OXYGEN UPTAKE RATE AS AN IN-SITU INDICATOR FOR SHOCK LOADING EVENT AT SEWAGE TREATMENT PLANT

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ABSTRAK

Air buangan berkaitan dengan sisa buangan manusia, bahan kimia, minyak, dan pelepasan sisa ini akan kembali ke persekitaran hidrologi. Oleh itu, penting bagi jurutera untuk menyertai dalam pengurusan air sisa dan pengetahuan yang diperlukan mengenai sistem air sisa. Untuk merawat air sisa, terdapat beberapa proses yang perlu dilakukan, untuk memastikan bahawa loji rawatan air sisa sentiasa berada pada tahap terbaik, parameter kawalan yang sesuai adalah penting untuk kes ini. Terdapat pelbagai jenis parameter kawalan seperti Kadar Pengambilan Oksigen, Indeks Isipadu Enapcemar, nisbah Makanan kepada Mikroorganisma dan Kadar Pengambilan Oksigen Khusus. Dalam kajian ini, hubungan Kadar Pengambilan Oksigen sebagai parameter pemantauan akan dibincangkan. Di loji rawatan kumbahan, mengenal pasti masalah dan parameter pemantaun adalah sangat penting untuk memahami jenis proses rawatan yang diperlukan untuk loji rawatan. Pada era ini, pelbagai jenis proses yang boleh digunakan untuk mengolah kumbahan seperti, Enapcemar Teraktif Konvesional dan Enapcemar Berbutir Aerobik. Oleh yang demikian jurutera memerlukan kemampuan untuk membezakan parameter operasi dan pemantaun yang penting untuk proses tersebut. Kajian ini juga memfokuskan pada hubungan antara pemuatan kejutan dan Kadar Pengambilan Oksigen sebagai parameter pemantauan mengunakkan data sekunder. Parameter pemantauan ini akan membantu jurutera memahami air sisa yang datang ke STP dari isi rumah atau industri. Dengan mengunakkan SPSS dan excel, data akan dianalisis untuk melihat hubungan antara parameter yang disarankan dengan Kadar Pemuatan Organik. Fluktuasi kumbahan boleh menyebabkan banyak masalah kepada STP kerana boleh menyebabkan limpahan kumbahan terutamanya pada waktu hujan. Kaedah analisis adalah dengan mengunakkan analisis Deskriptif Korelasi Pearson, Korelasi Spearman, Kovarians, Uji

T Berpasangan Dua Sampel untuk Bermakna, dan Regresi. Hasil dari ujian-T yang dipasangkan dua sampel untuk menujukkan bahawa Kadar Pengambilan Oksigen , Indeks Isipadu Enapcemar, Campuran Liquor Pepejal Terampai dan Makanan ke Mikroorganisma lebih unggul berbanding dengan Kadar Pemuatan Organik sebagai parameter pemantaun terhadap Organik yang berfluktuasi memuatkan dengan kadar 0.01925, 0.02198×10^{-2}, 0.01147, dan 0.02826. Semua nilai ini berada di bawah 0.05 yang mana hipotesis nol ujian-t dapat ditolak. Sebagai ringkasan, kajian ini menunjukkan bahawa Kadar Penyerapan Oksigen, Indeks isi eneapcemar, Campuran Liquor Pepejal Terampai, dan Makanan kepada Mikroorganisma boleh menjadi parameter pemantauan kepada keadaan aliran masuk air sisa sebenar ke sistem sistem Enapcemar Granul Aerobik kerana data dari Awang (2016) menggunakan Sekumpulan Kumpulan Penjujukan untuk mendapatkan hasilnya.

