BIOTREATMENT OF ACID MINE DRAINAGE USING SEQUENCING BATCH REACTORS (SBR_S) IN THE SARCHESHMEH PORPHYRY COPPER MINE

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Abstract
This paper presents the biotreatment of acid mine drainage (AMD), containing metals (Fe, Cu, Mn) and sulphate, which was sampled from Shoor River in the Sarcheshmeh porphyry copper mine (Kerman province, South of Iran). The biotreatment process was carried out using the sequencing batch reactors (SBRs) technique. The mixed culture of microorganisms was prepared from the Geytarieh municipal wastewater treatment plant (Tehran, Iran). The biotreatment and removal of metals were then attempted with high concentrations of Fe, Cu, Mn and sulphate using three sequencing batch reactors. The biotreatment process was performed in a wide range of pH (4.5–8) and AMD flow rates (5-60 mL/min). The optimum removals of 100% Fe, 98% Cu and 90% Mn from AMD were obtained at pH 5 and for a flow rate of 5 mL/min.

Introduction
Among the problems associated with mining activities, AMD (Acid Mine Drainage) is the most important throughout the world (Kuyucak and St-Germain, 1994). AMD causes the destruction of plants, the mortality of marine creatures, surface and ground water pollution, soil acidity and salinity and mine equipment corrosion.
AMD is considered to be a major cause of mine water poor quality that often contributes to quality deterioration of receiving waters and must therefore be treated before it can be discharged (Kuyucak and St-Germain, 1994).
AMD is produced when sulphide minerals, especially pyrite, are exposed to the atmosphere (Atkins and Pooley, 1982). The overall stoichiometric reaction describing the oxidation of pyrite and generation of AMD can be written as follows:

$$4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_3 + 8SO_4^{2-} + 16H^+ \qquad (1)$$

AMD is often characterised by high concentrations of iron, sulphate, variable concentrations of metals (e.g. Cu, Mn, Al) and low pH (Akcil and Koldas, 2005).
AMD emanating from the Sarcheshmeh copper mine is discharged to Shoor river. Therefore, it pollutes the river and has a detrimental effect on plant life. This porphyry copper mine is located in south of Iran, Kerman province. Since the fresh water resources are decreased in Iran year by year and the country faces to the problem of the shortage of water, so the neutralisation of AMD and prevention of the pollution problems is a necessary task to conserve the environment against this harm (Tabak and Govind, 2003). In such mine sites remediation facilities will be necessary before acidic drainage can be discharged into the receiving environment.
There are several methods to treat AMD. The most common methods are based on the neutralization processes and settling the toxic materials. This method is not cost-effective and also produces large amounts of sludge creating numerous environmental problems (Johnson and Hallberg, 2005).
Another method is based on the biological refinement. This method operates with the help of microorganisms living in municipal sludge. The process can be well performed in the sequencing batch reactors.
Sequencing Batch Reactors (SBRs) treatment method is considered as an attractive alternative against the conventional waste water treatment systems, mainly due to their simplicity and flexibility of the operation. The SBR is a periodically operated, fill and draw reactor (EPA, 1999).
SBR systems have been successfully used to treat industrial waste effluents (Orhon and Artan, 2006; Ong and Seng, 2003). In this research, a biotreatment process was performed incorporating three sequencing batch reactors for AMD treatment.

Materials and Methods
1. AMD Preparation
AMD in the Sarcheshmeh copper mine was sampled using the 20 litres containers and carried to the laboratory. Before refining operation, the parameters EC (Electrical Conductivity), pH, COD, BOD_5, heavy metals and sulphate were determined. The results are shown in Table 1.

Table1. Composition of the sludge from the municipal wastewater treatment plant of Tehran and of the AMD from the Sarcheshmeh copper mine.

Parameter		Sludge	AMD
Fe	ppm	573	57.2
Mn	ppm	4.06	7.07
Cu	ppm	0.48	10.6
Zn	ppm	ND	ND
Ni	ppm	1.18	0.17
Pb	ppm	1.98	0.56
Cr	ppm	0.52	0.03
Hg	ppm	1.28	ND
Sn	ppm	ND	ND
Cd	ppm	0.17	0.32
Co	ppm	0.69	0.48
SO_4^{2-}	ppm	240	680
EC	mS/cm	0.62	1.92
pH		4.9	5.9
BOD_5	mg/L	275	225
COD	mg/L	423	350

ND = Not Detected

2. Preparation of activated sludge

Active sludge taken from the Gheytarieh municipal wastewater treatment plant was provided in 1.5 L locked containers and analysed for EC, pH, COD, BOD_5, heavy metals and sulphate. The results are given in Table 1.

