Treatment of Leachate Using Sequencing Batch Reactor (SBR)

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Abstract

Rapid urbanization and industrialization changed the characteristics of solid waste generated and leads to severe environmental problems. Solid waste disposed of in landfills will go through several stages of decomposition, will eventually result in the liquid at the bottom of the landfill leachate. Now days, according to the increasingly restrictive limits for wastewater discharge, complicated and costly treatment facilities are imposed. This research will examined the performance of Sequencing Batch Reactor (SBR) on removal of suspended solid (SS), turbidity, chemical oxygen demand (COD), ammonia-nitrogen, total nitrogen (TN), and total phosphorus (TP). The variables are reaction time in differences condition (anaerobic, anoxic, and aerobic). Then, follow by combination of difference steps consisting anaerobic/ anoxic/ aerobic in order to achieve maximum removal. The characteristic of Pasir Gudang, Johor's landfill leachate is pH, turbidity, BOD, COD, suspended solid, colour, ammonia nitrogen, total phosphorous, total nitrogen, total organic carbon, tannin and lignin, and sulfate, 8.06, 841 NTU, 2107 mg/L, 6000 mg/L, 576 mg/L, 1050 ADMI, 50.638 mg/L, 24 mg/L, 700 mg/L, 185 mg/L, 17 mg/L, 1005 mg/L. The expected outcomes parameter of suspended solid (SS), turbidity, chemical oxygen demand (COD), ammonia-nitrogen, total nitrogen (TN), and total phosphorus (TP) from leachate which is 80%, 80%, 90%, 76%,80%, and 70% respectively.

Keywords: aerobic, anaerobic, anoxic, leachate, sequencing batch reactor

I. Introduction

The sources of Malaysia's official statistics report that Malaysia's population is about 27,565,821 people (Malaysia Statistics Department). During the census period, there are 6,396,174 households and 7,380,865 living quarters in Malaysia. In average, each citizen in Malaysia was produces 0.8 kg of solid wastes. This amount is even larger when taking into account the individuals who live in the city. The occupant of the urban areas is estimated to produce 1.5kg of solid wastes. Based on that number, total of solid waste in this country is 22,056 tonnes per day [8].

In the solid waste management, sanitary landfill is the most economic and widely employed methods for the municipal solid waste (MSW). The large number of disposal solid waste may cause a serious impact to the management of sanitary landfill. Solid waste landfill sites are often defined as hazardous and heavily polluted wastewaters with considerable variations in both composition and volumetric flow [9]. Waste entering the landfill undergoes biological, chemical and physical transformations influencing factor by water fluxes. In the landfill, there are three physical phase are present which is solid phase (waste), liquid phase (leachate), and gas phase (CO_2, CH_4). Solid waste disposed of in landfills will go through several stages of decomposition, are eventually result in the liquid at the bottom of the landfill leachate.

I.1 Leachate characteristic

Landfill leachate is generated as a consequence of rainwater percolation through wastes, chemical biological processes in waste and the inherent water content of wastes themselves [17]. Leachate is a very dark colored liquid formed primarily by the percolation of precipitation through open landfill or through the cap of the completed site. The decomposition of organic matter such as humic acid may cause the water to be yellow, brown or black [33].

The discharge of landfill leachate may contain a large amount of organic matter (both biodegradable and non-biodegradable carbon), ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salt [22, 26]. Although some of these pollutants can be degraded by microorganisms, the limitation of common biological processes (degradation is only a part of COD and limited removal of bio-refractory organic pollutants) has made it difficult to meet the correlative discharge standard [26]. The generated of wastewater contains colloidal solid, coloring compound, suspended solid, and oil and grease.

A solid waste initially decomposes aerobically, with carbon dioxide, waster, and nitrates the decomposition products. As oxygen is used up in aerobic pond, facultative and anaerobic microorganisms predominate. These bacteria produce volatile acids and carbon dioxide. These organic acids reduce the pH to 4 or 5, which in turn solubilizes some inorganic materials in the landfill. During this time, conductivity will be very high. The low pH is toxic to methane producing bacteria, so methane will be produced during this period. The first anaerobic stage is characterized by low pH, high volatile acid production, high chemical oxygen demand (COD), high conductivity, and low methane production.

In Malaysia, leachate pollution is a major problem that must be handled immediately. Unfortunately, the treatment system and leachate management in Malaysia is still in early stages of operation and studies relating to the management and leachate treatment are in progress. In an effort to Malaysia to achieve developed nation status towards 2020, the sustainable management of solid waste and leachate effective treatment should be given serious attention [4]. The addition of solid waste causes the several problems in this country which local streams could become polluted with toxins seeping through the ground from the landfill site.

