemicals	pH, COD, TSS, AN, phenolic compounds, aluminum, cadmium, lead, chromium, mercury, nickel, zinc, arsenic, cyanide
Petrochemicals	T, pH, BOD_5, COD, TSS, O&G, phenolic compounds
Fruit and vegetable processing	T, pH, BOD_5, COD, TSS
Food and Beverage	T, pH, BOD_5, COD,TSS, O&G
Glass manufacture	T, pH, COD, TSS, O&G, barium, boron, cadmium, chromium
Sugar production	T, pH, BOD_5, COD, TSS, O&G, pesticides, nitrogen

Detergent manufacture	pH, COD, O&G, an-ionic detergent, foam
Photographic industry	pH, COD, silver, cyanide, fluoride
Glue manufacture	pH, BOD_5, COD, phenolic compounds, formaldehyde
Vegetable oil processing	T, pH, BOD_5, COD, TSS, O&G, glycerine
Solar panel manufacture	T, pH, BOD_5, COD, TSS, flouride
Plastic materials and products	T, TSS, endocrine disruptors
Wood Products	pH, TSS, COD, Phenolic compounds
Semiconductor and electronics industry	T, pH, TSS, BOD_5, COD, O&G, lead, copper, nickel, chromium, tin, mercury, fluoride, cyanide, sulfates, nonchlorinated solvents, AN,
Poultry processing	T, BOD_5, TSS, COD, O&G, AN
Dairy industry	T, BOD_5, COD, TSS, O&G, AN, chlorides
Pharmaceutical	T, pH, BOD_5, COD, TSS

Note: Both the list of industries and significant parameters identified are not exhaustive; Significant effluent parameters depend on actual process and raw materials used.
AN = Ammoniacal nitrogen; TSS= Total suspended solids; COD = Chemical oxygen demand;
BOD = Biochemical oxygen demand O&G = Oil and grease

;

Table 8.2: Typical industrial sources discharging metals in effluents

Metal	**Industrial source**
Arsenic	Metallurgical industry; glassware and ceramic production; tannery operation; dyestuff manufacture; pesticide manufacture; petroleum refining; some organic and inorganic chemical manufacture; rare earth industry
Barium	Paint and pigment industry; metallurgical industry; glass manufacture; ceramics industry; dye manufacture; rubber vulcanization process; explosive industry
Cadmium	Metallurgical alloying process; ceramics industry; electroplating industry; photographic industry; pigment works; textile printing; chemical industry
Copper	Metal pickling bath and plating baths; chemicals manufacturing employing copper salts or copper catalyst; printed wire board industry; solar sell manufacture
Fluoride	Glass manufacture; electroplating industry; steel and aluminum industry; pesticides manufacture; fertilizer manufacture; photographic industry; silicon wafer industry; cathode ray tube industry; steel industry; solar panel manufacture
Iron	Mining operation; ore milling; chemical industry; dye

	manufacture; metal processing; textile industry; petroleum refining
Lead	Lead acid battery manufacture; printed wire board industry
Manganese	Steel alloy industry; dry cell battery manufacture; glass and ceramics industry; paint and varnish manufacture; ink and dye works; tannery
Mercury	Chlor-alkali industry; electrical and electronics industry; explosives manufacture; photographic industry; chemical and petrochemical industry; laboratory effluents; incinerator; battery manufacture; bulb and lamp manufacture
Nickel	Metal processing industry; steel foundries; motor vehicle industry; air craft industry; printing industry; chemicals industry; nickel electroplating industry; printed wire board
Selenium	Flyash pond from fossil fuel combustion; sulfide ore processing; coal-fired power plant cooling water discharge
Silver	Porcelain works; photographic industry; electroplating industry; ink manufacture; printed wire board
Zinc	Steelworks; rayon yarn and fiber manufacture; rubber glove industry; wood-pulp production; recirculating cooling water using cathodic treatment

CHAPTER 9 - RECORD KEEPING

Industries are required to maintain the records of **performance monitoring (PM) activities** of the industrial effluent treatment systems (IETSs) and **corrective actions** taken to address **upset conditions** encountered in the daily operation of the IETSs. The recommended tables to be used for recording IETS performance and activities corrective actions taken to address IETS upset situations are given in the Appendix.

All the tables can be **modified** to capture more PM activities and data collected to suit individual situations and requirements. The modified tables are acceptable as long as the major performance monitoring activities and essential parameters are captured and recorded. The items specified in the tables are the **minimum requirements,** which must be met. Additional activities and more frequent data collection are recommended wherever relevant. The tables must be maintained and made available to the DOE inspectors for **inspectional purposes**.

9.1 Records to be maintained

The performance monitoring (PM) record keeping requirements are summarized as follows:

- All **performance monitoring activities** must be recorded and the records maintained.
- The minimum records to be maintained are the information and entries made in the tables shown in the Appendices. The records include records of "**corrective actions**" and "**calibration logs**" of performance monitoring instruments.
- In cases where performance monitoring parameters are monitored by **on-line sensors,** the records of PM data must be saved in a computer file, or on a compact disc, or compiled in handwritten or printed form.
- At the end of each month, the performance monitoring data collected must be plotted, at a minimum as an **X-Y graph** shown with the upper control and lower control limits.

9.2 Maintenance of performance monitoring records

The performance monitoring records must be kept in a **dedicated file** and made available for the inspection by the DOE inspectors during their enforcement duties. The records must be maintained for a minimum of **three years** after they were prepared. Maintenance of the records also constitutes compliance with the requirement on maintaining records of **operation, maintenance and performance monitoring** of the IETS as stipulated in regulation 27(1) of the IER.

CHAPTER 10 –ANALYSIS OF PERFORMANCE MONITORING DATA

This chapter is dedicated to the discussion of the **analysis** of the data obtained from the performance monitoring activities. The methods of data analysis discussed in this chapter are only minimum **recommended procedures** to assist the IETS operators or supervisors on how to tabulate, interpret and present data to the factory management or the Environmental Performance Monitoring Committee (EPMC) in a systematic and technically acceptable fashion. The industry personnel who are in charge of the analysis of the IETS performance data are at liberty to modify the procedures to suit the industry's specific requirements and style.

10.1 Biological treatment processes (BPs)

10.1.1 From raw data to descriptive statistics

The data that has been obtained from the performance monitoring activities fall into two different categories, namely "**direct measurements**" and "**computed data**". Direct measurements include data on flowrate, pH, temperature, dissolved oxygen (DO), mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), settled sludge volume in 30 minutes settling test (SV_{30}), nitrogen (N) and phosphorus (P). The above data is obtained either from equipment readings, field tests, flow readings or from measurements or laboratory tests. Computed data include sludge volume index (SVI), oxygen uptake rate (OUR), specific oxygen uptake rate (SOUR), food to microorganism (F/M) ratio, return flow (Q_R), percent return flow (Q_R/Q), hydraulic retention time (HRT), solids inventory (SI), sludge age (θ_c), and waste sludge (Q_W).

The next important step is to transform the "**raw data**" that has been collected through IETS performance monitoring activities into some **useful information**. **Statistical analysis** is a means for effective interpretation of the raw data. **Descriptive statistics** helps us to simply summarize large amounts of data in a sensible way. Each descriptive statistic reduces lots of data into a simple summary. Descriptive statistics can include **graphical summaries** that show the spread of the data, and **numerical summaries** that either measure the **central tendency** of a data set or describe the **spread** of the data. Graphical summaries include the **histogram**,

dispersion graphs and **trend charts** while measures of central tendency are commonly reported as the **mean**, **median**, and **mode**. Today with advancement in computers, statistical analysis can easily be performed by using **statistical packages,** which can produce results quickly and will minimize the chance of committing errors.

