

ENHANCING PHENOL REMOVAL FROM WASTE WATER BY ADDING POWDER ACTIVATED CARBON TO THE LAB-SCALE ACTIVATED SLUDGE SYSTEM

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ABSTRACT

In this study, the commercial powder activated carbon (PAC) was added to a bench scale conventional activated sludge (CAS) system to enhance phenol removal. The mixed liquor suspended solid (MLSS) concentration of CAS with adding PAC was stable in all stages of operation, while MLSS concentrations in CAS without PAC addition sharply decreased as the Phenol loading reached 1.8 g phenol/L.day. Higher removal of chemical oxygen demand (COD) and Phenol achieved with the CAS by PAC addition compared with those achieved with CAS without PAC addition. The difference in COD removal efficiency was 7 - 9% in stages 3 and 4 (0.8 and 1.2 g phenol/L.day, respectively), and about 33% in stage 5 (1.8 g phenol/L.day). The advantage of CAS with PAC addition was clearly observed in the highest phenol loading (1.8 g phenol/L.day) because the MLVSS/MLSS ratio of CAS with PAC addition increased and the COD and phenol removal efficiencies kept stable in this stage, while reverse trends were found for CAS without PAC addition. The results indicated that the adaptive ability of the CAS by adding PAC was significantly higher than the CAS without AC addition. This study offers useful preliminary results for applying a hybrid system between CAS and adsorption with PAC for further research and application in future.

Keywords: *Phenol removal; hybrid activated sludge process; COD removal; activated carbon; MLVSS/MLSS ratio.*

1. INTRODUCTION

Recently, water contamination by phenolic compounds has raised major public concern due to its influence on human health and ecosystem. Phenol is released into surface water from various industrial effluents, such as those from gasoline, plastic rubber proofing, paint, coal conversion, pharmaceutical, and steel industries [1-4]. According to US-EPA [1], Phenol is highly irritating to the skin, eyes, and mucous membranes in humans after acute (short-term) inhalation or dermal exposures. Therefore, it is quite toxic to humans via oral exposure. Due to its toxicity and feasible accumulation in the environment, phenol is highly concerned to be eliminated from the wastewater before discharging into the water streams [1, 4-6].

Many approaches can be applied for phenol removal, including physical and chemical methods such as thermal decomposition, chemical oxidation, electrochemical treatment, catalytic oxidation, and photoelectric oxidation. However, these methods are expensive and difficult to apply on a large scale. The current feasible approach is to use biological treatment combined with physical and chemical treatment, which is economical and efficient for Phenol removal. The conventional activated sludge system (CAS) is applied widely for effective removal of organic contaminants with low operating and investment costs. However, as a toxin, phenol inhibits the development of microbial population in activated sludge, causing low efficiency of the CAS system. Powder activated carbon (PAC) is a common

adsorbent with high adsorbing affinity with organic contaminants, which might act as a good additive for reducing the load shock of phenol and stabilizing the operation of CAS system. [7-10] In this study, PAC was added into CAS system in order to improve the treatment efficiency of the activated sludge method. The aim of this study is to assess and compare the influences of phenol loading rate on activated sludge properties and phenol removal efficiency using two lab-scale models, which include addition of PAC and without addition of PAC, respectively.

2. MATERIALS AND METHOD

2.1 Wastewater properties

In order to reduce the fluctuation of contaminants and provide a stable source of phenol and nutrients in the influent, simulated wastewater was prepared from glucose, ammonium sulphate and potassium dihydrogen orthophosphate, and phenol. The synthetic wastewater has emical oxygen demand (COD) of 330–360 mg/L, ammonium nitrogen (N-NH₄) of 80 mg/L and orthophosphate (P-PO₄) of 14 mg/L, phenol concentration of 200 mg/L. NaOH or H₂SO₄ was used to adjust pH to about 7.

