SEQUENCING BATCH REACTOR FOR THE REMOVAL OF NICKEL FROM REFINERY WASTEWATER

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JUNE 2010

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by

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Dissertation submitted in partial fulfillment of

The requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

JUNE 2010

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Civil Engineering Programme

Universiti Teknologi PETRONAS

In Partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(CIVIL ENGINEERING)

Approved by,

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June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

UMI NAJUA BINTI MOHD NASOHAH

ABSTRACT

A petroleum refinery is a complex combination of interdependent industrial processes that generate wastewater effluent containing oil, ammonia, sulfides, chlorides, mercaptans, phenols and other hydrocarbons. The most important pollutants are organics, oils, suspended solids and other toxic materials referred to as priority pollutants. 80% of which may be considered hazardous because of the presence of toxic organics and heavy metals. Accidental discharges of large quantities of pollutants can occur as a result of abnormal operation in a refinery and potentially pose a major local environmental hazard. Previous studies have shown the reasonable performance of biological systems in refinery wastewater treatment. Therefore, in this study a Sequencing Batch Reactor (SBR) was studied for treatment of wastewater from equalization tank of PETRONAS Refinery Plant (PPMSB) at Melaka. A 4-litres SBR was fed with real wastewater and seeded with the sludge from same plant. A 12-hour cycle (15, 585, 60, 15 and 45 minute for fill, reaction, settle, draw and idle phases, respectively) was conducted in the SBR for treating 4 litres of wastewater per cycle. Initially the wastewater was characterized and then the influent, effluent and sludge samples were analysed for COD, MLSS, MLVSS and SVI. Next and after acclimatization period, nickel was added to the system in concentrations of 0.1 and 0.2 mg/l to study the efficiency of SBR in treating wastewater contains nickel. Results show the wastewater characteristics of refinery wastewater according to measured parameters which are COD, Nickel, Phosphorus, Nitrate, Turbidity and pH which contains of 322 mg/l, , 2.3 mg/l, 1.80 mg/l, 1.0 mg/l, 79.9 NTU and 6.72 respectively. After going SBR treatment, the result of measured parameters of COD, Nickel, Phosphorus, Nitrate, Turbidity and pH are 29.70 mg/l, 0.017 mg/l, 3.10 mg/l, 15.70 mg/l, 16.80 NTU and 6.95 respectively. The COD and Nickel removal efficiency were achieved approximately 70-90% and 78-80% correspondingly.

ACKNOWLEDGEMENT

With great honour, I would like to express my highly gratitude to Allah, The Almighty, for giving us the ability to complete this project, without counting the tough and challenging experienced during this project being carried out. Special thanks to the supervisor, Dr. Amirhossein Malakahmad for his patient guidance, infinite suggestions and support throughout this project.

I would like to wish thanks to the security staff and technicians for their valuable help throughout this projects days and nights. Sincere thanks are also extended to all the lab assistants especially to Mr. Zaaba, Mr. Khairul Anuar and Ms Yusyawati for their kind assistance in helping me about laboratory matters. Special mention is due to Petronas Penapisan Melaka Sdn. Bhd. for allowing me to collect sampling of refinery wastewater and sludges.

I would also like to record my gratitude to Ms Izzah, Ms Ammira, Ms Farashida, Ms Dhamina and others for their support and encouragement. Last but not least, my deepest gratitude goes to my parents, Mohd Nasohah Bin Haji Ilias and Siti Rasmi Binti Ahmad for their unconditional love, patience, understanding and support through the study.

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ABBREVIATIONS AND NOMENCLATURES

COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
TSS	Total Suspended Solid
AAS	Atomic Adsorption Spectrometry
MLVSS	Mixed Liquor Volatile Suspended Solid
MLSS	Mixed Liquor Suspended Solid
SVI	Sludge Volume Index

CHAPTER 1

INTRODUCTION

1.1. Background

Every community produces both liquid and solid wastes. The liquid portion-wastewater is essentially the water supply of the community after it has been fouled by a variety uses. From the standpoint of sources of generation, wastewater may be defined as a combination of the liquid or water carried wastes removed from the residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water, and stormwater as may be present [1].

Large amounts of water are used in the petroleum refinery activity and consequently, significant volumes of wastewater are generated (0.4–1.6 times the volume of processed oil) [2].

In Malaysia, there are standards established to control the quality of the effluent discharged into the streams. There are two types of standards set by Environmental Quality Act 1974; Standard A and Standard B (Table 1.1) [3]. Standard A is for effluent discharged upstream of a water supply intake while Standard B is for effluent discharged downstream of a water supply intake. To ensure that effluent discharge meet the standards set, the effluent is sampled and tested at regular intervals in laboratories.

Table 1.1: Parameter Limits of Effluent of Standard A and B
(Source: Environmental Quality (Sewage and Industrial Effluent) Regulation, 2009)

Parameter	Unit	Standards	
		A	B
Temperature	C	40	40
pH Value	-	6.0-9.0	5.5-9.0
BOD_5 at 20°c	mg/l	20	50
COD	mg/l	50	100
Suspended Solids	mg/l	50	100
Mercury	mg/l	0.005	0.05
Cadmium	mg/l	0.01	0.02
Chromium, Hexavalent	mg/l	0.05	0.05
Arsenic	mg/l	0.05	0.10
Cyanide	**mg/l**	**0.05**	**0.10**
Lead	mg/l	0.10	0.5
Chromium, Trivalent	mg/l	0.20	1.0
Copper	mg/l	0.20	1.0
Manganese	mg/l	0.20	1.0
Nickel	mg/l	0.20	1.0
Tin	mg/l	0.20	1.0
Zinc	mg/l	2.0	2.0
Boron	mg/l	1.0	4.0
Iron (Fe)	mg/l	1.0	5.0
Silver	mg/l	0.1	1.0
Aluminium	mg/l	10.0	15.0
Selenium	mg/l	0.02	0.50
Barium	mg/l	1.0	2.0
Fluoride	mg/l	2.0	5.0
Formaldehyde	mg/l	1.0	2.0
Phenol	mg/l	0.001	1.0
Free Chlorine	**mg/l**	**1.0**	**2.0**
Sulphide	mg/l	0.50	0.5
Oil and Grease	mg/l	1.0	10.0
Ammoniacal Nitrogen	mg/l	10	20
Colour	*ADMI	100	200

*ADMI- American Dye Manufacturer Institute

1.2. Problem Statement

A petroleum refinery is a complex combination of interdependent industrial processes that generate wastewater effluent containing oil, ammonia, sulfides, chlorides, mercaptans, phenols and other hydrocarbons. The most important pollutants are organics, oils, suspended solids and other toxic materials referred to as priority pollutants [4]. 80% of which may be considered hazardous because of the presence of toxic organics and heavy metals. Accidental discharges of large quantities of pollutants can occur as a result of abnormal operation in a refinery and potentially pose a major local environmental hazard [5]. Some of the treatment options for the removal of heavy metals from metal refineries wastewater that have been researched include chemical precipitation, coagulation–flocculation, flotation, membrane filtration and ion exchange [6]. The complete range of available treatment technologies has been applied in this field, very often with disregard to high treatment costs [4].