Besides, wastewaters have a complex composition and normally contain more than one organic pollutant, synergistic effects may take place. Because of the potential of leachate to ultimately find its way into the groundwater, causing contamination with chemical species in dissolved or suspended forms, the generation of landfill leachate creates the potential for a long-term impact on the surrounding environment. Toxic compounds such as adsorptive organic halogen (AOX) compounds, humic acids and chloride compounds that remain in stabilized leachate, ammonia nitrogen (NH_3–N) has been identified as one of the major toxicants to living organisms [7]. High concentration of untreated NH_3–N can stimulate algal growth, deplete dissolved oxygen through eutrophication and have toxic effects on aquatic organisms [5].

The proposed of this research is to investigate the effect of leachate using sequencing batch reactor (SBR). Specifically this study aims to investigate the effect of different condition consisting anaerobic, anoxic, and aerobic with different reaction time in removing suspended solid (SS), turbidity, chemical oxygen demand (COD), ammonia-nitrogen, total nitrogen (TN), and total phosphorus (TP). Then, to determine the effectiveness performance of SBR system in combination phases consisting anaerobic/ anoxic/ aerobic in order to achieve maximum removal.

II. Biological Process in Wastewater Treatment

Biological treatment has a lot of potential in wastewater treatment industry. It has a good removal ability of the biodegradable substrates and this method can reduce cost of treatment residues with respect to ecological and economical requirements [14, 16]. The primary purpose of biological wastewater treatment was to remove organic compounds, colloidal and suspended solids and also to reduce the concentration of pathogenic organisms released to receiving waters.

It will transform (oxidized) dissolved and particulate carbonaceous organic matter into acceptable end product and addition biomass [11]. The biological organic matter removal requires sufficient time between wastewater and heterotrophic microorganisms, sufficient oxygen and nutrients, the organic compounds (Carbon, Oxygen, Hydrogen, Nitrogen and Sulphur) serves as the electron donor while the oxygen serves as the electron acceptor [11, 14, 27].

The biological process by which the organic matter in the sludge produced from the primary settling and biological treatment of wastewater is stabilized, usually by conversion to gasses and cell tissue. Depending on whether this stabilization is carried out under or anaerobic conditions, the process is known as aerobic or anaerobic digestion. The biomass has specific gravity slight greater than that of water, it can be removed from the treated liquid by gravity settling. Without the removal of biomass from the treated liquid, the only treatment achieved is that associated with the bacterial oxidation of a portion of the organic matter originally present.

During the initial biological uptake of organic material, more than half of it is oxidized and the remainder is assimilated as new biomass, which may be further oxidized by endogenous respiration. For organic matter removal, pH in the range of 6.0 to 9.0 is tolerable, while optimal performance occur near a neutral pH. A reactor Dissolved Oxygen (DO) concentration of 2 mg $O_2.L^{-1}$ there is little effect on the degradation rate. In some wastewater care must be taken to assure that sufficient nutrients (N and P) are available for the amount of organic matter to be treated [11].

II.1. Biological Nitrogen Removal

The forms of nitrogen are transformed biochemically, whether under aerobic, anoxic or anaerobic conditions, allowing the development of various microbial communities, which simultaneously transform the organic matter and nitrogen. The organisms involved in these processes can be classified according to the source of carbon in autotrophic and heterotrophic species. The autotrophic are those organisms able to synthesize organic matter from minerals and the heterotrophic are those in need of organic matter for their development and maintenance.

Biological nitrogen removal requires a two-step process: Nitrification and denitrification. During the removal of nitrogen by microbial processes by nitrification – denitrification, the ammonium ion is oxidized to nitrite and subsequently to nitrate in the presence of oxygen and inorganic carbon (nitrification) and then nitrate is reduced to molecular nitrogen in the absence of oxygen and presence of organic carbon (denitrification).

Nitrification is affected by a number of environment factors including pH, toxicity, metals, un-ionized ammonia, un-ionized nitrous acid and reduced sulphur components. The alkalinity of the wastewater must be enough to maintain the pH in the optimum interval for nitrification because: 7.13g of alkalinity is consumed per 1 g of ammonium ($N\text{-}NH_4^+$) oxidized to nitrate ($N\text{-}NO_3^-$) under aerobic conditions and using oxygen as the electron acceptor [14, 27].

Aerobic autotrophic bacteria are responsible for nitrification in activated sludge and biofilm processes. Nitrification is involving two groups of bacteria. In first stage, ammonia is oxidized to nitrite (eq 1) by one group of autotrophic bacteria called *Nitrosomonas sp*. bacteria or Ammonia Oxidizing Bacteria (AOB) however, members of the genera *Nitrospira sp., Nitrococcus sp., Nitrosolobus sp. and Nitroovibrio sp.* are also involved in the process [18]. In the second stage, nitrite is oxidized to nitrate (eq 2) by one group of autotrophic bacteria called Nitro-bacteria or Nitrite Oxidizer Bacteria (NOB) e.g *Nitrobacter sp*. bacteria and also by *Nitrospina sp.* and *Nitrococcus sp.* bacteria (Rodriguez et al, 2011). The conditions of bacteria are aerobic and therefore need oxygen for their vital functions, and a decrease of oxygen in the treatment system favors the accumulation on nitrite in the medium. It should be noted that the two groups of autotrophic bacteria are distinctly different [14, 27].

