WASTEWATER TREATMENT SYSTEMS FOR SMALL SITES IN SARAWAK

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Abstract

The discharge of untreated or inadequately treated wastewater will impose heavy loads on the capacity of the receiving water body, endangering public health and the surrounding environment. For Sarawak, this is crucial as most of its source of water supply comes from rivers. The predominant domestic wastewater treatment system in Sarawak is primary treatment of municipal sewage (blackwater), accomplished with individual septic tanks (ISTs). There are also a handful of small, centralized wastewater treatment facilities for small sites. Effective alternative wastewater treatment systems need to be explored to improve wastewater management. In this study, examples of sustainable wastewater treatment systems from a variety of sites and situations will be presented and discussed. In addition, various existing methods used for both domestic and commercial wastewater treatment in Sarawak are presented. The principle treatment processes for each method are briefly discussed, and benefits for the system are presented. Furthermore, there is a need for a study on centralized wastewater treatment facilities for small, commercial or institutional sites, such as a University, or other institution of higher learning. The wastewater generation patterns for such sites may be different from the expected characteristics for domestic wastewater generation. The Intermittent Decanted Extended Aeration (IDEA) Activated Sludge System used in Curtin University Sarawak Campus, Miri is investigated and the viability and sustainability of the system to be adopted for other institutions of higher learning or campuses in Malaysia is discussed. Furthermore, to characterise wastewater generation for a commercial site, the wastewater production and generation pattern in Curtin University Sarawak Campus is studied. The main finding from this study is that diurnal wastewater generation patterns for commercial sites are different from diurnal domestic generation patterns. The overall wastewater production during the semester break is significantly less than during teaching weeks, and is comparable to wastewater production during the weekends of the teaching weeks. The main factors that influence the wastewater variations in an institution of higher learning is the size of the population and the activities carried out in the institution, including seasonal activities. The data collected from the wastewater quantification study could be used as a useful reference data for other similar institutions of higher learning, in choosing a viable and sustainable wastewater treatment system.

Keywords: Wastewater treatment, wastewater generation, domestic wastewater, sustainable wastewater treatment

1. Introduction

Wastewater management is an increasingly serious issue, demanding attention in both developing and fully industrialised nations worldwide. It is one of the associated problems that developing countries like Malaysia experiences due its rapid development and urbanisation. In Malaysia, about six million tons of wastewater is generated annually by its 26 million inhabitants (Asian Development Bank 2006). The wastewater is treated to varying levels and discharged into the rivers, from which most of Malaysia's fresh water supply comes from. This is certainly unhealthy and an unsustainable means of disposing wastewater. A more effective and sustainable wastewater management would be required.

Similar to the rest of the country, the state of Sarawak is also growing and developing rapidly. Most cities in Sarawak such as Kuching, Miri, Sibu and Bintulu are experiencing explosive development. While this is an encouraging sign towards the growth of the nation, such rapid development could quickly degrade the quality of the surrounding environment if it is not planned carefully.

The predominant domestic wastewater treatment system in Sarawak is primary treatment of municipal sewage (blackwater), accomplished with individual septic tanks (ISTs) as with most of Malaysia (Tan, 2006). The discharge of this partially treated wastewater will impose heavy loads on the capacity of the receiving water body, endangering the health of the various rivers and streams. This will in turn affect public health and the surrounding environment. This is a crucial issue as most of the source of water supply comes from rivers.

A river quality baseline study (Larsen & Lynghus 2004) for Sarawak River in Kuching showed that the river was seriously polluted with faecal derived coliform bacteria due to discharge of partially treated or untreated wastewater rom the city into the river. This result created an alarming warning to the authorities to have a more effective wastewater management system for the city and for the whole state of Sarawak. Therefore all sustainable and feasible solutions for wastewater management in Sarawak and indeed Malaysia need to be explored urgently. It is important to have a wastewater treatment system that is appropriate in scale, cost, efficiency and flexibility, according to local situations.

In this study, sustainable wastewater management practices from various sites and situations are presented as case studies. A study of practices and management practices from overseas could be a starting point for our authorities to design and implement our own wastewater management techniques. Also, different wastewater treatment systems used in Sarawak were investigated and presented, particularly in the cities of Kuching, Miri and Bintulu. The principle treatment processes for each method are briefly presented, and any tangible benefits or disadvantages are discussed as well. This outlines the current wastewater management in practice in Sarawak.

