Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 001–010

PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Biofilm System Design and Comparative Study of Biomedia using in Domestic Wastewater Treatment

Nur Shaza Syahirah Sharipuddin[1], Zarizi Awang[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Panchor, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.02.001
Received 13 January 2021; Accepted 01 March 2021; Available online 02 December 2021

Abstract: The sewage treatment plant (STP) system is very important because of the need of treatment that must comply with the regulatory standard discharge. Because of the high population people especially in the urban area, the important of the efficient and small footprint of treatment will become choice of the developer. The current conventional domestic sewage treatment required a longer time and more space in treating wastewater pollutants. Since there are huge potential on upgrading an existing plant to cater more capacity of wastewater, these attach growth technology will be the option for the developer to construct or upgrade existing sewage treatment plant with lower cost. Hence, these study focuses to compare with the various types of attach growth system and media in the market. From the study, shows that attach growth system using media namely Cosmo Ball works effectively compared to other type of media, where it is 20.00 % more efficient. It also seems to be the most efficient biomedia when it effectively works on the other factor such arrangement of biomedia and surface properties. This study also shows that biofilm system is the best system in term of performance compliance, plant sizing and maintenance issue.

Keywords: Biofilm, Cosmo Ball, Wastewater, Biomedia, Arrangement, Surface

1. Introduction

Wastewater is referring to any water that contains a wide variety of pollutants, including plant nutrients, pathogenic micro-organisms, metallic and organic toxins, and micro-contaminants [6]. Wastewater is the harmful product of human impacts on the aquatic environment from a range of everyday activities, including agriculture, industry, domestic and manufacturing operations. Based on their origins, wastewater derived from anthropogenic agents can be categorised as domestic wastewater (excrete black water and grey water resulting from household washing), agricultural wastewater (pesticides, vegetables and animal waste may affect the quality of nearby water supplies) and industrial wastewater (metallurgy and nuclear industry, chemical and pharmaceutical industries

*Corresponding author: azarizi@uthm.edu.my

and food industries are few industrial sectors responsible to produce wastewater). Therefore, to reduce the contaminant in river water when the effluent is discharge, wastewater should be treated.

The wastewater parameters are considered in physical, chemical and biological characteristics. Wastewater is 99.9 % of water and 0.1 % solids. The wastewaters are treated to remove most of all this 0.1 % solids. Chemically, the constituents of wastewater composed of organic and inorganic substances derived from plants, animals and man activities. Organic substances are proteins (40.0-60.0 %), carbohydrates (25.0-50.0 %) and fat, oils and grease (10.0 %) while inorganic substances consist of chlorides, nitrogen, phosphorus, sulfur, toxic inorganic compounds and heavy metal. Biological characteristics are composed of several microorganisms (bacteria, fungi, protozoa, algae, viruses).

Biological treatment of wastewater is commonly accepted approach to tackle a wide range of domestic / residential, farming, retail and industrial commercial applications. As pollution degradation occurs at natural temperature and pressure, biological wastewater treatment is a proven energy-efficient technique compared to alternative energy-intensive approaches to physical and chemical degradation (catalytic oxidation, incineration, accelerated oxidation, scrubbing, regenerative adsorption) [5].

1.1 Biofilm and Cosmo Ball

Biofilm can be defined as a complex, coherent structure of cells and cellular products, such as extracellular polymers that either spontaneously form large, dense or growing granules attached to static solid surfaces (static biofilms) or suspended carriers (biofilms protected by particles) [1]. Biofilm in wastewater treatment plants is handled by the technology implemented called "cosmo ball." In the treatment of effluent, devices such as the cosmo ball are primarily used as filter material. A very large surface area could be obtained for microbial attachment, as the cosmo ball has a configuration such that the surface can interact with the full fluid microbial. Microbial activities can greatly increase the degradation of organic matter in wastewater. Cosmo ball is a medium used in wastewater treatment with a view to increase contact surface area and providing longer contact time for biological activities. It is usually placed in an aeration tank, or in an activated sludge tank, as a medium or as a packaging. It induces the growth of bacteria on its surface, which will serve as a contact area for wastewater and microbials [9].