10.1.2 Comparing the computed statistics with the recommended ranges

The statistics computed earlier must be presented in a suitable format for reference, ease of comparison, and effective communication between the IETS personnel and the others. The recommended table by which the **computed statistics** can be presented is shown in Table 10.1. The performance monitoring data which includes data on pH, dissolved oxygen, MLSS, MLVSS, BOD, COD, nutrients, SVI, OUR, SOUR SV_{30}, SVI, F/M, Q_R, Q_R/Q, HRT, SI, θ_c, and Q_W as well as the **recommended ranges** are shown in this table. The recommended ranges for most of the PM parameters have been highlighted in Chapter 6. Any parameter which falls outside the recommended ranges is easily noticed, thereby **prompt attention** can be given. Sometimes, the situation calls for immediate **corrective actions** to be taken. In other situations, it calls for **further investigation** to determine or confirm the cause of the problem. Whatever the circumstances are, for the most part, prompt action is necessary in order to avoid the worsening of situations leading to effluent **noncompliance** problems.

10.1.3 Process control charts (PM Charts)

Process control charts in IETS operation referred to simply as **performance monitoring charts (PM Charts)** can be easily plotted by using a **statistical package** commonly available on a personal computer. Typically, the PM chart has a central line for the **average**, an upper line for the **upper control limit** (UCL) and a lower line for the **lower control limit** (LCL). The control limits are generally dictated by the technical characteristics of the treatment process to be controlled. **PM charts** of various parameters such as F/M ratio, DO, MLSS, influent BOD and COD, effluent BOD and COD, SVI, SOUR, and θ_c versus time can be plotted to evaluate treatment process control performance and its stability.

10.1.4 Summary and Status Reports

It is highly recommended that a **Summary Report** and a **Monthly Status Report** are prepared to summarize the status of IETS performance based on the descriptive statistics that have been tabulated in Table 10.1 and 10.2. Such reports can be regularly submitted to the **Environmental Performance Monitoring Committee** (EPMC) or factory management. Examples of a Summary Report and a Monthly Status Report are illustrated in the Appendices.

Table 10.1: Example of performance monitoring test results for an activated sludge system

Type of process: Conventional Activated Sludge System
Operator's name: ....
Competent person's name: ....
Shift number: ....
Date: ....Time:...................................

Sampling Location Parameter	Parameter	Units	Value/ Remarks	Recommended range
Influent or Equalization tank	Q	m^3/d		Design value [a]
	BOD	mg/L		Design value [a]
	COD	mg/L		Design value [a]
	pH	-		Actual condition [b]
	T	°C		Actual condition [b]
	TIN	mg/L		Actual condition [b]
	P	mg/L		Actual condition [b]
	BOD:TIN:P	-		100:5:1
Aeration tank	DO	mg/L		> 2 (non nitrifying system) [c]
	X	mg/L		(1500 to 3000) [d]
	X_V	mg/L		(1200 to 2400) [e]
	SV_{30}	mL/L		-
	SVI	mL/g		(50 to 100) [f]
	pH	-		6.5 to 8.5
	X_{RAS}	mg/L		Actual condition
	X_{WAS}	mg/L		Actual condition
	Q_R	m^3/d		Actual condition
	Q_R/Q	%		(50 to 150) [g]
	Q_W	m^3/d		-
	F/M ratio ***	kg/(kg.d)		0.15 to 0.5
	OUR	$mgO_2/(L.h)$		-
	SOUR	mgO_2/h per g MLVSS		(8 to 20) [h]
	Microscopic examination	-		-
Secondary clarifier*	BOD	mg/L		Standard A or B
	COD	mg/L		Standard A or B

	SS	mg/L		Standard A or B
	pH	-		Standard A or B
	TIN	mg/L		1.0
	P	mg/L		0.5 to 1.0
	Overall BOD removal	%		-
	Sludge blanket	m		-
	Weir cleaning	-		-

NOTE:

a. Considered at design stage of IETS.
b. Depends on the actual condition of the incoming effluent
c. D.O. typically 1 - 2 mg/L for CAS and 2.5 to 3.5 mg/L for EAAS with nitrification
d. Typical range for conventional activated sludge system
e. X_V is assumed to be 80% of X
f. SVI = 50-100: Good settling characteristics
g. Typical range for industrial effluents
h. Compute OUR from gradient of "DO versus Time" graph. SOUR = OUR/MLVSS

TIN = ammonia + nitrite + nitrate; P as ortho phosphate
X = mixed liquor suspended solids; X_V = mixed liquor volatile suspended solids
X_{RAS} = suspended solids of return activated sludge; X_{WAS} = suspended solids of waste activated sludge
Q_R = return flow; Q_R/Q = ratio of return flow; Q_W = waste sludge flow
OUR = oxygen uptake rate; SOUR = specific oxygen uptake rate.
Discharge standards: BOD [20, Standard A] [SS: 50,Standard A] pH [6-9, Standard A]
Temperature [<40°C]
* Secondary clarifier: DO may also be monitored

Table 10.2: Example of daily performance monitoring test results for upflow anaerobic sludge blanket (UASB)

Type of process: upflow anaerobic sludge blanket (UASB)
Operator's name: ....
Competent person's name: ....
Shift number: ....
Date: ....Time

Parameter	Unit	Value	Recommended range
Flowrate	m^3/d		Design value
BOD	mg/L		Design value
COD	mg/L		Design value
pH	mg/L		6.5-7.5
Temperature	°C		30 to 38 (mesophilic); 50 to 57 (thermophilic); Temperature change < 0.5/d
COD:N:P ratio	-		100/2 to 10/0.5 to 1
*VFA	mg/L		50 to 300
Alkalinity	mg $CaCO_3$/L		2,000 to 5,000
VFA/Alkalinity	-		0.05 to 0.25, preferably < 0.1

ORP	mV		-520 to -530 (for methanogenesis stage)
Nutrients (N)	mg/L		250 BOD: 5 N
**OLR	kg/(m^2. d)		Design value (*1.8 to 13.9)
Mixing	-		-
Biogas (pressure and analysis)	-		-

Notes:

* Volatile acids.

** OLR = organic loading rate. A source quotes a value of 1.06 kg to 3.53 kg COD/m^3 of filter (Young and McCarty, 1969)

10.2 Physical chemical treatment processes (PCPs)

10.2.1 Performance monitoring from equipment readings

In general, physical chemical treatment processes (PCPs) are monitored by observing and recording **equipment readings** directly. The data obtained from performance monitoring activities depends on the type of **unit operations** and **unit processes** of the IETS. The physical treatment processes do not usually have well defined performance monitoring parameters while the chemical treatment processes do. The performance monitoring data of PCPs include: flowrate, SS, T, pH, COD, ORP, P, metals concentration, color, chemical dosing rate, and metering pump setting. Other PM activities also include jar test experiments conducted to determine the optimum coagulant dosing and observations of floc formation in the coagulation process.

