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Phenol biological treatment in wastewater by laboratory scale

Xử lý phenol trong nước thải bằng công nghệ sinh học ở quy mô phòng thí nghiệm

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ABSTRACT

Experiments used an aerobic-activated sludge reactor to investigate the removal of phenol and formaldehyde from wastewater on a laboratory scale. An activated sludge reactor module with a volume of 70 L, starts up with 10 hours of hydraulic retention time pH value in the range of 6.8-7, the DO in the anoxic compartment is always less than 0.5 mg/L, in the aerobic compartment between the values of 3.0 and 4.5 mg / L. The results showed that the activated sludge after the start-up process was stable with MLSS 2800 mg/L to 3170 (mg/L), sludge volume index (SVI_{30}) was 156.7 ml/g, and activated sludge showed good sedimentation ability. Phenol in influent less than 200 mg/L, the removal performance of activated sludge reactor is very good, almost all phenol is removed from the wastewater. When treating wastewater with a mixture of phenol and formaldehyde, there is a reduction in treatment efficiency when increasing the pollutant concentration, at a concentration of 300 mg/L of formaldehyde and phenol, only 82.36%. and 72.63% respectively is eliminated. Activated sludge reactor can be used to treat industrial phenol and formaldehyde-containing wastewater.

Keywords: Activated sludge reactor; industrial wastewater; phenol removal

TÓM TẮT

Các thí nghiệm trong nghiên cứu này sử dụng thiết bị xử lý bùn hoạt tính hiếu khí để nghiên cứu quá trình loại bỏ phenol và formaldehyde khỏi nước thải ở quy mô phòng thí nghiệm. Một mô-đun xử lý với bùn hoạt tính có thể tích 70 L, giai đoạn khởi động với thời gian lưu thủy lực là 10 giờ, giá trị pH trong khoảng 6,8-7, DO trong ngăn thiếu khí luôn nhỏ hơn 0,5 mg/L, trong ngăn hiếu khí trong khoảng giá trị 3,0 và 4,5 mg/L. Kết quả cho thấy bùn hoạt tính sau quá trình khởi động ở trạng thái ổn định với MLSS 2800 mg/L đến 3170 (mg/L), chỉ số thể tích bùn (SVI_{30}) là 156,7 ml/g và bùn hoạt tính cho thấy khả năng lắng tốt. Phenol trong nước thải đầu vào dưới 200 mg/L, hiệu suất loại bỏ của thiết bị xử lý bùn hoạt tính rất tốt, hầu như toàn bộ phenol đều được loại bỏ khỏi nước thải. Khi xử lý nước thải bằng hỗn hợp phenol và formaldehyde, hiệu suất xử lý giảm khi tăng nồng độ chất ô nhiễm, ở nồng độ 300 mg/L formaldehyde và phenol, chỉ có 82,36% và 72,63% tương ứng được loại bỏ. Công nghệ sinh học với bùn hoạt tính có thể được sử dụng để xử lý phenol và formaldehyde trong nước thải công nghiệp.

Từ khóa: Thiết bị xử lý sinh học; bùn hoạt tính; nước thải công nghiệp; xử lý phenol.

1. INTRODUCTION

Phenol is produced through two natural and artificial pathways. In nature, phenol is found in some foods, animal and human waste, and in the decomposition products of organic substances, or phenol is also produced inside living organisms due to the metabolic process of amino acids. Phenol can be produced during the combustion of wood, fuel exhaust, and tobacco. In nature, phenol is formed from the decomposition of benzene (2). Phenol and phenol derivatives are found in industrial wastewater. The presence of phenol compounds in water is one of the causes of water odor and is harmful to the ecosystem and human health. Currently, there is no research on the effects of low concentrations of phenol on the development of the body, however, many scientists believe that frequent exposure to phenol can lead to slow development, causing abnormal changes in the next generation, increasing the rate of premature birth in pregnant women (3).

Formaldehyde is a colorless substance, that has a very strong gas smell, this substance is often found in some liquid solutions. However, in practice, they are often used as preservatives in laboratories or morgues, in addition, formaldehyde is also found in many types of chemical products, household products, glues, permanent press fabrics, paper product coatings, and many types of plywood (MDF, HDF ...). This substance is also commonly used with phenol in the phenol-formaldehyde adhesive production industry (5).