In particular, the Intermittent Decanted Extended Aeration (IDEA) activated sludge wastewater treatment system used in Curtin University of Technology Sarawak Campus is studied, and the viability of the system to be adopted in other commercial or institutional sites such as institutions of higher learning are discussed.

There is also a need to investigate the centralized wastewater treatment for commercial sites, starting with small to medium sites such as a University or other institution of higher learning. The reason for this is because the wastewater generation patterns may be different from the established domestic diurnal wastewater generation patterns. If so, a study would be required to aid in design and planning of wastewater treatment and management facilities in such sites. In addition, commercial sites constitute major land usage in Sarawak and Malaysia, similar to residential sites. Thus the information and data derived from such studies could be useful for planners and engineers.

To characterise the wastewater generation for an institution of higher learning, a study on the quantification of wastewater based on water consumption was performed for Curtin University of Technology Sarawak Campus, which is located in Miri. From the obtained data, generation patterns of the wastewater could be derived. For new institutions of similar type in Malaysia, the data developed from this project will be a useful reference for estimating wastewater flow in the planning and design of their wastewater treatment facilities.

2. Research Methodology

To carry out this research, a desktop study of sustainable wastewater treatment and management practices around the world was undertaken. In addition, various wastewater treatment systems currently being used in Sarawak to the authors' knowledge was undertaken. In addition, numerous site visits were made to investigate the different wastewater treatment systems in Kuching, Miri and Bintulu. To collect data and information, interviews were carried out with engineers, maintenance technicians and other personnel-in-charge from local councils and other government regulatory bodies. Special attention was paid to the Intermittent Decanted Extended Aeration (IDEA) Activated Sludge Wastewater Treatment System at Curtin University Sarawak Campus, to investigate its feasibility for other institutions of higher learning or campuses in Malaysia. This is presented in the following sections of this paper.

A study into wastewater generation was also carried out at Curtin University Sarawak Campus, where the results and discussion are presented in the fourth section of this paper. Water consumption is used in many international surveys as an indicator of wastewater generation (Larsen & Lynghus 2004; Tchobanoglous, Burton & Stensel 2004). The fundamental assumption is that tap water consumed equal wastewater discharged into the wastewater treatment system. Therefore, the same approach is adopted for the wastewater generation study, by monitoring the water meters in Campus. Readings from the water meters, in units of litres, were taken every day from morning to night (7am to 9pm), for time intervals of 1 - 3 hours. These readings were collected everyday for the duration of a week, representing one wastewater generation data set. A total of three data sets were collected from the campus water meters for the study, during two typical teaching weeks and one semester break. The collected readings were then converted to cubic metres (m^3) and plotted against time as seen in Fig. 1 and 2.

3. Some Instances of Sustainable Wastewater Treatment

Many communities around the world are studying and testing alternative, small-scale and decentralized wastewater treatment systems. These systems are designed to be more environmentally friendly and sustainable. Some examples are presented here.

In anticipation of the 2008 Olympic Games in Beijing, the city is working with German collaborators, striving for long term solutions for wastewater treatment and its reuse with an Olympic-oriented programme (Ernst, et al. 2007). The main thrust of the initiative is to reclaim and reuse the treated wastewater. A total of 14 new wastewater treatment plants will be constructed to collect and treat 90% of the city's wastewater. Higher rates of reclamation are planned so that 50% of the treated wastewater will be reused mainly in the "Olympic Green", the centerpiece of the Olympic Games, consisting of stadiums, athletes' accommodation and artificial surface waters. The Beixiaohe and Qinghe Sewage Treatment Plants will supply the reclaimed water. At the moment, the envisaged treatment scheme had not been finalized yet. A partial choice of membrane bioreactor (MBR) at Beixiaohe and a submerged microfiltration system at Qinghe is decided for the moment. Testing on the usage of fixed-bed granular ferric hydroxide (GFH) absorbers for the MBR are already underway. This pilot project would be a good example for sustainable reuse technology throughout China and indeed the rest of the world.

In Australia, it appeared that there was no development of sustainable on-site wastewater treatment systems for remote resorts, which were not connected to the mains water and sewerage network. As presented in Kavanagh and Keller 2007, a pilot-scale engineered ecosystem (PSEE) system was designed to treat wastewater for a population equivalent (PE) of five persons, and operated for two years. The objective was to assess the performance of the system in terms of chemical oxygen demand (COD), solids and nutrients removal. It was found that the system was effective in removing influent COD (over 90%) but had low removal of nutrients (5% and 6% of influent nitrogen and phosphorus each). This is due to poor performance of some components of the system, indicating that further development may be necessary.