1.3. Objectives

i) To develop a low cost biological process, Sequencing Batch Reactor as an alternative for refinery wastewater treatment.
ii) To evaluate the performance of Sequencing Batch Reactor for Nickel removal from refinery wastewater.

1.4. Scope of Study

The study focuses on the use of Sequencing Batch Reactor (SBR) in treating Nickel in the refinery wastewater. The wastewater sample and sludge were taken from PETRONAS Penapisan Melaka Sdn. Bhd. (MG/LSB) and a set of test and experiment were conducted according to some parameters which are Mixed Liquor Volatile Suspended Solids (MLVSS), Mixed Liquor Suspended Solid

(MLSS), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), Nitrate, Phosphate, Nickel, Turbidity and pH. A reactor of 4L working volume is used for Sequencing Batch Reactor system and is set up based on two cycles per day which takes 12 hours per cycle. The performance of the SBR is measured by conducting experiments based on the measured parameters which are COD, MLVSS, MLSS, TSS and SVI. Next, various amount of nickel of 0.1 and 0.2 mg/l were gradually added to the system to study the efficiency of Nickel removal.

CHAPTER 2
LITERATURE REVIEW

2.1. Heavy Metals

Heavy metals are perhaps the most common of all metabolic poisons. The mechanism of metal toxicity is different from other metabolic poisons. Metal toxicity can affect enzymes, the cellular proteins that regulate many important chemical reactions [7]. The presence of heavy metals in wastewater and surface water is becoming a severe environmental and public health problem [8].

Increased use of metals and chemicals in process industries has resulted in generation of large quantities of effluent that contain high level of toxic heavy metals and their presence poses environmental–disposal problems due to their non-degradable and persistence nature. These toxic metals ions are not only potential human health hazards but also to other life forms. Toxic metal ions cause physical discomfort and sometimes life-threatening illness including irreversible damage to vital body system [9].

2.2. Nickel

Nickel, discovered and named by Cronstedt in 1751, is the 24^{th} element in order of natural abundance in the earth's crust. It is widely distributed in the environment. Natural sources of atmospheric nickel include dusts from volcanic emissions and the weathering of rocks and soils. Natural sources of aqueous

nickel derive from biological cycles and solubilisation of nickel compounds from soils. Global input of nickel into the human environment is approximately 150,000 metric tonnes per year from natural sources and 180,000 metric tonnes per year from anthropogenic sources, including emissions from fossil fuel consumption, and the industrial production, use, and disposal of nickel compounds and alloys [10].

Nickel is one of the toxic heavy metals present in raw wastewater due to industries [11]. Exposure to nickel compounds can produce a variety of adverse effects on human health. Nickel allergy in the form of contact dermatitis is the most common reaction. Although the accumulation of nickel in the body through chronic exposure can lead to lung fibrosis, cardiovascular and kidney diseases, the most serious concerns relate to nickel's carcinogenic activity [10].

For humans, nickel can cause serious health problems such as allergic sensitization, dermatitis and lung and nervous system damage. The Ni concentration in surface water was approximately 0.01– 0.002 mg/l. Although nickel is known to be essential for plants at low concentrations, it is phytotoxic at high concentrations [11]. Nickel has also carcinogenic effects on animals, and it is necessary to consider the potential accumulation of nickel in food items through aquatic food chains [12].

2.3. Biological Treatment

For industrial wastewater, the objective of the biological treatment is to remove or reduce the concentration of organic and inorganic compounds. It is used a variety of microorganism, principally bacteria in biological treatment by the removal of dissolved and particulate carbonaceous biologically oxygen demand and the stabilization of organic matter found in the wastewater is accomplished

biologically [13]. The biological wastewater treatment options are rapidly gaining support as the option is being shown to be technologically and economically feasible [6].

The major biological processes used for wastewater treatment are identified as five major groups; aerobic processes, anoxic processes, anaerobic processes, combined aerobic, anoxic and anaerobic processes and pond processes. The individual processes are further subdivided, depending on whether treatment is accomplished suspended growth systems, attached growth systems, or combination thereof [1].

Both processes of suspended growth system and attached growth system are described in Table 2.1. The successful design and operation of the processes require an understanding of the types of microorganism involved the specific reactions that they perform, the environmental factors that affect their performance, their nutritional needs, and their reaction kinetics [13].

Table 2.1: Treatment Processes and the Definitions (Source: McGraw-Hill Inc.)

Treatment process	**Definition**
Suspended-growth	Biological treatment process in which the microorganisms responsible for the conversion of the organic matter or other constituents in the wastewater to gases and cell tissues are maintained in suspension within the liquid.
Attached-growth	Biological treatment process in which the microorganisms responsible for the conversion of the organic matter or other constituents in the wastewater to gases and cell tissues are attached to some inert medium, such as rocks, slag, specially designed ceramic or plastic material. Attached growth treatment process is also known as fixed-film process.

Aerobic degradation in the presence of oxygen is considered to be a relatively simple, inexpensive and environmentally sound way to degrade wastes. It has been shown to be successful in many processes and in the treatment of a variety of wastes. Activated sludge systems are very useful in the treatment of metal refinery wastewaters, demonstrating their potential. Factors that are critical in the optimal degradation of the selected substrate include the temperature, moisture, pH, nutrients and aeration rate that the bacterial culture is exposed to, with temperature and aeration being two of the most critical parameters that determine the degradation rates by the microorganisms. During this process organic materials are converted into carbon dioxide, water and mineral organic matter. There are many mechanisms that are utilised by the microorganisms during the aerobic degradation process. Some of these include the attack on the xenobiotics by organic acids produced by the microorganisms, the production of noxious compounds like hydrogen sulphide and the production of chelating agents which are able to increase the solubility of any insoluble xenobiotics, making them more available to the microorganisms and mechanical degradation [6].

The F/M ratio (food to microbes) ratio is the most useful design and operational parameter of activated sludge systems. The activated sludge system is a continuous process with growth and decay of microorganism. A system achieves equilibrium when the food substrate and the microorganism consuming it are in balance. Out of balance can mean too much substrate, too little substrate, too many organism, too little organism, etc. The equilibrium parameter is known as the F/M ratio or the food to microbes ratio. This ratio controls the rate of biological oxidation and the mass of organism, by maintaining microbial growth in either the log, declining or endogenous phase. The type of activated sludge system can be defined by its F/M ratio (see Figure 2.1) [14].