Upflow Sludge Blanket Filter (USBF) biological sludge filtration technology is designed based on the dynamic model of BOD, nitrification, and denitrification treatment by Lawrence and McCarty, Inc., first introduced in the US in the 1900s and then

applied in Europe from 1998 onwards (6). However, currently in the world, the Lawrence and McCarty model is applied in many different forms depending on the characteristics of each country. This technology has not been used in Vietnam, although activated sludge technology has been used as a classic technology in wastewater treatment commonly in our country (9). This study uses the improved USBF technology model of the activated sludge process, which combines 3 processes: Anoxic, Aeration, and up-flow biological filtration to simultaneously treat phenol and formaldehyde in wastewater. This is the difference with the traditional activated sludge treatment system, which often separates the above three processes, resulting in low processing speed and efficiency.

2. MATERIALS AND METHOD

2.1. USBF equipment

The experiment was conducted in a USBF system with a total volume of 70 liters, the volume ratio of the anaerobic tank: aerobic tank: and sedimentation tank is 3:7. The water layer depth is 36 cm, the DO content in the anaerobic compartment is lower than 0.5 mg/L, dissolved oxygen in the aerobic compartment is 2-4 mg/L, the water retention time is operated stably at 10 hours. The start-up phase of the phenol-contaminated wastewater treatment system lasts at least 1 month to stabilize the growth of activated sludge, then conduct experiments to evaluate the efficiency of pollutant treatment.

2.2. Experimental operation

The assumed wastewater contains 14.3 mg/l NH_4Cl, 4.8 mg/l KH_2PO_4, 1.3 mg/l $CaCl_2$, 31.1 mg/l $NaHCO_3$, 0.7 m/l $MgSO_4.7H_2O$, 3.6 mg/l $FeSO_4.7H_2O$, 1 ml of trace element solution (Eiroa, 2005), the mineral components in the assumed wastewater are intended to provide the minerals necessary for microorganisms to grow in the wastewater. Phenol was used at different concentrations as the main carbon source for the treatment system. The activated sludge used in the experiment was taken from an industrial wastewater treatment plant in Tan Truong Industrial Park, Hai Duong Province. In the tests to evaluate the efficiency of phenol and formaldehyde removal, the equipment was operated stably with MLSS values in the range of 3000 mg/L.

2.3. Analytical methods

The parameters of MLSS, SVI_{30}, and formaldehyde concentration were determined according to the standard method (1). Phenol in water was analyzed by spectrophotometry, colorimetrically with aminoantipyrene solution (4-AAP), in which 0.2 ml of 0.1 M glycine solution containing 5% (w/v) $K_3Fe(CN)_6$ was mixed with 2 ml of filtered water sample. The mixture was left to react for 5 min, 2 ml of glycine buffer solution (prepared by dissolving 5.58 g glycine hydrochloride and 3.75 g glycine in 0.9 l distilled water and adjusting to pH 9.7 with 5N NaOH, then making up to 1 liter) was added, this buffer solution contained 0.25% (w/v) 4-amino antipyrine. The color of the solution was developed for 20 min, then measured at 506 nm with a spectrophotometer. The concentration of phenol was calculated through a standard curve established with pure phenol. Data were processed using Microsoft Office 2017 and Sigma Plot 14.0 software.

3. RESULTS AND DISCUSSION

3.1. Growth of activated sludge

The USBF system was maintained with simulated wastewater, the substrate concentration (phenol) was gradually increased from 30 to 150 mg/L, for 15 days, and the following days were maintained to develop the concentration of microbial biomass. Observation of activated sludge in the USBF system showed that the microorganisms grew stably, there was no phenomenon of sludge flocculation, sometimes foaming and floating scum, but no foul odor and the MLSS value was recorded in the range of 2800 mg/L to 3170 (mg/L).

