

Bioremoval of Lead by Use of Waste Activated Sludge

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ABSTRACT: Biological removal of lead was observed in this study during treatment of synthetic solutions of this heavy metal by a sample of waste activated sludge (WAS) having MLSS concentration of 10000 mg/L. The objective was determining the capability of WAS in removal of lead in three different conditions of treatment: without any aeration and feeding, by simultaneous aeration and feeding and by aeration without feeding. Besides, the effect of initial metal concentration and contact time in these treatment stages were determined. Results showed that the efficiency of lead removal was reduced by increasing the initial metal concentration, but the changes of contact time had resulted in different responses depending to the test condition. Moreover, it was found that the effects of aeration and feeding in increasing the efficiency of treatment were more pronounced for the stage of treating lower concentrations of lead. The maximum removal of lead in the first step (without aeration and feeding) was 55.2 % in contact time of 75 minutes, in the second step (without feeding and by 12 hours aeration) 63.3% and third step it was 94.2 % in contact time of 48 hours. The initial lead concentration in these experiments was 5 mg/L.

Key word: Industrial wastewaters, Lead, Waste Activated Sludge, Wastewater treatment, Adsorption process

INTRODUCTION

The removal of heavy metal ions from industrial wastewater is a problem of increasing concern that has been mostly solved by chemical and physical methods of treatment. However, these procedures have significant disadvantages, such as incomplete metal removal, high reagent or energy requirements, or generation of toxic sludge or other waste products and are generally very expensive when the contaminant concentrations are in the range of 10–100 mg/L (Sag and Kutsal, 1995).

In recent years, increasing awareness about water pollution and its far reaching effects has prompted concerted efforts towards pollution abatement (Dönmez *et al.*, 1999). Contamination of aqueous environments by heavy metals is a worldwide environmental problem due to their toxic

effects and accumulation through the food chain (Kapoor *et al.*, 1999; Perez-Rama *et al.*, 2002; Sternberg and Dorn, 2002). Heavy metals are major pollutants in marine, ground, industrial and even treated wastewaters (Valdman *et al.*, 2001). The presence of heavy metals in drinking water can be hazardous to consumers; these metals can damage nerves, liver and bones and block functional groups of vital enzymes. Elevated levels of Pb (II) can be traced to industrial discharges from various sources, such as electric battery manufacturing, lead smelting and mining activities. The presence of Pb(II) in potable water is known to cause various types of serious health problems. Although the inorganic form of lead is a general metabolic poison and enzyme inhibitor, organic forms are even more poisonous (W. Lo, 1999). Therefore, treatment of Pb(II) contaminated

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effluents is essential before discharging into receiving bodies of water. Various methods are available to isolate and remove heavy metals from the environment. Adsorption is one of the easiest, safest and most cost-effective methods because it is widely used in effluent treatment processes (Balkose and Baltacioglu, 1992).

Other techniques for removing heavy metals from industrial effluents include precipitation, ion exchange, electrodialysis and filtration. However, these methods have limitations on selective separation and high costs of investment and operation (Ajmal *et al.*, 2003; Cheung *et al.*, 2001; Dae and Young, 2005; Dezuane, 1990; Peternele *et al.*, 1999). In the last few years, adsorption has been shown to be an economically feasible alternative method for removing trace metals from wastewater and water supplies (Allen and Brown, 1995; Gabaldon, *et al.*, 1996; Mahvi *et al.*, 2004). Activated carbon is the most common adsorbent; nevertheless, it is relatively expensive and its use depends on the degree of the required treatment process and the local availability of activated carbon (Bailey *et al.*, 1999). Biosorption is the uptake of heavy metal ions and radionuclides from aqueous environments by biological materials, such as algae, bacteria, yeast, fungi, plant leaves and root tissues, which can be used as biosorbents for detoxification and recovery of toxic or valuable metals from industrial discharges (Davis *et al.*, 2003; Figueira *et al.*, 2000; Ma and Tobin, 2003; Veglio and Beolchini, 1997). Biosorption technology has been shown to be a feasible alternative for removing heavy metals from wastewaters (Benguella and Benaissa, 2002; Ma and Tobin, 2003; Volesky, 2001). In recent years, some studies have been carried out on biosorption, a biophysico-chemical process to remove pollutants from solution by attachment on microbial surfaces. Many heavy metals and organic contaminants have been successfully eliminated from solution through biosorption under different conditions (Esparza-Soto, and Westerhoff, 2003; Egil, 1994). Biosorption processes, defined as the sorption of metal ions by biomass, are being employed as an alternative technique for the decontamination of industrial effluents and for the recovery of the retained metals (Volesky, 2003; Gadd, 1999). Different types of biomass, such as: algae, bacteria, fungi and yeasts (Kuyucak and