ABSTRACT

Sewage is related to human waste, solid waste, chemicals, oil, and this discharge will return to the hydrological cycle. Therefore, it is essential for the engineer to participate in sewage management and requisite knowledge of the sewage system. To treat the sewage, many processes need to be done to ensure that the efficient sewage treatment plant is always at its peak; a suitable control parameter is important for this case. There are many control parameters such as Oxygen Uptake Rate, Sludge Volume Index, Food to Microorganisms, and Specific Oxygen Uptake Rate. This study will discuss the oxygen uptake rate as an in-situ for shock loading event at a sewage treatment plant. In a sewage treatment plant, identifying the problem and crucial monitoring parameters is crucial to understanding the treatment process needed for the treatment plant. Nowadays, many types of the process can be used to treat sewage, such as Conventional Activated Sludge and Aerobic Granular Sludge process. Hence, engineers need the ability to differentiate the crucial operating and monitoring parameters for the process. This study also focuses on the relationship between the shock loading and Oxygen Uptake Rate as monitoring parameters using secondary data. These monitoring parameters will help the engineer to understand the influent that come to the Sewage Treatment Plants from the household or industry. Using the SPSS and excel, the data taken from Awang (2016) will be analysed to see the relationship between recommended parameters and Organic Loading Rate. The fluctuation of the sewage can cause many problems to the STP as it may cause an overflow of sewage, especially during a rainy day. The analysis method is by using Descriptive analysis, Pearson's Correlation, Spearman's Correlation, Covariance, T-Test Paired Two Sample for Means, and Regression. This test has been conducted to test the which the null hypothesis can be rejected or not. The result from the T-test paired two samples for means shows that the

Oxygen Uptake Rate, Sludge Volume Index, Mixed Liquor Suspended Solid, and Food to Microorganism ratio is superior to the Organic Loading Rate as a monitoring parameter to the fluctuated Organic Loading Rate with 0.01925, 0.02198×10^{-2}, 0.01147, and 0.02826, respectively. All of this value is below 0.05, which the null hypothesis of the t-test can be rejected. As a summary, this study shows that Oxygen Uptake Rate, Sludge Volume Index, Mixed Liquor Suspended Solids, and Food to Microorganism ratio can be a parameter to monitor the actual influent condition of the Aerobic Granular Sludge system as the data from Awang (2016) were using the Sequencing Batch Reactor to gain the result.

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LIST OF ABBREVIATIONS

STP	Sewage Treatment Plant
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
SVI	Sludge Volume Index
MLSS	Mixed Liquor Suspended Solid
MLVSS	Mixed Liquor Volatile Suspended Solid
OUR	Oxygen Uptake Rate
SOUR	Specific Oxygen Uptake Rate
F/M	Food to Microorganism ratio
AGS	Aerobic Granular Sludge
CAS	Conventional Activated Sludge
HRT	Hydraulic Retention Time
SRT	Solid Retention Time
OLR	Organic Loading Rate
TOC	Total Organic Carbon
DO	Dissolved Oxygen
VSS	Volatile Suspended Solid
GHG	Green House Gas
SBR	Sequencing Batch Reactor
SPSS	Statical Package for the Social Science

CHAPTER 1

INTRODUCTION

1.1 Background of study

Characteristics of sewage can be divided into three categories which are physical, chemical, and biological. Physical characteristic in sewage parameter is measure as temperature, solids, odor, and color. While chemical characteristics of sewage are often measured based on pH value, the concentration of organic matter like chemical oxygen demand (COD), phosphorus, nitrogen, and heavy metal. Lastly, biological characteristics that happen due to the contaminant of sewage are biochemical oxygen demand (BOD), oxygen required for nitrification, and microbial population.

Sewage treatment removes contaminants from municipal sewage, primarily household sewage with a small amount of industrial wastewater. In the treatment process, the removal of impurities, physical, chemical, and biological procedures are utilized to produce treated sewage that the sewage can safely discharge into the environment. At a sewage treatment plant (STP), a routine inspection and monitoring of parameters like pH, Sludge Volume Index (SVI), solids (MLSS, MLVSS), influent and effluent characteristic (such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (BOD)), Oxygen Uptake Rate (OUR) and Specific Oxygen Uptake Rate (SOUR) will be carried out by the engineer daily. This test is critical for identifying contaminants in sewage that cannot be detected by physical tests alone.