- Extended aeration $0.03 < F/M < 0.8$
- Conventional $0.8 < F/M < 2$
- High rate $F/M > 2$

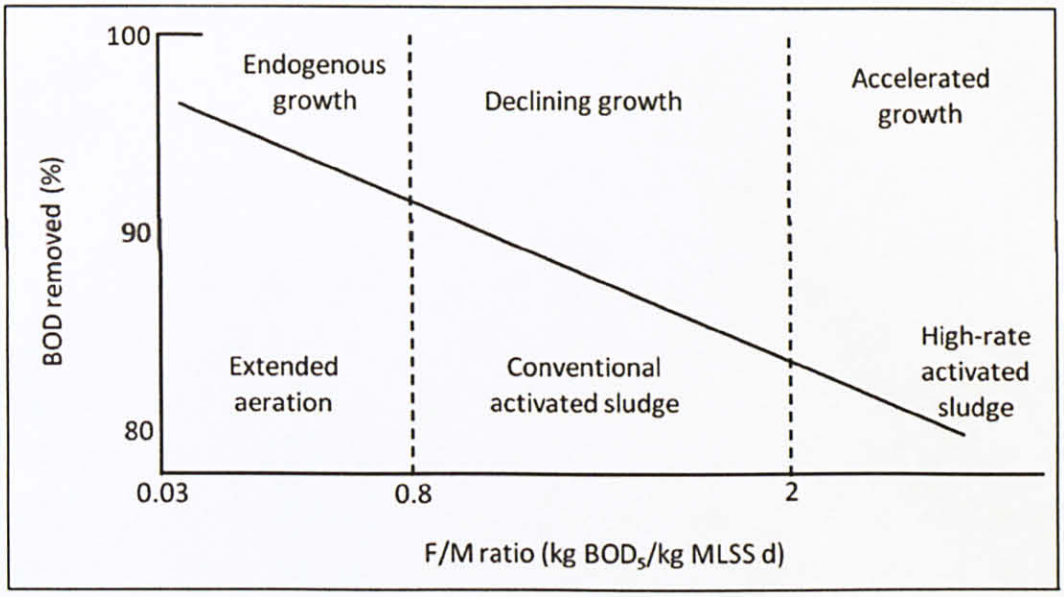

Figure 2.1: Schematic of F/M ratio (not to scale)
(Source: Environmental Engineering, 1999)

The F/M ratio is defined as

$$\frac{F}{M} = \frac{BOD\ of\ sewage\ (kg/m) \times Influent\ flow\ (m/d)}{\text{Re}actor\ solid\ (kg/m) \times \text{Re}ctor\ Volume\ (m)}$$

$$= \frac{(S)(Q)}{XV}$$

Therefore

$$\frac{F}{M} = \frac{S}{\phi X}$$

where

S = Concentration of influent BOD, (kg/m^3)

Q = Influent flow rate, (m^3/day)

X = Concentration of reactor solids

V = Reactor volume, (m^3)

Φ = Hydraulic retention time, (days)

In the log or accelerated growth phase there is an excess of substrate, characterizing a high F/M ratio (>1.0). In the endogenous phase the F/M ratio is low at values generally less than 0.4 and ideally at around 0.2 for plug flow and 0.1 for complete mix systems. Removal rates of BOD are then highest, and this is conventionally called extended aeration [14].

2.4. Sequencing Batch Reactor

The Sequencing Batch Reactor (SBR) is the name given to a wastewater treatment system based on activated sludge and operated in a fill-and-draw cycle. In this system, wastewater is added to a single reactor which operates in a batch treatment mode repeating a cycle (sequence) continuously. All the operations (fill, react, settle, and draw) are achieved in a single batch reactor [15].

SBR technology is not new. In fact, it precedes the use of continuous flow activated sludge technology. The precursor to this a fill-and-draw system operated on batch, similar to the SBR. Between 1914 and 1920, many difficulties were associated with operating these fill-and-draw systems, most resulting from the process valving required to switch from one reactor to another, operator attention required. Interest in SBRs was revived in the late 1950s and early 1960s, with the development of new equipment and technology. Improvements in aeration devices (i.e. motorized valve, pneumatically actuated valves) and controls (level sensors, flowmeters, automatic timers, microprocessors) have allowed SBRs to successfully compete with conventional activated sludge systems [15].

The SBR technology, despite its simplicity as a batch reactor, offers a great flexibility of operation where the sequence of successive phases can be adjusted

to sustain any desired combination of growth conditions for different biochemical processes [16].

The most importance difference between SBR and the conventional activated sludge is that the reaction and settle take place in the same reactor. Basically all SBR have five phases in common (Figure 2.2), which is carried out in sequence as follows:

1) Fill - Raw wastewater flows into the reactor and mixes with the biomass held in the tank, which already present in the reactor. Static fill is characterised by no mixing or aeration, meaning that there will be a high substrate (food) concentration when mixing begins. A high food to microorganism (F/M) ratio creates an environment favourable to floc forming organism versus filamentous organism, which provides good settling characteristics for the sludge. Additionally, static fill conditions favour organisms that produce internal storage products high substrate conditions, a requirement for biological phosphorus removal. Static fill may be compared to using selector compartments in a conventional activated sludge system to control the F/M ratio [16].

2) React - During the react phase, the biomass is allowed to act upon the wastewater constituents. The biological reactions (the biomass growth and substrate utilization), initiated in the fill phase, are completed in the react phase.

3) Settle - Mixing and aeration are stopped and biomass is allowed to separate from the liquid, resulting in a clarified supernatant.

4) Draw - Supernatant or treated effluent is removed.

5) Idle - This is the time between cycles. Idle is used in a multitank system to adjust cycle between SBR reactors. Because idle is not necessary phase, it is sometimes omitted. In addition, sludge wasting can occur during this phase.

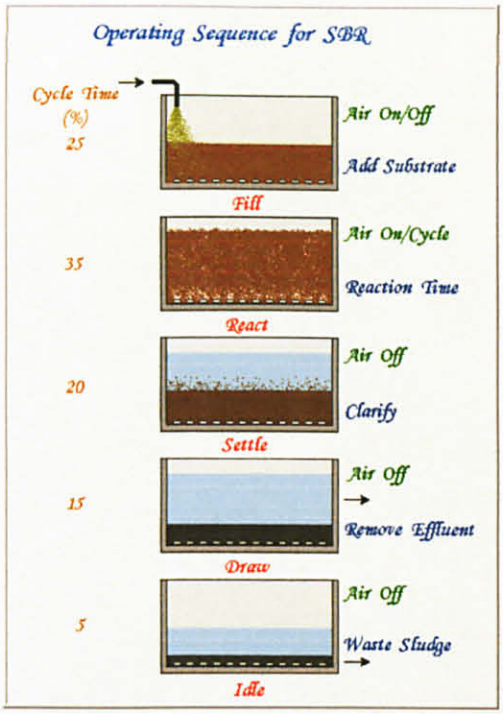

Figure 2.2: Typical Sequence Operation in a SBR process
(Source: http://web.deu.edu.tr/atiksu/toprak/sbrsema.gif)

The advantages of Sequencing Batch Reactor are;

a) The easily modifiable operation is adequate for sludge bulking control. The cyclic change of substrate concentration is known to be a selection factor against certain strains of filamentous bacteria. The operational flexibility of an SBR allows the control of no need clarifier [16].

b) No need modification / interruption [17].

c) Consumes less electricity [17].

d) High degree of operational flexibility [17] whereby the SBR system provides the flexibility needed to treat a variable wastewater (load and composition) by

simply adjusting the cycle time (e.g. using the time set aside for the idle phase), the duration of each phase or the mixing/aeration during each cycle [16].

e) The ability to hold contaminants until they have been completely degraded makes the system excellent for the treatment of hazardous compound [16].

f) Reduce capital cost, maintenance, initial capital – the capacity to adjust the energy input and the fraction of volume used according to the influent loading can result in a reduction in operational cost. In addition, less space is required as all operation occur in one basin [16].