A wind-aerated, lagoon-based system was designed for the community in Errol, near Dundee in Scotland (Horan, et al. 2006). There was no history of wastewater treatment in the town. The treatment system treated screened sewage by both oxidative and reductive reactions. This would be similar to an oxidation pond treatment system. However, diffused air was provided to the lagoon when wind power was not sufficient. The system was found to be effective, producing highly treated effluent with low levels of biochemical oxygen demand (BOD) and suspended solids (SS), as well as nutrients and faecal coliforms. However, the cost incurred for the system per capita was quite high at 420 pounds.

4. Wastewater Treatment Systems in Sarawak

For most wastewater management systems in Sarawak, wastewater is separated at the generation source into blackwater and greywater. Blackwater is commonly treated in septic tanks or similar communal treatment facilities in housing estates or commercial buildings (Larsen & Lynghus 2004). Greywater is discharged directly into the local storm water drainage system or any receiving water body without any treatment; except in a few places where centralized wastewater treatment facilities are used, in which all the blackwater and greywater are collected together.

4.1 Individual Septic Tanks (ISTs). The predominant wastewater treatment system in Sarawak is primary treatment via individual septic tanks (ISTs) and there are only a few centralized wastewater treatment facilities for small sites. There are about 65,000 septic tanks in use in Kuching, 39,638 in Miri and 8,649 in Bintulu (Tan, 2006). Recent advances in the use of ISTs for domestic wastewater treatment to achieve complete or near-complete treatment of wastewater includes the use of infiltration trenches (Quisenberry et al., 2006), drainfields (Rainwater et al., 2005) and other modifications to the traditional ISTs. A low-cost, high-efficiency treatment system involving a combination of septic tanks, baffled facultative ponds and aerated rock filters was designed and used in the United Kingdom (Mara, 2006). However, to the authors' knowledge, these systems are not used in residential wastewater treatment in Sarawak.

Typical septic tanks have two simple chambers connected in series and a filter. Proprietary prefabricated septic tanks, which are typically cylindrical in shape, are made of fibreglass material. The performance of ISTs is greatly dependent on the retention time and regular desludging of the tanks; hence do not consistently achieve effluent quality Standard B of Environmental Quality Act 1974.

The main disadvantage of ISTs is that it only provides primary sewage treatment and is not an efficient means to treat wastewater. Properly designed and regularly maintained and desludged ISTs can only reduce the organic matter by about 50 % (Larsen & Lynghus 2004). In addition, pathogens and nutrients in the wastewater are not significantly reduced by the treatment. Effluent from the ISTs is discharged into the local drainage system, which is a network of open sewers that eventually outfalls into the local river system.

4.2 Imhoff Tanks (ITs). Imhoff tanks (ITs) are the second most commonly used wastewater treatment systems in Sarawak after septic tanks. The Imhoff tank used in Wisma Sarawak Electricity Supply Corporation (SESCo), Kuching serves a population up to 500 PE. Basically, the imhoff tank comprises of two compartments; namely the sedimentation compartment and sludge compartment. Sedimentation of solids takes place in the upper sedimentation compartment. The settled solids (sludge) pass through an opening in the bottom of sedimentation compartment into the lower sludge compartment, where they undergo anaerobic digestion (Crites & Tchobanoglous1998, p. 328). Similar to ISTs, ITs only provide primary treatment and the efficiency in treating wastewater is not consistent.

4.3 Open Aeration Wastewater Treatment System. The wastewater treatment system used in the Normah Medical Specialist Centre (NMSC), which is located at Petra Jaya, Kuching, is an elevated open-aeration centralized treatment system. It treats domestic wastewater from the medical centre and has a design capacity of 500 PE. The system consists of two aerators that operate alternatively, three pumps, one settlement tank and two chlorine injection points. The wastewater flow goes through the aeration process at the aeration tank before entering the sedimentation tank. After the sedimentation process, the treated wastewater will go through the chlorination process and lastly discharged into the local drainage system. The open aeration wastewater treatment system is capable of treating wastewater to a high extent. However, regular maintenance works are needed.