Biological or secondary treatment is the most crucial stage in sewage treatment. Secondary treatment has a wide variety of microorganisms; primarily, bacteria involved in aerobic and anaerobic processes. At non-settleable organics from primary or physical methods, bacteria will biodegrade or break down into simpler substances to safely discharge the sewage into the environment.

In biological proses, oxygen is needed to degrade organic matter. For STP, the required amount of oxygen needed to degrade organic matter can be determined using COD, BOD, and respiration rate, also known as microorganism Oxygen Uptake Rate (OUR). Typically, COD and BOD are standard parameters used to measure the effectiveness of the applied treatment process. However, when dealing with the biological treatment process, monitoring of OUR value is crucial. OUR is the microorganism oxygen consumption per unit time. OUR response to the substrate loading rate fluctuation and the disturbance caused by a slug of toxic material. Specific Oxygen Uptake Rate (SOUR) immediately reflects the presence of shock loads that the conventional F/M ratio does not (Chalasani and Sun, 2007).

Usually, sewage treatment plants use an activated sludge system for biological treatment, which requires large surfaces areas for treatment and biomass separation units due to generally poor settling properties of the sludge. Therefore, Aerobic Granular Sludge (AGS) system was developed as an alternative to the Activated Sludge system (de Bruin *et al.*, 2004). Aerobic granules are a type of sludge that can self-immobilize flocs and microorganisms into spherical and strong structures. The advantages of this AGS are excellent stability, high biomass retention, simultaneous nutrient removal, and tolerance to toxicity.

Thus, this study is conducted to determine the Oxygen Uptake Rate (OUR) as an in-situ indicator for shock loading events at the sewage treatment plant that uses AGS technology using the data from Awang (2016).

1.2 Problem statement

Activated Sludge systems are usually used in sewage treatment plants where a large surface area for treatment and biomass separation unit is required due to generally

poor settling property in sludge. Activated sludge can cause a problem if there are any chances of the volume or types of sewage being delivered. These may manifest in a reduced quality of effluent quality. The performance of the process may be affected as the activated sludge may always not remain activated and aerated.

When there is fluctuation in organic loading rate (OLR) in the sewage treatment plant, also in some cases, the instability can be referred to as shock loading because it has fluctuated. It can cause problems to the treatment process and requires adjustment to the standard operational procedure. According to Chandra et al. (1987), an increase in the influent substrate concentration results in a corresponding rise in the OUR. Abou-Elela *et al.* (2018) reported that shock loading is very contaminated with organic and inorganic pollutants. Shock loading can cause a decrease in bioreactor performance for sewage treatment due to disruption in the microbial community structure (Bhattacharya, Dev, and Das, 2018). To encounter this problem, the engineer needs to analyze whether the treatment plant can still be operated as usual or stop taking sewage for a period because it can cause overflow in the treatment plant. The efficiency of the STP will be decreased. OUR control parameter can respond to the fluctuation of the influent loading rate and the disturbance caused by a slug of toxic material.

1.3 Objectives

The main objectives of this study are to determine the Oxygen Uptake Rate as an in-situ indicator for shock loading events at STP. This study was also carried out to accomplish the objective by using the data from Awang (2016) as below;

1. To identify the problem and crucial monitoring parameters at the sewage treatment plant.

2. To differentiate crucial operating and monitoring parameters between conventional activated sludge process and Aerobic Granular Sludge (AGS).
3. To determine the relationship between shock loading and Oxygen Uptake Rate (OUR) as monitoring parameter using secondary data.

1.4 Scope of study

The scope of this study is limited to control parameters in sewage treatment plants when there is shock loading in the influent of sewage throughout the process. Oxygen Uptake Rate (OUR) will be used as the control parameter in a sewage treatment plant. To determine OUR, the recommendation by American Public Health Association (APHA) by using 23rd edition Standard method for the examination of Water and Sewage used as a reference.