But, the SBR also has some disadvantages. The main drawbacks of the SBR process are outlined below:

a) A higher level of sophistication, (compared to conventional systems), especially for larger systems, of timing units and controls is required [16].

b) Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches and automated valves [16].

c) Potential of discharging floating or settled sludge during the draw or decant phases with some SBR configurations [16].

d) Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer [16].

e) Potential requirement for equalization after SBR, depending on the downstream processes [16].

CHAPTER 3
METHODOLOGY

3.1. Experimental Setup

SBR was operated in a fill-react-settle-draw-&-idle mode with an operation maximum volume of 5 litres. The reactor was seeded with sludge from the PETRONAS Refinery Plant, PP(M)SB Treatment Plant and fed with the industrial wastewater from equalization tank.. A 12-hour cycle was conducted in the SBR, treating 4-litres of wastewater per cycle. An air pump and diffuser provided sufficient aeration of the mixed liquor. The operational temperature was kept around room temperature, between 20°C to 25°C. Figure 3.1 and 3.2 illustrate the schematic and experimental setup of the system.

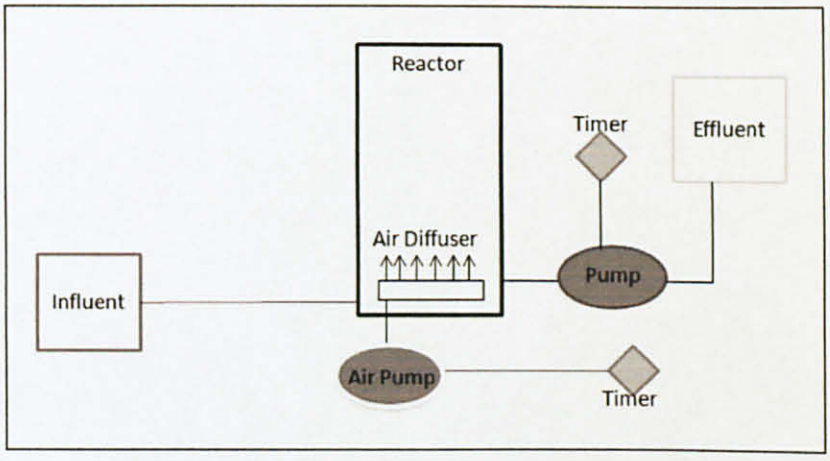

Figure 3.1: Schematic Diagram of SBR System

Figure 3.2: Experimental Setup in the Laboratory

3.2. Operational Conditions

The SBR was operated with 12-hour cycle (720 min.) composed of a fill phase (15 min.), a reaction phase (585 min.), a settling phase (60min.) and a draw phase (15min.) and an idle phase (45 min.).

3.3. Analytical Method

The wastewater was taken from PP(M)SB and then stored in a cold storage room by keeping the temperature at 4°C. The wastewater characteristics then were determined. The analytical methods used during the whole experimental part are described below:

3.2.1 Chemical Oxygen Demand (COD)

Total and Soluble Chemical Oxygen Demand was analysed by adapting the analytical method of HACH, Method 10212.

The COD was determined by an oxidation of a boiling mixture of chromic and sulphuric acids. The sample was refluxed in a strong acid solution with an excess of potassium dichromate ($K_2Cr_2O_7$). After two hours of digestion, the oxidizable matter was calculated in terms of oxygen equivalent.

3.2.2 Biological Oxygen Demand (BOD_5)

Biological Oxygen Demand (BOD_5) was analysed according to the analytical methods 8043 of Standard Methods (APHA (1998)).

The BOD was determined by measuring the dissolved oxygen by the microorganism in the biochemical oxidation of organic matter. The sample was poured into the BOD bottles and seeded with the activated sludge of influent. Then, the BOD bottles were placed in the refrigerator at 20°C for 5 days. The initial and final dissolved oxygen (DO) are measured by using DO probe.

3.2.3 Mixed Liquor Suspended Solids (MLSS) and Mixed Liquor Volatile Suspended Solids (MLVSS)

Mixed Liquor Suspended Solids (MLSS) and Mixed Liquor Suspended Solid (MLVSS) were analysed according to the analytical methods 2540D and 2450E of Standard Methods (APHA (1998)).

For MLSS determination, a well-mixed sample was filtered through a weight standard glass-fibre filter (GF/C 47mm) and the residue retained on the filter was dried an hour to a constant weight at 103-105°C. The weight of the filter and the dried residue was determined and used to calculate the MLSS in mg/l.

MLVSS was determined by the combustion of the MLSS filter in a furnace at a temperature of 550°C for 15-20 minutes. Then, partially cooled in air until most of the heat had been dissipated and transferred between the weight with the dried residue and the combustion residue were used to calculate the MLVSS in mg/l.

3.2.4 Total Suspended Solids (TSS)

Total Suspended Solids (TSS) was analysed according to the analytical methods 2540B of Standard Methods (APHA ((1998)). An amount of well-mixed sample was put in a filter paper and dried overnight to a constant weight at 103-105°C. The weight of filter paper and the filter paper with the dried residue was determined and used to calculate the TSS in mg/l.

3.2.5 Nitrate

Nitrate was determined by the HACH Method, Nitrate HR Method 10020. A 10 ml sample was added with NitraVer 5 Nitrate Reagent Powder Pillow before letting 5-6 minutes of reaction occurred. An amber colour will develop if nitrate is present. The reading of nitrate was measured then.

3.2.6 Total Phosphate Determination

Total Phosphorus was determined by the HACH Method, Phosphorus, Total HR Method 10127. The sample was added to a Total and Acid Hydrolyzable Test Vial with Potassium Persulfate Powder Pillow. After heating the sample in DRB200 Reactor for 30 minutes, A 1.54N Sodium Hydroxide Standard Solution and PhosVer 3Powder Pillow were added before taking the reading of total phosphorus.

3.2.7 Nickel Determination

Nickel Concentration can be analysed in two different ways during the experimental part which are using Method 8150 of HACH and Atomic Absorbance Spectrometry of (APHA (1995)) Method.

- **1-(2 Pyridylazo)-2-Napthol (PAN) Method of Method 8150**
  A 10 ml sample was added with Phthalate-Phosphate Reagent Powder Pillow and 0.3% PAN Indicator Solution. EDTA Reagent
  Powder Pillow was added after letting reaction for 15 minutes. The reading of Nickel was determined then.