10.2.2 Comparing measured data with the recommended ranges

The performance monitoring data obtained from equipment readings are then compared directly with the **recommended ranges** or **set points**. The ranges are specified based on the treatment processes involved. Additionally, a recommended practice is to set a more conservative value for each PM parameter to serve as "**warning level**" to alert the IETS personnel to initiate response actions when the warning level is reached. The recommended ranges for most of the PM parameters have been highlighted in Chapter 7. For some parameters the recommended ranges or set points are typically **interlocked** with the values specified for chemical dosing pumps to deliver the chemical reagents for the treatment process.

10.2.3 Process control charts (PM Charts)

As discussed in section 10.1.3, a statistical package can be used to plot the **performance monitoring charts (PM Charts)** which have a central line for the average, an upper line for the **upper control limit** (UCL) and a lower line for the **lower control limit** (LCL). The control limits are treatment process-specific. Typical PM parameters for physical-chemical treatment processes (PCPs) include T, pH, P, COD, ORP, and metal concentration. The control charts can serve as a tool for monitoring the PCPs to ensure the **control parameters** are maintained within the **acceptable ranges**, hence the processes are occurring in an optimal manner.

10.2.4 Summary and status reports

It is strongly recommended that a **Summary Report** and a **Monthly Status Report** are regularly prepared and be submitted to the management or **Environmental Performance Monitoring Committee.** The reports are based on the descriptive statistics that have been tabulated in Table 10.3. Examples of a Summary Report and a Monthly Status Report are illustrated in the Appendices.

Table 10.3: Example of daily performance monitoring test results for several PCPs

Type of process: Conventional Activated Sludge System
Operator's name: ……………….………………
Competent person's name: ……………………..…………….
Shift number: ……………………
Date: ……………..Time:……………………………..

Process	Test/Check/Observation	Unit	Value	Recommended range
Equalization	Flowrate	m^3/d		Design value
	pH	-		Design value
	COD	mg/L		Design value
	Metals	mg/L		Design value
Cooling	Flowrate	m^3/d		Design value
	Temperature	°C		Design value
Dissolved Air Flotation (DAF)	Flowrate; recirculation flow	m^3/d		-
	SS	mg/L		-
	Pressure	bar		2.5 to 4.5
Oil and Grease Removal **(i) API**	Flowrate	m^3/d		Design value
	O&G	mg/L		-

	Physical inspection	-		-
(ii)Emulsion breaking - Chemical addition	pH	-		Design value
	Coagulant dose	mL/mn		Determined by testing
- Centrifugation				
	Reynolds number	-		50,000 to 100,000
- Electrocoagulation				
	Flowrate	m^3/d		Design value
	Voltage	V		Design value
	Ferrous ions	mg/L		Determined by testing
	Oil and grease	mg/L		-
Coagulation and flocculation	Flowrate	m^3/d		Design value
	pH	-		Determined by testing
	Jar test	-		-
	Inspection of chemical dosing system	-		-
Metals removal **(i) Hydroxide**				
	Flowrate	m^3/d		Design value
	pH	-		Determined by testing
	Chemical dosing system			-
	Metal concentration	mg/L		-
(ii) Sulfide	Flowrate	m^3/d		Determined by testing
	pH	-		Determined by testing
	Inspection of chemical dosing system	-		-
(iii) Ion exchange	Flowrate	m^3/d		Design value
	pH	-		-
	Inspection of regenerant dosing system			-
	Metal concentration	mg/L		Design value
	Breakthrough time	month		
Electrowining	Flowrate	m^3/d		Design value
	Current	Amp		Determined by testing
	Voltage	V		Determined by testing
	Temperature	°C		Determined by testing
	Metal concentration	mg/L		-
Redox process (i) Chromium removal	Flowrate	m^3/d		Design value
	pH	-		Determined by testing

(ii) Cyanide treatment	ORP	mV		Design value
	Chromium	mg/L		-
	Flowrate	m^3/d		Design value
	pH	-		Design value
	ORP	mV		Design value
Carbon adsorption				
(i) Carbon adsorption Column	Flowrate	m^3/d		Design value
	Pressure	bar		Design value
	COD	mg/L		Design value
	Breakthrough time	month		-
(ii) Batch operation	Flowrate	m^3/d		Design value
	Adsorptive capacity	mg/mg		Determined by testing
	Carbon dose	m^3/d		Calculated value
Oxidation				
(i) Chemical oxidation	Flowrate	m^3/d		Design value
	pH	-		Determined by testing
	ORP	mV		Determined by testing
(ii) Wet Air Oxidation (WAO)				
	Flowrate	m^3/d		Determined by testing
	Temperature	°C		Determined by testing
	Pressure	bar		Determined by testing
(iii) Advanced Oxidation Processes (AOP)	Flowrate	m^3/d		Design value
	pH	-		Determined by testing
Filtration				
(i) Membrane filtration	Flowrate	m^3/d		Design value
	pH	-		Design value
	TMP	bar		Design value
	Physical chemical cleaning	month		-
(ii) Media filtration	Flowrate	m^3/d		Design value
	Pressure drop	bar		Design value
	SS	mg/L		Design value
	Turbidity	NTU		Design value
(iii) Bag filtration	Flowrate	m^3/d		Design value
	Pressure drop	bar		Design value
Stripping				
(i) Air stripping	Flowrate (Effluent, Air)	m^3/d		Design value

	Pressure	bar		Design value
	Temperature	°C		Design value
	VOC	mg/m^3		-
(ii) Steam stripping				
	Flowrate (Effluent, Air)	m^3/d		Design value
	Pressure	bar		Design value
	Temperature	°C		Design value
	VOC	mg/m^3		-
	Flowrate (Effluent, Air)	m^3/d		Design value
iii) Ammonia stripping	Pressure	bar		Design value
	Temperature	°C		Design value
	Ammonia	mg/L		-
Struvite precipitation				
	Flowrate (Effluent)	m^3/d		Design value
	pH	-		Determined by testing
	Magnesium chloride or sulfate	mg/L		Determined by testing
Vacuum evaporation	Flowrate	m^3/d		Design value
	Distillate quality	mg/L		Design value
	Temperature	°C		Design value
	Pressure	bar		Design value

Note:
Processes listed in the Table 10.2 and parameters identified are not exhaustive. The industry personnel may monitor more parameters when necessary; 1kpa = 0.01 bar

MODULE 11: SOLIDS HANDLING AND DEWATERING OPERATIONS

A full package of an industrial effluent treatment system (IETS) will invariably include a **sludge handling and disposal system** (SHDS). In effluent treatment scenarios in Malaysia, whether an IETS(BP) or IETS(PCP) is employed, the sludge is commonly dewatered using one of the several **mechanical dewatering technologies** available in the market. These include pressure filters, belt presses, rotary presses, screw presses, centrifuges, or less commonly, sludge drying beds, or drying lagoons, or dryers. Before undergoing the mechanical dewatering process, the sludge may be **chemically conditioned** to improve its dewatering characteristics.

11.1 Polymer selection and dosage determination

Laboratory tests should be conducted to select the **right polymer** and determine its **optimum dosage**. Such tests include the capillary suction test or the Buchner funnel test. Tests performed and results obtained must be maintained.

11.2 Performance monitoring of sludge dewatering systems

Typically, sludge volume generated, operation hours of the sludge dewatering system, polymer use, feed solids, cake solids, solids capture, and sludge generation are monitored.