Volesky, 1988) or even extracellular material as exopolysaccharides have been used for the clean-up of industrial effluents (Loae'cm *et al.*, 1997). Interactions between metals and biomass lead to the binding of both depending on the functional groups contained in the cell walls or the biopolymers of dead microorganisms, such as carboxylic, amino, phosphate and sulphate groups, among others (Naja *et al.*, 1999). Additionally, the physicochemical properties of these organic constituents can be seriously affected by the characteristics of solutions employed. In this way, variables such as pH, redox potential, metal concentration, presence of certain anions of complexing character or not, ionic strength, etc., play an important role in the process (Leding *et al.*, 1977; Fourest and Roux, 1992; Schiewer and Volesky, 1997; Pagnanelli *et al.*, 2000).

In this study, the capability of the waste activated sludge formed in a conventional municipal wastewater treatment plant had been determined in adsorption of lead from synthetic solution.

MATERIALS & METHODS

All the synthetic solution of lead were prepared by use of a soluble salt of lead [Pb (NO₃)₂] and deionized water. This salt had been first used for preparation of a stock solution (1g lead per liter) and samples for experiments were then prepared by dilution of this stock to the desired concentrations. In order to prevent shock load to the treatment system the lead samples had been added to the activated sludge system gradually. The activated sludge sample used in this study had been supplied from the return activated sludge line of wastewater treatment plant (WWTP) in West Residential District (in Tehran). The MLSS of this sample was 6000-7000 mg/L and pH was equal to 6.7-7. This sludge sample was first settled for 2 hours, then the settled fraction was concentrated to 10 g/L by 12-24 hours aeration and feeding.

The pH value of wastewater is important in biological adsorption of metals. In low pH_s, hydrogen ions are produced which may interfere in adsorption of metal cations on microorganisms surfaces, and in pH_s more than 7, the metals tend to leave soluble phase because of precipitation by hydroxide ions. Thus it is necessary to check pH

fluctuations. In this study, 1N solution of sodium hydroxide and sulfuric acid had been used for pH adjustment.

Alive microorganisms of the activated sludge need food for growth and remaining active in continuous treatment so the sludge feeding may be considered a necessary process. For this purpose, a mixture of essential salts and compounds as reported in Table 1. had been prepared and used for this study.

Table 1. Ingredients of the feeding solution used in the experiments (Yinguang Chen, Guowei Gu., 2005)

Composition	Final concentration in reactor (mg/L)
Glucose	281.3
NH ₄ SO ₄	100
KH ₂ PO ₄	33.3
NaCl	29.2
MgSO ₄	16.2
FeSO ₄	10
CaCl ₂	4
CuSO ₄	4
MnSO ₄	2.5
ZnSO ₄	2.5
H ₂ MoO ₄	2
CoCl ₂	1

The experiments were accomplished in three steps. At the first step, one liter solution of lead in three concentrations of 5, 10 and 50 mg/L were completely mixed with the prepared activated sludge samples in different contact times of 15, 30, 45, 60, 75 and 90 minutes. At the second step, the same solutions were contacted to the activated sludge samples by aeration without feeding in retention times of 12, 24, 36 and 48 hours. Finally, the third step was accomplished similar to the second step but feeding of the sludge was also exercised. During these experiments, the pH_s of solutions were adjusted to be neutral (6.5-7) and the temperature to be 24-25°C.

At the end of three steps of experiments, the treatment systems were remained motionless for sludge settling. Then, a sample was taken from the clear supernatant and it was filtered through use of an 0.45 µm fiber glass filter. The concentration of lead was then determined in the resulted filtrate by atomic adsorption spectrophotometry.

RESULTS & DISCUSSION

Fig. 1. shows the removal efficiency of lead obtained in the first step of the experiments namely adsorption of metal by waste activated sludge without any aeration and feeding. In fig. 2. the result of lead adsorption obtained for the second step of the experiments (treatment by waste sludge without feeding but by aeration) can be seen. Fig. 3. shows the removal efficiency of lead in the third step of the experiments namely by simultaneous aeration and feeding of the activated sludge.