$$NH_4^+ + 3/2O_2 \rightarrow NO_2^- + H_20 + 2H^- \quad \text{------------------- eq 1}$$

$$NO_2^- + 1/2O_2 \rightarrow NO_3^- \quad \text{-------------------------------------- eq 2}$$

Therefore, total oxidation reaction is described as eq 3 :

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_20 + 2H^+ \quad \text{------------------------ eq 3}$$

These autotrophic microorganisms derive energy for growth from the oxidation of inorganic nitrogen compounds, using inorganic carbon as their source of cellular carbon. The H+ produced during nitrification is neutralized by HCO3- in the water, reducing the alkanity and causing a decrease in pH [27]. It required to carry out the reaction (eq 3) can be estimated as eq 4.

$$NH_4^+ + 2HCO_3^- + 2O_2 \rightarrow NO_3^- + 2CO_2 + 3H_20 \quad \text{----- eq 4}$$

In above equation, for each g of ammonia (an N) converted, 7.14 g of alkalinity as $CaCO_3$ will be required [11].

Ammonia and nitrite oxidizing bacteria activity is influenced by several factors. Temperature (T) is a key factor in biological processes. Biological and chemical reactions take place at higher rates when temperature increases. However, at certain level, high temperatures result in the denaturalization of proteins and damage to bacteria membranes, which in turn lead to sharp reduction in biological activity. Therefore, that microorganism is conditioned by lower temperatures (below which no growth is detected), an optimal temperature where the growth rate is at its maximum and a maximum temperature (over which no growth is possible). Nitrification can take place in the range 4^o to 40^oC, with a maximum activity between 30^o to 37^oC (mesophilic condition).

Nitrification is pH sensitive, and reaction rates decline significantly at pH values below 6.8. At pH values around 5.8 to 6 the rates may be 10 to 20 percent of the rate at pH 7. On the other hand, pH over 8 may also lead to the inhibition of nitrifying activity. This effect is due to the activation-deactivation of the nitrifying bacteria, linked to the inhibition of active sites of enzymes by the bonding of H^+ and OH^-. Nitrification is an aerobic process, so the availability of dissolved oxygen (DO) in the media is essential for the development of AOB and NOB activity. However, these two bacterial groups have different affinities to this substrate. The present of salt in the media in the media may negatively affect bacteria and inhibit their activity.

There are two modes of nitrate reduction can occur in biological systems. Firstly, is an assimilating nitrate reduction involves the reduction of nitrate to ammonia for use in cell synthesis. Secondly, dissimilating nitrate reduction or denitrificition is coupled to the respiration electron chain and involves the reduction of nitrate (highly oxidized forms of nitrogen available for consumption by many groups of organisms) to nitrite to nitric oxide to nitrous oxide to gaseous nitrogen, which is far less accessible to life forms but makes up the bulk of our atmosphere. Denifrication is considered to be anoxic process, occurring in the absence of oxygen and requires an organic electron donor. Bacteria capable of denitrification are both heterotrophic and autotrophic. Most of these heterotrophic bacteria are facultative aerobic organisms with the ability to use oxygen as well as nitrate or nitrite, and also carry out fermentation in the absence of nitrate or oxygen [11].

Biological denitrification process involves the reduction of nitrate to nitrite and subsequently the reduction of nitrite to nitric oxide (NO), then to nitrous oxide (N_2O) and finally to molecular nitrogen (N_2), which released into the atmosphere. These transformations are carried out by a group of bacteria that are capable of using nitrate as an electron acceptor instead of oxygen to respire, with the electron donor being organic carbon. In the absence of DO or under limited DO concentrations, the nitrate reduce enzyme in the electron transport respiratory chain is induced, and help to transfer hydrogen and electrons to the nitrate as the terminal electron acceptor.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

The electron donor as an organic substrate is obtained through: the easily biodegradable COD in the influent wastewater (eq 5) or produced during endogenous decay, or an exogenous source such methanol (eq 6) or acetate (eq 7). Different electron donors give different reaction stoichiometries as observation below.
The equation of organic matter of the influent:

$$C_{10}H_{19}O_3N + 10NO_3^- \rightarrow 5N_2 + 10CO_2 + 3H_20 + NH_3 + 10OH^{-} \text{------ eq 5}$$

The equation of organic matter produced during the endogenous decay and an exogenous source such as methanol or acetate.

$$5CH_3OH + 6NO_3^- \rightarrow 3N_2 + 7H_2O + 6OH^- \text{------------------------- eq 6}$$

$$5CH_3OOH + 8NO_3^- \rightarrow 4N_2 + 10CO_2 + 6H_2O + 8OH^- \text{------- eq 7}$$

Denitrification process originates an increase in the medium alkalinity. One equivalent of alkalinity is produced per equivalent of $N\text{-}NO_3^-$ reduced, which equates to 3.57g of alkalinity as a $CaCO_3$ production per 1g $N\text{-}NO_3^-$ reduced [14, 27]. Electrons originated from e.g. organic matter, reduced sulphur compounds or molecular hydrogen are transferred to oxidized nitrogen compounds instead of oxygen in order to build up a proton motive force usable of ATP. Dissolved oxygen can inhibit reduction by repressing the nitrate reduction enzyme [11].