1.2 Problem statement

The design of the sewage treatment plant (STP) system affects the wastewater composition significantly. People all over the world needs best quality of water for their daily life.The current conventional domestic wastewater treatment required a longer time and more space in treating the wastewater pollutants. Since there are huge potential on upgrading an existing plant to cater more capacity of wastewater, these attach growth technology will be the option for the developer to upgrade their sewage treatment plant with lower cost. Thus, an alternative has been made to design small sewage treatment plant (STP) with attach growth system technology using cosmoball biofilm. The design also will be focus on STP design using activated carbon coated cosmoball and uncoated cosmoball to analyse how much space reduce from these two systems applications on site without compromise the discharge standards.

This study is conducted to study and compare various biofilm systems from various studies. Furthermore, this study is also carried out to investigate the effectiveness of activated carbon (AC) coated cosmo ball biofilm and uncoated cosmoball biofilm. The data of the quality of effluent produced will be analyzed to find the best systems to be implemented in today’s STP technologies to maintain the sustainability. Furthermore, analysis on the best system through aspects such as performance, sizing and maintenance will be done.

1.4 Objectives

The objectives of this study are:

i. To study and compare various attach growth biofilm system using in the wastewater treatment plant.

ii. To carry out comparison study between coated and uncoated cosmoball biofilm.

iii. To analyze the best system in term of performance compliance, plant sizing and maintenance issue.

1.5 Scope of study

The study is going to be carried out as home-based research. The data will be obtained from the existing biofill technology from the company Pakar Management Technology Sdn. Bhd. and other relatable biofilm studies by comparing the system through its performance, specific surface area and its effectiveness in nutrient removal. Undergoes research and reading on previous study on AC biofilm system to make sure this research meets the objectives. There will be no physical test undergoes because this is home-based research due to the pandemic occurs in Malaysia that restrict us to move and do the test at laboratory.

2. Methodology

An organized and efficient workflow is very important to determine a project's effectiveness. The study was carried out as a comparative study from previous research. To achieve the objectives, the methodology could help researcher go through step by step until get the outcomes. The method use for collecting the data is by comparative study. After that, research and data collection needs to be done after the drafting of the plan. Data collecting is the process of gathering and measuring information. In completing this study, data are collected from a company Pakar Management Technology. This company is the owner of the biofill system and very vast experience in managing wastewater treatment plant. Besides that, the data was also collected from previous study done by researcher from Universiti Putra Malaysia (UPM) and various institutional studies.

Next, the calculation of the design for the selected population equivalent is produced. In this phase, the calculation of the 150 PE biofill and extended aeration system for wastewater treatment is performed by referring to the basic parameters such as, hydraulic retention time (HRT), pollutant loading, mechanism of the treatment and others. The data analysis summarises the data collected. It includes the analysis of the data collected through the use of empirical and logical reasoning to determine patterns, relationships or trends. For this analysis, the data will be analysed in terms compliance performance, size and maintenance. Finally, the study will conclude whether or not it achieves the objectives, and some suggestions for further improvement of the study will be proposed.