As shown in fig. 1. the efficiency of lead removal versus time had been increased up to 45

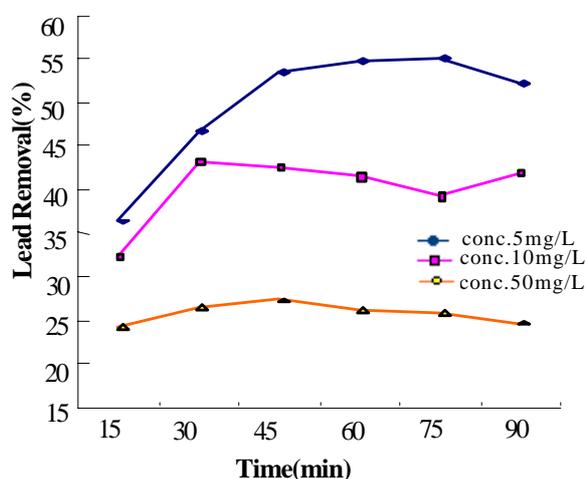


Fig. 1. Removal efficiency of lead by WAS without aeration and feeding

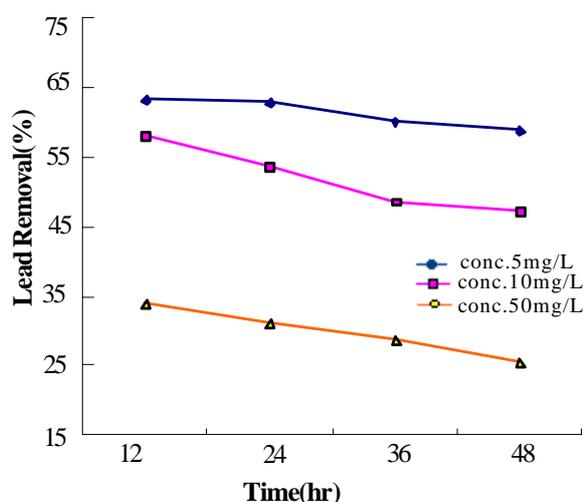


Fig. 2. Removal efficiency of lead by WAS by aeration (without feeding)

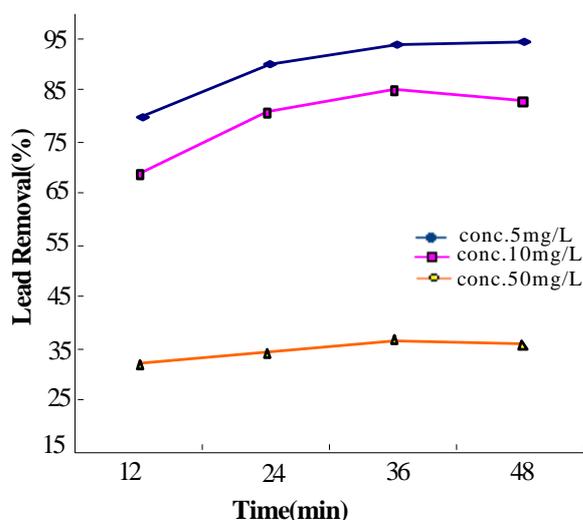


Fig. 3. Removal efficiency of lead by WAS by simultaneous aeration and feeding

minutes for the initial lead concentration of 5mg/L. Then the amount of this efficiency had become relatively constant and in other words no significant increase in treatment efficiency was observed at longer contact times. Thus, we could consider this period as the equilibrium time. For treatment of lead solution with 10 mg/L concentration this equilibrium time was reduced to 30 minutes and for 50 mg/L lead it was about 15 minutes. Increased contact time was not profitable and even it was somehow deleterious.

The second step of this study was accomplished by continues aeration of activated sludge, but feeding of the sludge was not practiced. Again, increase of lead removal efficiency was observed versus time for all the three solutions of lead (5, 10 and 50 mg/L) but at much higher contact times (more than 12 hours for 5 mg/L lead solution) the concentration of lead in solution had considerably increased. The interpretation is that the activated sludge sample was not capable to continue lead adsorption without required nutrients and as expected the microorganism had reached to endogenous phase. Thus, we saw a good lead removal at the beginning of the tests and a final high lead increase after reaching to the endogenous phase.