Aerobic Granular Sludge (AGS) secondary data from Awang (2016) is being used for this study to identify the OUR of the sewage in the treatment plant. Secondary data has been collected by primary sources and made readily available for researchers to use. The set of the data was taken from Awang (2016). The data that is being used for this study are Dissolve Oxygen (DO), Mixed Liquor Suspended Solid (MLVSS), Food to Microorganism (F/M) ratio, and Sludge Volume Index (SVI).

1.5 Significant study

pH from the inflow of rainwater and heavy metal compounds in the sewage and sewage temperature. In treatment plants, especially in a biological reactor, the problem can result from a susceptible microorganism to many factors such as variability and quality of organic and biogenic substances in sewage. Meanwhile, the factors influencing bioreactors with activated sludge systems for a proper sludge metabolism of microorganisms are the maintenance of appropriate aerobic, anoxic, and

anaerobic conditions in the individual's stages of sewage treatment. In real situations, the engineer needs to find a solution to ensure the reactor can process efficiently by using OUR as a control parameter.

This study can help fresh graduates understand OUR to apply in the industry because OUR is a vital control parameter used in a sewage treatment plant. On the other hand, this study also can expose more to fresh graduates on the effect of the shock load in STP, which can cause some problems in the treatment process

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, journals relevant to this study will be reviewed to understand better the fundamental aspect of OUR analysis and its indicator as a control parameter in determining the efficiency of STP operations. In addition, this chapter is being written to investigate if there is any significant relationship between OUR and shock loading events that occur at STP under unusual circumstances. This chapter also provides the groundwork for understanding other crucial monitoring parameters at STP such as influent and effluent characteristics, specific oxygen uptake rate (SOUR), mixed liquor suspended solid (MLVSS), sludge volume index (SVI), and food to microbial (F/M) ratio.

2.2 Operational challenges at STP

There are several challenges regarding STP operation, such as energy consumption by the STP, sludge production, and footprint. Energy consumption in STP is one of the most significant expenses in operating a sewage treatment plant (Ye *et al.*, 2019). Ye *et al.* (2019) also reported that it is estimated to consume 3 – 5% of a developed nation's electrical power. The enormous energy used in sewage treatment plants is a biological treatment, which generally uses 50% to 60% of the plant. The excessive number of sludge production is also one of the challenges of operating STP during the process and the footprint of the sewage treatment plant. As activated sludge plants are costly to construct, it also occupies a large area space. Apart from what has

already been addresses above, other specific technical issues that frequently occur at STP will be discussed in Section 2.1.1 to Section 2.1.3

2.2.1 Fluctuated Organic Loading rate

A different sufficient quantity or strength exceeding the normal loading ranges in concentration received by sewage treatment plants can be called shock loading. Shock load will cause problems to the treatment process and will require adjustments to standard operating procedures. Fluctuation in OLR also can be referred to as shock loading because it fluctuates. Changes in OLR are due to the dynamic character of the wastes utilized as the primary substrate (manure, for example, experienced seasonal fluctuations) or as co-substrates (they could change regularly depending on availability) (Regueiro, Lema and Carballa, 2015). Kanimozhi and Vasudevan (2014) reported that a high loading rate greater than 3.6 kgCOD/(m3 day) would decrease the biomass concentration (MLVSS- 3,600mg/L), and the increase of inorganic in the reactor (high MLSS- 12,000 mg/L) can cause destabilization to the reactor and process failure.

2.2.2 Toxic Loading Rate

According to NPDES permits Sublethal effects such as suppression of fertilization, growth, and reproduction that occur over time as a long time of exposure about seven days are referred to as chronic toxicity. In municipal sewage, pharmaceuticals, personal care products, and other pollutants cause biological toxicity and endanger sewage reuse (Gao *et al.*, 2020). The toxic organic pollutants may cause inhibit algae growth and will lead to subsequently to the decline of primary

productivity (Singh, Sonal, and Mishra, 2021). Untreated toxic sewage can cause harm to the river ecosystem without being treated properly. As a result, in the recent decade, toxicity assessments of sewage treatment plants have gotten a lot of attention to examine what kind of risks micropollutants or other priority pollutants can create and what kind of precautions need to be taken, especially in vulnerable and sensitive locations (Rashid and Liu, 2021)

