Influence of Heavy Metal on Activated Sludge Activity: DO and SOUR Monitoring

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ABSTRACT

The objective of this study is to evaluate the inhibitory effect of heavy metals on activity of activated sludge microbes, under sequencing batch reactor (SBR) operation, based on dissolved oxygen (DO) and specific oxygen uptake rate (SOUR) monitoring. The SBR systems were operated with Fill, React, Settle, Draw and Idle periods in the time ratio of 0.5 : 3.5 : 1.0 : 0.75 : 0.25 for a cycle time of 6 hours. It was observed that the addition Cu(II), Cd(II) and combined Cu(II) and Cd(II)-containing wastewater into SBR A, B and C, respectively, had caused deterioration in bio-oxidation processes carried out by activated sludge microbes. From SOUR study, Cu(II) exhibited more toxic to the activated sludge microbes compared to Cd(II).

Keywords: *Inhibitory effect; Sequencing batch reactor; Heavy metal; Dissolved oxygen; Specific oxygen uptake rate*

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INTRODUCTION

Removal of heavy metals from aqueous solutions is a basic process in the treatment of wastewater from many industries, including metal plating, mining and battery manufacturing. Sequestration of heavy metals from wastewater has received a considerable amount of attention in recent years due to the concern that heavy metals can be readily absorbed by organisms and exert a high health risk to the community and biosphere in general.

The effect of heavy metals to biological wastewater treatment processes has been studied in numerous works [1-5]. In general, heavy metals present in the influent at relatively low concentrations can be toxic to the biological processes and can prevent the effective degradation of organic wastes. The result is the discharge of poorly treated wastewater which cannot meet the effluents standards and could have adverse effects on the receiving waters [6].

There are numerous methods for measuring metal toxicity. The most widely used are enzymatic and nitrification inhibition [7], effluent turbidity [8] and oxygen uptake rate [9]. The aim of this study is to investigate the influence of Cu(II), Cd(II) and combined Cu(II) and Cd(II) on the activity of activated sludge microbes based on DO and SOUR monitoring. The heavy metals selected in this study were Cu(II) and Cd(II) because of their widespread industrial use and known toxicity to aquatic organisms.

EXPERIMENTS METHODOLOGY

Sequencing Batch Reactor (SBR)

Three identical laboratory-scale reactors, A, B and C with a total volume of 10 l were operated to simulate the activated sludge process under SBR operation. The reactors were operated with Fill, React, Settle, Draw, and Idle periods in the time ratio of 0.5: 3.5: 1.0: 0.75: 0.25 for a cycle time of 6 h. Efficient mixing was provided using submerged aeration stones during the Fill and React periods. During each cycle, 7 l of the feed solution were introduced continuously for the full Fill period and the same volume of treated effluent was removed during the Draw period.

The activated sludge seed was obtained from a municipal wastewater treatment plant that received no industrial wastewater and was acclimatized in the laboratory by feeding it with a synthetic wastewater consisting of a base mix of peptone, sucrose, nutrients and buffer solution. The synthetic wastewater composed of a base mixture of the following composition (concentration in mg/l): bacto-peptone (188), sucrose (563), NH_4Cl (344), $MgSO_4$ (49), $FeCl_3$ (11 .3), and KH_2PO_4 (318). The sucrose and peptone were used as source of organic carbons and was added to the medium to maintain COD in the range of 800-850 mg/l. Phosphate salts were used to provide both buffer action and as a phosphorous source for microbes. When the systems were acclimatized to the feed, Cu(II), Cd(II) and combined Cu(II) and Cd(II) were added into SBR A, B and C, respectively. The dosages of each heavy metal used in the study are shown in Table 1.