II.2.1. Aerobic Treatment Systems

Aerobic treatment is a principle of which the use of free is or dissolved oxygen by microorganisms (aerobes) in the degradation of organic wastes. Since oxygen is available to working aerobes as an electron acceptor, the biodegradation process can be significantly accelerated, leading to increased through put capacity of a treatment system aerobic treatment has many advantages including minimum odor when properly loaded and maintained, large biochemical oxygen demand (BOD) removals providing a good quality effluent, high rate treatment allowing smaller scale systems, e.g., less land required, the final discharge may contain dissolved oxygen which reduces the immediate oxygen demand on a receiving water, and the aerobic environment eliminates many pathogens present in agricultural wastes. Aerobic digestion of waste is the natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste. During oxidation process, pollutants are broken down into carbon dioxide (CO_2), water (H_2O), nitrates, sulphates and biomass (microorganisms). By operating the oxygen supply with aerators**,** the process can be significantly accelerated**.** Aerobic bacteria are very efficient in breaking down waste products. The result of this is; aerobic treatment usually yields better effluent quality that that obtained in anaerobic processes. The aerobic pathway also releases a substantial amount of energy. A portion is used by the microorganisms for synthesis and growth of new microorganisms. The figure 1 had shown the aerobic biological oxidation of organic wastes.

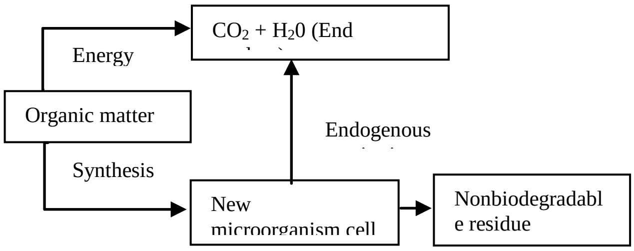

Figure 1: aerobic biological oxidation of organic wastes [10].

Nonbiodegradable residue

II.2.2. Anoxic Treatment Systems

A biological process in which a certain group of microorganisms use chemically combined oxygen such as that found in nitrite and nitrate. These organisms consume organic matter to support life functions. They use organic matter, combined oxygen from nitrate, and nutrients to produce nitrogen gas, carbon dioxide, stable solids and more organisms. Anoxic processes are typically used for the removal of nitrogen from wastewater. The process of biological nitrogen removal is known as denitrification. Denitrification requires that nitrogen be first converted to nitrate, which typically occurs in an aerobic treatment process such as a trickling filter or aerated suspended growth system. The nitrified water is then exposed to an environment without free oxygen. Organisms in this anoxic system use the nitrate as an electron acceptor and release nitrogen in the form of nitrogen gas or nitrogen oxides. A readily biodegradable carbon source is also needed for efficient denitrification processes to occur. It should be noted that sulfate can also be used as an electron acceptor, resulting in the formation of hydrogen sulfide.

II.2.2. Anaerobic Treatment Systems

Anaerobic treatment is that no aeration is applied. The absence of oxygen lead to controlled anaerobic conversions of organic pollutants to carbon dioxide and methane, utilized as energy sources. Many toxic and recalcitrant organic compounds are degraded under anaerobic conditions, with the compound serving as a growth substrate with fermentation. Advantages of anaerobic treatment are the very high loading rates that can be applied (10 to 20 times as high as in conventional activated sludge treatment) and the very low operating costs. Anaerobic treatment often is very cost-effective in reducing discharge levies combined with the production of reusable energy in the form of biogas. In this systems, most of the biodegradable organic matter present in the waste in converted into biogas (about 70 to 90%), which is removed from the liquid phase and leaves the reactor in a gaseous form. Only a small portion of the organic material is converted into microbial biomass (about 5 to 15%) which then constitutes the excess sludge of the system [16].

One of the most important steps in anaerobic treatment is the reactor start-up. The reduction of start-up period is therefore one of the key parameters in increasing the competitiveness of anaerobic reactors. From a microbial viewpoint, start-up represents a condition of imbalance and stress. Anaerobic degradation requires the coordinated metabolism of different microbial populations. These groups of microorganisms are interdependent, and a dynamic balance must be achieved for efficient treatment. The adaptation of the microbial populations to attain dynamic balance occurs during start-up and the use of granular biomass allows reduction in this phase operation because it presents better settling characteristics and higher specific methanogenic activity [19].