4.4 Extended Aeration Activated Sludge (EAAS) Wastewater Treatment System. Extended aeration activated-sludge system (EAAS) is one of the modified activated sludge treatment processes. The EAAS process requires a low organic loading and long aeration time (Crites & Tchobanoglous 1998; *Guidelines for Developers: Sewage Treatment Plants* 1998). By having longer hydraulic retention times, the system can operate more effectively over widely varying flow and waste loadings. The EAAS treatment system that serves Taman Jasmine is the only EAAS system in Bintulu.

The EAAS treatment process requires two operational units, in which aeration and settlement take place in each unit (Standards & Industrial Research Institute of Malaysia 1991). The screened wastewater will flow into the aeration unit where it is mixed with activated sludge and aerated. The sedimentation unit may be integrated with the aeration unit or it may be separated by partition. The sludge, which is separated from the wastewater in the settlement unit, is then recycled back to the aeration unit by gravity pump or airlift. This type of system requires less land use and is quite efficient in treating domestic wastewater. However, the excess sludge needs to be removed to eliminate operating problems. Other disadvantages include high maintenance costs as well as sound and odour nuisances to the nearby residents.

4.5 Hi-Kleen Wastewater Treatment System. The Hi-Kleen wastewater treatment system is an example of prefabricated package plants that function based on the principle of EAAS treatment process (PJBumi Berhad 2005). The incoming wastewater first passes through a screen chamber and a grit and grease chamber in order to remove the solids and inorganic materials. Then, the wastewater enters to the Hi-Kleen treatment system that consists of a series of tubular tanks. In the equalization tank, homogenous liquor is created by mixing the wastewater via air diffusers. The wastewater is then pumped into the flow control box, in which the flow will be regulated into the aeration tank. In the aeration tank, further mixing of wastewater takes place for a period of over 10 hours (PJBumi Berhad 2005). The mixing is created by the turbulence induced by diffused air from air diffusers. Sludge generated from the treatment process is separated in the sedimentation tank. A major portion of the sludge is recycled back to the aeration tank for continual operation of the treatment process. The excess sludge, on the other hand, is channelled to the sludge storage tank before disposal to the sludge drying bed.

The Hi-Kleen wastewater treatment system is used in University Malaysia Sarawak (UNIMAS). The two Hi-Kleen wastewater treatment plants in UNIMAS can serve up to 10,000 PE and 20,000 PE. The sludge from the treatment facilities is treated into horticultural fertilizer or soil conditioner for the university's plants.

4.6 Pond System. Pond or lagoon systems are engineered basins constructed to treat wastewater. Ponds are usually categorized by their aerobic status or dissolved oxygen concentration as well as the source of oxygen supply (Crites & Tchobanoglous 1998). Bintulu Town has a total of 33 pond systems to treat domestic wastewater, where by 30 ponds are individual temporary treatment ponds and the other 3 are centralized pond treatment systems, located in Kidurong 3, Jalan Tun Ahmad Zaidi and Jalan Tun Hussein Onn. Among the 33 ponds, only 5 of them are equipped with an aeration system. The ponds that are equipped with aeration system are known as aerated ponds, while the others are oxidation ponds.

Oxidation ponds are typically 1.5 m to 2.5 m deep. The treatment process in oxidation ponds is carried out by bacterial action in the upper layer, which is aerobic, and in a lower layer, which can be anaerobic. The oxygen is provided via photosynthesis by algae as well as natural surface aeration via wind action. The degree of wind-induced mixing affects the aerobic status of the lower layer of the pond. The advantage with this system is low construction and maintenance costs, minimal sludge generation and handling.

4.7 Ecological Sanitation (ecosan) Wastewater Treatment System. This pilot project at Hui Sing Garden in Kuching is a collaboration between the Sarawak Government and Danish International Development Assistance (DANIDA). A row of 9 terrace houses were selected for carrying out the pilot project (Bjerregaard 2004, p.14). The terrace houses are linked to the ecosan system, which is constructed at a large recreational park adjacent to the houses' backyards.

In the ecosan treatment system, the blackwater and greywater is treated separately. The greywater treatment system consists of oil and grease traps, biological vertical filters and a constructed wetland. The trap allows separation of the oil and grease from the greywater and settlements of solids. From the pilot project, it is found that the trap is 88% efficient in removing the oil and grease and effective in removing the bacteriological parameters and organic matter (Bjerregaard 2004). From the oil and grease trap, the wastewater is pumped into four domes, which act as biological filters (Bjerregaard 2004) to degrade the organic matters. After the filtering process, the wastewater flows to a constructed wetland before being discharged through an outlet pipe into the existing storm water drain (Bjerregaard 2004). The wetland consists of a layer of particle filter made of crushed limestone, which is used to absorb phosphorous from treated wastewater. The limestone can be used as fertilizer.For blackwater management in the ecosan system, holding tanks are used to collect the blackwater from toilets. The holding tanks should be emptied or desludged at a regular interval and the collected sludge will be sent to the sludge treatment plant at Matang, Kuching by tanker trucks for further treatment.

