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Effects of a Heavy Metal (Zinc) on Organic Adsorption Capacity and Organic Removal in Activated Sludge

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ABSTRACT

Effects of a common heavy metal (zinc) on activated sludge were studied with a sequencing batch reactor (SBR). Organic removal in activated sludge was postulated to proceed by a rapid adsorption of organics on the sludge, followed by a slower metabolic assimilation mechanism. Metal-laden waste water at a subtoxic level affected the SBR performance to different extents depending on the hydraulic retention time (HRT). Heavy metal acted as a strong competitor for active sites on the sludge, hampering organic adsorption, and affected the COD reduction efficiency under a short HRT.

Index Entries: Activated sludge; COD adsorption capacity; COD removal; heavy metal, zinc.

INTRODUCTION

Heavy metals are commonly found in municipal sewage and industrial effluents, such as electroplating and metal-processing waste waters *(1)*. The discharge of heavy metals into surface waters can have severe effects on the environment, and metals may enter the food chain and adversely affect human health. Accumulation of lead and cadmium in plants, aquatic fauna, and microorganisms in contaminated habitats has been reported *(2,3)*. Metal-laden municipal sewage, with metal contents above a certain concentration level, is toxic to biological processes in municipal sewage treatment works and affects the organic removal efficiency *(4)*. Suthirak and Sherrard *(5)* reported that microorganisms in the activated sludge were inhibited by chromium and nickel at concentrations above 10 mg/L, and COD removal efficiency of the process was adversely affected. A nickel concentration of 25 mg/L caused serious upsets in biological processes.

On the other hand, heavy metals, such as iron, copper, and zinc, have very low toxicity if kept within a few mg/L, although copper at 1 mg/L has been reported to inhibit algal growth *(6)*. These metals gain access to the water environment from

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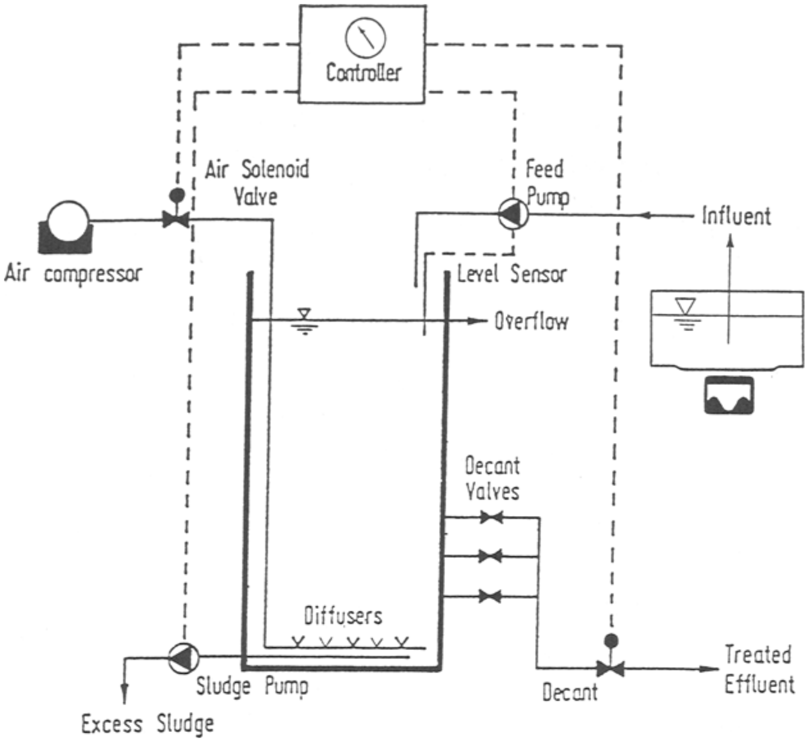

Fig. 1. Schematics of SBR system.

mining operations, metal work, and metal-finishing industrial effluents and corrosion of galvanized piping. In trace concentrations, many of these metals are essential as micronutrients for microbial growth. However, Tan and Chua *(7)* observed that heavy metals, including copper and zinc, at subtoxic concentrations—as low as 1 mg/L—also affected COD removal in activated sludge. It has been postulated that, in addition to the toxicity and inhibitory effects on the microorganisms, heavy metals could also physically affect activated sludge in the uptake of organic matter *(8)*.

In this study, the effects of zinc-laden waste water at a subtoxic concentration on activated sludge was determined. The mechanism through which the heavy metal affected organic removal efficiency was investigated.

MATERIALS AND METHODS

Sequencing Batch Reactor

A 10-L sequencing batch reactor (SBR) was used to simulate the activated sludge process (Fig. 1). Aeration and mixing were achieved by an air-diffuser system at the bottom of the reactor. Returned activated sludge from a municipal sewage treatment plant was diluted, screened with a 2-mm sieve to remove coarse particles, and used to seed the reactor. Mixed-liquor volatile suspended solids (MLVSS) of the seeded reactor were maintained at approx 1500 mg/L, and a synthetic waste water, prepared with reconstituted milk at 500 mg/L, was fed at 10 d