2.2 Equipment

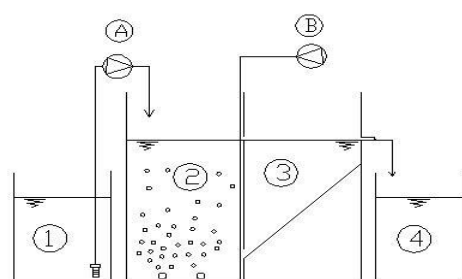


Figure 1. Schematic diagram of experimental apparatus; 1. Influent tank; 2. Aerobic tank; 3. Sedimentation tank; 4. Effluent tank; A. Pump; B. Air compressor.

The design of lab-scale models is depicted in Figure 1. Two similar models include an influent tank; an aerobic tank which is connected with the sedimentation tank. Finally, the output wastewater is stored in the effluent tank.

2.3 Conditional operation

Activated sludge was initially filled in aerobic tanks with MLSS concentration of about 4000 mg/L. Wastewater was diluted and fed into the system with concentration of phenol in the range of 200 - 300 mg/L which is equivalent to the phenol load rate from 0.4 g phenol/L.day to 0.6 g phenol/L.day. The concentration of DO in aerobic tank is maintained from 2 to 4 mg/L. The COD concentrations at the input and output of two models and MLSS, MLVSS in aerobic tanks were monitored daily to assess characteristics of microbial population in the systems and evaluate the removal efficiencies of two systems.

After operating in the adaptive phase, the operative phase was started. The model I was added 1500 mg/L commercial activated carbon powder ($d_p < 0.108 \mu\text{m}$) while the model II remained only activated sludge. Figure 2 describes the experimental setup of this research and states the flow rate, hydraulic retention time as well.

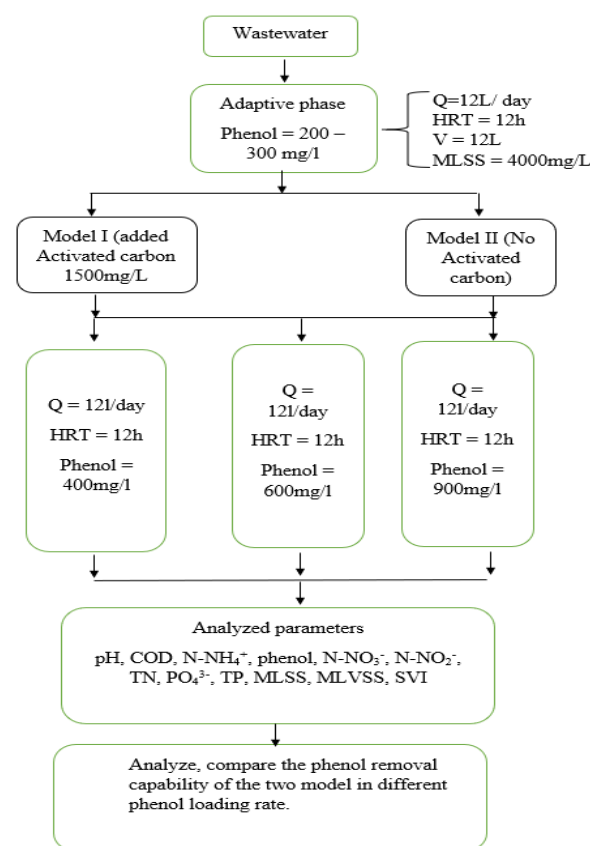


Figure 2. Diagram of experimental setup

2.4 Analytical methods

Parameters of COD, MLSS and MLVSS were determined according to standard methods [2]. Phenol was analyzed using the photometric method.