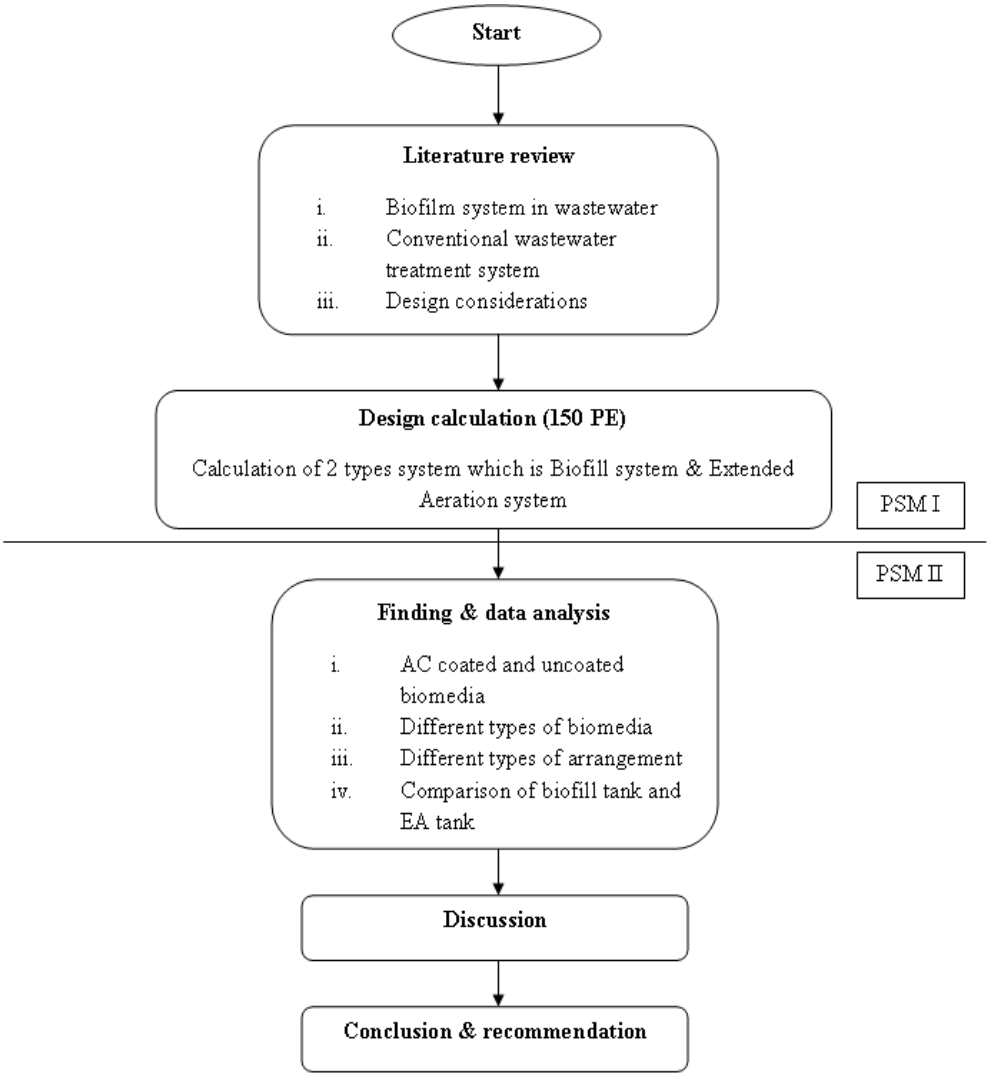

Figure 1: Study flow chart

2.1 Design requirement

As referred to Malaysian Sewerage Industry Guidelines (MSIG) [2], sewage treatment plants are also classified in accordance with the design capacity in terms of population equivalent (PE). Table 1 shows 4 classifications to be adopted.

Table 1: Classification by Treatment Plant Capacity

Classification	PE
Class 1	≤ 1000
Class 2	1001 – 5000
Class 3	5001 – 20000
Class 4	> 20000

The land area requirement for the construction of a sewage treatment plant is listed in the SPAN Guidelines. In selecting the land area requirement there are 4 classes, referring to the population equivalent (PE). The population equivalent (PE) for this study is 150 which have been graded as plants of class 1. The land area requirement for 150 PE is 285 m^2 which is equivalent to 0.070 acre excluding the buffer zone.

3. Findings and Analysis

Table 2: Best biomedia performance

No.	BOD		COD		AN	
	Name	Value (%)	Name	Value (%)	Name	Value (%)
1.	Cosmo Ball	88	Cosmo Ball	65.5	Spawning Brush	58
2.	String Media	68	String Media	65	String Media	52
3.	Biocaged	53	Vitagen Bottle	63	Cosmo Ball	51

Based on the data analyses in Table 2, it shows that Cosmo Ball biomedia has the highest efficiency in removing nutrients from wastewater according to BOD and COD parameter which is 88.0 % and 65.5 % respectively. Whereas, for removing of ammoniacal nitrogen (AN) spawning brush biomedia has the highest value of 58.0 % rather than Cosmo Ball which only has the value of 51.0 %. From the result, it shows that Cosmo Ball biomedia should have another implementation to improve it efficiency in nutrient removal for wastewater. In addition, there must be some factor to be considered according to the differences in performance of those types of biomedia such as arrangement of the biomedia, material use, physical characteristics and others.

In previous study, stated that Cosmo Ball is a medium used in wastewater treatment system in order to provide larger contact area and longer contact time for biological activities [4]. It is suitable to be use in both aerobic and anaerobic situations. The characteristic of cosmo ball/bio ball are light weight and floats on water which making it easier to remove and clean whenever required. Strong polyethylene plastic was used to produce this Cosmo Ball where the characteristics of polyethylene plastic have high resistant to corrosive and hazardous effluent. Void fraction of cosmo ball is 85.0 % which makes is less prone to clogging.