- **Atomic Absorption Spectrometry**

  A sample is filtered in the field through a 0.45 μm membrane filter and preserved with nitric acid. The sample aliquot is heated, usually in three stages in a graphite furnace or an electrically heated atomiser where: at the first stage, a low current is applied to dry the sample; the second stage chars the sample by destroying the organic matter and volatilising other matrix compounds; finally, the third stage applies a high current which heats the tube to incandescence and atomises the nickel to be determined. The absorbance of the resultant ground state atoms is measured at 232.0 nm and is compared to identically-prepared standard and blank solutions.

3.2.8 Sludge Volume Index (SVI)

Sludge Volume Index was determined by the analytical method of 2710D of Standard Method (APHA (1998)). The settled sludge volume was measured after 30 minutes of sludge settling. The SVI then was measured by dividing the settled sludge volume with TSS.

3.2.9 pH Determination

pH of the wastewater sample was determined using a digital pH meter based on the HACH method, pH Method 8156.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1. Wastewater Characteristics

Table 4.1: Comparison of Wastewater Characteristics and Effluent Discharge for Malaysian Standard

Parameters	Wastewater Characteristics	Maximum Limit for Effluent Discharge	
		Standard A	Standard B
COD	322 mg/l	50 mg/l	100 mg/l
BOD_5	121 mg/l	20 mg/l	50 mg/l
Nickel	2.3 mg/l	0.20 mg/l	1.0 mg/l
Phosphorus	1.80 mg/l	-	-
Nitrate	1.0 mg/l	-	-
Turbidity	79.9 NTU	-	-
pH	6.72	6.0-9.0	5.5-9.0

Table 4.1 contains the characteristics of refinery wastewater. From the experiment conducted, it is proven that the wastewater characteristics' value of COD, BOD_5 and Nickel are exceeded from the value of Standard A and B. It is merely acceptable for the pH parameter. Nevertheless, the process parameters for phosphorus, nitrate and turbidity are not stated in the list as the parameters that should comply to the DOE Standards stipulated under Environmental

Quality Act 1974, the Environmental Quality Regulations (Sewage and Industrial Effluents) 2009.

4.2. COD Removal Efficiency

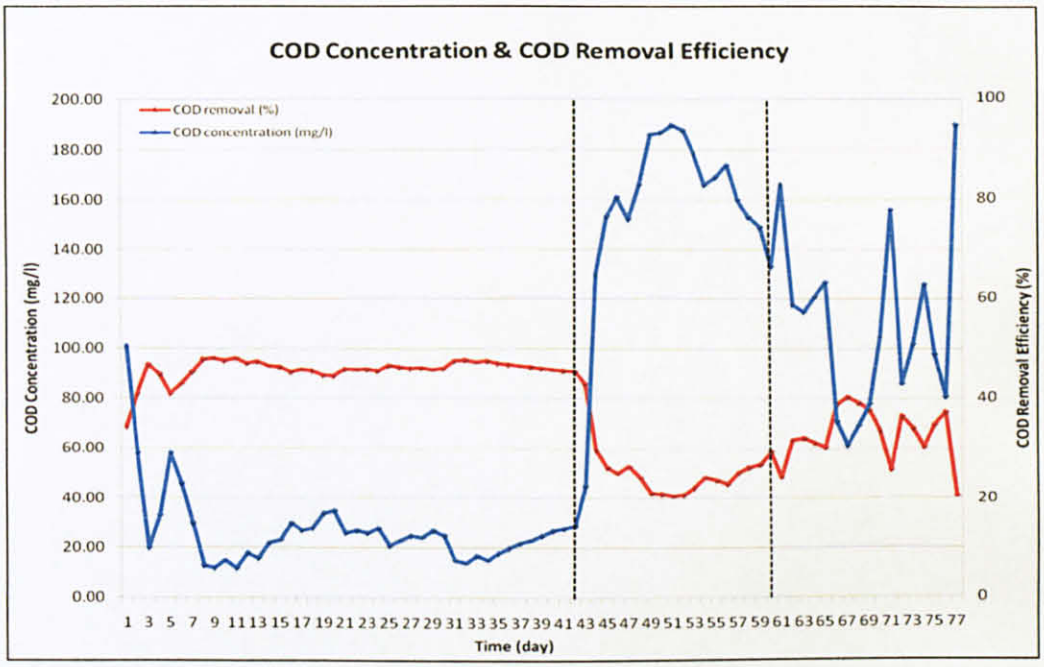

Figure 4.1: Monitored COD Concentration and COD Removal Efficiency for 77 days

Figure 4.1 exhibits the COD concentration of the SBR system and its COD removal efficiency for 77days. During the initial 8 days, the COD concentrations were fluctuating ranging from 13 mg/l to 100 mg/l and the COD removal efficiency was varied between 70–90%. From day 9 to day 20, the COD concentrations were still fluctuating corresponding to effluent COD ranging from 12 to 35 mg/l. This shows good adaptability and tolerance of the microorganisms to the system. Starting from day 21 to day 42, the COD has gradually having stable concentration which ranging from 21-28 mg/l. Thus, the

microorganisms in the system were already acclimatized to the new environment, and the Nickel is ready to be discharged to the system.

The new concentration of Nickel of 2.4 mg/l and 2.6 mg/l were added to the system on day 43 and day 60 respectively. The COD values had sudden increased after injecting new amount of nickel showing the acclimatization of microorganisms in the system.

4.3. MLVSS, MLSS and SVI

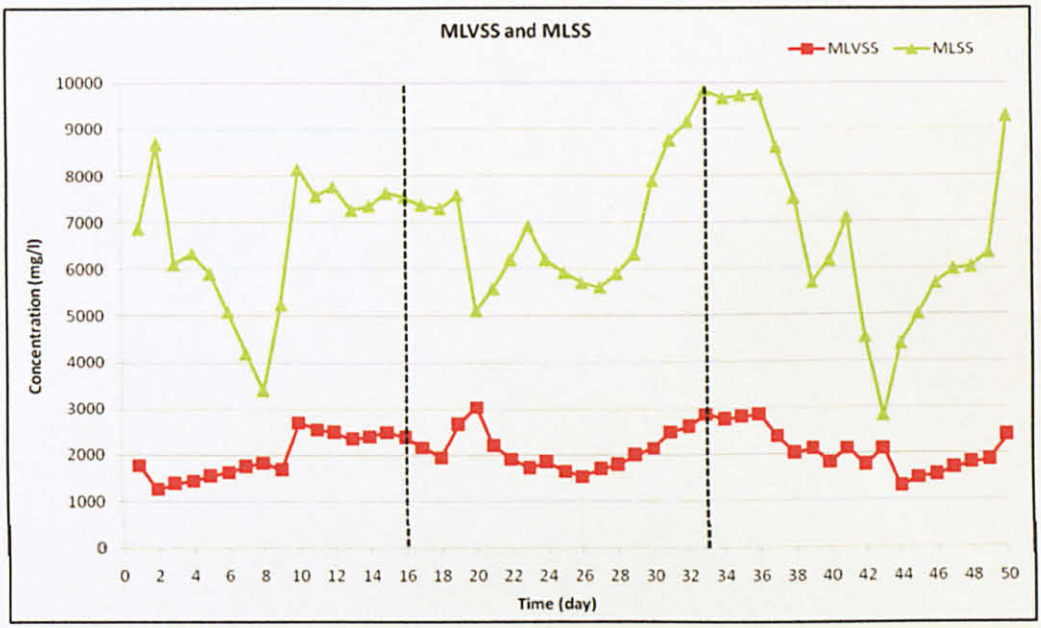

Figure 4.2: Monitored MLVSS and MLSS for 50days

Figure 4.2 indicates the MLVSS and MLSS throughout 50 days. At day 2, there value of MLVSS was dropped because of the dead microorganism in the system and resulted a cloudy colour of the effluent. Some of the microorganism has died and caused the cloudy in the effluent. And that is why the value of the MLSS is

higher on day 2 as it includes both dead and old mass. Later, the sludge has been added on day 3 to get the balance of F/M and the concentration increased with time. The dropped values of MLVSS shows the system sometime suffered from limited amount food and the microorganisms have decayed. The phenomenon occurred continually at day 9, 18, 26, 36 and 44.