3. RESULTS AND DISCUSSION

3.1 Characteristics of biomass in the reactors

MLSS is one of the key parameters in the wastewater treatment process. In the system of wastewater treatment by biology, maintaining a high MLSS density, it has a great effect on improving processing efficiency and reducing processing time, as well as being able to treat wastewater with high organic matter content. During the

adaptive phase (phase 1) the model was run at a phenol load rate of 0.4 g phenol/L.day, which is equivalent to a phenol concentration of 200 mg/L. The concentration of MLSS in the model was not stable, decreasing continuously. The MLSS concentration decreased sharply, specifically from day 1 to day 9, the MLSS concentration decreased from 4,010 mg/L to 3,585 mg/L, because microorganisms could not adapt to the phenol. Phenol poisons and inhibits the growth of microorganisms. During the adaptation phase, the microorganism groups which are not affected by the phenol, participating in the phenol treatment will be selected and developed in the subsequent stages.

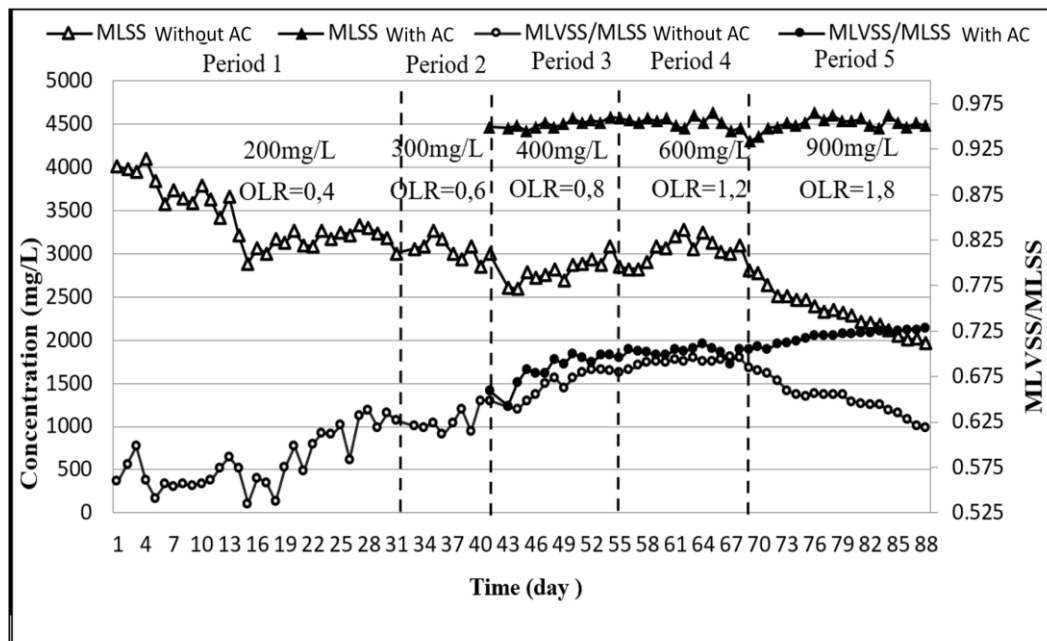


Figure 3. The change of MLSS/MLVSS in reactors

Figure 3 shows the influence of phenol on the stability of activated sludge. During the adaptive phase, the significant difference between MLSS concentrations in the beginning and after 10 days was found, the average concentration was $3,425 \pm 337$ mg/L. In Stage 2, the microorganism population was more stable but still under great influence when the input phenol concentration of 300 mg/L with MLSS of $3,051 \pm 121$ mg/L. At the period 3, it was

showed that the combination of activated carbon reduced the effect of phenol on the activated sludge. When the Phenol loading increased to 0.8 g phenol/L.Day, the MLSS concentration was stable in the range of $4,501 \pm 48.1$ mg/L. In the model without AC, as similar to previous stages, when the phenol loading rate increased, the microorganisms affected much, the concentration of MLSS fluctuated in the range of $2,819 \pm 145$ mg/L.