3.1 Calculation of biofilm and EA system

The design calculation of 150 PE tank between biofilm system and EA system were made to differentiate the system. Calculation was made to compare the size of these two systems need to cater 150 PE complying to Malaysian Sewerage Industry Guidelines (MSIG), Volume IV. Table 3 and Table 4 show the summarization of calculation for biofilm system and EA system respectively.

Table 3: Calculation summary of biofilm system for 150 PE

No.	Description	L (m)	W (m)	D (m)	Vol (m^3)	Nos. Of Tank	Act Vol (m^3)
1.	Grit chamber	2.00	1.00	0.50	1.00	1.00	0.81
2.	Grease chamber	2.00	1.00	0.50	1.00	1.00	0.81
3.	Anoxic tank	1.00	1.50	2.00	3.00	1.00	2.81
4.	Extended aeration tank	2.50	3.00	2.00	15.00	2.00	12.66
5.	Sec clarifier	3.00	3.00	2.00	18.00	1.00	16.29
6.	Sludge holding tank	2.50	2.00	2.40	12.00	2.00	11.02

Table 4: Calculation summary of EA system for 150 PE

No.	Description	L(m)	W(m)	D(m)	Vol (m^3)	Nos. Of Tank	Act Vol (m^3)
1.	Grit chamber	2.00	1.00	0.50	1.00	1.00	0.45
2.	Grease chamber	2.00	1.00	0.50	1.00	1.00	0.68
3.	Anoxic tank	1.00	1.50	2.00	3.00	1.00	2.81
4.	Biofill tank	1.50	1.50	2.00	9.00	2.00	8.44
5.	Sec clarifier	1.50	1.50	2.00	4.50	1.00	2.81
6.	Sludge holding tank	1.50	1.50	2.00	4.50	1.00	2.99

The result shows, biofilm system require smaller capacity than EA system when the volume obtained for biofilm system four times lower than EA system. Based on the result, it shows that biofilm system is more effective than EA in both plant sizing and maintenance issue. As for todays, land values were higher which developer needed to produce smaller STP but still maintain the effectiveness in treated wastewater. Besides that, biofilm system is seemed to be the best system in maintenance issued when (1) biofilm system do not generate too much sludge in the process and (2) it use filter system which it can filter wastewater in early stage of the process. Other than that, biofill tank only required low HRT which is around 6-12 hours to operate compared to EA tank which need 18-24 hours. By having such advantages, bioilm system could help to lower the maintenance and operating cost.

3.2 Factor affecting the performance of reactor

The efficiency of a reactor is based on some factor that can lead to a successful process which require less maintenance time and cost. In designing STPs, some factor should be considered as for today's development in Malaysia becomes higher in cost. Therefore, smaller and efficient STPs should be implemented.

The carrier media properties play an important role for the performance of reactor. Larger surface area of carrier media allows abundant of biofilm to attach on it in a smaller reactor which may help to increase the reactor performance. Ødegaard H. et.al (2000) in their experiments shows that the key factor in designing a reactor for organic matter removal is the effective surface area on which the biomass may grow. The size and shape of the carriers will affect this efficient area, but there does not appear to be any difference between the carriers once this area is defined for the carrier in consideration. Therefore, the nature of the process should be based on the removal rate of organic surface area. The smaller carrier will need much less bioreactor volume than larger carriers at a specified organic effective surface area load (Ødegaard H. et. al, 2000). From the studies, the formation of biofilm depends strongly on the specific surface area and surface roughness of the carried media.

One of the most important factors of reactor performance was the arrangement of the carrier/bioball. Bio-balls arrangement was important to ensure the better biofilm growth and to prevent bio-carrier clogging. Gasim Hayder et.al (2018) in their study by using three different bio-balls arrangement illustrates which arrangement was working effectively in for biofilm growth and for preventing the clogging. [3].

Based on the factor stated such as types of bio-carrier, arrangement of bio-carrier and carrier media surface properties it shows that which one is the best in performance of nutrient removal in wastewater treatment. Nowadays, capital cost in land or any maintenance was higher but by applying effective technology such as biofilm technology in STPs, it could help in reducing the expenses. Figure 2 and Figure 3 below shows the graph of types of bio-carrier and arrangement of bio-carrier in nutrient removal for clearer overview.