MODULE 12: MAINTENANCE OF IETS COMPONENTS AND PM INSTRUMENTS

To accomplish a success story in the treatment of industrial effluents, not only the IETS must be **designed** adequately, but the IETS hardware must also be **maintained** in smooth working conditions and the processes occurring in the various treatment components must be **operated** optimally. All the above factors must be given adequate attention in order to ensure quality effluent is produced on a sustained basis.

12.1 Maintenance of IETS hardware components

Whether an IETS is a small, simple system or a large, complex, state of the art system, a comprehensive **operation and maintenance (O&M) plan** must be drawn up and implemented. O&M plan must include both aspects of maintenance: **preventive maintenance** and **corrective maintenance**. The preventive maintenance in turn consists of **periodic maintenance** and **predictive maintenance** of the structural, mechanical and electrical engineering components and equipment to prevent structural, mechanical and electrical failures from occurring. **Corrective maintenance** addresses and fixes the problems after they have occurred. The O&M must cover both the IETS structural, mechanical, and electrical components and performance monitoring equipment and instrumentation system.

The IETS hardware includes a whole range of **structural** and **mechanical** components such as pumps, screens, aeration tanks, aeration system (blowers, compressors), mixers, skimmers, equalization tank, pH adjustment tank, precipitation tank, carbon adsorption column, dissolved air flotation system, piping system, valves, motors, chemical dosing systems, chemical storage tanks, clarifiers, etc. **Electrical components** may also form an essential part of the IETS. Successful achievement of the goal to treat the raw effluent and produce compliant effluent on a continuous basis depends on the **uninterrupted operation** of all the IETS components. The latter in turn depends on rigorous implementation of the O&M plan.

12.2 Maintenance of performance monitoring instruments

Another group of hardware components is the **PM equipment and instrumentation systems** installed for the purpose of monitoring the **processes** occurring in the IETS treatment components. Table 12.1 summarizes the typical PM equipment and their use in monitoring the operation of IETS.

Table 12.1: IETS performance monitoring instruments and their use

Instrument	**Used principally for monitoring PCP or BP?**
pH meter	Both BPs and PCPs
DO meter	BPs
ORP meter	Both BPs and PCPs
BOD associated equipment and on line BOD analyzers	BPs
COD reactor and spectrophotometer	Both BPs and PCPs
TOC meter and associated equipment	Both BPs and PCPs
SS meter	Both BPs and PCPs
'Sludge Judge" or automatic sludge depth meters	BPs
Graduated cylinder, settleometer, Imhoff cone	BPs
Respirometer	BPs
Spectrophotometer	Both BPs and PCPs
Thermometer	Both BPs and PCPs
Turbidity meter	Both BPs and PCPs
Ion specific electrodes	Both BPs and PCPs
Pressure gage	Both BPs and PCPs
Flow meter and totalizer	Both BPs and PCPs
Interface level analyzer	Both BPs and PCPs
Colorimeter	PCPs

12.3 Maintenance of IETS hardware and PM instruments according to manufacturers' recommendations

Proper functioning of the IETS hardware and PM instruments is a prerequisite to achieving success in the operation of the IETS. Proper functioning of the hardware and instruments depends on their **maintenance and calibration**, which needs to be performed in accordance with the procedure specified in the manuals produced by the **manufacturers**. The importance of instrument maintenance and calibration cannot be over emphasized.

12.4 Record keeping requirements

The industries must maintain records of the O&M of the IETS components and PM instruments for management purposes and the inspection by the DOE officers. A file must be kept for each piece of equipment or instrument which contains the operator's **manual**, the **preventive** and **corrective maintenance** schedule, and records of all maintenance and repairs performed, including exact nature of the problem, the date of repair, what was done, and who did it. Examples of meter calibration logs and instrument maintenance and repair records are shown in the Appendices.

CHAPTER 13-ENVIRONMENTAL MAINSTREAMING

With the lofty goal to develop an industrial society that has an intrinsic culture of **pride in environmental excellence (EE)**, the Department of Environment (DOE) has embarked on a program entitled "**Guided Self-Regulation**" **(GSR).** To assist the regulated sectors to achieve the state of self-regulation, the DOE has formulated a set of **environmental mainstreaming (EM)** tools to be implemented in the organizations and industrial premises. The **EM tools** include:

- Environmental policy (EP)
- Environmental budgeting (EB)
- Environmental monitoring committee (EMC)
- Environmental facility (EF)
- Environmental competency (EC)
- Environmental reporting and communication (ERC)
- Environmental transparency (ET)

The EM tools are briefly explained in the following sections.

13.1 Environmental policy (EP)

The environmental policy (EP) of successful organizations uses **strong and unequivocal statements** to convey their environmental commitment to their employees, clients, stakeholders and the public. The EP is disseminated to all relevant parties and translated into action in the organization's work procedures, materials purchasing policy, business decision making process and cascades down to the **supply chain**.

13.2 Environmental budgeting (EB)

Sufficient budget must be set aside solely for the purpose of taking measures to comply with the **environmental regulatory requirements** and other **environmental-related efforts**. At the design stage, budget must be available for the design and installation of the pollution control facilities, while at the operational stage, budget must be allocated for proper operation and maintenance of pollution control systems and management of waste generated by the industry. The environmental budget also includes the cost for setting up of laboratory facilities, provision of personnel, and purchase of performance monitoring equipment.

13.3 Environmental monitoring committee (EMC)

The success of an organization to comply with the environmental requirements is contingent upon the relevant personnel in different departments in the organization playing their role in an effective manner. To promote **collective responsibility** to be environmentally compliant, two monitoring committees are set up: one at the working level, the other at the policy level. At the working level, the committee known as the **environmental performance monitoring committee (EPMC)** is chaired by a senior official of the organization and it meets on a monthly basis, or at a minimum, once in a quarter. At the policy level, the committee is known as the **environmental regulatory compliance monitoring committee (ERCMC),** which meets at a minimum, once a year. The chief executive officer or chairman of the organization chairs the ERCMC.

13.4 Environmental facility (EF)

The primary components of the environmental facilities (EFs) include industrial effluent treatment system, air pollution control system and associated support facilities such as laboratory, performance monitoring equipment, on-line instrumentation system, and waste management infrastructure. The above form an integral part of the company's overall **infrastructural planning**, which cannot be compromised.

13.5 Environmental competency (EC)

The relevant personnel involved in discharging various environmental responsibilities within an organization need to possess the required competencies. The personnel include those who have been assigned the task to perform **DOE-regulated functions**: to manage waste and supervise the operation of air pollution control and effluent treatment systems. The organizations must draw up a comprehensive **training program** to produce **competent persons** and trained **support staff** to ensure full compliance with the DOE requirements in the regulated activities.

13.6 Environmental reporting and communication (ERC)

A formal **communication channel** must be established for reporting environmental concerns and system upsets which warrant prompt actions to be instituted. **Internal reporting** can be initiated to report on a regular basis the regulatory compliance status of the organization to the **chief executive officer (CEO)** and various heads of the department within the organization. Updates of new environmental requirements and their implications can be disseminated to the relevant company personnel. ERC requires **systematic analysis** of PM data, which must be summarized in appropriate format for easy understanding and communication and maintained for management review purposes.