5. IDEA Treatment System In Curtin University of Technology Sarawak Campus

The wastewater treatment facility used in Curtin University Sarawak Campus is the Intermittent Decanted Extended Aeration (IDEA) Activated Sludge Wastewater Treatment System, which is one of the modified activated-sludge processes. In the IDEA activated sludge treatment system, all steps of the activated sludge process happen in one single reactor (Crites & Tchobanoglous 1998). The biological treatment and sedimentation processes are carried out sequentially in the same operational unit, which generally is an aeration tank. The wastewater inflow into the aeration tank is continuous and the mixture remains in it for the whole activated sludge treatment process (*Guidelines for Developers: Sewage Treatment Plants* 1998). As returning of sludge is not needed to maintain the sludge content in the aeration tank, separate secondary sedimentation facility is not required in IDEA system.

The current system faces problem in maintenance after about 5 years of operation. Large quantities of sand and grit are frequently found in the wastewater pumped from the students' lakeside apartment. This may be caused by the leakage of the underground piping system due to uneven settlement of the ground. It is observable that the ground at many areas in the campus is settling down gradually, since its completion in year 2002. Kaniraj and Joseph (2006) stated that the campus sits on soft clayey soils and could have settled more than 100 mm since 2002.

The IDEA activated sludge wastewater treatment system is a reliable treatment system, which can treat wastewater effluent to a high quality, with provision that regular maintenance is carried out. Hence, this system is viable to be used in other campuses or institution of higher learning in Malaysia. However, for a big campus with large compounds, a long piping system for the IDEA treatment system would be costly. Additionally, if the campus is located on soft soils or peaty areas, then the problems caused by soil settlement to the piping system would further deplete the values of the IDEA system. The maintenance works in repairing the leakage of the piping system or other similar malfunction would need to be carried out throughout the life-span of the system, incurring a high cost.

6. Wastewater Generation for an Institution of Higher Learning

Wastewater flow rates can be estimated from water consumption records (Larsen & Lynghus 2004; Tchobanoglous, Burton & Stensel 2004). The data collected from water consumption records are very useful for areas where the water usage for landscape irrigation is insignificant and 90 percent or more of water consumed becomes wastewater. Wastewater generation for Curtin University Sarawak Campus is quantified by monitoring the main water meter for the campus. Three sets of data have been collected during (i) Week 11 of semester one (end of a typical semester), (ii) Week 2 of semester two (beginning of a typical semester) and (iii) week free (semester break). The readings were collected from 7 a.m. until 9 p.m. with a time interval of between 1 to 3 hours. The three periods are chosen in order to investigate the difference in water consumption during regular sessions when classes are carried out as well as when classes are not in session (week free) to show seasonal variations in water consumption.

The water consumption or wastewater flows varies according to the time of day, different days throughout the week and during different periods or seasons in a year. The first and second variations are referred to as short-term variations in this paper, while the third variation is referred to as seasonal variation. Due to space constraints, only results from Week 11 of the semester will be shown, as seen in Fig. 1 and 2.

6.1 Week 11 of Semester One. The average cumulative water consumption in a day for Curtin University Sarawak Campus for week 11 of semester one is presented in Fig. 1 and the corresponding average hourly variation of water consumption in a day is shown in Fig. 2.

From Fig. 1, the water consumption during the weekends is significantly lower (38%) than the water consumption during the weekdays. This variation in water consumption between weekdays and weekends is expected, as classes are not held during the weekends. Fig. 2 shows that there is a lag time of 1 hour between the occurrences of the peak average hourly water consumption during the weekdays and weekends of week 11 of semester one. The peak average hourly water consumption during the weekends is about 44% less than that during the weekdays.