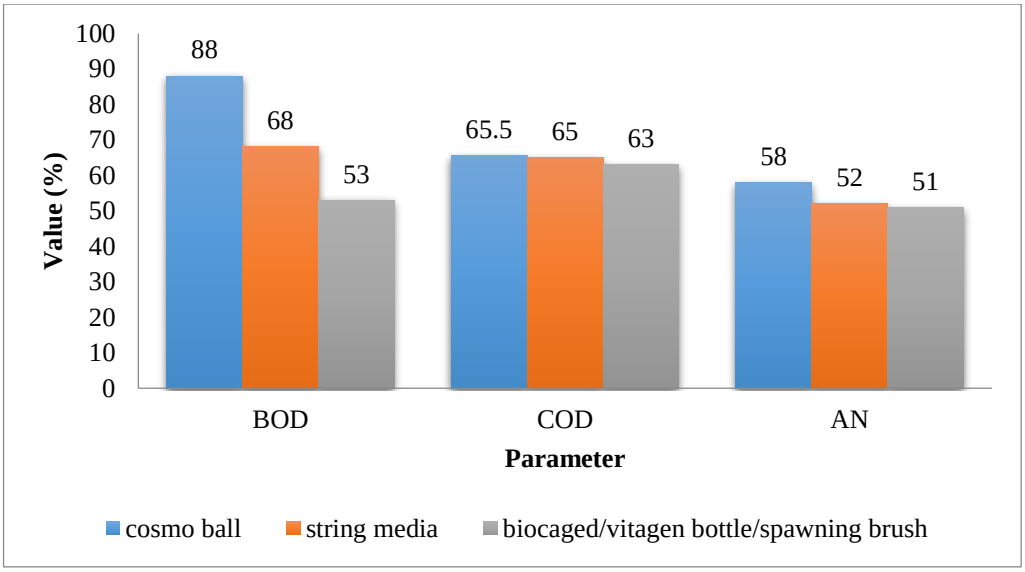

Figure 2: Nutrient removal from different types of bio-carrier

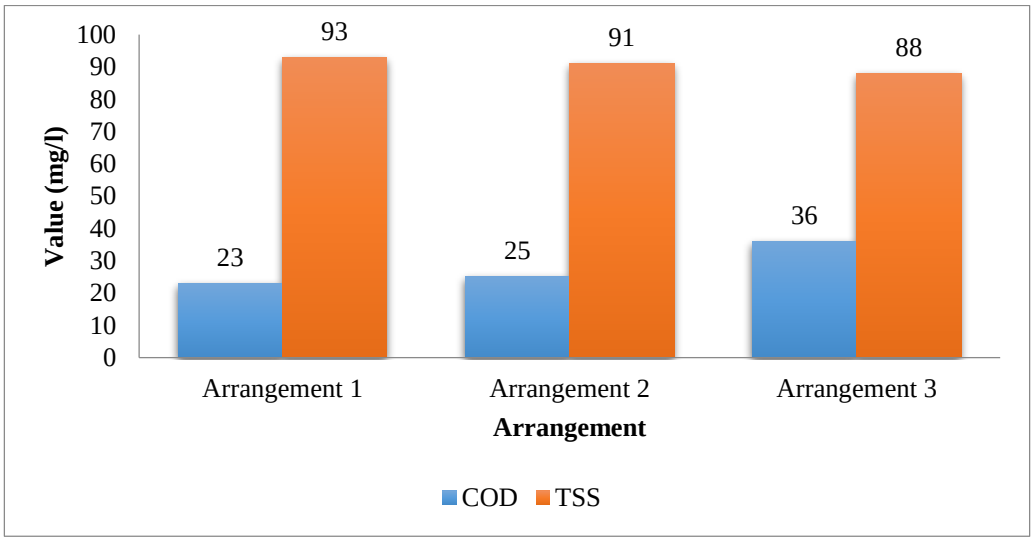

Figure 3: Nutrient removal from different arrangement of bio-carrier

3.3 Comparison in performance of coated cosmo ball with uncoated cosmo ball

Khaled Muftah Shahot stated that the activated carbon coating achieved a high surface roughness of 7µm, 10 times higher than non-coated media. [10]. It also shows that the coated cosmo ball have higher surface area than non-coated one. In the study, clear formation of biofilm on the media was recorded after 11 days where 100.00 % of biofilm covered the coated area while only 70.0 % of non-coated area. The differences in performance for both coated and uncoated Cosmo Ball are also measured based on several parameter such as TP, BOD, COD, TSS and AN. Figure 4 shows the result obtained for coated and non-coated Cosmo Ball in different parameter.