3.2 Removal efficiency of COD

COD is a typical pollution parameter in wastewater, which is primarily used to assess the contamination of wastewater. In the model without AC, COD treatment efficiency was different from the adaptive phase; especially at period 5. COD treatment efficiency of each stage was $83.8 \pm 4.5\%$; $86.6 \pm 3\%$; $49.5 \pm 11.6\%$, respectively. As in the model with PAC, at the beginning of each period the effluent COD increased and decreased towards the end of the period. At the period 3, from day 41 to day 44, the effluent COD increased from 17.4 to 204 mg/L, then gradually decreased from 204 to 117 mg/L on day 54. At the beginning of period 4, from day 55 to 58, the output COD

increased from 117 to 265 mg/L on day 68. Especially at period 5, when increasing the input phenol load to 1.8 g phenol/L.day equivalent to an influent COD of 2,155 mg/L, the output COD increased from the beginning to the end of the period, 390 mg/L on day 1 and 1446 mg/L at the end of the period. With a high concentration of phenol (900 mg/L), microorganisms were in shock, inhibiting the ability to function almost all microorganisms, resulting in them not decomposing phenol and dying. From the effects of the above phenol, the sludge concentration in the model decreased drastically from 3,095 mg/L to 1,865 mg/L, leading to a sharp decrease in COD treatment efficiency as shown in Figure 4.

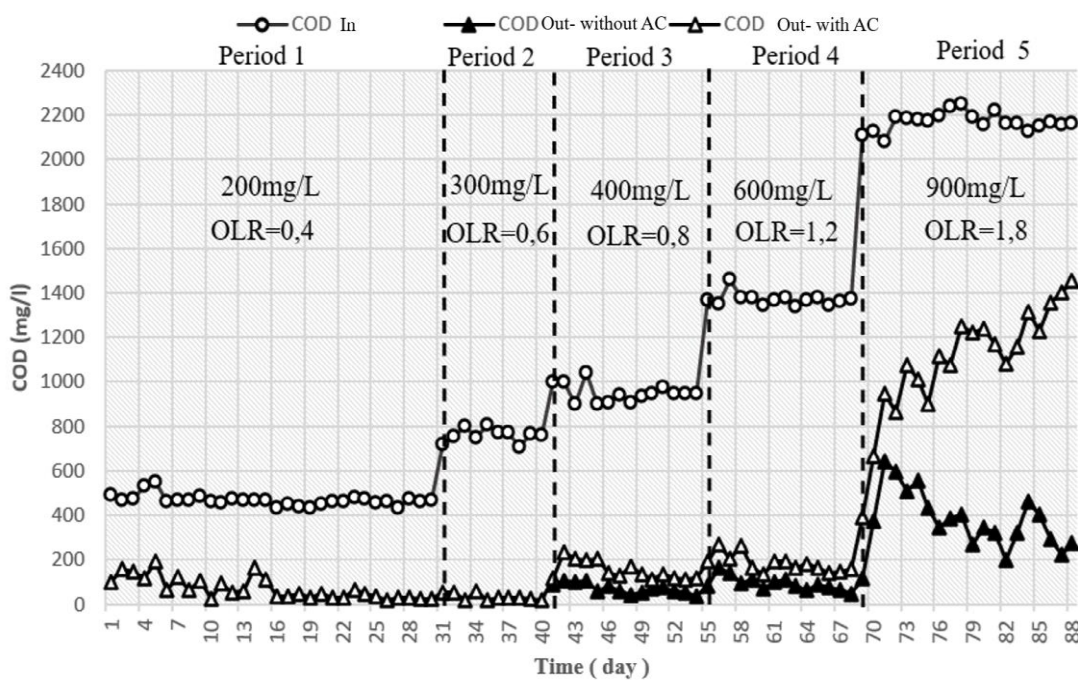


Figure 4. COD concentration in and out of the models within 5 periods

Figure 5 shows the difference between 2 models with and without PAC at the period 3, 4, 5. Adding activated carbon to the model significantly increased the treatment efficiency of high COD. Adding PAC could enhance COD removal efficiency of 7 - 9% in stages 3 and 4, and about 33% in stage 5. Through Anova analysis, there was a difference in the statistical significance of the treatment efficiency between the 2 models in stage 3 and 4 ($p < 0.05$), but this difference is

