

Using aerobic granular sludge to treat urban wastewater on SBR technology

Sử dụng bùn hạt hiếu khí để xử lý nước thải đô thị bằng công nghệ xử lý theo mẻ SBR

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ABSTRACT

Currently, in Vietnam only 10% - 15% of urban wastewater is collected and treated [18]. Wastewater collection systems in urban areas of Vietnam are mostly public drainage systems. Therefore, the operative parameters of water quality parameters such as COD, BOD₅, T-P are much lower than those of the design [18]. Therefore, most wastewater treatment plants in Vietnam do not work as efficiently as designed. In Vietnam, many wastewater treatment technologies have been applied, but in regard to capacity, SBR technology accounts for the largest amount with 43.8% [1].

Aerobic granular sludge has been applied in batch reactors SBR since the 1970s and it has been extensively studied with different substances in the following years [2][3]. Compared with activated sludge, aerobic granular sludge has a good granular structure, high biomass retention capacity, and ability to remove more toxic compounds in wastewater [4]. Therefore, it is applied to treat domestic wastewater, wastewater from food processing plants, livestock, industrial areas, leather processing factories, slaughter halls, breweries... [5]. It is a reliable guarantee for the studies on applying aerobic granular sludge on SBR technology to treat urban wastewater.

Keywords: Water aerobic granular sludge; treat urban wastewater; SBR technology; activated sludge; biomass.

TÓM TẮT

Hiện nay, tại Việt Nam mới chỉ có 10% - 15% lượng nước thải đô thị được thu gom và xử lý [18]. Hệ thống thu gom nước thải tại các đô thị của Việt Nam phần lớn là hệ thống thoát nước chung. Vì vậy thông số thực tế vận hành đối với các thông số như: COD, BOD₅, T-P thấp hơn nhiều so với thiết kế [18]. Điều này dẫn đến phần lớn các nhà máy xử lý nước thải tại Việt Nam làm việc không đạt hiệu quả như thiết kế. Tại Việt Nam áp dụng nhiều công nghệ xử lý nước thải (XLNT), tuy nhiên nếu tính theo công suất thì công nghệ SBR chiếm số lượng lớn nhất là 43,8% [1]. Bùn hạt hiếu khí đã được ứng dụng trong bể phản ứng theo mẻ SBR từ những năm 1970 và nó đã được nghiên cứu sâu rộng trong những năm sau đó với các chất nền khác nhau [2] [3]. So với bùn hoạt tính thông thường bùn hạt hiếu khí có kết cấu hạt tốt, có khả năng duy trì sinh khối cao, và có thể xử lý các hợp chất độc hại có trong nước thải [4]. Vì vậy mà nó được ứng dụng để xử lý nước thải sinh hoạt, nước thải của các nhà máy chế biến thực phẩm, nước thải chăn nuôi, nước thải công nghiệp, nước thải nhà máy thuộc da, nước thải lò mổ, nước thải nhà máy sản xuất rượu bia [5]... Đó là sự đảm bảo tin cậy cho những nghiên cứu ứng dụng bùn hạt hiếu khí bằng công nghệ xử lý theo mẻ (SBR) để xử lý nước thải đô thị.

Từ khóa: Bùn hạt hiếu khí; xử lý nước thải đô thị; công nghệ SBR; bùn hoạt tính; sinh khối.

1. INTRODUCTION

There are many types of urban wastewater treatment technologies in Vietnam, currently there are 6 main technologies applied to urban wastewater treatment plants in Vietnam. If calculated by capacity, SBR technology accounts for 43.81%; CAS technology accounts for 16.7%; Ho technology accounts for 13%; OD technology accounts for 9.5%; TF technology accounts for 4.5% of capacity; A2O technology accounts for 6.9% of capacity; MBBR technology with 1.5%; AO technology with 1.3%; other technologies account for 1.5%.

SBR wastewater treatment technology is an improvement from traditional activated sludge technology. Batch reactor (SBR) is an activated sludge technology process that operates in a "charge, aeration, rest, discharge" cycle. In the world, batch reactors have

been researched since the 1970s, even since 1914, the designs of wastewater treatment tanks by Arden and Lockett have operated on the principle of SBR tanks.

Aerobic granular sludge can be defined as the microbial biomass that utilizes the nutrients in the wastewater. Granular microbial biomass is described as a dense and compact collection of microorganisms in a spherical shape. The concept of aerobic granular sludge has been developed in recent years. Aerobic granular sludge is the self-fixing process of microorganisms into a spherical mass.