13.7 Environmental transparency (ET)

To foster rapport with the immediate neighbors, promote green image, and improve public confidence, companies are encouraged to be more transparent in their **environmental compliance** and achievement. Compliance status can be displayed on company website or billboard located at the boundary or entrance to the company's premise. An **environmental sustainability report** can be prepared for the company to showcase its success in managing the environmental concerns of the company and minimizing the **environmental footprint** of its business. The corporate image of the organization is markedly enhanced through environmental transparency.

13.8 IETS performance monitoring from the perspective of environmental mainstreaming

IETS performance monitoring is an activity, which is connected directly or indirectly to all of the environmental mainstreaming tools discussed above, especially, the environmental facility (EF), the environmental competency (EC), and the environmental reporting and communication (ERC). IETS performance monitoring is an integral part of the operation of the IETS, which is an environmental facility installed within an industrial premise to prevent water pollution and ensure its uninterrupted manufacturing operation.

13.9 Environmental mainstreaming leads to environmental excellence

Rigorous implementation of the above EM tools by the regulated sectors, particularly the industrial sector, will result in creating organizations and businesses which are successful and at the same time take pride in their achievement of **environmental excellence (EE)**. EE is exhibited in the intrinsic values of being **environment conscious** (where environmental agenda is factored into the industry's **management and decision making process)**, achievement of sustained environmental **regulatory compliance**, high degree of **environmental transparency and accountability**, and strong commitment to **continuous environmental improvement**. Highly successful organizations are also exemplary in their environmental compliance and achievements, which go beyond regulatory requirements.

14- CONCLUSION

Performance monitoring (PM) of industrial effluent treatment systems (IETSs) is a **proactive and preventive approach** to managing the IETSs to ensure all the treatment components are **functioning** in an optimal manner. The fruit of rigorous implementation of performance monitoring is **peak performance** of the IETSs on a **continuous basis** resulting in the discharge of quality effluent, which **complies** with the **regulatory discharge standards** on a sustained basis. Performance monitoring is a **win-win strategy** for all, i.e. the regulated sectors, the Department of Environment (DOE), and the environment, which culminates in the improvement in **regulatory compliance,** enhancement of organizations' **corporate image,** and the amelioration of **water quality** of our rivers.

IMPORTANT NOTICE

The specifications in this Guidance Document represent the minimum requirements to be complied with by the industries for conducting performance monitoring of their IETSs. Nevertheless, the DOE 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 IER. Compliance with the regulatory requirements and standards is solely the responsibility of the industries.

REFERENCES

Associated Water and Air Resource Engineers, Inc. *Handbook for Industrial Wastewater Monitoring*. U.S. Environmental Protection Agency, Technology Transfer, August 1973.

American Public Health Association. *Standard Methods for the Examination of Water and Wastewater*. 22th Edn., 2012.

Benefield. L. D., Judkins, Jr. J. F., and Weand., B. L. *Process Chemistry for Water and Wastewater Treatment*. Prentice-Hall, Inc. Englewoods Cliffs, New Jersey. 1982.

Black, H. H. *Procedure for Sampling and Measuring Industrial Waters*. Industrial Wastes, 24:45, January, 1992.

Drobny, N. L. *Monitoring for Effective Environmental Management*. Proc. ASCE National Water Resources Engineering Meeting. Atlanta, Georgia, January 24-28, 1972.

Eckenfelder, Jr. W. W. *Industrial Water Pollution Control*. 2nd Edn. McGraw-Hill, Inc. New York. 1989.

EPA. *Industrial Waste Treatment*. 2nd. Edn. vol. 1 and 2. Sacramento, CA. 1999.

EPA. *Treatment of Metal Wastestreams*. 2nd. Edn. Sacramento, CA. 1995.

Gunnerson, C. G. *Optimizing Sampling Intervals*. Proc. IBM Scientific Computing Symposium, Water and Air Resources Management. White Plains New York, 1968.

Harris D. J. and W. J. Keefer. *Wastewater Sampling Methodologies and Flow Measurement Techniques*. EPA 907/9-74-005, U.S. environmental Protection Agency, Region VII, 1974. 117 pp.

Henderson, F. M. *Open Channel Flow*. MacMillan Co., New York. 1966.

Jenkins, D., Richard, M. G. and Daigger, G. *Causes and Control of Activated Sludge Bulking and Foaming*, 2nd Edn. Lewis Publishers. Boca Raton, FL. 1993.

Metcalf and Eddy, Inc. *Wastewater Engineering: Treatment and Resource Recovery*. 5th Edn. vol 1 and 2. McGraw-Hill International Edition. 2014.

Montgomery, H. A. C. and I. C. Hart. *The Design of Sampling Programs for rivers and Effluents*. Water pollution Control (London, England), 73: 77-98, 1974.

Pakistan Environmental Protection Agency. *Sampling Procedure for Municipal and Industrial Effluent* No. EPA/Clean/SP1001/Rev 0/98 Central Laboratory for Environmental Analysis.

Rabosky, J. G. and D.T. Koraido. *Gaging and Sampling of Industrial Wastewaters*. Chemical Engineering, 80p. 111-120, January 8, 1973.

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

Shelley, P. E. and G. A. Kirkpatrick. *An assessment of Automatic Sewer Flow Sample*. Prepared for the Office of Research and Monitoring, U.S. Environmental Protection Agency, Washington, D.C. 20460, EPA R2-76-261 June 1973.

Spellman, F. R. *Handbook of Water and Wastewater Treatment Plant Operations*. 3rd. Edn. CRC Press. Boca Raton. Fl. 2014.

Tarazi, D.S. *Comparison of Wastewater Sampling Techniques*. J.W.P.C.F.. 42 pp. 708-732. May, 1970.

URS Research Co. *Procedure for Evaluating Performance of Wastewater Treatment Plants*. PB 228 849/6, National Technical Information Services Springfield, Virginia.

Von Sperling, M. *Activated Sludge and Aerobic Biofilm Reactors*. Vol. 5. IWA Publishing. London. 2007

Water Monitoring Task Force. R.L. Crim, (ed.), *Model State Water Monitoring Program*. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Washington, D.C. EPA-440/9-74-00.

Young, J. C. and P. L. McCarty. *The Anaerobic Filter for Waste Treatment*. Water Pollut Control Fed. May, 1969

Appendix A

Record of Performance Monitoring of Equalization Tank (influent/raw effluent) (Biological process)
Date:…………; Month:………………..…

Time/Date*	Flow rate, m^3/h	Total flow, m^3/d	BOD_5, mg/L	COD, mg/L	pH	Nutrients, mg/L	Remarks	Signature	
								**	***

Notes:
For frequency of sampling and analysis, refer to Table 6.9.
* Choose which ever is applicable
Nutrients: N, P
** *** One of the signatures must be by a competent person

Appendix B

Record of Performance Monitoring of Aeration Tank (Biological process)
Date:………..; Month:……………..…

Time/ Date*	DO, mg/L	MLSS, mg/L	MLVSS, mg/L	SVI, mL/mg	pH	X_{RAS}, m^3/d	X_{WAS}, m^3/d	Q_{RAS}, m^3/d	Q_{WAS}, m^3/d	θ, d	F/M, kg/kg	SOUR, mg/(g.h)	TIN**, mg/L	Signature	
														***	****

Notes:
For frequency of sampling and analysis, refer to Table 6.9
* Choose which ever is applicable
** Sampled at tank outlet
*** **** One of the signatures must be by a competent person

Appendix C

Record of Performance Monitoring Activity: Oxygen Uptake Rate (OUR) Test Results (Biological process)
Test performed by……………………..*Signature…………………….. Date……..………….. Reviewed by……………………..**Signature……………………..
Date……………..….