still not high. By period 5, it was shown that with an input load of 1.8 g phenol/L.day, corresponding to an input COD of 2,155 mg/L, the microorganism in the without PAC model was greatly affected at the end of the period with only 33% left. It reveals that the activated sludge combined with activated carbon increased the phenol removal efficiency of the process, making the output COD lower and more stable.

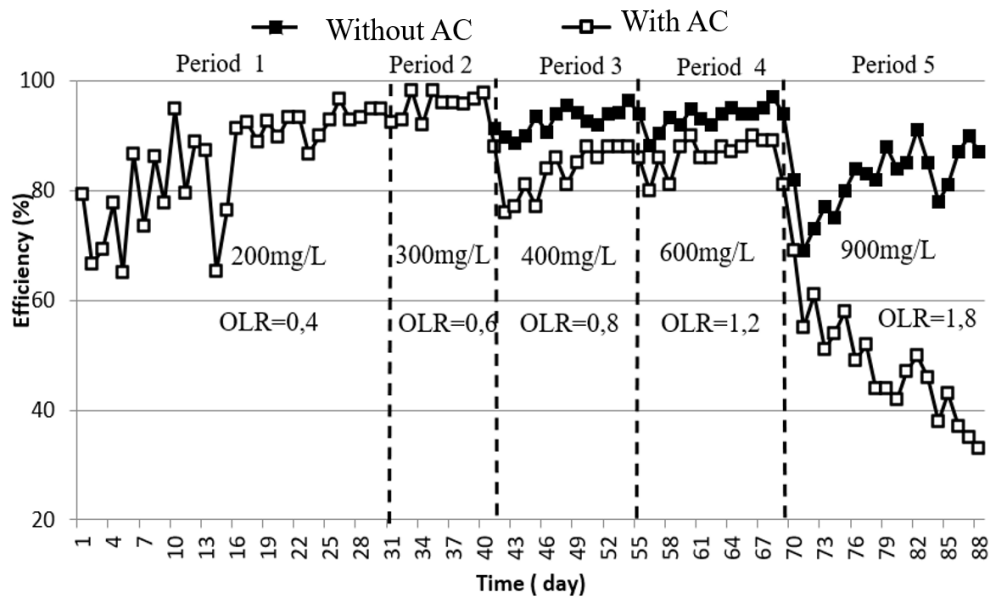


Figure 5. COD removal efficiencies

3.3 Phenol removal

At stage 5, the phenol treatment efficiency was different from the previous stages. The graph 6 shows that with a high phenol load rate of 1.8 g phenol/L.day equivalent to an input phenol concentration of 900 mg / L, which directly affects both models. In the with PAC model, the output

phenol increased from 0.13 ± 0.04 mg/L to 77.4 ± 25.1 mg/L, the treatment efficiency decreased from $99.98 \pm 0.01\%$ to $91.45 \pm 2.75\%$. In the model without AC, the output phenol concentration increased from 0.4 ± 0.11 mg/L to 350 ± 92.8 mg/L, the treatment efficiency decreased from $99.93 \pm 0.02\%$ to $61.2 \pm 10.28\%$.