Anaerobic digestion is a complex biochemical reaction carried out in a number of steps by several types of microorganisms that require little or no oxygen to live. During this process, a gas that is mainly composed of methane and carbon dioxide, also referred to as biogas, is produced. The amount of gas produced varies with the amount of organic waste fed to the digester and temperature influences the rate of decomposition and gas production. The flow pattern and the formation of intermediate metabolites during degradation depend on the microbial status and the operating condition.

There are 4 steps in anaerobic digestion. The first step is hydrolysis of biopolymers (complex organic matter) such as proteins, carbohydrates and lipid. The complex organic matter is decomposed into simple soluble organic molecules using water to split the chemical bonds between the substances which produce amino acids, sugars, and higher fatty acids. The next step in degradation is often referred to as fermentation or acidogenesis, the chemical decomposition of carbohydrates by enzymes, bacteria, yeasts, or molds in the absence of oxygen. Then, acitogenesis which the fermentation products are converted into acetate, hydrogen and carbon dioxide by what are known as acetogenic bacteria. These products are the only substrates that can be metabolized efficiently by the methanogens in the final stages of anaerobic digestion. The acetogenic bacteria grow in close association with the methanogenic bacteria during the fourth stage of the process. The reason for this is that the conversion of the fermentation products by the acetogens is thermodynamically only if the hydrogen concentration is kept sufficiently low. This requires a close relationship between both classes of bacteria. The methanogens are strict anaerobes and form methane gas as the end product of their metabolism. This formed from acetate and hydrogen/carbon dioxide by methanogenic bacteria [3]

II.3. Sequencing Batch Reactor (SBR) and the Fundamental

The sequencing batch reactor (SBR) was introduced by Irvine and Davis (1971) to describe a specific type of activated sludge periodic process designed to treat wastewater generated during the manufacture of specialty carbohydrate. SBR was characterized by continuous repetition of periods called fill, react, settle, draw and idle. The treatment cycle can be adjusted to undergo aerobic, anaerobic, and anoxic conditions in order to achieve biological nutrient removal, including nitrification, denitrification, and some phosphorus removal [29]. Advantages of is equalization and the ability to tolerate peak flow and shock loads of BOD_5. The primary clarification, biological treatment, and secondary clarification can be achieved in single reactor vessel. Operation flexibility and control of effluent discharge and can minimal the footprint. Then, the potential capital cost saving by eliminating clarifiers and other equipment SBR [28].

SBR technology is a conventional process for removing nutrients form wastewater. This configuration has a higher flexibility and controllability, allowing more rapid adjustment to changing influent characteristic. It has lower investment and recurrent cost is necessary because secondary settling tanks and sludge return systems are not required. All the SBR processes are conducted in a single reactor following a sequence of fill, reaction, settling and draw phase. The cycle configuration depends on the wastewater characteristic and legal requirements. The fill phase my be static, mixed or aerated, depending on treatment objectives. A static fill is characterized by no mixing or aeration which means that there will result in minimum energy input and high substrate concentration at the end of the fill phase or when mixing begin. A high food to microorganisms (F/M) ratio creates an environment favorable to floc forming organisms versus filamentous organisms, which provides good settling characteristics for the sludge. In static fill conditions favor organisms that produce internal storage products during high substrate conditions, a requirement for biological phosphorus removal. The mixed fill phase is the influent is mixed with the biomass, which initiates biological reactions. During mixed fill, bacteria biologically degrade the organics and use residual oxygen or alternative electron acceptors, such as nitrate will result in denitrification, if nitrates are present and provide under anoxic conditions. After the microorganisms use the nitrate, sulphate becomes the electron acceptor. In aerated fill phase, it will result in the beginning aerobic reactions hold substrate concentrations low, which may be of importance if biodegradable constituents exist that are toxic at high concentrations [14]

When focusing on the length of the fill phases both short and long fill phases are found. If the fill is short, the process will be characterized by a high instantaneous process loading factor, thereby making it analogous to a continuous system with a tank in series configuration. In that case, the biomass will be exposed initially to high concentration of organic matter and other wastewater constituents, but the concentration will drop over time. Conversely, if the fill phase is long, the instantaneous process loading factor will be small and the system will be similar to a completely mixed continuous flow system in it performance. This means that the biomass will experience only low and relatively constant concentrations of the wastewater constituents. The long fill can applied during the whole operational time becoming a continuous fill phase. The react phase is usually under mixing condition. The biomass consumes the substrate under controlled environmental conditions (aerobic, anoxic or anaerobic) depending on wastewater treatment. Aerobic react phases are organic matter oxidation and nitrifications take place. In an anoxic condition are classical heterotrophic denitrification process and the phosphorus uptake. During an anaerobic phase, phosphate is released into the liquid phase [14, 21, 27]. Table 1 and 2 shown the previous researches using SBR reactor and previous researches leachate using SBR reactor.

Table 1: Previous researches using SBR reactor.