The geometry of aerobic granular sludge is spherical. The average diameter of aerobic granules varies between 0.2 ÷ 5 (mm). The specific gravity of aerobic granules is usually about 1004 ÷ 1065 (kg/m³). The settling velocity of aerobic granular sludge is closely

related to the particle size and structure, the settling velocity fluctuates $30 \div 70$ (m/h), the settling velocity of aerobic granular sludge is at least three times as high as that of conventional activated sludge [6] [7]. The microbial population in aerobic granular sludge is more diverse than in conventional activated sludge [6] [7].

The application of SBR technology in urban wastewater treatment has been proven through many research projects such as: Research by Bernardes and Klapwijk [4] aimed at evaluating and investigating the effectiveness of SBR technology for removing nitrogen, carbon, and phosphorus from urban wastewater in the Bennekom WWTP in the Netherlands with a capacity of 22000 (m³/day); or research project by Umble and Ketchum [8], doing experiments with SBR technology in urban wastewater treatment. Basing on the ability of SBR technology to treat wastewater flexibly in removing organic matter, suspended solids, and nitrification; The project by Beccari et al [9] studied COD removal by acidogenic fermentation from organic wastes in municipal waste; The research project by De Sousa and Foresti [10], the one carried out on an experimental model of a UASB tank with a capacity of 4 (liters) and two identical cylindrical SBR models with a capacity of 3.6 (liters); The project by Steinmetz [11], demonstrated the effectiveness of SBR technology in 2 urban wastewater treatment plants with a capacity of 15000 (m³/day) and 25000 (m³/day). [12]

In recent years, the use of aerobic granular sludge for wastewater treatment tends to increase at different levels in the

world such as: Opfikon Klotten wastewater treatment plant - Switzerland, capacity 26000 (m³/day); Wemmershoek wastewater treatment plant - South Africa, capacity 5000 (m³/day); Highworth wastewater treatment plant - United Kingdom, capacity 1444 (m³/day); Clonakilty-Ireland wastewater treatment plant, capacity 5000 (m³/day); Ringsend wastewater treatment plant - Ireland, capacity 600.000 (m³/day); Kingaroy wastewater treatment plant - Australia, capacity 10.800 (m³/day); Longford wastewater treatment plant - Australia, capacity 2.838 (m³/day). Sappi Lanaken wastewater treatment plant - Belgium, capacity 14.400 (m³/day). Araguaína wastewater treatment plant, Tocantis, Brazil, with a capacity of 52.704 (m³/day) [13].

2. AEROBIC GRANULAR SLUDGE

Factors affecting the formation and development of aerobic granular sludge

The formation and development of aerobic granular sludge depends on many factors, the main factors include: composition of the substrate; organic loads in wastewater; aeration intensity; microbial selection time; hydraulic retention time; anoxic process; technological conditions; environmental conditions.

Advantages of aerobic granular sludge compared to conventional activated sludge

The outstanding advantages of aerobic granular sludge over conventional activated sludge are presented in Table 2.1

Table 2.1. Properties of aerobic granular sludge and conventional activated sludge [14];[5]

No	Properties	Aerobic granular sludge	Activated sludge
1	Settling ability	$30 \div 70$ (m/h)	$8 \div 10$ (m/h)
2	Biomass concentration	> 10 g/l	< 5 g/l
3	SVI ₃₀ index	< 50 (ml/g)	$60 \div 200$ (ml/g)
4	Microbial composition	Diverse, including aerobic, anaerobic, facultative bacteria	Aerobic bacteria mostly
5	Load shock resistance	high	Poor
6	Organic load	High organic load ($2 \div 15$ kgCOD/m ³ .day)	Low organic load ($< 2,5$ kgCOD/m ³ .day)
7	Size	$0,2 \div 5$ (mm)	$3 \div 150$ (μ m)
8	Mud age	About $12 \div 15$ days	About $6 \div 7$ days

Scientific basis for treating substrates of aerobic granular sludge

To make it easier to imagine, the granular sludge structure is roughly divided into 3 layers based on the percentage of predominant microbial species.

The first layer, the outermost layer of the granule sludge, includes plenty of active heterotrophic bacteria, so the COD removal process mainly occurs at the surface. Microorganisms absorb nutrients and oxygen in wastewater and release CO₂ and water.

The second layer, under the outermost layer of the granular sludge, contains many highly active nitrifying bacteria, so nitrogen removal mainly occurs in this layer.

The third layer, which is the innermost layer of the granular sludge, includes many highly active anaerobic bacteria, and phosphorus accumulation. The process of removing phosphorus and nitrogen, and sulfur mainly occur in this layer.

The ability of aerobic granular sludge to remove pollutants in wastewater

Aerobic granular sludge can be used for removing organic compounds, nutrients (nitrogen, phosphorus), heavy metals and toxic substances. Studies related to this matter have shown many advantages of aerobic granular sludge such as: capability to treat organic, N, P well; stable metabolic rate; good restoration and load shock resistance, long biomass storage time [15].