3. Construction of SBR_S system

In order to investigate the aerobic removal of heavy metals (Fe, Cu, Mn) and sulphate from AMD, three sequencing batch reactors were built with similar successive aerobic operation in the pilot scale (25×20×15 cm), with a shape of rectangle cube and with normal glass texture. Thickness of the bed glass in each SBR tank was 8 mm and four walls of the tank had a thickness of 5 mm. A gutter was placed on its length. The gutter had toothed edges. This gutter was 3 cm apart from the reactor edge. A pipe of 3 cm in diameter and 10 cm length was also constructed in order to discharge the content to the next reactor. The optimal volume of each reactor was 6 litres. Two aquarium pumps were used for aeration process into the tanks.

In all reactors, the process of mixture and air infusion during refining was done using aquarium stones with 15 cm length in the reactor bed. The dissolved oxygen concentration in each reactor was kept between 8 to 10 mg/L. Figure 1 shows a schematic representation of the biotreatment system which was used in this study.

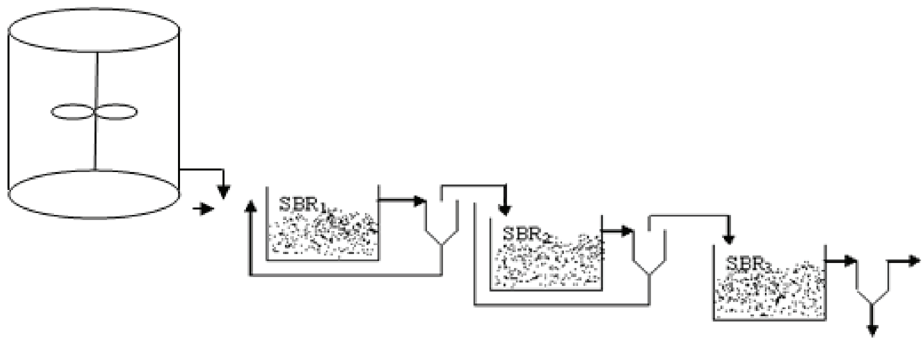

Figure 1. A schematic diagram of the biotreatment system.

4. Procedure

Two litres of activated sludge of municipal wastewater is added to the microorganisms' growth tank. The media composition for growth of microorganisms contains 4 L distilled water. Furthermore, 8 g phosphate dihydrogen potassium, 8 g ammonium nitrate and 12 g sucrose are dissolved in one litre distilled water and then added to the mixture. Air infusion is performed for a period of 24 hours. This is to let the microorganisms to have a suitable growth. Two litres of these proliferated microorganisms were then poured into the first SBR reactor and AMD with a flow rate of 5 mL/min arrived to the first reactor.

Two other reactors are located immediately after the first reactor and finally are followed by a settling reservoir which is divided into two phases after being filled. The upper phase contains refined AMD which can be discharged to the environment and the lower phase is microbial mass onto which the heavy metals have been settled. A total filling time of 15.88 hours was obtained for a water flow rate of 30 mL/min. Furthermore, the filling times were 9.21 and 2.21 hours for water flow rates of 60 mL/min and 120 mL/min, respectively.