Time	DO, mg/L

(Example)

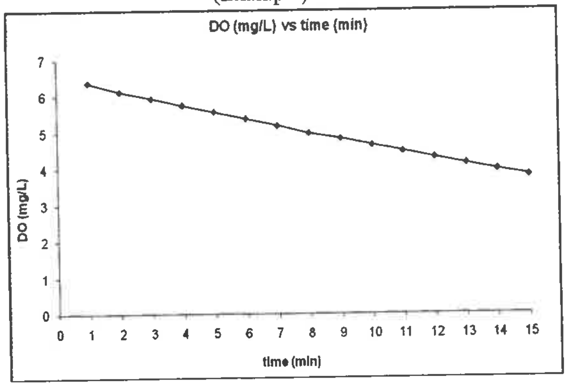


Fig 1: DO versus Time

OUR = Gradient of graph as shown in Fig 1. Units of OUR: $mgO_2/(L/h)$

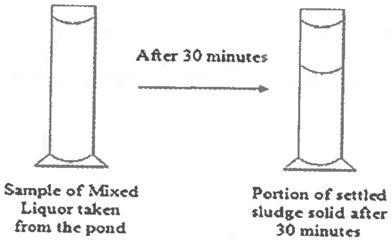
SOUR = OUR/MLVSS………… Units of SOUR: mgO_2 per h/(g MLVSS)

Notes:
* ** one of the signatures must be by a competent person
Frequency of performing OUR Test: Ranges from once a day to once a week depending on variability of influent characteristics and other factors

Appendix D

Record of Performance Monitoring Activity: Sludge Volume Index (SVI) Test Results (Biological process)
Test performed by……………………..*Signature…………………….. Date……..………….. Reviewed by……………………..**Signature……………………..
Date…………………..…

Results:



Settled sludge volume (SV_{30})……… mL/L

MLSS =…………..mg/L

$$\text{SVI, mL/g} = \frac{SV_{30}\text{, mL/L} \times 1000\text{ mg/g}}{\text{MLSS, mg/L}}$$

Notes:
* ** one of the signatures must be by a competent person
Frequency of performing SVI Test: Ranges from once a day to once a week

Appendix E

Record of Performance Monitoring of Membrane Filtration Unit in Membrane Bioreactor (MBR) System (Biological process)
(Note: See Appendix B for Record of Performance Monitoring of Aeration Tank)

Date:……….; Month:…………….…

Time/ Date*	TMP, bar	System vacuum pressure, bar	Membrane scour air flowrate, m^3/min	Membrane cleaning	Membrane backflushing	Remarks	Signature	
							**	***

Notes:
TMP = transmembrane pressure
For frequency of sampling and analysis, refer to Table 6.10
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix F

Record of Performance Monitoring of Trickling Filter (Biological process)
Date:………..; Month:………………..…

Time/ Date*	Influent			Recirculated flow			Effluent					Remarks	Signature	
	DO	pH	T	DO	pH	T	DO	pH	SS,	Settleable solids	BOD		**	***

Notes:
All units in mg/L except pH in pH value and T in °C
For frequency of sampling and analysis, refer to Table 6.11
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix G

Record of Performance Monitoring of Rotating Biological Contactor (Biological process)
Date:……….; Month:………………..…

Time/ Date*	Influent						Drum	Effluent					Remarks	Signature	
	DO	pH	T	SS	Settleable solids	BOD	Rotation speed	DO	pH	SS	Settleable solids	BOD		**	***

Notes:
All units in mg/L except pH in pH value, T in °C and drum rotation speed in mm/s
For frequency of sampling and analysis, refer to Table 6.12
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix H

Record of Performance Monitoring of Upflow anaerobic Sludge Blanket (Biological process)
Date:..........; Month:..................

Time/ Date*	Q, m^3/d	BOD, mg/L	COD, mg/L	OLR, kg/m^3	pH	T, °C	VFA, mg/L	VFA Alkalinity	ORP, mV	Nutrients	Biogas Pressure, mbar	**Biogas analysis	Signature	
													***	****

Notes:
For frequency of sampling and analysis, refer to Table 6.13
* Choose which ever is applicable
** Typically, O_2, CO_2, CH_4, and H_2S are monitored
*** **** One of the signatures must be made by a competent person

Appendix I

Record of Performance Monitoring of Ponding System (Biological process)
Date:……….; Month:………………..

Time/ Date*	DO**			pH			Nutrients	BOD		COD		Q		VFA**	Alk**	Signature	
	Inlet	Middle	Outlet	Inlet	Middle	Outlet	Inlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Middle	Middle	***	****

Notes:
All units in mg/L except pH in pH value
For frequency of sampling and analysis, refer to Table 6.14
* Choose which ever is applicable
** Not applicable to anaerobic ponds
Alk= Alkalinity
*** **** One of the signatures must be by a competent person
Additional requirement: Sludge depth measurement

Appendix J

Record of Performance Monitoring Data of Activated Sludge System (Biological Process)
Microscopic Examination

Date:………….; Time:……………….Performed by (Name and signature)*:………………Checked by (Name and signature)**…………

* **Note: One of the signatures must be by a competent person

Microorganism group	Slide 1	Slide 2	Slide 3	Slide 4	Total
Ameoboids					
Flagellates					
Free swimming ciiliates					
Rotifers					
Worms					

Relative importance
1……………..

2……………..

3……………..

Appendix K

Record of Performance Monitoring Data of Aeration Tank of Activated Sludge System (Biological Process)

Nutrient Addition

Notes: Nutrient Ratio Guide -100BOD:5N:1P

General formula: Commercial chemical required, kg/d = $\frac{\text{Nutrient addition required, kg/d}}{\text{Decimal \%Nutrient x Decimal \% pure commercial chemical}}$

Example calculation for N requirement

E.g. Commercial chemical used: 80% anhydrous ammonia (NH_3)
Decimal %N in NH_3 = 14/17 = 0.82
Decimal % pure commercial chemical = 80% = 0.8
Nutrient addition required, kg/d = (Influent flowrate, m^3/d x Ammonia shortfall, mg/L)/1000
Ammonia shortfall = Ammonia required calculated from the nutrient ratio guide - Total ammonia present in raw effluent

Nutrients Addition

Date*	Flow rate, m^3/d	Raw effluent total ammonia, mg/L	Calculated ammonia required, mg/L	Chemical (N) addition required, kg/d	Raw effluent total orthophosphate, mg/L	Calculated orthophosphate required, mg/L	Chemical (P) addition required, kg/d	Signature **	Signature ***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix L

Record of Performance Monitoring Data of Secondary Clarifier (for Biological Process)
Date:……….; Month:………………

Time/Date*	Flow rate, m^3/h	TSS_5, mg/L	pH-value	Sludge level, m	RAS flow % influent	Weir cleaning	Preventive & corrective maintenance	Remarks	Signature	
									**	***

Notes:
Sampling frequency is determined on a case to case basis.
* Choose which ever is applicable
Additional parameter, DO is measured for nitrifying system
** *** One of the signatures must be by a competent person

Appendix M

Record of Performance Monitoring of Equalization Tank (influent/raw effluent) (Physical process)
Date:………..; Month:…………….....

