CHAPTER 2

Literature Review

2.1 Overview

The main function of wastewater treatment plants (WWTP) is to protect the environment and human health from excessive overloading from different types of pollutants (Qasem & Qasem, 2011). Nowadays, WWTPs are continuously challenged to satisfy new constraints in term of quality of the discharged effluent for the compliance with stringent environmental regulations (Corona et al., 2013). Domestic wastewater usually contains grey water, which is wastewater generated from washrooms, bathrooms, laundries, kitchens etc. It also contains black water made up of urine, excreta and flush water generated from toilets (Sukumaran et al., 2015).

Physical, chemical and biological processes are applied to remove physical, chemical and biological contaminants. The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment (Sonune & Ghate, 2004). Treated wastewater should be optically clear and no longer contain any substances, which are harmful to nature or people. Discharge of domestic wastewater in any water body can be harmful to the environment. Therefore, treatment of any kind of wastewater to produce effluent with good quality is necessary. In this regard, choosing an effective treatment system is important. Adopting as low a level of treatment as possible is especially desirable in developing countries, not only from the point of view of cost but also in acknowledgement of the difficulty of operating complex systems reliably (Bhatia, 2005). In many locations, it will be better to design the reuse system to accept a low-grade of effluent rather than to rely on advanced treatment processes producing a reclaimed effluent that continuously meets a stringent quality standard.

The design of wastewater treatment plants is usually based on the need to reduce organic and suspended solids loads to limit pollution of the environment. Wastewater discharge permits are becoming more stringent and activated sludge and constructed wetland systems offer a cost-effective way to achieve lower effluent limits.

2.2 Activated Sludge Process

As generally known, the AS process was invented in England at the beginning of this century. Activated sludge is a process dealing with treatment of sewage and industrial wastewaters and developed around 1912-1914 (Metcalf et al., 2003).The AS process uses microorganisms to feed on organic contaminants in wastewater, producing a high-quality effluent. The basic principle behind all activated sludge processes is that as microorganisms grow, they form particles that clump together. These particles (floc) are allowed to settle to the bottom of the tank, leaving a relatively clear liquid free of organic material and suspended solids. Role of the microorganism in wastewater treatment has been shown in the following equation (Metcalf et al, 2003).

$$\upsilon_1(\textit{organic matter}) + \upsilon_2\, O_2 + \upsilon_3\, NH_3 + \upsilon_4\, NH_3^{\,3-} \xrightarrow{\textit{microorganism}} \upsilon_5(\textit{new cells}) + \upsilon_6\, CO_2 + \upsilon_7\, H_2O$$

where υ_i *= the stoichiometric coefficient*

Microorganism feed on the organic matter, nutrients and produced the new cell. These excess cells remove from the system as waste sludge and treated water elute the system.

The principle AS processes used for wastewater treatment can be divided in to two main categories: suspended growth and attached growth processes (Metcalf et al., 2003). The conventional AS process is a suspended growth technology comprising of an enrichment culture of microbial consortia in order to remove impurities and transform wastewater into environmentally acceptable quality. The schematic diagram of the AS process layout was shown in the Figure 1 (Metcalf et al., 2003).

Preliminary treatment consists with screening and grit chamber that removed the coarse and sand particles from the effluent.