Results and Discussion

The main results of AMD biotreatment in SBRs system are shown in Figures 2 and 3.
At first the experiment was carried out with a water flow of 5 mL/min. The analysis of heavy metal concentrations was carried out using an atomic absorption spectrometry equipment, model GBC plus 932. The pH of the AMD was 4.5-5. At this pH, Mn could not be removed well, whereas the removal of Cu, Fe and sulphate were 99%, 76% and 84%, respectively. Moreover, BOD_5 decreased to 72%.
The pH of the system was increased from 4.5-5 to 6.5-8 in order to remove Mn. The heavy metal removal process was performed at pH = 6.5-7 and with a water flow rate of 5 mL/min. At this pH, the removal of Mn, Cu, Fe and sulphate from aqueous solution were 23%, 88%, 100% and 96%, respectively.
At pH = 7-7.5, the removal of Mn, Cu, Fe and sulphate were 27%, 92%, 97% and 93% respectively, and BOD_5 decreased to 65%. At pH 7.5-8, about 91% Mn, 92% Cu and 100% Fe were removed and sulphate removal was up to 91%. As it is evident, pH = 7.5-8 is the optimal pH range for the simultaneous efficient removal of the above mentioned dissolved components.
After identification of the optimal pH, refining process was carried out at higher water flow rates. It was found that, for a water flow rate of 30 mL/min, the percentage removal for Mn, Cu, Fe and sulphate were 88, 85, 100 and 89 respectively, and BOD_5 decreased to 80%. While flow rate was increased from 30 mL/min to 60 mL/min, Mn, Cu, Fe and sulphate removal were 90%, 94%, 99% and 90% respectively, and BOD_5 decreased to 60%. In addition, for a water flow rate of 120 mL/min, about 77% Mn, 99% Cu, 100% Fe and 72% sulphate were removed, and BOD_5 decreased to 42%.
According to the results obtained with different water flow rates, only for a water flow rate of 30 mL/min metals have been efficiently reduced and pollution rate was approached to the standard rate, whereas for water flow rates of 60 and 120 mL/min, metals have been considerably removed but pollution rate was not reduced. Therefore, wastewater with these two water flow rates cannot be discharged to the environment. We should keep in mind that pollution rate is an important factor in wastewater effluents and should comply the international standards.
As it is obvious from the computation of filling time, stay and settle time for water flow rates of 60 and 120 mL/min is low, hence the microorganisms can not decompose biological materials and BOD_5 does not decrease. The experiments carried out before and after refining process show that ciliophora, rotifers, silitates and bacteria live in municipal waste water sludge. It was also observed that microorganism's variety of wastewater in both before and after refining process did not show a considerable change. Only the population of specific groups of microorganisms such as silitates and flagella reduced after refining process. In this phase some microorganisms could be seen with naked eye.

Conclusions

The optimum removal rate of heavy metals (Fe, Cu, Mn) and sulphate was obtained at pH = 7.5-8 and the most favourable water flow rates are 5 and 30 mL/min. These results show that the biological refinement using SBRs system is suitable for heavy metal and sulphate removal from AMD. The experiments revealed that in sequencing batch reactors the more the number of reactors the better the refining process and the higher the metal removal. This also depends on the kind of heavy metal. Therefore, Fe and Cu can be better removed using two reactors but in order to reach higher removal rates of Mn it is necessary to use three sequencing batch reactors. In sequencing batch reactors, the wastewater effluent has a uniform quality and the sludge settles quite well in this operation. SBR system is flexible and we have experienced that it can be constructed in different shapes and dimensions. This system reduces the incoming hydraulic shocks as well. Based on the observations made during the heavy metal removal process which was recorded every hour from each reactor, we observed that the most removal rate occurs during the initial filling time of each reactor. We also noticed that metals (Fe, Cu and Mn) are attracted to the outer surfaces of microorganisms in the form of biological absorption. Sulphate is also removed due to its reduction to hydrogen sulphide and successive precipitation of metal sulphides.

