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Development of Energy Saving Framework for Aeration Tank in Sewage Treatment Plant (STP)

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ABSTRACT

As the high power consumption in sewage treatment plant operations especially in extended aeration sewage treatment plant (STP) is a burden for the sewage treatment plant operator to sustain its operations cost. The energy cost substituting about 30% of overall STP operations cost. Oxygenation of aeration tank is the highest energy consuming unit process in the extended aeration (EA) STP. It is vital to develop an energy saving framework to reduce the energy cost in operating EA plants. The main aim from this research study is to investigate the key parameter that contribute to energy consumption in extended aeration STP. This study discussed design and actual plant condition aspects in developing the energy saving framework. Then to validate the framework at other similar plants for the benefits of other plants.

Keywords:
Sewage treatment plant, extended aeration, energy saving, framework

1. Introduction

In Malaysia, the history of sewerage development started with traditional open defecation, bucket latrines, hanging latrines and pit latrines. In certain area the bucket system prevailed for a very long time until as late as 1990. Then in the 60's and 70's, septic tanks formed the majority of sewerage systems [2]. As the population grows, traditional treatment systems evolved such as oxidation lagoons, settlement tanks, filter beds, and solids separation [12]. These traditional treatment processes designated at the low lying area to enable gravity flow with aim to circumvent energy consumptions by raw sewage pumps[9]. In the situation where the gravity conveyance is unachievable, then the pumping system was installed for sewage pumping [4]. As both communities and industry grew, the traditional treatment processes system found unable to accommodate the new requirement and demands. This lead to the development of new processes that were capable of treating higher flow and loads, with stringent statutory effluent compliance requirements [2]. In lieu, the modern sewerage treatment system evolution starts to progress [5]. The plant's design started became more sophisticated, with many complex treatment processes that require more or large equipment's for treatment process[6]. When the plants designed with many types of equipment, this automatically increases the energy utilization in sewage treatment plant [7].

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In recent years, the rise in energy prices and increase legislation requirements on statutory effluent discharge requirements had increased the sewage treatment and disposal of cost [11]. The energy cost escalated due to the complexity of the treatment process [3]. Oxygenation of aeration tank is the highest energy consuming unit process in the extended aeration (EA) STP. It is vital to develop an energy saving framework to reduce the energy cost in operating EA plants. The main aim from this research study is to investigate the key parameter that contribute to energy consumption in extended aeration STP. This study discussed design and actual plant condition aspects in developing the energy saving framework. Then to validate the framework at other similar plants for the benefits of other plants.

2. Methodology

The procedures involve in the development of energy saving framework based on volumetric and biological loading for sewage treatment facility. It includes assessments and determination of existing energy consumption cost and STP operational cost (Objective 1). There is two parts in objective 1, one is determination if energy consumption and the other is determination of overall STP operation cost. Determination of existing energy consumption is very important part to gauge the energy utilization before the energy saving framework implementation and after the energy saving framework implementation at the selected plants. Then the determination of STP operational cost. These determinations depict what are the important STP operational cost and how the energy cost affects the overall STP cost. The operation cost review illustrates the behaviour of operational cost and how the energy cost influence the overall plant operation cost.

This is then followed by investigations of key design parameters that directly contribute to the energy consumption in selected sewage treatment plant (Objective 2). The energy utilization in STPs involves unit processes encompassing from inlet of the STP till effluent discharge and solid processes, this study concentrates on key design factor that contribute to the determination on oxygen requirement for aeration tank that determines air requirement for air blower sizing [8]. The key design factor and actual conditions of the STP that contribute for the oxygen requirement reviewed for theoretical oxygen requirements and actual oxygen requirement based on field condition [10]. The computation of oxygen requirement under field is an important feature owing to its considerations of various aspects and field conditions that contributes to oxygen requirements in aeration tank. The Standard Oxygen Requirement (SOR) is calculated from Equation 1 [6].