Kinetics of aerobic granular sludge formation

The kinetics of aerobic granular sludge formation and growth is described by equation of degree 1 [16].

$$D - D_0 = (D_e - D_0)[1 - e^{-\mu(t-t_0)}] \quad [16]$$

In which: + D_0 - is the size of microbial aggregate at time t_0

+ t_0 - is the stage when microorganisms begin to adapt

+ D - is the size of microbial aggregate at time t

+ D_e - is size of microbial aggregate at equilibrium

+ μ - is the specific growth rate of aggregate by size

3. APPLICATION OF SBR TECHNOLOGY USING AEROBIC GRANULAR SLUDGE TO TREAT URBAN WASTEWATER IN HANOI IN THE LABORATORY

3.1. Efficiency of removing organic and nutrients

a. COD removal efficiency

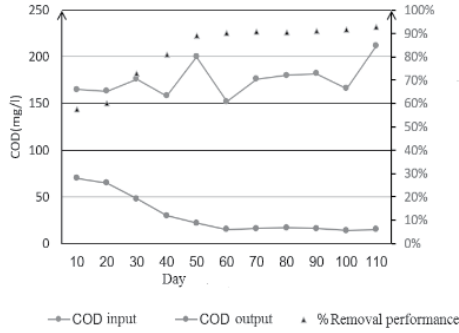


Figure 3.1. COD removal efficiency

b. NH_4^+ - N removal efficiency

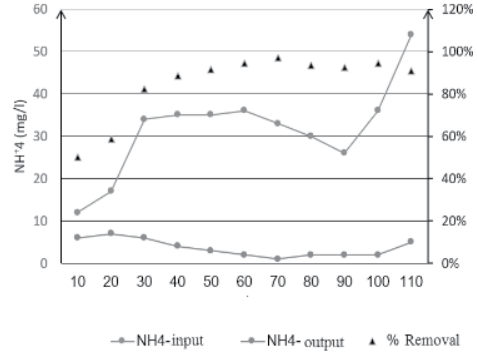


Figure 3.2. NH_4^+ - N removal efficiency

c. T - N removal efficiency

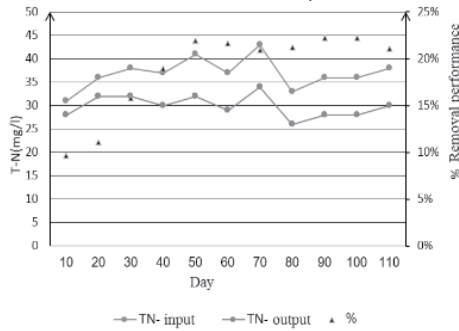


Figure 3.3. T - N removal efficiency

d. T - P removal efficiency

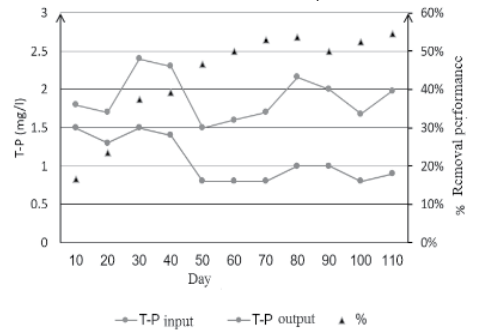


Figure 3.4. T - P removal efficiency

3.2. Evaluating the stability of the aerobic granular sludge culture process

a. MLSS sludge concentration and MLVSS/MLSS ratio

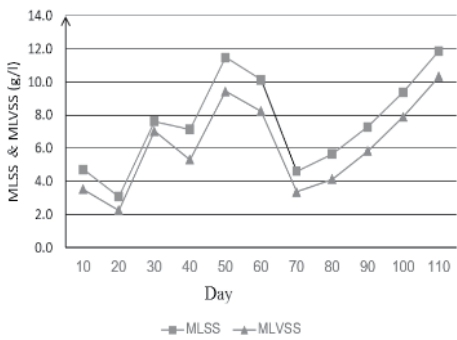


Figure 3.5. Changes in MLSS and MLVSS during the experiment

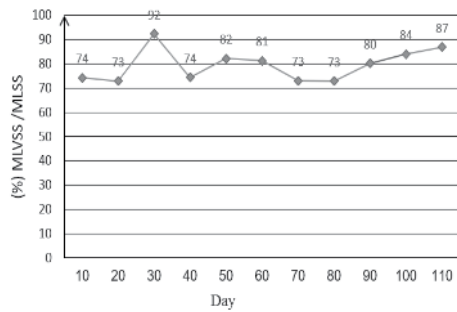


Figure 3.6. Changes in MLVSS/MLSS ratio

b. SVI_{30} index

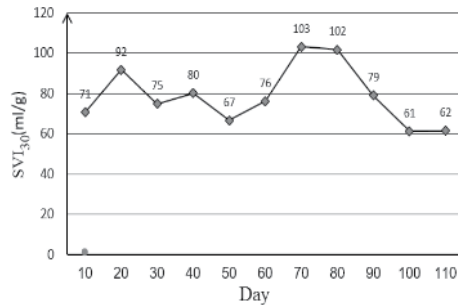


Figure 3.7. SVI_{30} index during the experiment

3.3. Proposing aerobic granular sludge application technology for urban wastewater treatment in Vietnam

a. The case for dilute urban wastewater with $OLR < 2.0$ ($\text{kgCOD}/\text{m}^3 \cdot \text{day}$)