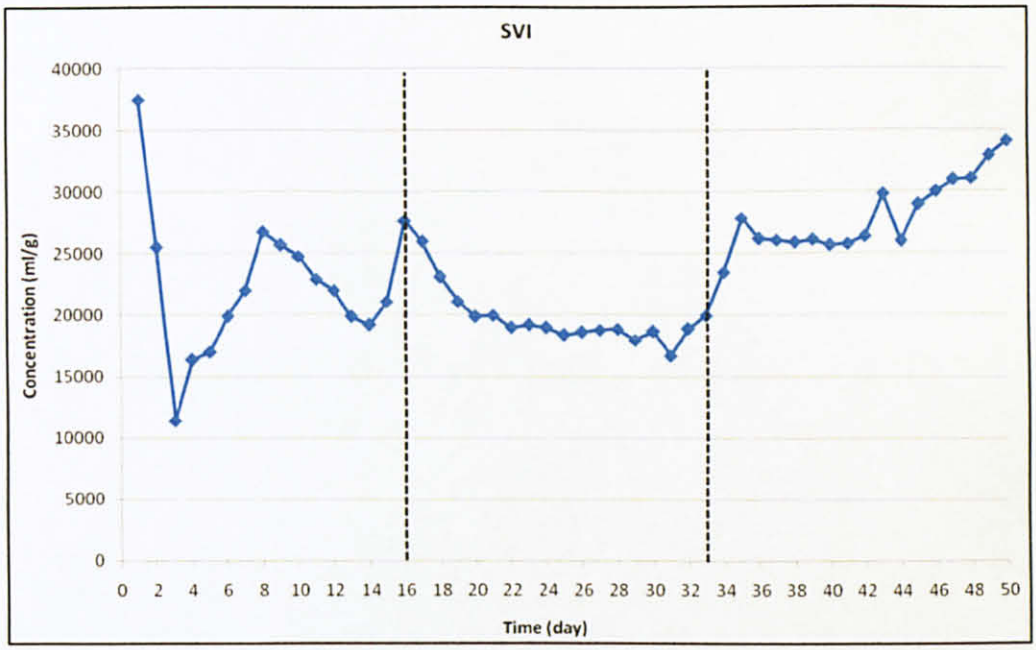

Figure 4.3: Monitored SVI for 50 days

From figure 4.3, the settling characteristics of activated sludge and other biological suspensions in the SBR system is least during the day 3. The phenomenon happened because of the quantity of the particles in the SBR system that settle to the bottom during wastewater treatment is less because there is some of the microorganisms had dead throughout the treatment. The filamentous type of the bacteria which is found in the SBR can increase the sludge volume index.

4.4. Nickel Removal Efficiency

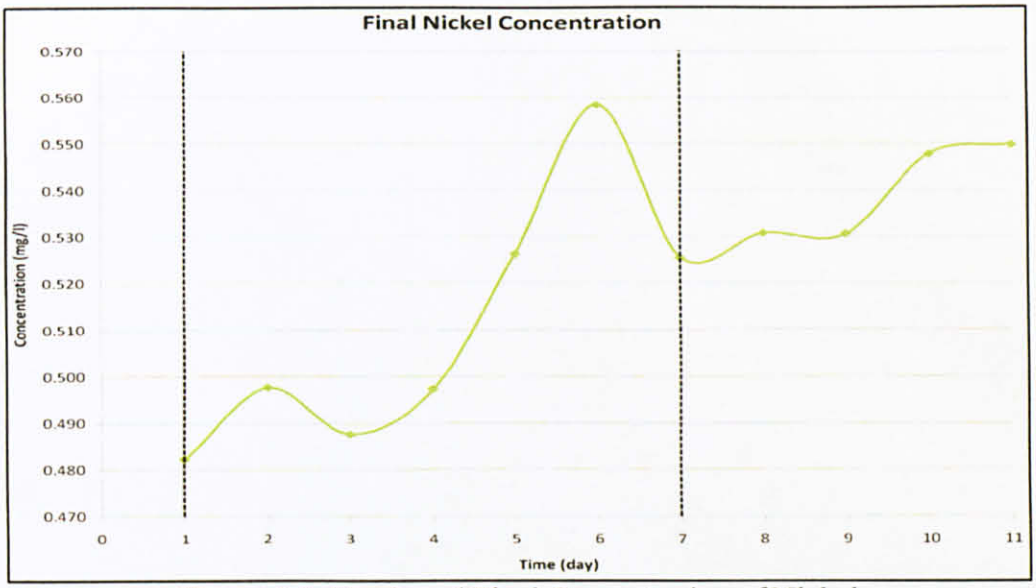

Figure 4.4: Monitored Final Concentration of Nickel

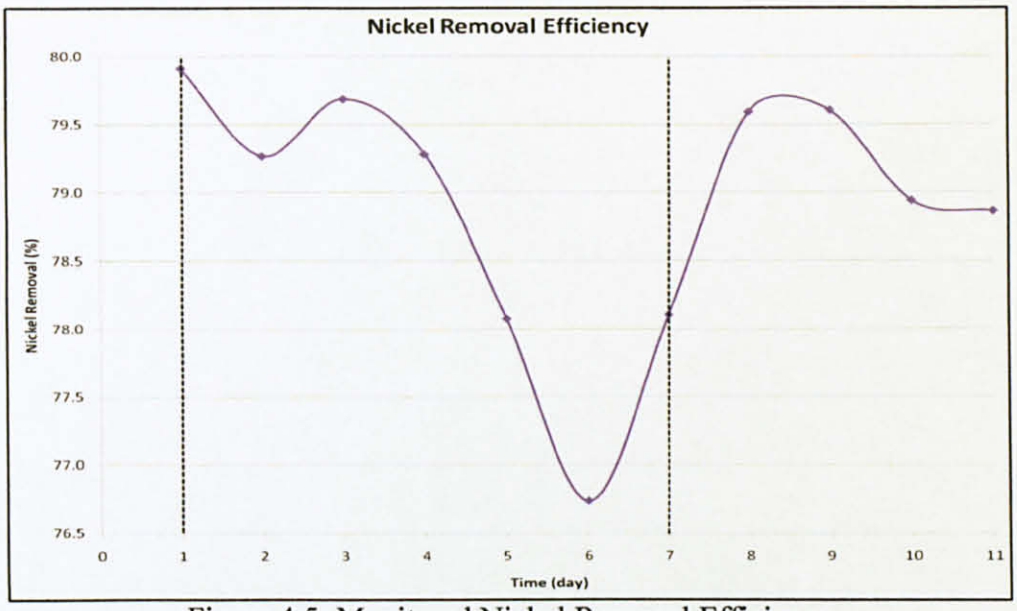

Figure 4.5: Monitored Nickel Removal Efficiency

Figure 4.4 and 4.5 depict the final concentration of every discharge of 2.4 mg/l and 2.6 mg/l of Nickel into the SBR system as well as the Nickel removal efficiency. The SBR system reduces the Nickel concentration ranging of 0.48-