Type of wastewater	Operation	Removal (%)			References
		COD	NH_4-N	PO_4-P	
Landfill leachate after the yielding water ammonia stripping and UASB	• Raw water, temperature, (120L, 22-25^{0}C) • Mode 1 (A/O) = inflow (0.25h), hypoxia mixing (6.0h), aerobic aeration (16.0h), precipitation (1.5h), drainage (0.25h) • Mode 2 (A/O/A/O) = inflow (0.25h), hypoxia mixing (3.0h), aerobic aeration (10.0h), hypoxia mixing (3.0h), aerobic aeration (6.0h), precipitation (1.5h), drainage (0.25h) • Mode 3 (A/O/A/O) many-point-water-inflow process= inflow (80L), hypoxia mixing (3.0h), aerobic aeration (10.0h), inflow (40L), hypoxia mixing (3.0h), aerobic aeration (6.0h), precipitation (1.5h), drainage (0.25h).	71.7	92.4		[31]
Piggery wastewater	• Temperature (30^{0}C),SRT (1d), HRT (11d), 8h cycle, MLSS (2420 mg/L) added external organic carbon source- acetic acid	70.2	99.7	97.3	[13]
Pre-treated landfill leachate	• Five step – An/Ax/Ox/Ax/Ox (1/1/2/1/2h • Pre-treated + domestic wastewater (1:1) • Pre-treated + domestic wastewater + 1 gL^{-1} PAC	62 64 75	31 23 44	19 26 44	[26]
Urban wastewater	• Reaction 6.5 h (anoxic – 23.1% of total reaction time and aerobic – 76.9% of total reaction time) • Settle (1h) • Draw (30 min)	92-98	87-92		[15]
Swine manure	• Reaction anerobic and anoxic stages • 3 cycles per day • 8h per cycle • Temperature 20^{0}C, SRT (15d), HRT (3d),	97.4	99.9	89	[32]
Landfill leachate	• Aerobic fill (0.15 h) • Aerobic react (2.0 h) • Anoxic react (1.0 h) • Settle (0.30 h) Draw (0.08 h)	90	70		[12]
Chemical industrial wastewater	• Temperature 30^{0}C, MLSS 3000-3100 mg/L		97		[30]
Palm oil mill effluent POME	• 2L, air flow = 4.5 L/min, 350 rpm, • 22 h cycle,(react = 20 h, settle = 2 h) Dilution factor 10.0, 2.0, 1.3, and 1.0 daily batch-fed into SBR ambient temperature 28±2^{0}C in 4 week.	91-96			[2]
Landfill leachate	• Fill (25 min) • Reaction anoxic (3 h), oxic (1 h) • Settle (5 min) • Draw (25 min)	88.9-94.9	94.6		[6]
Meat industry	• 8h three cycles performed per day. • 35 min of filling • 6h of reaction (oxic and anoxic), in reaction 8 min of aeration 15 min of mixing. • 2h of sedimentation .		71		[18]

Table 2: Previous Researches Leachate Using SBR Reactor

Type of wastewater	Operation	Removal (%)			References
		COD	NH_4-N	PO_4-P	
Landfill leachate after the yielding	• Raw water, temperature, (120L, 22-25^{0}C)	71.7	92.4		[31]

water ammonia stripping and UASB	• Mode 1 (A/O) = inflow (0.25h), hypoxia mixing (6.0h), aerobic aeration (16.0h), precipitation (1.5h), drainage (0.25h) • Mode 2 (A/O/A/O) = inflow (0.25h), hypoxia mixing (3.0h), aerobic aeration (10.0h), hypoxia mixing (3.0h), aerobic aeration (6.0h), precipitation (1.5h), drainage (0.25h) • Mode 3 (A/O/A/O) many-point-water-inflow process= inflow (80L), hypoxia mixing (3.0h), aerobic aeration (10.0h), inflow (40L), hypoxia mixing (3.0h), aerobic aeration (6.0h), precipitation (1.5h), drainage (0.25h).				
Landfill leachate	• HRT – 10d, 2-1 L • Influent wastewater – 3800- 15900 mgL^{-1}	85			[25]
Pre-treated landfill leachate	• Five step – An/Ax/Ox/Ax/Ox (1/1/2/1/2h	62	31	19	[26]
	• Pre-treated + domestic wastewater (1:1)	64	23	26	
	• Pre-treated + domestic wastewater + 1 gL^{-1} PAC	75	44	44	
Landfill leachate	• Aerobic fill (0.15 h) • Aerobic react (2.0 h) • Anoxic react (1.0 h) • Settle (0.30 h) Draw (0.08 h)	90	70		[12]
Landfill leachate	• Fill (25 min) • Reaction anoxic (3 h), oxic (1 h) • Settle (5 min) • Draw (25 min)	88.9-94.9	94.6		[6]

III. Research Methodology

III. 1. Wastewater Samples

This treatment of sequencing batch reactor (SBR) has been chosen as the method of leachate treatment derived from Pasir Gudang Sanitary Landfill. The experiment will be conducted at Environment Engineering Laboratory, Faculty of Engineering Civil and Environment, UTHM.