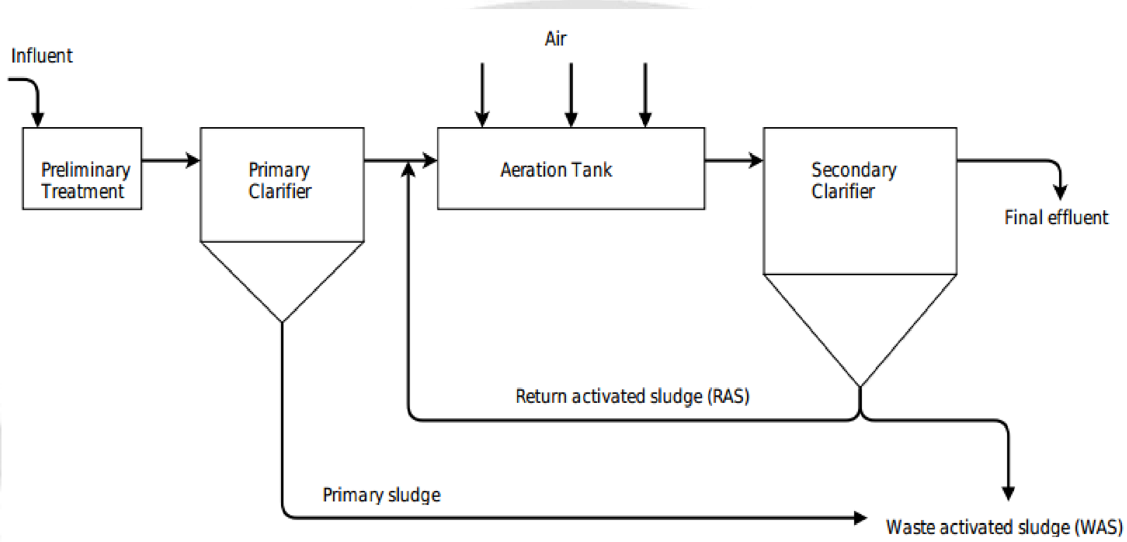

Figure 2.1 Schematic diagram of activated sludge process layout

This chamber only wants to remove coarse grit and the wastewater spends only a relatively short period in it (UNEP & Murdoch University, 2004). Smaller solids are removed in a primary clarifier. In this unit, the wastewater spends more time to allow for a good separation. The sludge from this mechanical primary treatment is called primary sludge and, as all excess sludge, requires an advanced further treatment chain. After this primary treatment, the main unit containing the AS follows. The pre-treated wastewater is mixed with the concentrated underflow AS from the secondary clarifier in an aerated tank. After a few hours in the aeration chamber, the mixture then enters the secondary clarifier, where the flocculated microorganisms settle and are removed from the effluent stream.

The settled microorganisms (the activated sludge) are then recycled to the head end of the aeration tank to be mixed again with wastewater and continue to grow and form new sludge and to degrade organics. Excess sludge produced each day (waste activated sludge) must be processed in a further treatment chain together with the sludge from the primary treatment facilities. A conventional excess sludge treatment chain consists in anaerobic digestion, thickening, incineration and the safe disposal.

2.3 Constructed Wetlands

Constructed wetlands (CWs) have been proven to be a suitable wastewater treatment system for developing countries in tropical areas where land is available at low cost and warm temperatures are suitable for biodegradation (Kantawanichkul et al., 2013). CWs are artificial system, designed and constructed to utilize the natural processes of wetland vegetation, soil and their microbial consortium to treat the contaminants in waste streams (Vymazal, 2010). They are fabricated to obtain advantage of processes that occur in natural wetlands, but designed within a more controlled environment. CWs for wastewater treatment may be classified according to the life form of the dominating macrophyte, into systems with free-floating, floating leaved, rooted emergent and submerged macrophytes (Brix & Schierup, 1989). Further division could be made according to the wetland hydrology for example, free water surface and subsurface systems. The subsurface flow CWs could be classified according to the flow direction (horizontal and vertical) (Vymazal, 2005). Various types of constructed wetlands were combined in order to achieve higher treatment effect, especially for nitrogen.

A typical floating aquatic macrophyte constructed wetlands (FAMCW) consisted with shallow sealed basin or sequence of basins, containing with a water depth of 20 – 40 cm. Dense vegetation covers a significant fraction of the surface, usually more than 50% (Vymazal, 2010). FAMCWs are commonly used for treatment of runoff waters such as urban (Scholes et al., 1999) , road and highway (Pontier et al., 2004), airport (Thorén et al., 2003), golf course (Kohler et al., 2004), agriculture (Raisin et al., 1997). Constructed wetlands are commonly used for secondary treatment in small communities (Kadlec, 2009). However, they need a large land area (Barros et al., 2008) .Therefore, it is sometimes necessary to add a previous treatment stage to the natural treatment system (Ansola et al., 2003). Sizing of FAMCW s is usually based either on volume or area. Volume-based methods use a HRT to assess the pollutant removal while area-based methods assess pollutant reduction using the overall wetland area (Wallace, 2006). The previous study shown that nitrogen removal efficiency was highest by water hyacinth fallowed by water lettuce and duckweeds, and phosphorus removal in summer was highest by water hyacinth (Reddy & Busk, 1985). Water hyacinth showed high efficiency of nutrient removal capacity due to vegetative reproduction and vigorous growth rate (Sanmuga & Selvan, 2017). Moreover, Oladejo et al., (2015) conduct the experiment on kitchen wastewater treatment with CW using water hyacinth and observed that 77.5% reduction of BOD and 66.7% reduction in nitrate during the experiment. Thus in this experiment, water hyacinth was selected as aquatic macrophytes due to the high efficiency of nutrient removal capacity from wastewater. Qiu et al, (2010) stated that the water hyacinths in the CW were transplanted from nearby waterways and initially about 59% of the total CW water surface area and 60% of the FAMCW was covered by water hyacinth initially.