Time/Date*	Flow rate, m^3/h	Total flow, m^3/d	SS, mg/L	COD, mg/L	pH-value	**Metal, mg/L	Remarks	Signature	
								***	****

Notes:
Sampling frequency is determined on a case to case basis.
* Choose which ever is applicable
** If relevant
*** **** One of the signatures must be by a competent person

Appendix N

Record of Performance Monitoring of Cooling Tower or Cooling Pond (Physical process)
Date:………..; Month:……………..…

Time/Date*	Flow rate, m^3/h	T, °C	Remarks	Signature	
				**	***

Notes:
Sampling frequency is determined on a case to case basis.
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix O

Record of Performance Monitoring of Dissolved Air Flotation (Physical process)
Date:……….; Month:…………….…

Time/ Date*	Q, m^3/d	Q_R, m^3/d	TSS, or O&G, mg/L	Pressurizing pump pressure, bar or kPa	Skimmer speed, cm/s (or visual observation)	A/S ratio, kg/kg or mL/mg	**Coagulant dose, mg/L	Remarks	Signature	
									***	****

Notes:
Sampling frequency is determined on a case to case basis.
Based on monitored parameters, SOR and SLR can be calculated and compared with design values.
* Choose which ever is applicable
** If coagulant addition is practiced
*** **** One of the signatures must be by a competent person

Appendix P

Record of Performance Monitoring of Oil Water Separator (Physical process)
Date:………..; Month:……………..…

Time/ Date*	Q, m^3/d	O&G, mg/L	Physical inspection (cleaning and maintenance)	Remarks	Signature	
					**	***

Notes:
Sampling frequency is determined on a case to case basis.
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix Q

Record of Performance Monitoring of Oil Deemulsification Process (Physical process)
Date:………..; Month:……………..…

Time/ Date*	**Acidification		**Electro coagulation		**Centrifugation		Remarks	Signature	
	Q, m^3/h	pH	Q, m^3/h	Current, Amp	Q, m^3/h	Re #		***	****

Notes:
Sampling frequency is determined on a case to case basis.
* Choose which ever is applicable
** Choose the deemulsification process or technique used. Identify other technique used other than those identified in the Table
*** **** One of the signatures must be by a competent person

Appendix R

Record of Performance Monitoring Activity: Jar Test Results (Physical process)
Test performed by……………………..*Signature…………………….. Date………………… Reviewed by……………………..**Signature……………………..
Date………………….
Coagulant type……………………………
Coagulant dose…………….mg/L

pH	SS, mg/L or Turbidity, NTU

(Example)

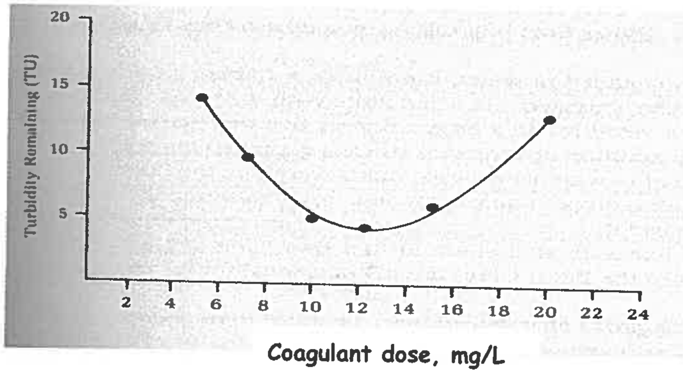


Fig 2: Graph of suspended solids or turbidity versus coagulant dose

pH……………

Coagulant dose, mg/L	SS, mg/L or Turbidity, NTU

Notes:
* ** one of the signatures must be by a competent person
Frequency of performing Jar Test: depends on variability of effluent characteristics

Appendix S

Record of Performance Monitoring Activities of Coagulation and Flocculation Process (Physical Process)
Month…………

Date/ Time*	Q, m^3/h	pH-value	Coagulant dose, mg/L	Coagulant pump setting, mL/s	Floc observation	Checking of chemical delivery system	Chemical feeder pump servicing	Checking of chemical levels in storage tanks	Remarks	Signature	
										**	***

Notes:
** *** One of the signatures must be by a competent person

Appendix T

Record of Performance Monitoring Activities of Metals Hydroxide Precipitation Process (Chemical Process)
Date:………..; Month:……………..…

Date/Time*	Q, m^3/h	pH-value	**Metal , mg/L		Checking of dosage system and general	Checking of chemical levels in storage tanks	Remarks	Signature	
			In	Out				***	****

Notes:
* Choose which ever is applicable
** Identify the metal (s) involved
*** **** One of the signatures must be by a competent person

Appendix U

Record of Performance Monitoring Activities of Metals Sulfide Precipitation Process (Chemical Process)
Date:………..; Month:…………….….

Date/Time*	Q, m^3/h	pH-value	**Metal , mg/L		Checking of chemical dosage system	Checking of chemical levels in storage tanks	Remarks	Signature	
			In	Out				***	****

Notes:
* Choose which ever is applicable
** Identify the metal (s) involved
*** **** One of the signatures must be by a competent person

Appendix V

Record of Performance Monitoring Activities of Ion Exchange Process (Chemical Process)
Date:……….; Month:………………..…

Date/Time*	Q, m^3/h	pH-value	Flow throughput, m^3	Metals,** mg/L		***Conductivity, Siemens	Remarks	Signature	
				In	Out			****	*****

Notes:
* Choose which ever is applicable
** Identify the metal (s) involved
*** If measured
**** ***** One of the signatures must be by a competent person

Appendix W

Record of Regeneration Activities of Ion exchange column (for Off Site Regeneration by Vendors)

Date	Name and address company performing regeneration	Contact # of the company	Signature	
			*	**

Notes:
* ** One of the signatures must be by a competent person

Appendix X

Record of Performance Monitoring Activities of Electrowining Process (Chemical Process)
Month:……………….…

Date/Time*	Q, m^3/h	pH-value	Current, Amp	Voltage, Volts	Temperature, °C	* Metal, mg/L	Remarks	Signature	
								***	****

Notes:
* Choose which ever is applicable
** Identify the metal (s) involved
*** **** One of the signatures must be by a competent person

Appendix Y

Record of Performance Monitoring Activities of Chromium Treatment (via Two Stage: Redox Reaction and Hydroxide Precipitation) (Chemical Process)
Date:……….; Month:………………..…

Date/Time*	First tank		Second tank	**Chromium, mg/L		Checking of chemical dosing system	Checking of chemical levels in storage tanks	Remarks	Signatures	
	pH value	ORP, mV	pH- value	In	Out				***	****

Notes:
* Choose which ever is applicable
** Frequency of analysis is determined on a case to case basis. More frequent at the outlet as breakthrough is approaching
*** **** One of the signatures must be by a competent person

Appendix Z

Record of Performance Monitoring Activities of Cyanide Treatment (via Two Stage Alkaline Chlorination) (Chemical Process)
Date:………..; Month:………………..…

Date/Time*	First tank		Second Tank		Cyanide**, mg/L		Checking of chemical dosing system	Checking of chemical levels in storage tanks	Remarks	Signature	
	pH-value	ORP, mV	pH-value	ORP, mV	In	Out				***	****

Notes:
* Choose which ever is applicable
** Frequency of analysis is determined on a case to case basis
*** **** One of the signatures must be by a competent person

