Biological fluidized-bed reactors for the treatment of sulfate- and nitrate-containing mine waters

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Keywords: Acid mine drainage; fluidized-bed reactors; sulfate-reducing bacteria; denitrification; electron donor.

Sulfate and nitrate are often discharged from mining operations to the aquatic environment (Johnson and Hallberg, 2005; Zaitsev et al., 2008). Sulfate is naturally released with heavy metals through oxidation of sulfide minerals generating waste streams known as acid mine drainage (AMD) (Tichy et al., 1998). The main source of nitrate in mine waters originates from blasting agents (Koren et al., 2000) and cyanide used as leaching compounds in gold and silver mining activities (Akcil and Mudder, 2003). Both sulfate and nitrate can be removed biologically supplying an external organic electron donor to the solution. Biological sulfate reduction is conducted by sulfate-reducing bacteria (SRB), that are anaerobic microorganisms capable of oxidizing simple organic compounds using sulfate as electron acceptor (Postgate, 1984). Denitrification occurs mainly under anoxic conditions in the presence of heterotrophic bacteria using nitrate as electron acceptor (Dahab and Lee, 1988; dos Santos et al., 2004). Among the different bioreactor configurations, fluidized-bed reactors (FBRs) have been shown to be very suitable both for sulfate-reduction (Kaksonen et al., 2003; Sahinkaya and Gungor, 2010) and denitrification (Green et al., 1994).

In the present work, the biological sulfate-reducing process was developed and studied in two inverse-fluidized bed reactors (IFBRs), whereas the denitrification process was assessed both in classical FBRs and batch assays using serum bottles.

The results showed that an almost complete sulfate reduction (97%) was obtained with COD/SO_4^{2-} ratios as high as 4.00 gram/gram at feed pH of 5 using lactate as carbon source. On the contrary, under stoichiometric conditions ($COD/SO_4^{2-} = 0.67$), the sulfate reduction efficiency was limited to 35% by acetate accumulation and microbial competition for the electron donor. The reactor operated with higher COD/SO_4^{2-} ratios was also tested by suddenly decreasing the feed pH to 3. Under these conditions, the process did not occur since the acidic feed solution was not neutralized and sulfate was not reduced to sulfide. This was due the necessity to use low fluidization degrees (10%) to attain a satisfactory attachment of the biomass on the polypropylene support. At this fluidization degree, the dilution of the acidic feed solution did not occur, leading to the failure of the process.

Using ethanol as carbon source in bench-scale FBRs, the denitrification process efficiently removed nitrate (>99%) both at psychrophilic conditions (7-8℃) and room temperature (22℃). Ethanol was completely oxi dized and nitrite was detected in the effluent below the detection limit. The feed pH of 7 was increased to final values higher than 8 due to the biological alkalinity produced. Besides the continuous reactors, batch tests were carried out to evaluate the lowest feed pH the denitrifying bacteria could tolerate. It was observed that even at pH as low as 4 more than 75% of nitrate was removed and the acidic pH was neutralized in 9 hours.

Based on the results obtained in the batch tests, low-pH feed conditions will be also applied to the FBRs. Because FBR characteristics permit the dilution of the influent inside the bioreactor volume, denitrification is expected to occur even at influent pH lower than 4. Furthermore, as mine waters are also characterized by high metal concentrations, future efforts will be made for evaluating the toxic effects of several metals on the activity of the denitrifying bacteria in batch assays. Finally, denaturing gradient gel electrophoresis analysis will be performed to investigate the bacterial communities present in the reactors.

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