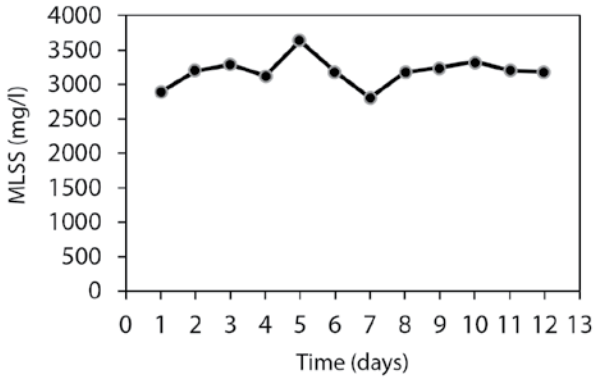

Figure 3.1. Biomass growth of activated sludge in USBF

Although the microbial biomass did not show significant growth, it also showed good adaptation of activated sludge from industrial wastewater treatment plants to phenol. In other words, at a phenol concentration of 150 mg/L, it would not cause too much inhibition of microorganisms, and would not cause a decrease in biomass concentration. Dey et al. (2010) in their study also found that the growth of microorganisms in the population was not inhibited at phenol concentrations below 300 mg/L. Increasing the concentration of phenol in wastewater to 600 mg/L increased toxicity by 63%, compared to the lowest concentration studied (3). This showed the importance of the adaptation process to reduce toxicity when treating high concentrations of toxic organic compounds such as phenol.

3.2. Settling capacity of activated sludge

The sludge volume index is an important index showing the settling ability of microorganisms in the wastewater treatment process. The lower the sludge volume index, the better the settling ability and the level of attachment of microbial cells. On the contrary, if this index increases, it is not favorable for the settling process. Research shows that if SVI_{30} is equal to or less than 150 mL/g, the sludge has very good settling properties, while SVI_{30} above 150 mL/g often shows the presence of filamentous bacteria, which makes it difficult for the settling process of activated sludge, which is unfavorable for wastewater treatment (8). In this test, it was found that the average SVI_{30} value was 156.7 mg/L, which is quite good for a continuous anoxic and aerobic wastewater treatment system. However, due to operational factors, there were times when the SVI_{30} value was at a high value of 200 ml/g.

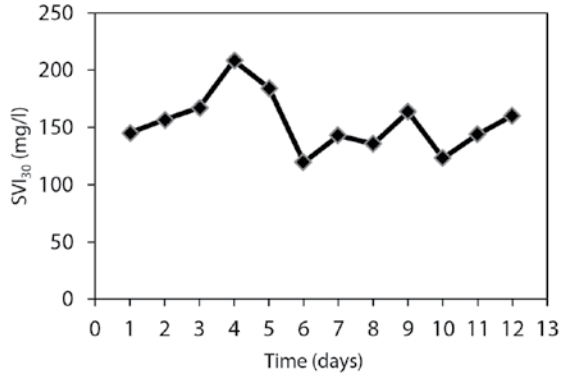

Figure 3.2. Sludge volume index (SVI_{30})

3.3 Effective treatment of phenol and formaldehyde mixture

The data on the phenol treatment capacity in the USBF system are shown in Figure 3.3. When the input phenol concentration

increased from 30 mg/L to 200 mg/L, most of the phenol was removed with a hydraulic retention time of 10 hours. In another experiment conducted by the authors (Le Ngoc Thuan et al., 2020), it was found that the phenol treatment capacity decreased significantly when the input phenol concentration increased from 300 mg/L or more, and only 36.8% of phenol was removed at a concentration of 450 mg/L.