0.55 mg/l (78.8%) and 0.52-0.55 mg/l (79.0%) for Nickel's initial concentration of 2.4 mg/l and 2.6 mg/l correspondingly.

4.5. Comparison of wastewater characteristics between the treatment at PP(M)SB and the SBR system.

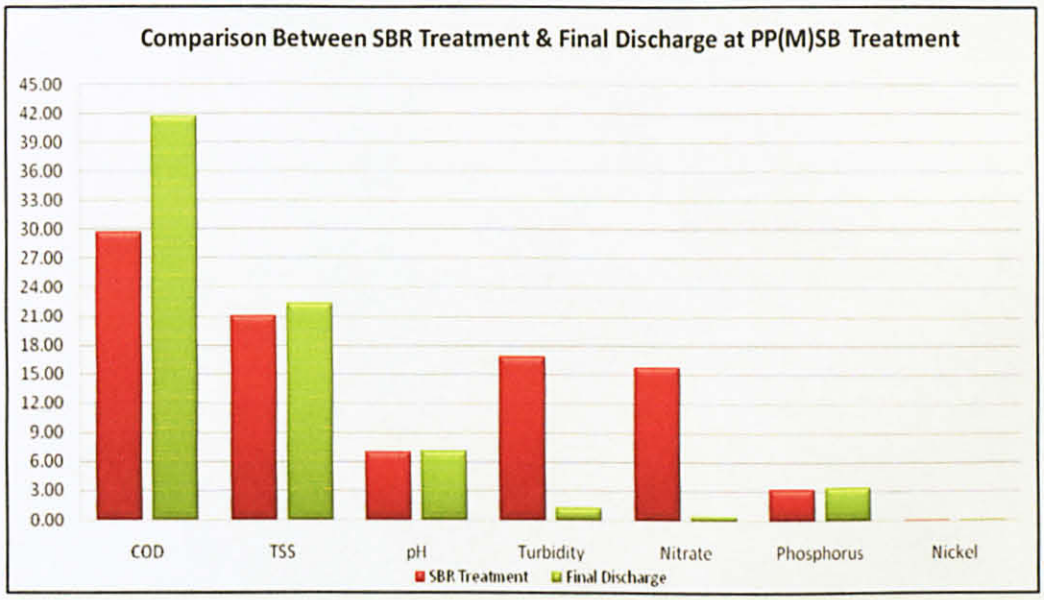

Figure 4.6: Comparison between SBR Treatment and PP(M)SB Treatment

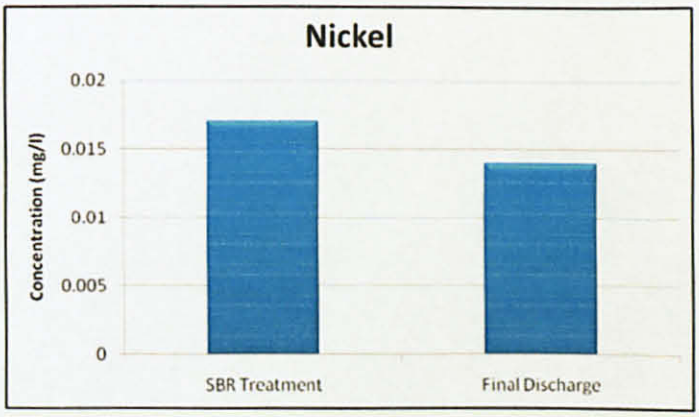

Figure 4.7: Comparison of Nickel Concentration after both treatments

Figure 4.6 shown that, the achieved COD of the SBR is lesser compared to the final discharge at PP(M)SB. The value of TSS, pH and Phosphorus, more or less are same for both treatments. Nevertheless, there is huge differences between SBR system and PP(M)SB system in term of turbidity and nitrate. It is believe that there is tertiary treatment (advanced system) used at PP(M)SB which is using the sand filter to increase the reduction of suspended solid and turbidity. In addition to the SBR system, the predominance of nitrate nitrogen in the wastewater indicates that the waste has been stabilised with respect to oxygen demand. Besides, all of the achieved values of measured parameters are acceptable based on Standard A and Standard B.

While Figure 4.7 shows the treatment at PP(M)SB having less nickel concentration compared to SBR system. Yet, the differences between both treatments are small which is 0.003 mg/l.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The SBR has shown excellent performance of COD removal efficiency ranging from 70% to 90%. The nickel concentrations are proven to reduce 78.4%, 78.7% and 79.2% from initial Nickel's concentration of 2.3mg/l, 2.4mg/l and 2.6mg/l respectively.

For further measuring the efficiency of SBR in removing heavy metals from refinery wastewater, heavy metals of Iron and Zinc are recommended for further research.

CHAPTER 6

ECONOMIC BENEFIT

Physicochemical is seen to have less economical values compared to biological treatment is because of some matters which are;

- The items like large crushers, mills, shredders and macerators can be expensive to purchase, particularly with associated material handling plant.
- Equipment capital costs are high and power consumption and maintenance contribute to high operating costs.

For example in chemical precipitation - Reagents very variable in cost - lime usually inexpensive but sulphide generation can be more costly.