In the fig. 3. the results of lead adsorption by activated sludge at the best condition of simultaneous aeration and feeding are represented. In this step the efficiency of lead removal had been

increased considerably versus time but similar to previous steps the efficiency had reduced in treatment stage of higher initial lead concentrations. However, the overall the treatment was successful which should be attributed to development of more resistant microorganisms. In this study, maximum efficiency of lead removal which was 94.2 % was obtained in treatment of 5 mg/L lead solution at the third step of the experiments, namely after 48 hours of aeration and feeding and the minimum efficiency at this step was determined to be 32% obtained in treatment of 50 mg/L lead solution after 12 hours contact time. For the second step, the maximum efficiency was 63.3% (for 12 hours aeration of 5mg/L lead solution) and the minimum amount was 25.4 % (for 48 hours aeration of 59 mg/L lead solution). Ultimately, it should be noted that even by using waste activated sludge without any aeration or feeding we could expect some treatment which is reported to be maximum 55% and minimum 24%.

CONCLUSION

Waste activated sludge is an available material which is produced daily in the majority of WWTPs. Based on results of this study, waste activated sludge should be considered as a useful product in removal of lead and perhaps other similar heavy metals from wastewater and industrial wastes. In addition, it is possible to improve this treatment by performing additional aeration and feeding.

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REFERENCES

- Ajmal, M., Rao, R. A., Anwar, S., Ahmad, J. and Alunad, R. (2003) Adsorption studies on rice husk: removal and recovery of Cd (II) from wastewater. *Bioresour. Technol.*, **86** (2), 147-149.
- Akbal, F., Allen, S. J. and Brown, P. A. (1995). Isotherm analyses for single component and multicomponent metal sorption onto lignite. *J. Chem. Technol. Biotechnol.*, **62**, 7-24.