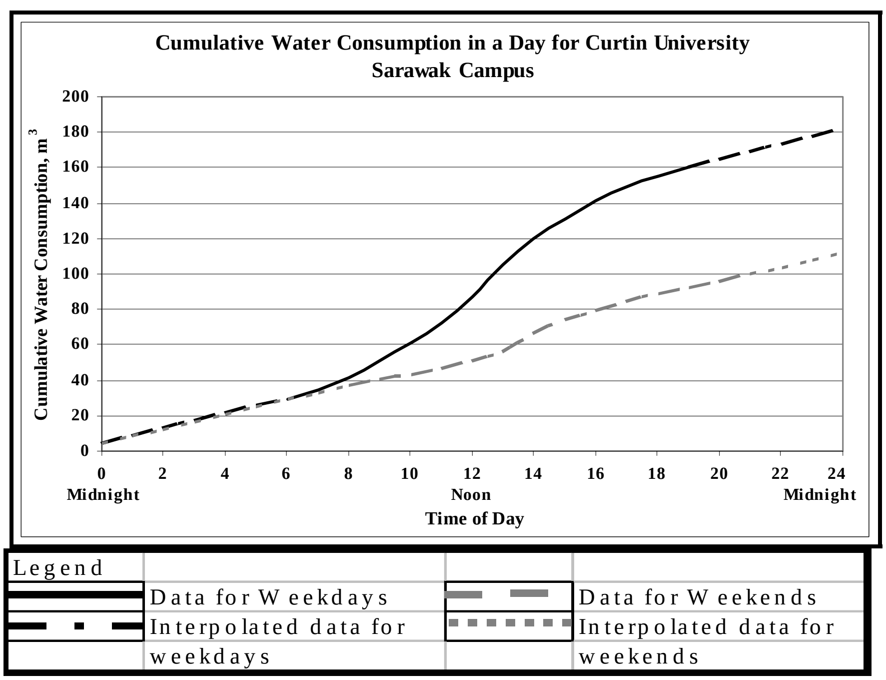

Fig. 1: Cumulative Water Consumption in a Day for Curtin University Sarawak Campus for Week 11 of Semester One.

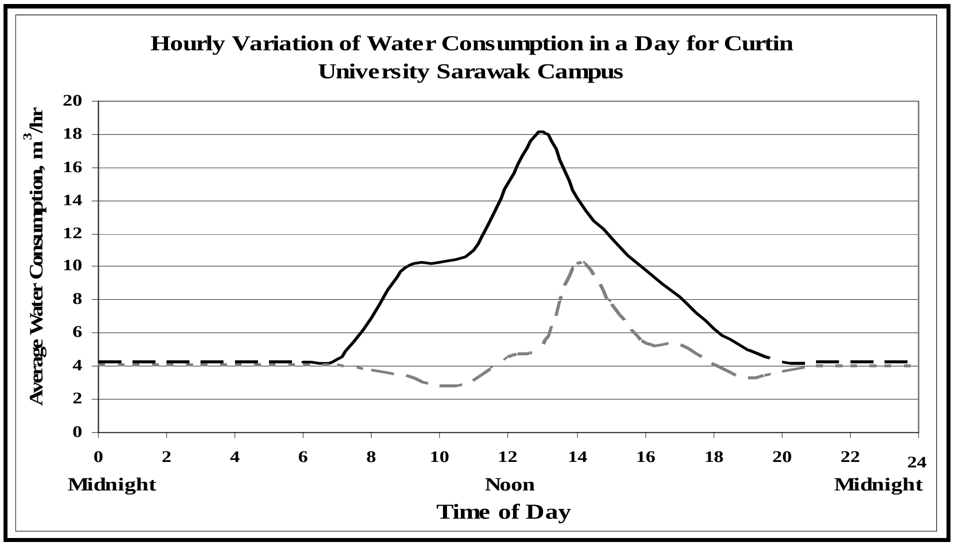

Fig. 2: Average Hourly Variation of Water Consumption in a Day for Curtin University Sarawak Campus for Week 11 of Semester One.

6.2 Week 2 of Semester Two. The total average water consumption for Curtin University Sarawak Campus during the weekdays for week 2 of semester two (145 m^3) is about 29% more than that during the weekends of the week (105 m^3). Similar to the average hourly variation of water consumption for week 11 of semester one (Fig. 2), a lag of time for the occurrence of peak hourly water consumption for weekdays and weekends is observed for week 2 of semester two. The peak of average hourly water consumption during the weekends (11 m^3) is 32% less than weekdays (7.5 m^3).