Pasir Gudang Sanitary Landfill is located. The landfill was constructed in June 2002. The raw wastewater and activated sludge were collected from the landfill. Leachate was preserved at 4^0C in the cold room to prevent the occurrence of chemical and biological activities.

Sample was removed and left at room temperature prior to analysis and further treatment. Leachate samples were removed from the refrigerator and were placed about 2h at room temperature.

III. 1. Apparatus

In this study, the equipment will use is sequencing batch reactor (SBR), spectrophotometer DR5000, Hach Program 435 COD HR, pH meter, MLSS measurements, Oven –Model Memmert, Dissolved Oxygen meter (DO), peristaltic pump, and air pump. Table 3 has shown the dimension of SBR reactor.

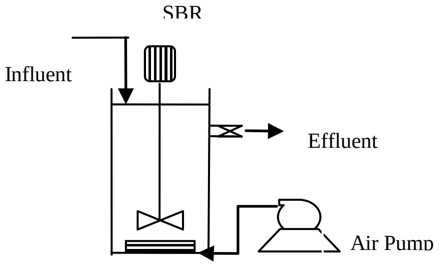

Figure 2: A Schematic diagram of the laboratory scale of SBR

Table 3: Dimensions of the SBR reactor

Dimension	Measurement value
Height, H	31.5 cm
Inside Diameter	15.0 cm
Depth, D	28.5 cm
Working volume, V_w	3 L

III. 2. Experimental set-up

In biological treatment the equipment used is laboratory-scale SBR reactor which was designed as in the schematic diagram shown (Figure 2). Figure 3 had shown a flow chart diagram of the laboratory scale of SBR. Working volume up to 3 L was used as the sequencing batch reactor (SBR). The bioreactor was microprocessor controlled for aeration, agitation, and dissolved oxygen (DO). Aeration was provided by using an air pump and a sparger. Agitation system is close system by mechanical seal/magnetic driving speed and was varied between 20-200 rpm, dissolved oxygen (DO) and oxidation-reduction potential (ORP) of the nutrient medium were continuously monitored by the relevant probes. Table 3 and table 4 have shown the typical of the SBR processes and typical of the SBR operation.

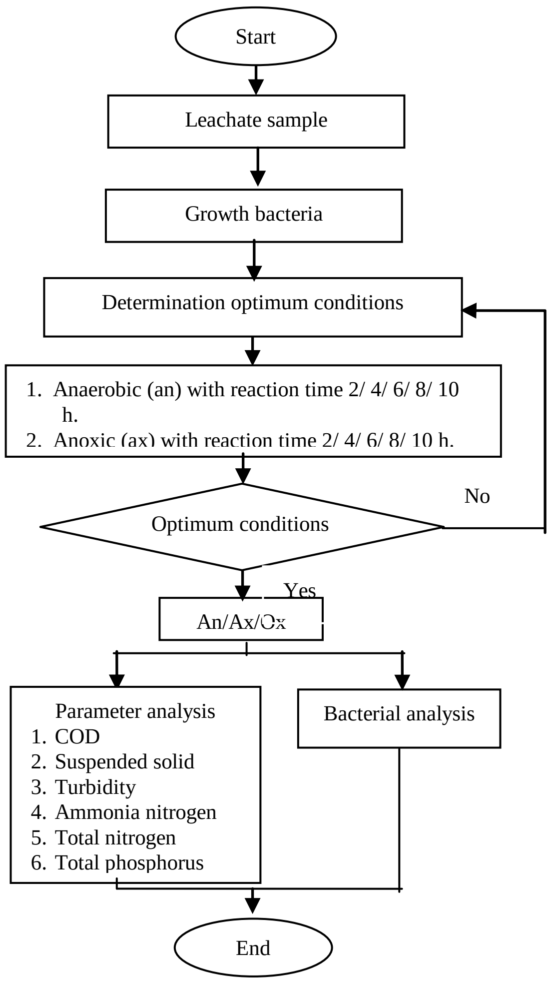

Figure 3: A flow chart diagram of the laboratory scale of SBR

Table 4: Typical of the SBR processes

Condition	Anaerobic	Anoxic	Aerobic
Fill	• 3L of raw leachate were pump and mixes with activated sludge in the reactor	• 3L of raw leachate were pump and mixes with activated sludge in the reactor.	• 3L of raw leachate were pump and mixes with activated sludge in the reactor.
React	• Agitation system is close system by mechanical seal. • Nitrogen gas was passed though media during anaerobic operation • Biological reactions occur until the desired degree of treatment has been achieved.	• Agitation system is close system by mechanical seal. • Biological reactions occur until the desired degree of treatment has been achieved.	• Agitation system is close system by mechanical seal. • Air supply was provided during the aerobic phase of react period. • Biological reactions occur until the desired degree of treatment has been achieved.
Settle	• The activated sludge solids settle down to form a blanket on the base of the reactor tank, leaving an over-layer of treated effluent.	• The activated sludge solids settle down to form a blanket on the base of the reactor tank, leaving an over-layer of treated effluent.	• Aeration is stopped • The activated sludge solids settle down to form a blanket on the base of the reactor tank, leaving an over-layer of treated effluent.
Decant	• The liquid surface which is effluent (supernatant) is removed from tank.	• The liquid surface which is effluent (supernatant) is removed from tank.	• The liquid surface which is effluent (supernatant) is removed from tank.
Idle	• Period between Decant and Fill.	• Period between Decant and Fill.	• Period between Decant and Fill.