In this case, it is difficult to successfully grow the granular sludge and maintain the sludge concentration in the reactor. Therefore, on the technology diagram, it is necessary to have additional solutions and maintain a stable particle sludge concentration. The granular sludge will be raised in a separate tank with the appropriate addition of nutrients and COD. The amount of granular sludge that needs to be added includes dissolved and washed sludge, old sludge. The addition of granular sludge to always ensure the required F/M ratio. The diagram looks like Figure 3.8.

3

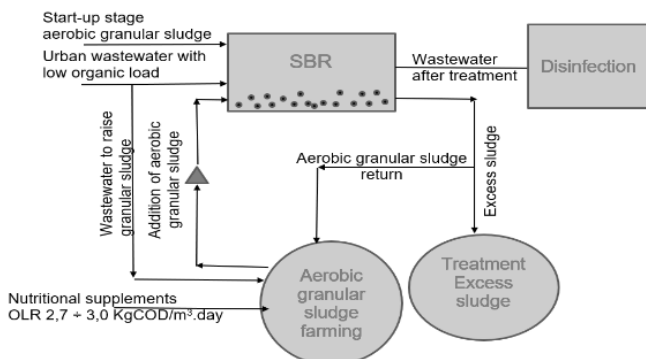


Figure 3.8. Technological line diagram for application of aerobic granular sludge on SBR technology to treat urban wastewater with low organic load

b. The case for solid urban wastewater with $OLR > 2.5$ ($\text{kgCOD}/\text{m}^3 \cdot \text{day}$)

For urban wastewater with high organic load, the concentration of granular sludge is always ensured due to the sludge formation process right in the reactor. On the technology diagram, there is no need to have additional solutions and maintain the particle sludge concentration to always ensure the required F/M ratio. The diagram looks like Figure 3.9.

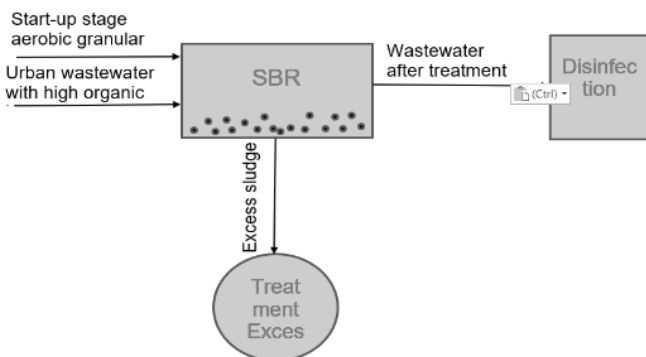


Figure 3.9. Technological flow diagram for application of aerobic granular sludge on SBR technology to treat urban wastewater with high organic load

4. CONCLUSIONS

From the results of the actual survey at urban wastewater treatment plants in Vietnam and the analysis, comparison of the experimental results of the thesis, it can be seen that the application of aerobic granular sludge on the SBR technology model to treat dilute urban wastewater in Vietnam bases on scientific basis for the following reasons: The BOD, COD, NH_4^+ - N removal efficiency is stable and high when making comparison between wastewater treatment plants applying the SBR technology and those using other technologies.

Suitable for urban wastewater with low organic load. Most urban areas in Vietnam currently use a common sewer system, so wastewater has a low organic load. Wastewater treatment plants applying SBR

technology are very popular in Vietnam, so it will be very convenient to apply aerobic granular sludge on the SBR technology model.

The research results of the thesis show that the possibility of applying SBR technology using aerobic granular sludge to treat urban wastewater has a scientific basis for the following reasons: The COD, NH_4^+ - N removal efficiency is stable and high efficiency when compared to other wastewater treatment plants applying SBR technology in Vietnam and compared with current discharge standards in Vietnam (Vietnam standard 14/2008-BTNMT and 40:2011/BTNMT)

Suitable for urban wastewater with low organic load, since most urban areas in Vietnam use a common drainage system, wastewater usually has a low organic load. Wastewater treatment plants in Vietnam applying SBR technology are very popular, the application of aerobic granular sludge on the SBR technology model is very convenient.

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