Acknowledgements

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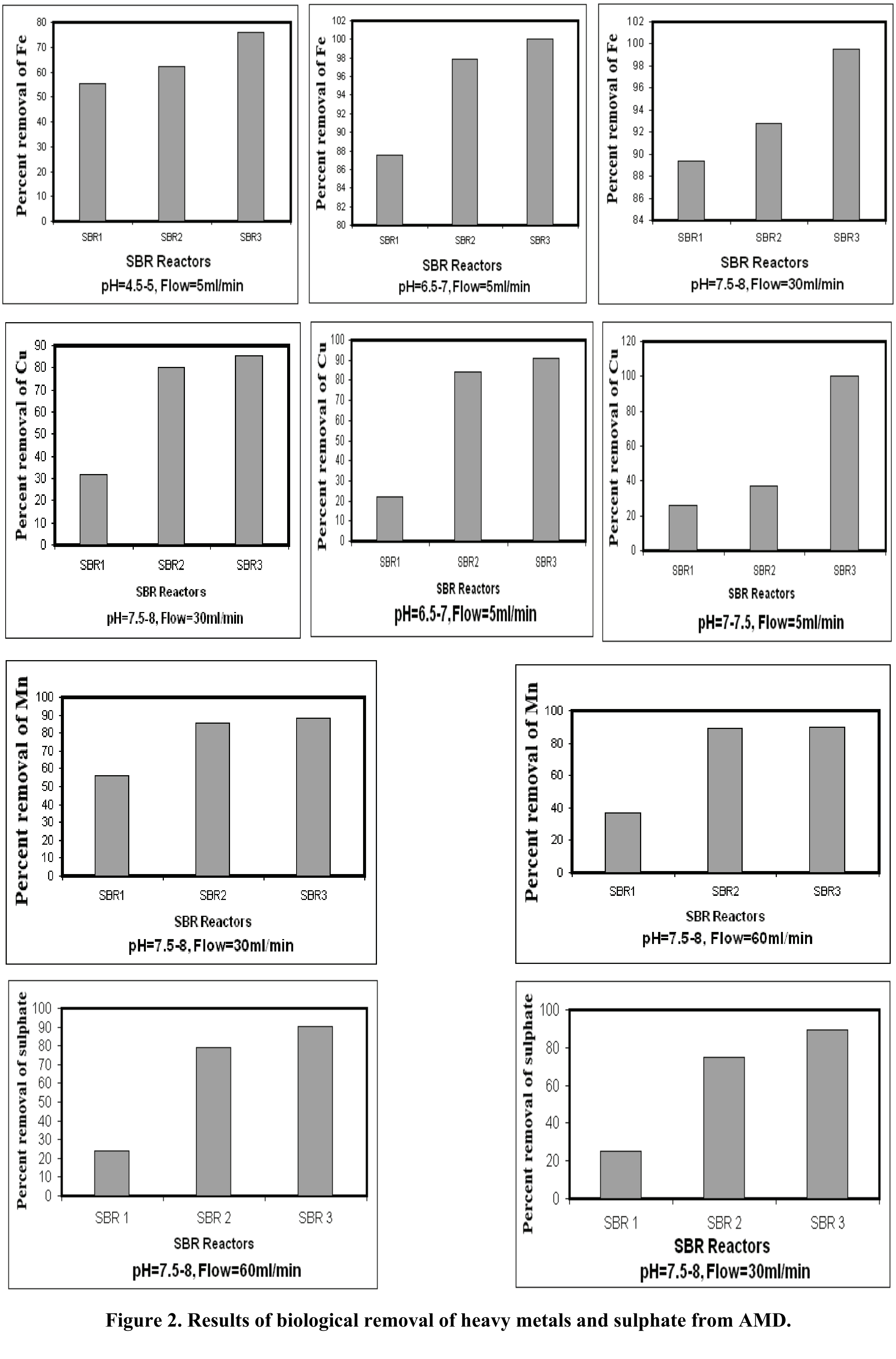
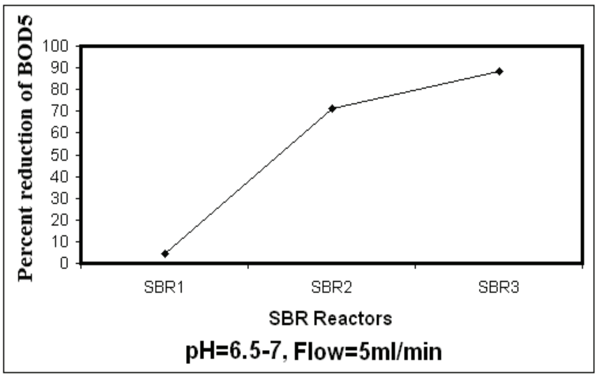


Figure 2. Results of biological removal of heavy metals and sulphate from AMD.



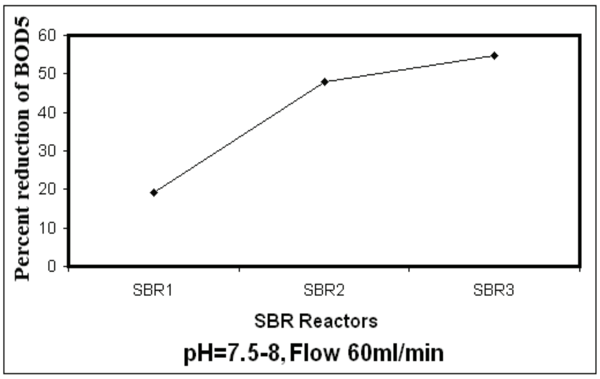


Figure 3. Reduction of BOD_5 in SBRs.

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