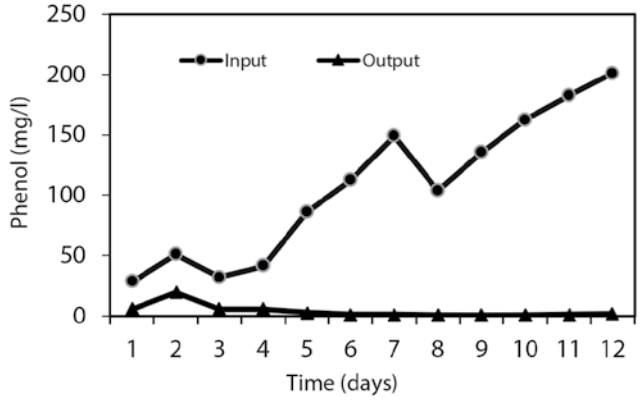

Figure 3.3. Phenol treatment efficiency

Phenol is a substance that can inhibit the activity of microorganisms, usually, the treatment efficiency will decrease when the concentration is higher, and the toxicity of phenol is increased. Research by Afzal et al. showed that at phenol concentrations higher than 250 mg/L, phenol inhibits microorganisms by increasing the lag phase in the biodegradation process, requiring a retention time of more than 12 hours to completely decompose phenol from wastewater (2). When studying the simultaneous removal of phenol and formaldehyde in the USBF tank, the data in Figure 3.4 showed that the treatment efficiency was very good in the range of values from 20 mg/L to 50 mg/L of phenol and formaldehyde, almost all (99.8%) of the substrate was removed from the wastewater. The efficiency of pollutant treatment will decrease when the concentration of phenol and formaldehyde increases. At a concentration of 100 mg/L, only formaldehyde is completely treated, while phenol is only removed by 95.7%; at a concentration of 300 mg/L of formaldehyde and phenol, only 82.36% and 72.63% are removed, respectively.

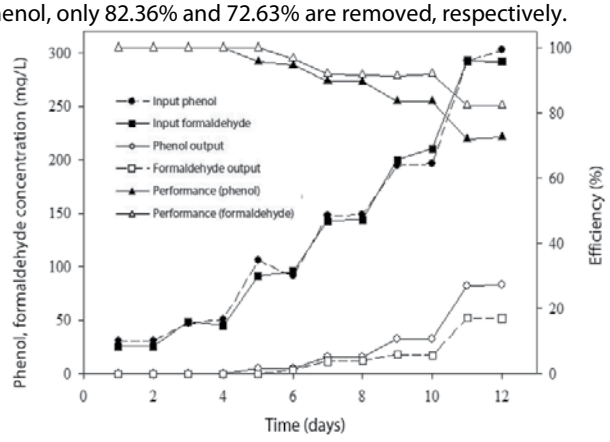

Figure 3.4. Concentration evolution of phenol and formaldehyde mixture in wastewater-treated

In experiments with increasing substrate concentrations, it was found that phenol was treated more slowly than formaldehyde in the same period of time, which may be due to the complex nature of the aromatic ring in the chemical structure of phenol. The slower degradation of phenol compared to formaldehyde in wastewater mixtures was also shown by Eiroa et al. (2010), when studying the treatment of phenol and formaldehyde under aerobic conditions with a concentration of phenol of 30 mg/L and formaldehyde of 180 mg/L (4). There are not many studies on the simultaneous removal of phenol and formaldehyde by biological methods. Hidalgo et al. (2002) investigated the biodegradation of 107 mg/L formaldehyde and 93 mg/L phenol using a pure strain of *Rhodococcus erythropolis* and recorded 87.4 and 55% removal rates, respectively (5). Kochany et al (2009) evaluated the aerobic biodegradation of phenol (560 mg/L) and formaldehyde (480 mg/L) and recorded treatment efficiencies of only 46 and 48%, respectively (6).

4. CONCLUSIONS

Activated sludge biotechnology was used to test the removal of phenol and formaldehyde from wastewater. The activated sludge after the start-up process was maintained at a stable value of 2800 mg/L to 3170 (mg/L), the average sludge volume index was 156.7 ml/g, and the activated sludge showed good settling ability. In the range of phenol values less than 200 mg/L, the treatment efficiency of the activated sludge method was very good, almost all phenol was removed from the wastewater. When treating wastewater with a mixture of phenol and formaldehyde, there was a clear decrease in treatment efficiency as the pollutant concentration increased, at a concentration of 300 mg/L of formaldehyde and phenol, only 82.36% and 72.63% were removed, respectively. Phenol and formaldehyde are both considered to be substances that can inhibit the life processes of microorganisms. The complex decomposition process of these two substances in wastewater by activated sludge technology requires further research.

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