Table 1. SBRs operating conditions

Day	SBR A Cu(II) (mg/l)	Day	SBR B Cd(II) (mg/l)	Day	SBR C Cu(II) + Cd(II) (mg/l)
0 - 18	0	0 - 17	0	0 - 25	0
19 - 30	5	18 - 36	15	26 - 51	5 + 15
31 - 60	10	37 - 58	30	52 - 88	10 + 30

Specific Oxygen Uptake Rate (SOUR) Study

The toxic effect of Cu(II), Cd(II) and combined Cu(II) and Cd(II) on activated sludge microbes were investigated based on Specific Oxygen Uptake Rate SOUR study. To determine the toxic effect of the heavy metals on activated sludge microbes, the mixed liquor withdrawn from the SBRs was placed in a 300 ml BOD bottle. Then the BOD bottle is filled with a fully aerated heavy metal-containing base mixed solution. The DO concentration was monitored at appropriate time interval until it had reached about 1 mg/l. The SOUR can be calculated by using the following equation:

$$SOUR = -(60\ G/X)\ (mgO_2/gMLSS.h) \quad (1)$$

Where G is the slope of the linear portion of the DO decline curve in mg/l.min and X the mixed liquor suspended solid (MLSS) concentration in g/l.

Dissolved oxygen (DO) Monitoring

This study was carried out to investigate the influence of heavy metals on the trend of dissolved oxygen in SBRs. The dissolved oxygen was taken throughout the experiments by using a DO meter (YSI Model-57). The DO meter was put into the center of SBRs during Idle period and the DO readings were taken at certain time interval from Fill period until it became stable in React period.

RESULTS AND DISCUSSION

Specific Oxygen Uptake Rate (SOUR) Study

The SOUR is the SOUR per unit of dry biomass. As oxygen consumption by activated sludge is directly proportional to its BOD removal rate, SOUR has been measured since the activated sludge process was first used in Manchester, England in 1913 [10].

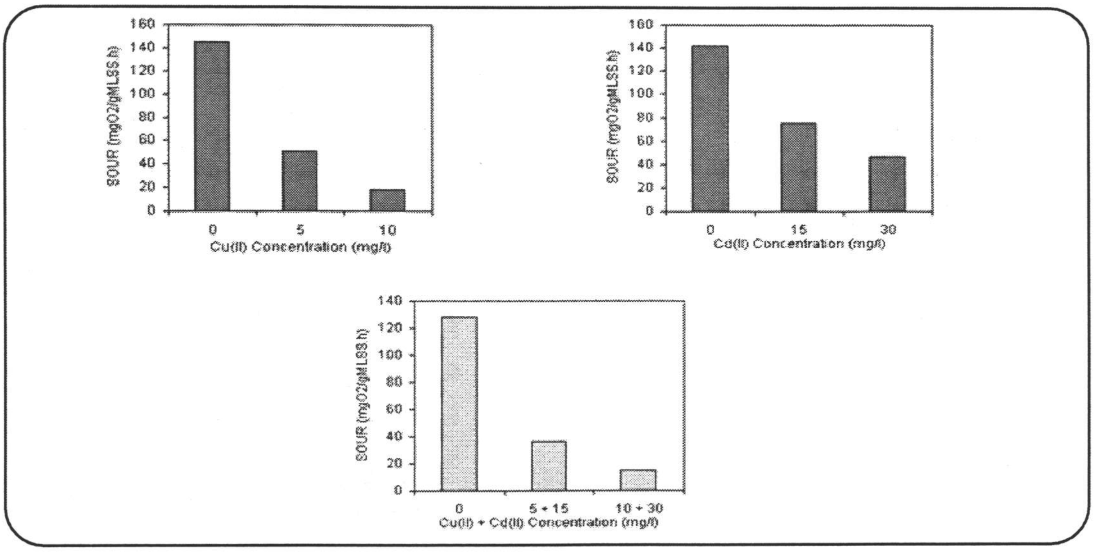

Figure 1. Inhibitory effect of heavy metals on SOUR in activated sludge microbes

Figure 1 shows the inhibitory effect of heavy metals on SOUR in activated sludge microbes. In heavy metal-free condition, the SOUR in each SBR was about 138 $mgO_2/gMLSS.h$. The addition of heavy metals had caused the reduction of SOUR by activated sludge microbes. Generally, increasing the heavy metal concentrations resulted in corresponding reduction in the oxygen uptake rate by activated sludge microbes. The addition of heavy metals inhibited the activities of microorganisms in biodegradation processes. Subsequently the oxygen uptake by microorganisms to degrade the organic substrates was decreased. It is very obvious that Cu(II) was very toxic to the activated sludge microbes compared to Cd(II) as shown in the drastic decrease of the SOUR after the addition of 5 mg/l Cu(II). The combined heavy metals did not exert synergistic effects on the activated sludge microbes. Synergistic effect is one in which the effects of the metals in combination is greater than the summed effects of the individual metals. Conversely, an antagonistic effect is one in which the metals counteract each other diminishing the resulting effect. In an early study, Dawson and Jenkins [11] reported that Ni(II) and Cu(II) acted synergistically to depress oxidation in a respirometric study.