Appendix AA

Record of Performance Monitoring Activities of Carbon Adsorption Column (Physical Process)
Date:………..; Month:………………..…

Date/Time*	Q, m^3/h	Flow throughput, m^3	COD, mg/L		Backwashing**	General remarks	Signature	
			In	Out			***	****

Notes:
* Choose which ever is applicable
** Pressure difference may be monitored
*** **** One of the signatures must be by a competent person

Appendix AB

Record of Performance Monitoring Activities of Carbon Adsorption in Batch Operation (Physical Process)
Date:……….; Month:………………..…

Date/Time*	**V, m^3	***COD, mg/L		General remarks	Signature	
		In	Out		****	*****

Notes:
* Choose which ever is applicable
** V is volume of effluent treated
*** If there is residual effluent generated after the adsorption process and COD is monitored
**** ***** One of the signatures must be by a competent person

Appendix AC

Record of Performance Monitoring Activity: Adsorption Isotherm Study Results (Physical process)
Test performed by……………………..*Signature…………………….. Date……..………….. Reviewed by……………………..**Signature……………………..
Date………………..…
Activated carbon type:……………………..……….
Carbon density:………………..kg/m^3
Effluent volume used:…………..mL

Carbon dose, mg	Residual COD, mg/L

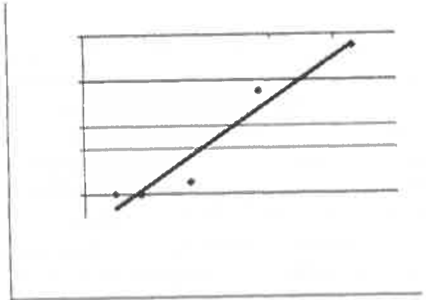


Fig 3: Plot of (X/M) versus residual COD

The study results are plotted out as shown in Fig. 1.3.

From the graph:

Read off the value of adsorptive capacity (Y axis) at the residual COD (X axis) required

Adsorptive capacity:……….. mg COD/mg carbon

Note: Frequency of conducting Adsorption Isotherm Study: depends on variability of influent characteristics

Appendix AD

Record of Performance Monitoring Activities of Chemical Oxidation (Chemical Process)
Date:………..; Month:……………..…

Date/Time*	Q, m^3/h	pH-value	ORP, mV	COD, mg/L	General remarks	Signature	
						**	***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix AE

Record of Performance Monitoring Activities of Electrocoagulation (Chemical Process)
Date:………..; Month:……………..…

Date/Time*	Q, m^3/h	Voltage, Volts	COD, mg/L	General remarks	Signature	
					**	***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix AF

Record of Performance Monitoring Activities of Wet Air Oxidation (Chemical Process)
Date:………..; Month:……………..….

Date/Time*	Q, m^3/h	Temperature, °C	Pressure, kPa	COD, mg/L	General remarks	Signature	
						**	***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix AG

Record of Performance Monitoring Activities of Fenton's Process (Chemical Process)
Date:……….; Month:………………..…

Date/Time*	Q, m^3/h	pH-value	COD, mg/L	Checking of chemical dosing system	Checking of chemical levels in storage tanks	General remarks	Signature	
							**	***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix AJ

Record of Performance Monitoring Activities of Bag Filtration System (Physical Process)
Date:……….; Month:………………..…

Date/Time*	Q, m^3/h	ΔP, bar	**SS, mg/L		Backwash	General remarks	Signature	
			In	Out			***	****

Notes:
* Choose which ever is applicable
** If monitored
*** **** One of the signatures must be by a competent person

Appendix AK

Record of Performance Monitoring Activities of Air Stripping System (Physical Process)
Date:.........; Month:..................

Date/Time*	Q_g, m^3/h	Q_L, m^3/h	G/L	Temperature, °C	P, bar	VOC, mg/m^3		Remarks	Signature	
						In	Out		**	***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix AN

Record of Performance Monitoring Activities of Chemical Solids Clarifier (Physical Process)
Date:……….; Month:………………..…

*Date/Time	Q, m^3/h	**SS, mg/L	Notes		Remarks	Signature	
			Observation of effluent clarity	Observation of solids carryover		***	****

Notes:
* Choose which ever is applicable
** SS or turbidity (NTU) may be monitored
*** **** One of the signatures must be by a competent person

Appendix AO

Record of Upset Conditions and Corrective Actions Taken to Address Them
Date:………..; Month:………………..…

*Date/Time Upset Condition Occurred	Nature of upset condition	Diagnosis of cause of upset condition	Any non compliance of discharge standard occurred? – Give explanation	Corrective action taken	When conditions returned to Normalcy	Remarks	Signature	
							**	***

Notes:
* Choose which ever is applicable
** *** One of the signatures must be by a competent person

Appendix AR

Record of Maintenance Activities of IETS Hardware Components
Month…………….

Date	Time: from…… to……….	Name of IETS component or equipment	Nature of maintenance work	Was the discharge stopped totally during the maintenance period? YES or NO	If effluent discharge was stopped, describe how effluent generated was managed	Remarks	Signature	
							**	***

Note:
* ** One of the signatures must be by a competent person

Appendix AS

Record of Calibration Activities of IETS Performance Monitoring Instruments
Month...............

Date	Name of PM instrument, make and model number	Nature of personnel who performed the calibration	Was the calibration performed according to the manufacturer's recommendation? YES or NO	Date of next calibration scheduled	Remarks	Signature	
						*	**

Note:
* ** One of the signatures must be by a competent person
Calibration records for all instruments must be maintained for inspectional purposes

Appendix AU

Example of Summary Report for Biological Process

Daily or Shift Summary Report:

Findings

Based on the performance monitoring conducted from 8 a.m. to 5 p.m. on Dec 3, 2016 and the data collected which were plotted as control charts (X-Y graph), the following conclusions can be made about the operation of the activated sludge system:

(a) The AS system was functioning in good operating condition with an overall BOD_5 removal efficiency of ....

(b)The operational parameters of SVI, OUR, SOUR, ... were all within the recommended ranges

(c) The mean DO level of......mg/L in the aeration tank was slightly on the low side

(d) The N:P ratio of ....was a little out of range on the low side

(e) The final effluent BOD_5 complied with the stipulated Standard A.

Recommendations

(a) The cause for the low DO in the aeration tank needs to be investigated and corrected promptly

(b) The N:P ratio which was out of range needs to be further investigated. Measurements may be repeated immediately to ascertain this finding.

Name of IETS operator:...........................Signature:........................

Date & Time:..........................

Appendix AV

Example of Summary Report for Physical Chemical Process

Example of Daily/Shift Summary Report:

Findings

Based on the performance monitoring conducted today (August 29, 2016) from 8 a.m. to 4 p.m and the data collected, the following conclusions can be made about the IETS-PCP operation:

(a) The IETS was functioning in good operating condition with the discharge of effluent complying with all the parameters stipulated in Standard B, IER.

(b) For chromium removal:

- pH values in the first tank and the second tank were maintained according to the set points all the time
- ORP values in the first tank were maintained at the set point all the time

(c) The following metals: Cr (6+) and Cr (3+) concentrations were well below the discharge standards

Recommendations

(a) The setting on the chemical dosing pump needs to be checked to ensure it is delivering the correct dosing rate

Name of IETS operator:...........................Signature:........................

Date & Time:..........................

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