- Bailey, S. E., Olin, T. J., Bricka, R. M. and Adrian, D. A. (1999). A review of potentially low-cost sorbents for heavy metals. *Wat. Res.*, **33** (11), 2469-2479.
- Balkose, D. and Baltacioglu, H. (1992). Adsorption of heavy metal cations from aqueous solution by wool fiber. *J. Chem. Tech. Biotechnol.*, **54** (4), 393-397.
- Benguella B. and Benaissa, H. (2002). Cadmium removal from aqueous solutions by chitin: kinetic and equilibrium studies. *Water Res.*, **36** (10), 2463-2474.
- Berthelin, J. (1999). Potentiometric titration: a dynamic method to study the metal binding-mechanism of microbial biomass. In: Amils, R., Ballester, A. (Eds.), *Biohydrometallurgy and the Environment Toward the Mining of the 21st Century*. Elsevier, Amsterdam, 201-210.
- Cheung, C. W., Porter, J. F., and McKay, G. (2001). Sorption kinetic analysis for the removal of cadmium ions from effluents using bone char. *Water Res.*, **35**(2), 605-621.
- Dae, W. C. and Young, H. K. (2005). Chromium (VI) removal in a semi-continuous process of hollow fiber membrane with organic extractants. *Korean J. Chem. Eng.*, **22**(6), 894-898.
- Davis, T. A., Volesky, B. and Mucci, A. (2003). A review of the biochemistry of heavy metal biosorption by brown algae. *Wat. Res.*, **37** (18), 4311-4330.
- Dezuane, J. (1990). *Handbook of drinking water quality standards and controls*. Van Nostrand Reinhold, New York, 64-69.
- Dönmez, G. Ç., Aksu, Z., Öztürk, A. and Kutsal, T. (1999). A comparative study on heavy metal biosorption characteristic of some algae, *Proc. Biochem.*, **34**(5), 885-892.
- Figueira, M. W., Volesky, B., Ciminelli, V. S. and Roddick, F. A. (2000). Biosorption of metals in brown seaweed biomass. *Wat. Res.*, **34** (1), 196-204.
- Fourest, E. and Roux, J. C. (1992). Heavy metal biosorption by fungal mycelial by-products mechanisms and influence of pH. *Applied microbiology and Biotechnology*, **67**, 215-226.
- Gabaldon, C., Marzal, P. and Seco, A. (1996). Cadmium and zinc adsorption on to activated carbon: influence of temperature, pH and metal/carbon ratio. *J. Chem. Tech. Biotechnol.*, **66** (7), 279-285.
- Gadd, G.M. (1999). Bioremediation potential of microbial mechanisms of metal mobilization and immobilization. *Current Opinion in Biotechnology* **11**, 271-279.
- Kapoor, A., Viraraghavan, T. and Cullimore, D. R. (1999). Removal of heavy metals using the fungus *Aspergillus niger*, *Biores. Technol.*, **70** (1), 95-104.
- Khalifaour, B., Meniai, A. H., Borja, Perez-Rama, M., Alonso, J. A., Lopez, C. H. and Vaamonde, E.T. (2002). Cadmium removal by living cells of the marine microalga *tetraselmis suecica*. *Bioresource. Tech.*, **84**(3), 265-270.
- Kuyucak, N. and Volesky, B. (1988). Biosorbents for recovery of metals from industrial solutions. *Biotechnology Letters*, **10**, 137-142.
- Naja, G., Deneux-Mustin, S., Mustin, C., Rouiller, J., Munier-Lamy, C., Leding, M., Peterson, K. and Allard, B. (1977). Effects of pH and ionic strength on the adsorption of Cs, Sr, Eu, Zn, Cd and Hg by *Pseudomonas putida*. *Water, Air, and Soil Pollution*, **93**, 367-381.
- Loae`cm, M., Oliver, R. and Guezennec, J. (1997). Uptake of lead, cadmium and zinc by a novel bacterial exopolysaccharide. *Water Research*, **31**, 1171-1179.
- Ma, W. and Tobin, J. M. (2003). Development of multimetal binding model and application to binary metal biosorption onto peat biomass. *Water. Res.*, **37**(16), 3967-3977.
- Mahvi, A. H., Maleki, A. and Eslami, A. (2004). Potential of rice husk and rice husk ash for phenol removal in aqueous system, *Am. J. Appl. Sci.*, **1**(4), 321-326.
- Esparza-Soto, M. and Westerhoff, P. (2003). Biosorption of humic and fulvic acids to live activated sludge biomass. *Water Res.*, **37**, 2301-2310.
- Pagnanelli, F., Petrangeli Papini, M., Toro, L., Trifoni, M. and Veglio, F. (2000). Biosorption of metal ions on *Arthrobacter* sp.: Biomass characterization and biosorption modeling. *Environ. Sci. and Technol.*, **34**, 2773-2778.
- Peternele, W. S., Winkler-Hechenleitner, A. A. and GomezFineda, E. A. (1999). Adsorption of Cd (II) and Pb (II) on to functionalized formic lignin from sugar cane bagasse. *Bioresource. Tech.*, **68**(1), 95-100.
- Schiewer, S. and Volesky, B. (1997). Ionic strength and electrostatic effects of biosorption of divalent metal ions and protons. *Environ. Sci. and Technol.*, **31**, 2478-2485.
- Sternberg, S. P. K. and Dorn, R. W. (2002). Cadmium removal using *Cladophora* in batch, semi-batch and flow reactors, *Bioresource. Tech.*, **81**(3), 249-255.
- Egil, T.G. (1994). The role of humic substances in the acidification response of soil and water: results of the humic Lake acidification experiment (Humex). *Environ. Int.*, **20**, 363-368.

Valdman, E., Erijman, L., Pessoa, F. L. P. and Leite, S. G. (2001). Continuous biosorption of Cu and Zn by immobilized waste biomass *Sargassum* sp. *Process Biochem.*, **36** (8-9), 869-873.

Veglio, F. and Beolchini, F. (1997). Removal of metals by biosorption: a Review. *Hydrometallurgy*, **44**(3), 301-316.

Lo, W., Chua, H., Lam, K.H. and Bi, S.P. (1999). A comparative investigation on the biosorption of lead by filamentous fungal biomass. *Chemosphere*, **39**, 2723-2736.

Volesky, B. (2003). Sorption and Biosorption. BV Sorbex, Inc., Montreal – St. Lambert, Quebec, Canada.

Volesky, B. (2001). Detoxification of metal-bearing effluents: biosorption for the next century. *Hydrometallurgy*, **59**(2-3), 203-216.

Yinguang, C. and Guowei, G. (2005). Short-term batch studies on biological removal of chromium from synthetic wastewater using activated sludge biomass. *Bioresource Technology*, **96**, 1722-1729.

Sag, Y. and Kutsal, T. (1995). Copper (II) and nickel (II) adsorption by *Rhizopus arrhizus* in batch stirred reactors in series. *Chem. Eng. J.* **58**, 265-273.