2.2.3 Sludge Bulking

Sludge bulking tend to happen when the sludge fails to separate in the sedimentation tanks. The presence of filamentous bacteria is the main reason for the sludge bulking in the sewage treatment plant. Filamentous bacteria grow in long strands with significantly more volume and surface area than typical floc and settle slowly. Filamentous bacteria are the backbones of sludge flocs, and they are essential for floc development and stability (Li *et al.*, 2020). In two bioreactors of an urban sewage treatment facility, the use of low ozone dosage to reduce the issues caused by filamentous foaming was tested (Barbarroja *et al.*, 2019). Poor sludge settleability can clog the pipe system, decrease oxygen transfer efficiency in mixed liquor, reduce biological process performance, and result in solid particle carry over into the final effluent (Deepnarain *et al.*, 2019).

2.3 Control Operating Condition at STP

In Malaysia, the STP operator, who is generally under the jurisdiction of Indah Water Consortium, is required to follow the standard control condition or procedure as stipulated in the Malaysia Sewage Industry Guideline (MSIG) (National Water Services Commission, 2009). The control operating condition must be

monitored to ensure any problem that arises during the operation at STP, such as fluctuated OLR, toxic loading, and sludge bulking events. It is essential to make sure it will not affect the biological treatment process, such as hydraulic retention time (HRT), organic loading rate (OLR), and solids retention time (SRT).

2.3.1 Hydraulic Retention Time (HRT)

HRT is a measured length of time that a soluble compound remains in a constructed bioreactor. The ratio of the volume of the aeration tank to the influent flowrate is hydraulic retention time HRT. The hydraulic retention time (HRT) has a direct effect on the reaction time of sewage in the Biological Aerated Filter (BAF), with high HRT boosting the removal efficiency (Yu *et al.*, 2021). Based on MSIG, volume 4, 2009, (National Water Services Commission, 2009), the HRT for activated sludge and sequencing batch reactor systems. HRT recommended they are 6-16 hours (for the scenario where only ammonia removed is required) and 12-16 (for plants require total nitrogen removal) for the AGS system, and 18-24 hours for sequencing batch reactor.

2.3.2 Organic Loading Rate (OLR)

According to the Washington State Department of Health (Price, 2020), the definition of OLR is the application of particulate and soluble organic matter, which can be expressed by area basis as kg BOD per unit area. Increasing OLR will decrease oxygen chemical oxygen demand (COD) removal, pH, and methane production. Variations in the food-to-microorganism (F/M) ratio or dissolved oxygen (DO) levels, two key factors related to microbial behavior, may be caused by changes in the

OLR. As a result, biomass parameters (such as sludge concentration, floc structure, particle size, biomass–liquid separation, and surface qualities) are linked to changeable microbial features (Yang *et al.*, 2018).

2.3.3 Solids Retention Time (SRT)

The activated-sludge solids average duration is in the system is known as the Solids Retention Time (SRT). The SRT, commonly given in days, is a critical design and operating parameter for the activated-sludge process. To preserve slow-growing nitrifying bacteria in sufficient proportions in the sludge, SRTs in CAS systems that require nitrogen removal are generally in the order of 10–20 days—even as high as 50–80 days are utilized (Eggen and Vogelsang, 2015).

2.4 Monitoring parameter at STP

At STP, monitoring parameters play an important role in attaining a continuous effective treatment process, particularly during the biological stage. According to Katoria *et al.* (2013), the problem can happen in the operational control as the number of microorganisms is too few or too many. This problem can cause less efficiency on STP and added load on the receiving waters. There is 2 type of method to monitor the influent sewage by using in-situ test and laboratory test. (Solagaistua *et al.*, 2018) reported that field measures did not show any significant response compared to laboratory experiments, probably due to the high dilution of the effluent in stream water (average of 1.6%). There is some control method that can be used for operational control strategies such as; SVI, SRT, sludge age, F/M, MLSS, OUR and last but not least SOUR.