$$\text{SOR kg/d} = \frac{N}{[(C`_{sw}\ ßF_a - C)/C_{sw}]\ (1.024)^{T-20\alpha}} \quad (1)$$

The 'N' – is theoretical oxygen requirement(TOR) for this study is computed based on MSIG guideline, weight of Oxygen (kgO_2) required to remove weight of substrate (kgsubstrate) removed. The 'substrate' is BOD loading with design criteria of $2.0kgO_2$ required to remove kgsubstrate ($2.0kgO_2$/kg BOD removed).

$$\text{TOR kg/d} = [(S_o - S_e) \text{x } Q_{avg}] \text{kg } BOD_5\text{/d X } [2.0 \text{ kg}O_2\text{/kg BOD removed}] \quad (2)$$

The main part of the study is developing framework concerning Oxygen requirement for aeration tank for energy optimization in the STP (Objective 3). The key process parameter that sustain the plant process to ensure the treatment performance established. Finally, the evaluation and validation of the developed framework was discussed (Objective 4). The research methodology summarised as per Figure 1.

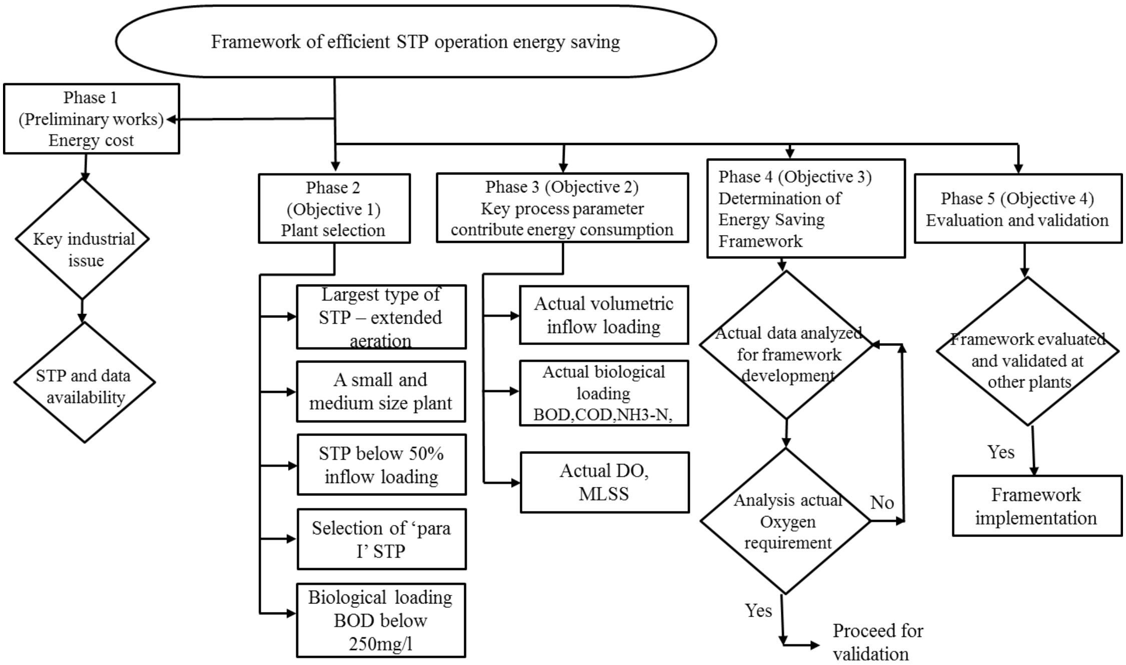

Fig. 1. Summary research methodology

3. Results & Discussion

The data collection and evaluation of the research study is still on going and in this section the preliminary findings are discussed. Firstly, the on the determination of the current energy consumption in the selected STPs, followed by the STP operations cost analysis.