Dissolved Oxygen (DO) Profile Monitoring in Sequencing Batch Reactors (SBRs)

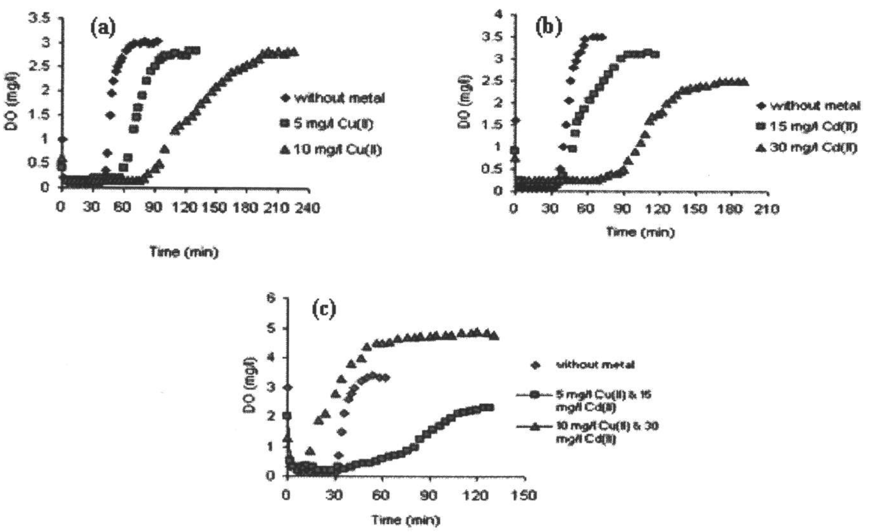

Figure 2. DO profiles for (a) SBR A, (b) SBR B and (c) SBR C in treating Cu(II), Cd(II) and combined Cu(II) and Cd(II)-containing wastewater, respectively.

The DO profiles were monitored during Fill and React periods in SBRs. Figure 2 shows the changes of DO profile after the addition of Cu(II), Cd(II) and combined Cu(II) and Cd(II) into SBR A, B and C respectively. During Fill period, the DO in the SBRs was very low (0.1 – 0.2 mg/l) due to the high consumption of oxygen by activated sludge microbes, which actively carried out the bio-oxidation processes to degrade the organic matter in synthetic wastewater. In the system without heavy metal addition, the DO increased rapidly after entered React period. This may indicated that almost all of the organic matter in synthetic wastewater was biodegraded by activated sludge microbes during Fill period in the reactors. As the organic matter remained in the reactors was low during React period, the oxygen consumed by activated sludge was decreased rapidly. However, in the cases of heavy metals addition, the bio-oxidation processes period was prolonged until to the React period in SBRs due to the toxic effect of heavy metals on the activity of activated sludge microbes. The increase of heavy metals concentration had increased the bio-oxidation processes period in the SBRs.

After the addition of 10 mg/l Cu(II) and 30 mg/l Cd(II) [Figure 2(c)], the DO in the SBR was increased rapidly during Fill period. This showed the oxygen consumed by activated sludge microbes was low due to the low activity of activated sludge microbes in degradation of organic matter. This is because the SBR system was placed under toxic condition and the activated sludge microbes could not carry out the biodegradation processes, effectively after the addition of 10 mg/l Cu(II) and 30 mg/l Cd(II).

CONCLUSIONS

The addition of Cu(II), Cd(II) and combined Cu(II) and Cd(II) caused significant deterioration in the bio-oxidation processes carried out by activated sludge microbes. Based on the SOUR study, Cu(II) exhibited more toxic to activated sludge microbes compared to Cd(II). The DO and SOUR monitoring can be used as a useful tool to monitor the changes of the activity in activated sludge microbes due to the presence of heavy metals or other toxicants.

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