6.3 Week Free (Semester Break). The average total water consumption during weekends for a week free during semester break is about 6% than during the weekdays. The peaks average hourly water consumption during the weekdays and weekends for the week free occur at 12 noon, with the peak average hourly water consumption during weekends 25% less than that during weekdays.

6.4 Short-term Variations: Diurnal Variation. From all the figures presented, it is obvious that the water consumption changes during the course of a day. Fig. 2 shows that the variations in water consumption for the whole campus tend to follow a diurnal pattern. This is also seen in the results for Week 2 and Week Free. However, this pattern for an institution of higher learning is different from the typical diurnal pattern of domestic water consumption.

From the observation of the typical domestic water consumption or wastewater generation curve, there are two peaks in a day: the first peak generally occurs around 8 a.m. in the morning, while the second peak arises in the early evening between 6 p.m. to 8 p.m. (Tchobanoglous, Burton & Stensel 2004). However, the hourly variations in water consumption in Curtin Sarawak Campus during the teaching weeks of semester 1 and 2 present another type of pattern: the maximum peak usage occurs around 1 p.m. during weekdays and 2 p.m. during weekends. In addition, the peak average hourly water consumption occurs around 12 noon during the weekdays and weekends of the week free of July's semester break.

In general, the water consumption for Curtin University Sarawak Campus during weekdays starts to increase around 8 a.m. in the morning when all the activities are just starting and reaches the maximum during the lunch break in the midday. The water consumption decreases during late evening when the classes end, and there are less people in the campus.

Hence, from the results an important conclusion is that the diurnal variation for water consumption in an institution of higher learning is different from diurnal variation in domestic water consumption, and varies according to its population's activities during the day.

6.5 Short-term Variations: Variation for different days in a Week. Water consumption in the campus during the weekends is significantly less (ranging from 29% - 38% less) than during the weekdays. It was also found that the water consumption during the teaching week 2 of semester two is comparatively less than teaching week 11 of semester one. This is because during week 2 of semester two, some departments in the University have not commenced their teaching weeks yet; hence, the students' population in that period of time is relatively smaller than in the week 11 of semester one.

Therefore, it can be seen from these main observations that the population in the campus has direct influence on the quantity of water consumed during the day in a week.

6.6 Seasonal Variations. Seasonal variation is observed to be dependent on the activities in the campus. The extent of seasonal variation is expected to be dependent on the size of the community and the seasonal activities (Tchobanoglous, Burton & Stensel 2004). Seasonal activities are not held regularly over the period of the year. For an institution of higher learning like Curtin University Sarawak Campus, this would be the variation between the period during commencement of classes and the period during holidays where there are no classes. It is shown that the water consumption during a non-teaching week is as expected, less than the water consumption during a teaching week due to significant decrease in students' population during the non-teaching week. However, the water consumption for the weekends of the non-teaching week is as high as the water consumption for the weekends of a teaching week.

Conclusion

It is of utmost importance to investigate the feasibility of different wastewater treatment systems in the effort to improve our wastewater management system. Examples of different designs and plans used in foreign countries could be investigated for use in Sarawak. In selection of wastewater treatment system, the criteria to be considered are cost, capacity of the plant, land requirements, efficiency and reliability of the plant, operation, maintenance and sustainability of the plant, environmental impacts as well as energy and chemical consumption. For any institution of higher learning or campus, IDEA activated sludge wastewater treatment system would be viable to be adopted, provided the soil condition of the site is suitable for long piping system.

From analysis of water consumption data, the diurnal variations in water consumption for an institution of higher learning are shown to be different from the diurnal variations for domestic water consumption. Additionally, the main factors that influence the variations in wastewater generation in an educational institution are found to be the size of the population and the activities carried out in the institution. The data collected in quantifying wastewater generation in Curtin University Sarawak Campus could be used as a useful reference data for other similar institutions of higher learning in Malaysia.

It is proposed that future study on effective sludge management system should be carried out. Sludge treatment is another important part in wastewater management. Malaysia produces 3.2 million cubic meters of domestic sludge annually, but the facilities to treat and dispose the sludge are very limited (Indah Water Konsortium Sdn. Bhd. n.d.). Most of the sludge produced is sent to 230 landfills, which have been operating close to their full capacity (Asian Development Bank 2006; Ng, K.B. 2006). From these studies, it is estimated that only 1 to 13 percent of the sludge produced by Malaysians are recycled. An effective, efficient and environmentally sound sludge management is a milestone in Malaysian's approach in moving towards a sustainable wastewater management system.

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