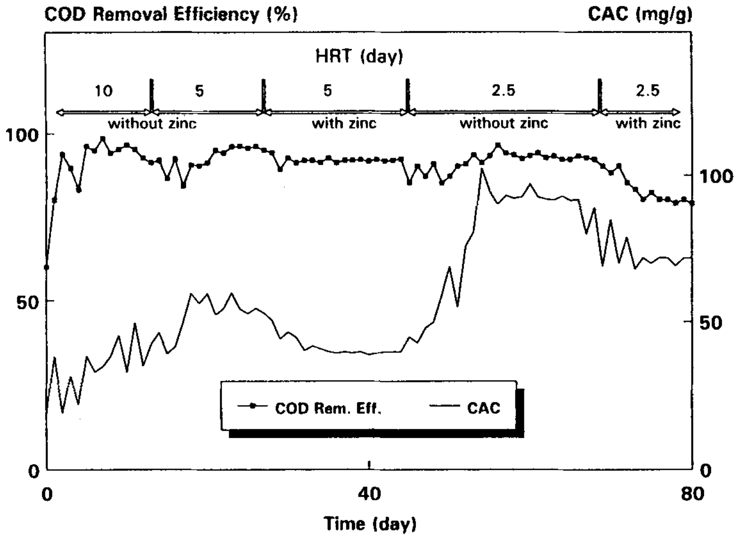

Fig. 2. Performance of SBR.

of HRT. The SBR was operated in a 24-h fill-and-draw cycle, as described by Chambers *(9)* and Ng *(10)*. Each cycle consisted of five stages: fill (5 min), react (6.5 h with aeration), settle (1 h), decant (25 min), and idle (16 h) with 15-min aeration every 2 h. The operating cycle was automated with timer-controlled feed, draw-off, and aeration pumps. When the system was acclimatized to the feed, as indicated by a stable COD removal efficiency, the HRT was reduced stepwise. The reactor was first allowed to attain stable performance at 5 d of HRT. A zinc-laden synthetic feed was then introduced, and the reactor was allowed to re-establish a new stable operation. The synthetic feed was dosed with zinc sulfate to an equivalent concentration of 1 mg Zn/L. This procedure was repeated at 2.5 d of HRT.

Analytical Methods

MLVSS and COD were measured in accordance with *Standard Methods (11)*. COD adsorption capacity (CAC) in mg COD/g MLVSS was used to monitor the ability of activated sludge to adsorb organic matter. CAC was calculated by dividing the difference between theoretical soluble COD after the FILL stage and the actual soluble COD measured 10 min after the FILL stage, by the MLVSS.

RESULTS AND DISCUSSION

Performance of the SBR in terms of COD removal efficiency and the variation in CAC are shown in Fig. 2. The average MLVSS, CACs, and COD removal efficiencies under stable operation at each HRT are listed in Table 1. After 30 d of start-up operation, the reactor stabilized at 5 d of HRT. The average CAC was 53.8 mg/g, and the corresponding COD removal efficiency was 95.3%. After the zinc-laden waste water was introduced, the reactor stabilized within 15 d to an average CAC of 39.7 mg/g and a COD removal efficiency of 91.9%. This was equivalent to a 26% drop in CAC, whereas the COD removal efficiency was not significantly changed. When the HRT was reduced to 2.5 d, increased residual COD level resulted in a drastic

Table 1
Average[a] MLVSS, COD Adsorption Capacity,
and COD Removal Efficiency Under Stable Operation

HRT, d	MLVSS, mg/L	COD adsorption capacity, mg COD/g MLVSS	COD Removal Efficiency, %
5			
Without Zinc	1507	53.8	95.3
5			
With Zinc	1482	39.7	91.9
2.5			
Without Zinc	1553	92.0	92.5
2.5			
With Zinc	1598	71.3	72.4

*All average values were calculated with the relevant data obtained after the SBR had achieved stable performance at that HRT. Generally, the performance at each HRT was considered stable after operation for a period equivalent to three times that HRT.

increase of CAC to a maximum of 103.8 mg/g. During operation at the shorter HRT, the average CAC and COD removal efficiencies under stable operation were 92.0 mg/g and 92.5%, respectively, in the absence of zinc, and 71.3 mg/g and 70.4%, respectively, in the presence of zinc. These represented a 23% drop in CAC and a 22% drop in COD removal efficiency.

When the reactor was operated at the longer HRT of 5 d, retention of organic matters within the SBR was sufficiently long for biological assimilation, and organic adsorption was not a critical factor governing SBR performance. Therefore, presence of zinc affected the CAC, but had little effect on COD removal. On the other hand, at the shorter HRT of 2.5 d, presence of zinc caused a drop in CAC, which in turn, affected the COD removal efficiency to a comparable extent. It was postulated that COD removal in activated sludge proceeded by a rapid adsorption of organic matters on the sludge, followed by a slower metabolic assimilation mechanism. Zinc possibly acted as a strong competitor against organic matters for active sites on the sludge, thus hampering organic adsorption and affected the COD removal efficiency under the shorter HRT.

CONCLUSION

Removal of COD by activated sludge depended on a rapid adsorption of organic matters on the sludge, which retained the organic matters sufficiently long for the slower metabolic assimilation mechanism to take place. Zinc-laden waste water at a subtoxic level could cause a decrease in CAC and a corresponding drop in COD removal efficiency, under a short HRT. Zinc acted as a strong competitor against organic matter for active sites on the activated sludge. The presence of zinc hampered organic adsorption, which in turn, affected COD removal efficiency.

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