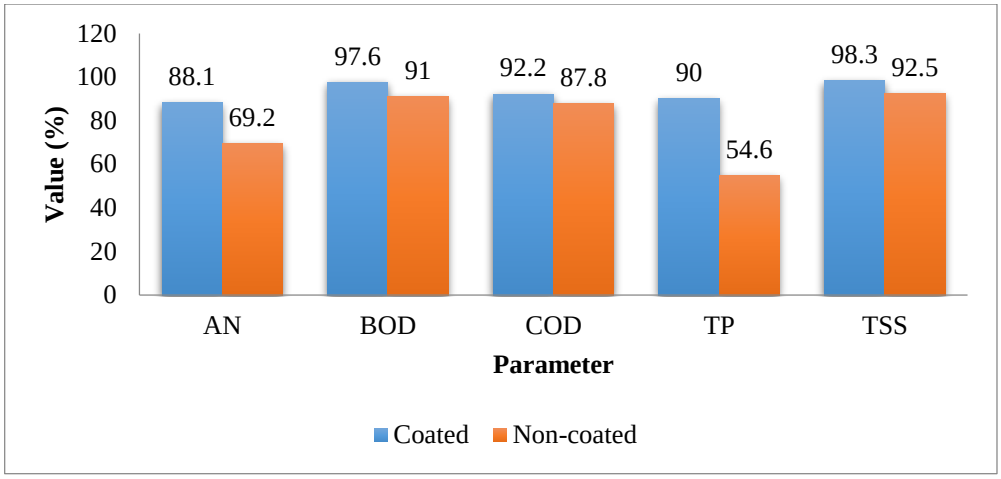

Figure 4: Value of nutrient removal obtained for coated and non-coated Cosmo Ball

Based on the obtained result, coated Cosmo Ball shows high effectiveness for nutrient removal in wastewater. The improving method using activated carbon gives positive impact for the biofilm system. The mixing of various materials, such as HDPE mixed with coke powder, zeolite and activated carbon nanoparticles for both aerobic and anaerobic MBBRs for the treatment of landfill leachate, has also been aimed at enhancing microbial attachment by growing the area and roughness of the carrier surface [7]. Equally important, longer retention time of organic matter could lead to financial problem because it requires extra operational cost to construct larger treatment system or tanks where it is required a wide construction land area.

3.4 Mechanism factor

The differences between the nutrient removals in some considered factor may be affected by some mechanism such as slow water flow, lack of aeration and lack of backwashing. In order to produce an effective wastewater treatment plant, this factor should be overcome to produce effluent that according to MSIG.

a. Water flow

The elimination of excess microorganisms would be inhibited by slow water flows. If the turbulence is too bad, it can cause insufficient biofilm shearing and build up more biomass than it should be and block biofilm voids as it limits the free passage into the inner layer of biofilm of wastewater and substrates [11]. The system of activity of the reactor also caused a disturbance of the flow of water, which ultimately hinders the biological treatment process. If the flow of water slows or blocks, the transfer of oxygen to the bio-medium can decrease and gradually clog the media. It is therefore necessary for the media to provide a uniform flow of water to avoid dead zones and channels that will ultimately reduce the rate of nitrification [12].

b. Aeration

Aeration is an essential part of the supply of oxygen and can prevent clogging of the media. Gasim Hayder et.al (2018) in their study by using ANSYS CFX to examine the impact of aeration on bio-balls and to define the effect of different aeration arrangements on two separate simulations. From the first simulation, the close arrangement of the fin ball was chosen as the best arrangement, since the forces acting on the surface of the fin ball and within the fin ball is optimal in this arrangement. When the forces are too low, there will be no scouring mechanism that encourages the growth of thicker and excessive biofilm, which will lead to clogging, while when the forces acting on bio-balls are strong, biofilm detachment from the surface will occur. In the second simulation, the loose fin ball arrangement and the loose cage ball arrangement were chosen as the better arrangement, since there is

less blue contour zone signaling faster saturated wastewater [13]. An optimum aeration design is therefore important, as it will have an overall effect on the efficiency of the treatment system.

c. Backwashing

Xie et.al (2017)], found that low backwash frequency resulted to clog the media. Under 24 times backwashes, the BOD removal rate was 67.10 % and the T-N nitrification rate is 40.90 %, while BOD removal and T-N nitrification increased significantly after over 30 backwashing. As a result, a sufficient frequency of backwashing is necessary to avoid media clogging as it improves the attachment and biofilm growth process [14].