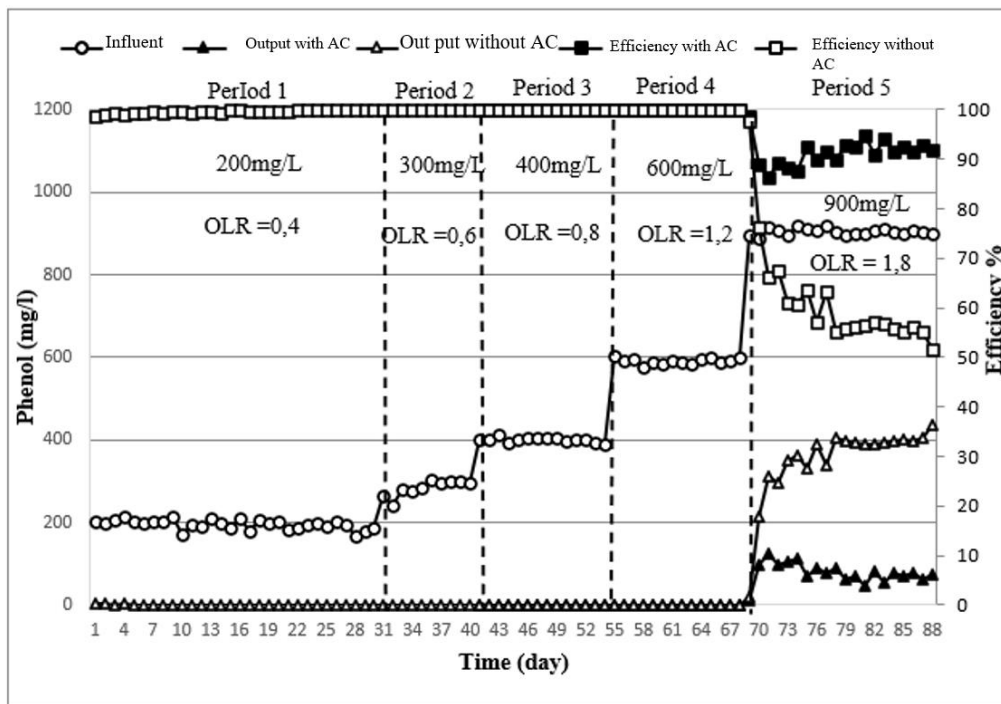


Figure 6. Phenol output concentration and removal efficiencies

Although the treatment efficiency of the two models decreased, in the with PAC model, at the beginning of the period from day 69 to 74, the output phenol increased, but from day 75 to the end the phenol phase began to decrease and gradually stabilized at concentration of 70 mg/L. In the without PAC adding model, the output phenol concentration increased from the beginning to the end of the period, increasing from 20.66 mg/L to 435 mg/L. This increase in phenol output due to the direct effect of phenol on the microorganism of its degradation, microorganisms that cannot tolerate this concentration will be eliminated, reducing the number of microorganisms in the tank. But in general, the COD and phenol treatment efficiency of the model with powder activated carbon is higher and more stable than the model without activated carbon, the added powder activated carbon reduces the load shock, and increases the treatment efficiency of the model. The results indicated that the adaptive ability toward phenol removal of the CAS with adding PAC was significantly higher than the CAS without PAC addition, which is consistent with those reported previously [3, 4].

4. CONCLUSION

Activated sludge was shocked and decreased rapidly when exposed to phenol at the beginning of the adaptive phase and stabilized at the end of the period with the concentration of MLSS in the range of $3,000 \pm 50$ mg/L. Phase 3, 4, due to the addition of powder activated carbon, the model is more stable. At stage 5, operating with a load of 1.8 g phenol/L. The MLSS stabilized with a concentration of 4,550 mg / L, MLVSS/MLSS ratio corresponding to 0.72. At a phenol loading rate of 1.8 g phenol/L.day, the treatment efficiency was significantly different between the 2 models. In the CAS with PAC addition, the COD treatment efficiency was $82.8 \pm 6\%$, the phenol was $91.45 \pm 2.75\%$. In the model without PAC, the removal efficiency decreased significantly compared to the other, COD treatment efficiency was $49.5 \pm 11.6\%$, phenol was $61.26 \pm 10.28\%$. The results showed that the load of 1.8 g phenol/L day is a strong influence on the ability to remove COD and phenol of both models.

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