Table 5: Typical of the SBR operation

Condition	Anaerobic	Anoxic	Aerobic
DO (mg/L)	0	0-0.3	4-6
HRT (h)	5/7/9/11/13	5/7/9/11/13	5/7/9/11/13
ORP (mv)	-200	+60	+200

III. 3. Experimental procedure

Experiment on laboratory scale of SBR was carried out to investigate the removal efficiency of suspended solid (SS), color, chemical oxygen demand (COD), ammonia-nitrogen, total nitrogen (TN), and total phosphorus (TP). The operational of the experiment were performed following the order: Fill, React, Settle and Decant. Before starting SBR operation, the reactor was filled with the leachate were pump and mixes with activated sludge for several days to obtain a dense culture to start with. After sedimentation of the organisms, 2 L of the clear supernatant was removed and the reactor was filled up to 3 L total volume. A friction of the culture was removed from the reactor before sedimentation everyday to adjust the MLSS to the desired level. pH was controlled around T = 25 ^{0}C.

Then, operation is starts with anaerobic condition to get the optimum reaction time in 2/4/6/8/10 h. The MLSS range 8000 - 12000 mg/L. Agitation speed during anaerobic and anoxic cycles was 25 and 50 rpm, respectively. The media was aerated and agitated (200 rpm) vigorously during aerobic phases. Nitrogen gas was passed through the media only during anaerobic operation. Dissolved oxygen (DO) concentration in anaerobic and anoxic phase was kept 0 and 0.3 mg/L while the DO during aerobic phases was kept above 2 mg/L. The sequencing batch reactor is operated consisting of fill, react, settle, decant. At the end of each SBR operation, the organisms were sediment for 2 h and 2 L of treated leachate was removed. Experiment with is repeated three times to obtain average values. Step was repeated with anoxic and aerobic phases. Table 6 has shown the experimental condition.

Condition	Fill (hours)	React (hours)	Settle (hours)	Decant (hours)
anaerobic	0.5	2/4/6/8/10	2	0.5
anoxic	0.5	2/4/6/8/10	2	0.5
aerobic	0.5	2/4/6/8/10	2	0.5

Table 6: Experimental condition

In studies to investigate the effects of the SBR's performance in combination condition operation consisting anaerobic, anoxic and aerobic. Reaction time of each phases depend on optimum reaction time each phases before. The MLSS range 8000 - 12000 mg/L. Agitation speed during anaerobic and anoxic cycles was 25 and 50 rpm, respectively. The media was aerated and agitated (200 rpm) vigorously during aerobic phases. Nitrogen gas was passed through the media only during anaerobic operation. Dissolved oxygen (DO) concentration in anaerobic and anoxic phase was kept 0 and 0.3 mg/L while the DO during aerobic phases was kept above 2 mg/L. The sequencing batch reactor is operated consisting of fill, react, settle, decant. At the end of each SBR operation, the organisms were sediment for 3 h and 2 L of treated leachate was removed. Experiment with is repeated three times to obtain average values.

IV. Result

Characteristic of treated Pasir Gudang Sanitary Landfill leachate.

Parameter	Result
pH	8.06
Turbidity (NTU)	841
BOD (mg/L)	2107
COD (mg/L)	6000
Suspended Solid (mg/L)	576
Colour (ADMI)	1050
Ammonia Nitrogen (mg/L)	50.638
Total Phosphorous (mg/L)	24
Total Nitrogen (mg/L)	700
Total organic carbon (TOC) (mg/L)	185
Tannin and Lignin (mg/L)	17
Sulfate, SO_4^{2-} (mg/L)	1005

V. Expected Research Outcomes

The expected outcomes of this research is the effectiveness performance of on removal of suspended solid (SS), turbidity, chemical oxygen demand (COD), ammonia-nitrogen, total nitrogen (TN), and total phosphorus (TP) from leachate which is 80%, 80%, 90%, 76%,80%, and 70% respectively.

VI. Conclusion

Wastewater treatment has been a challenge throughout the years due to varying influent chemical and physical characteristics and stringent effluent regulations. The availability of technology has now made the option of a SBR process more attractive thus providing better controls and results in wastewater treatment. The flexibility of a SBR in the treatment of variable flows, minimum operator interaction required option for anoxic or anaerobic conditions in the same tank, good oxygen contact with microorganisms and substrate, small floor space, and good removal efficiency.

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