4. Conclusion

The differences in physical properties, arrangement and surface area of bio-media are the factors that can affect its performance. In this study, it eliminates those factors to make clear understanding on it. It can be effectives when the surface of the bio-media is rougher and have larger surface area because biofilm grows, and attachment will be more on that. The arrangement of bio-media in the tank also important to avoid clogging occur on the bio-media that may be affected the plant performance and its maintenance. Besides that, the performance on two different types of bio-media which is AC coated and uncoated Cosmo Ball was also investigated. The objectives were achieved. The AC coated Cosmo Ball seems to be effective that uncoated one based on the results obtain by few parameters which is ammoniacal nitrogen, BOD, COD, TP and TSS. In conclusion, this study manages to analyze the best system to be implemented for wastewater treatment system. It also seems to be valuable in helping Malaysia's wastewater treatment system to reduce operational cost in term of energy use because this system uses minimum power consumption and also it could be operated in smaller size of system without compromise to achieve standard parameter compliance. It is important because nowadays, the land value is become higher especially in the urban area.

Acknowledgement

Authors would like to express their heartfelt thanks to Pakar Management Technology for sharing and collaborating on this study. This research was carried out as part of a project supported by Universiti Tun Hussein Onn Malaysia.

References

[1] C. Nicolella, M. v. (2000). Wastewater treatment with particulate biofilm reactors. Journal of Biotechnology 80 , 1-33.

[2] Commission, N. W. (2009). Mlaysian Sewage Industry Guidelines Volume IV Sewage Treatment Plant Third Edition . Selangor: Suruhanjaya Perkhidmatan Air Negara (SPAN).

[3] Gasim Hayder, L. M. (2015). Comparison of various types of biomedia in river water treatment using attached growth activated sludge process. International Journal of River Basin Management , 1-6.

[4] Hussain, D. I. (2012). Cosmo Ball in Wastewater Treatment. 14th Asia Pacific Confederation of Chemical Engineering (APCChE 2012). Serdang.

[5] Ion Iliuta, F. L. (2005). Modeling simultaneous biological clogging and physical plugging in trickle-bed bioreactors forwastewater treatment. Chemical Engineering Science, 1477-1489.

[6] Mariana Oana Mihaela Fufa, R. C. (2017). Microorganisms: New Trends in Environment-Friendly and Energy-Saving Water Purification. Water Purification , 263-288.

[7] Morgan-Sagastume, F. (2018). Biofilm development, activity and the modification of carrier material surface properties in moving bed biofilm reactors (MBBRs) for wastewater treatment. Environmental Science and Technology, 1-32.

[8] Ødegaard H, R. B. (1994). A new moving bed biofilm reactor-applications and results. Water Sci Techno , 157-165.

[9] S. Yeoman, T. S. (1988). The Removal of Phosphorus During Wastewater Treatment: A Review. Environmental Pollution , 183-233.

[10] Shahot, K. M. (2017). Activated Carbon-coated Cosmo Ball Biomedia for Wastewater Treatment. Selangor, Malaysia: Universiti Putra Malaysia.

[11] Gasim Hayder, A. N. (2017). A Review on Media Clogging in Attached Growth System. International Journal of Applied Engineering Research , 12 (19), 8034-8039.

[12] Odd-Ivar Lekang, H. K. (2000). Efficiency of nitrification in trickling filters using different filter media. Aquacultural Engineering , 181-199.

[13] Gasim Hayder, P. P. (2018). Numerical Simulation of the Attached Growth Reactor with Different Arrangement of Bio-balls. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences , 10-20.

[14] Gasim Hayder, A. N. (2017). A Review on Media Clogging in Attached Growth System. International Journal of Applied Engineering Research , 12 (19), 8034-8039.