The energy cost reviewed with overall STP operation cost to gauge the percentage of energy cost compared with the overall operational cost. From the Table 1, can be seen, the electricity cost and other operational cost centres for the selected plants. The other cost operational cost centres except for the few fixed reoccurrence cost like O&M outsourcing and telephone expenditure, the other are non-fixed cost of which based on wear and tear of the items. As such, from the Table 1, the electricity cost can be seen clearly, electricity cost for Plant A is 38% and Plant B is 78%. The inconsistency in the energy cost between the both plants is due non fixed cost.

Table 1
Plant operation cost compared with electricity cost

Cost center	Plant A	Plant B
Aeration system	13,990.00	-
Elctric control panel	4,237.44	151.45
Elect Inps	300.00	-
Electricity	73,999.61	34,830.30
Security	3,281.40	-
Ground Maintenance	329.12	-
Pipework	2,400.00	-
Pre-treatment	3,550.00	-
Fence	7,213.56	-
painting	360.00	-
Pumps	20,635.30	-
Civil	6,074.00	-
O&M outsourcing	7,830.00	8,000.00
Sewage clarification	49,400.00	-
tele exp	266.38	266.38
Water	432.00	1,136.12
Others		18.96
Total cost	194,298.81	44,403.21
Electricity cost vs total operational cost	38%	78%

Next, the key parameters that contributing for energy consumption for plant aeration in term of plant design and actual plant condition reviewed. The two key parameters that influence the oxygen requirement for aeration tank in extended aeration plant is inflow volume capacity and biological loading tabulated in Table 2 and Table 3.

Table 2
Actual inflow loading capacity

ASSET NO	Plant A	Plant B
Design PE	4700	1220
Design Flow(M$_3$/day)	1057	274
January (M3/day)	217	145
February (M3/day)	210	150
March (M3/day)	201	216
April (M3/day)	209	154
May (M3/day)	224	153
June(M3/day)	210	134
July (M3/day)	193	147
August (M3/day)	269	176
September (M3/day)	177	175
October (M3/day)	62	169
November (M3/day)	261	149
December (M3/day)	306	141
Average	212	159
% Ave vs Design flow	20%	58%

Table 3
Actual biological loading

Plant Ref.	STP Type	Sample type	Sampling Date	BOD
Designed Influent Biological loading				250
Plant A	EA	Cs	3-Apr-18	78
Plant A	EA	Cs	5-Apr-18	55
Plant A	EA	Cs	9-Apr-18	70
Plant A	EA	Cs	12-Apr-18	63
Plant A	EA	Cs	16-Apr-18	127
		Average		78.6
Plant Ref.	STP Type	Sample type	Sampling Date	BOD
Designed Influent Biological loading				250
Plant B	EA	Cs	3-Apr-18	164
Plant B	EA	Cs	5-Apr-18	175
Plant B	EA	Cs	9-Apr-18	162
Plant B	EA	Cs	12-Apr-18	200
Plant B	EA	Cs	16-Apr-18	227
		Average		185.6
*CS -crude sewage				

The table 2, depicts actual inflow volume to the plant which is much less than the design value. Design inflow for Plant A is 1057m^3/day and Plant B is 274m^3/day, but actual inflow volume is low with average for Plant A is 212m^3/day and Plant B is 159m^3/day. The table 3, depicts the similar where the actual biological loading is much lower compared with design value. The actual oxygen requirement based on actual inflow volume and biological loading compared with design requirements and then the aeration device setting readjusted accordingly to optimise energy utilisation in the STP.

4. Conclusions

The research study still on going for energy framework development for implementation. From the gathered data, the selected plant's inflow loading and biological loading depicts viability for energy optimisation. The gap between the design value and actual value computed to maximise the actual oxygen requirement. The actual oxygen requirements turned lower compared with design oxygen requirements. The framework would developed in easy flow sequence to ease the operative to compute the actual oxygen requirement and reset the plant operational setting. Overall from the study, energy saving framework is viable and expected to give energy saving for other similar plant.

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