2.4 Hydraulic Retention Time (HRT)

HRT is regarded as one of important operating parameters affecting the performance and microbial community of activated sludge process. HRT in the sewage treatment system has an important effect for controlling wastewater treatment efficiency and the volume of the biological reactor. Recently, the effect of HRT on pollutant removal rate was researched in activated sludge system, membrane bioreactor system, biological aerated filter (BAF), anaerobic sequencing batch reactor (ASBR) and constructed wetlands.

Wang et al., (2015) and Abbas et al., (2001) stated that boosting of HRT was directly proportional to the removal efficiency of BOD and COD. Wang et al., (2015) determined that average removal efficiencies of COD and ammonia nitrogen decreased from 90 and 85 % to 68 and 71 % with the decrease in hydraulic retention time from 17 to 9 h, respectively. Durai et al., (2011) investigated the effect of HRT on the performance of SBR treating tannery wastewater by salt-tolerant bacterial strains, and they found that the COD removal efficiency significantly decreased with the decrease in HRT from 3 to 2 days. Kumar et al., (2014) evaluated the Effect of mixed liquor volatile suspended solids (MLVSS) and hydraulic retention time on the performance of activated sludge process and they found that decolourization and chemical oxygen demand removal increased with increase in MLVSS and HRT. Yu et al., (2014) studied on hospital wastewater treatment and effect of HRT on BOD, COD and Suspended solid removal was investigated. The results showed that the removal rate of BOD, and COD was ascending with the increase of HRT using the contrast test of five different HRTs.

Krumins et al., (2002) had tested prototype reactor with aqueous leachate from wheat crop residue at 24, 12, 6, and 3 h HRTs and found that BOD removal efficiency was decreased significantly from 92% at the 24 h HRT to 73% at 3 h Lateef et al., (2013) ware researched to evaluate the performance of a laboratory-scale biological treatment unit for dairy-industry wastewater and found that BOD_5 and COD removal efficiency improved with increase in HRT.

Merino et al., (2015) assessed the performance of a municipal pilot wastewater treatment system employing an up-flow anaerobic filter (UAF) followed by a horizontal subsurface constructed wetland (HSSCW) and evaluated three HRT of 18, 28 and 38 h in the UAF, which corresponds to two, three and four days in HSSCW over 66 weeks. The mean efficiencies found for the complete system were 80% and 90% of BOD, 80% and 86% of COD, 30% and 33% of N_{tot} and between 24% and 44% of P_{tot}. It was possible to remove almost 80% of organic matter in 18 h in the UAF while the HSSCW reached 30% of removal for N_{tot} in a HRT of three days. Those results showed that the UAF was responsible for removing most of the organic matter and the HSSCW removed most of the nitrogen.

2.5 Relative Growth Rate of Water Hyacinth

The water hyacinth is a perennial, mat forming, floating aquatic plant of wide distribution in tropical, subtropical, and warm temperate regions throughout the world (Penfound & Earle, 1948). The characteristics make this plant grow rapidly in polluted waters make it an ideal candidate for large-scale application for nutrient removal and water purification (Reddy & Sutton, 1984). Relative growth rate (RGR) is a prominent indicator of plant strategy with respect to productivity as related to environmental stress and disturbance regimes (Hunt, 1982). The RGR is measured based on dry-mass basis including roots and used to calculate the rate of plant growth. It is measured as the mass increase per total biomass per day.

The fresh (FW) to dry weight (DW) ratio was calculated and the relative growth rate (RGR, d^{-1}) was calculated by (Equation 2.1) (Beadle, 1985):

$$RGR = \frac{\ln(W_2/W_1)}{t_2 - t_1} \quad \text{Equation 2. 1}$$

where W_1 and W_2 are the initial and final DW (g), and t_1 and t_2 are the initial time of pant growing in the reactor (days) respectively.