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APPENDICES

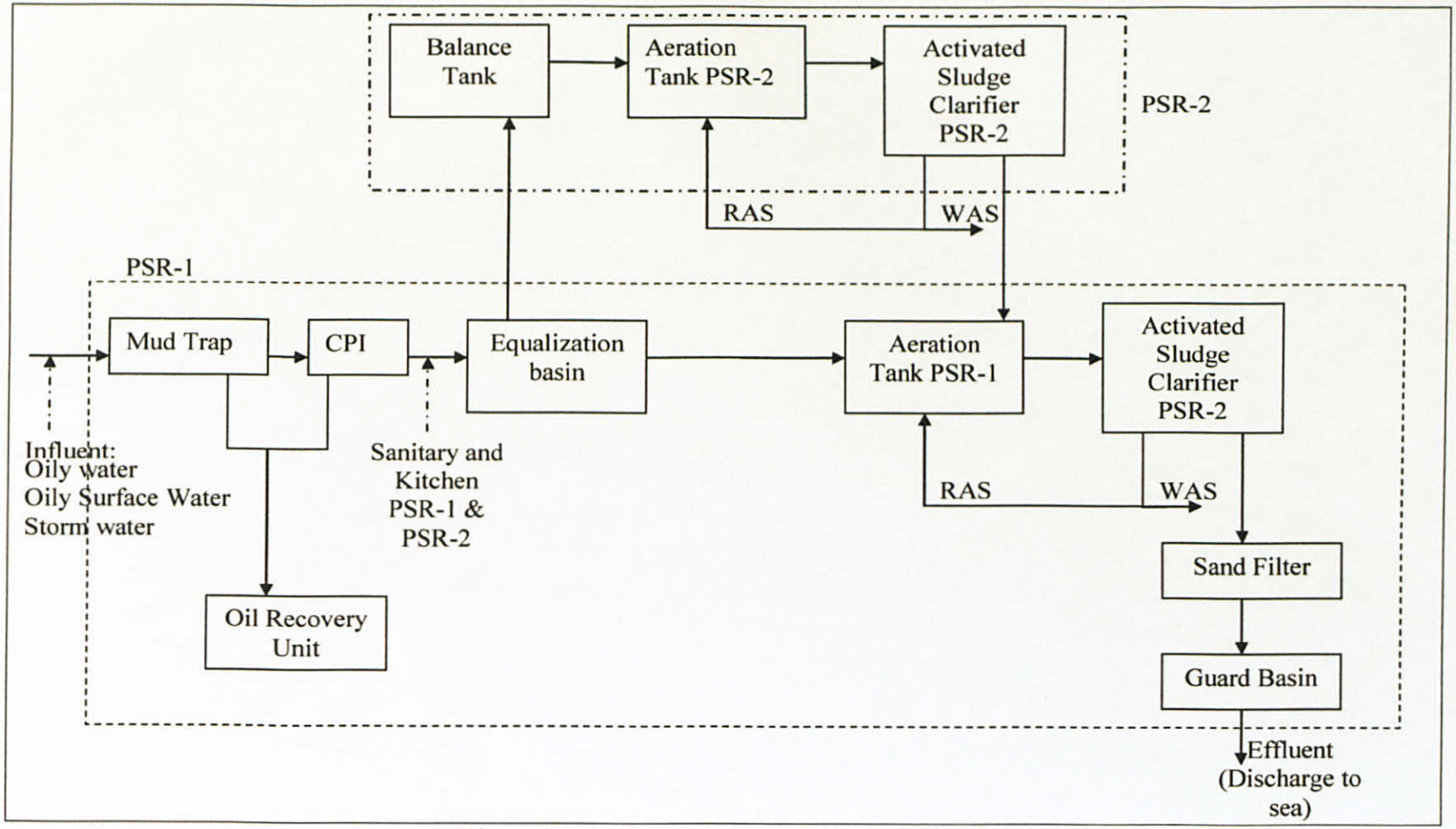

Figure A-1: Effluent Treatment Process at PP(M)SB

Table A-1: Monitored COD Readings

Time (day)	Initial COD Concentration (mg/)	Final COD concentration (mg/l)	COD removal efficiency (%)
1	322	101	68.63
2	322	58	81.99
3	322	20	93.79
4	322	33	89.75
5	322	58	81.99
6	322	46	85.71
7	322	30	90.68
8	322	13	95.96
9	322	12	96.27
10	322	15	95.34
11	322	12	96.27
12	322	18	94.41
13	322	16	95.03
14	322	22	93.17
15	322	23	92.86
16	322	30	90.68
17	322	27	91.61
18	322	28	91.30
19	322	34	89.44
20	322	35	89.13
21	322	26	91.93
22	322	27	91.61
23	322	26	91.93
24	322	28	91.30
25	322	21	93.48
26	322	23	92.86
27	322	25	92.24
28	322	24	92.55
29	322	27	91.61
30	322	25	92.24
31	322	15	95.34
32	322	14	95.65
33	322	17	94.72
34	322	15	95.34
35	322	18	94.41
36	322	20	93.79
37	322	22	93.17
38	322	23	92.86
39	322	25	92.24

40	322	27	91.61
41	322	28	91.30
42	322	29	90.99
43	322	45	86.02
44	322	130	59.63
45	322	153	52.48
46	322	161	50.00
47	322	152	52.80
48	322	166	48.45
49	322	186	42.24
50	322	187	41.93
51	322	190	40.99
52	322	188	41.61
53	322	179	44.41
54	322	166	48.45
55	322	169	47.52
56	322	174	45.96
57	322	160	50.31
58	322	153	52.48
59	322	149	53.73
60	322	133	58.70
61	322	166	48.45
62	322	118	63.35
63	322	115	64.29
64	322	121	62.42
65	322	127	60.56
66	322	71	77.95
67	322	62	80.90
68	322	69	78.57
69	322	78	75.78
70	322	105	67.39
71	322	156	51.55
72	322	86	73.29
73	322	102	68.32
74	322	126	60.87
75	322	98	69.57
76	322	81	74.84
77	322	190	40.99

Table A-2: Monitored MLVSS, MLSS and SVI

Time (day)	MLVSS	MLSS	SVI
1	1782	6864	37500
2	1254	8679	25547
3	1386	6105	11413
4	1452	6336	16364
5	1551	5907	17000
6	1633	5087	19870
7	1749	4191	21987
8	1833	3399	26789
9	1683	5247	25698
10	2706	8151	24765
11	2554	7569	22908
12	2487	7765	21987
13	2343	7260	19876
14	2409	7351	19209
15	2500	7636	21098
16	2377	7549	27675
17	2167	7368	25981
18	1947	7293	23100
19	2660	7590	21099
20	3036	5115	19879
21	2198	5576	19999
22	1908	6198	18972
23	1716	6930	19209
24	1848	6204	18978
25	1654	5932	18367
26	1539	5713	18603
27	1699	5610	18783
28	1789	5908	18866
29	1992	6314	17982
30	2148	7892	18678
31	2499	8756	16699
32	2601	9156	18890
33	2871	9834	19998
34	2751	9657	23478
35	2801	9712	27890
36	2838	9735	26200
37	2393	8612	26099
38	2014	7521	25909
39	2100	5698	26128
40	1815	6171	25699

41	2112	7095	25798
42	1756	4509	26389
43	2091	2805	29807
44	1287	4356	25986
45	1489	5012	28976
46	1528	5672	29999
47	1678	5978	30987
48	1789	6023	31098
49	1848	6336	32909
50	2376	9273	34129

Table A-3: Monitored Nickel Concentration

Time	Initial Nickel Concentration (mg/l)	Final Nickel Concentration (mg/l)	Nickel Removal Efficiency (%)
1	2.4	0.4822	79.91
2		0.4976	79.27
3		0.4876	79.68
4		0.4973	79.28
5		0.5262	78.07
6		0.5584	76.73
7	2.6	0.5256	78.10
8		0.5307	79.59
9		0.5304	79.60
10		0.5477	78.93
11		0.5497	78.86