

Bioregenerated ion-exchange process: The effect of the biofilm on the ion-exchange capacity and kinetics

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Abstract

A new process for ammonium removal from wastewater using zeolite has been developed. The zeolite (chabazite) serves the dual purpose of an ion exchanger and a physical carrier for nitrifying bacteria which bio-regenerate the ammonium-saturated mineral. The entire process is carried out in a single, compact reactor and takes place in two phases: ion-exchange phase and bioregeneration phase.

This paper describes the effects of the biofilm on ion-exchange capacity and kinetics. Batch and continuous experiments showed a reduction of about 25 to 30% in the ion-exchange rate in biofilm covered chabazite as compared to virgin chabazite, while the ion-exchange capacity did not change. Experiments conducted indicated that the rate-controlling step for ion exchange shifted from pore diffusion in the virgin chabazite to film diffusion in the biofilm-covered chabazite. The diffusion rate of NH_4^+ inside biofilms is of the same order of magnitude as diffusion rate of NH_4^+ in water and 3 to 4 orders of magnitude greater than typical pore diffusion rates reported in zeolites. Therefore, the biofilm coverage of the chabazite was originally not expected to affect the ion-exchange rate. In addition, chemical precipitation was experimentally found not to be the cause for the ion-exchange rate reduction.

It was hypothesised that the rate-limiting factor for ion exchange was caused by the part of the biofilm adjacent to the chabazite which differs from the rest of the biofilm and is characterised by a much higher density which impedes diffusion.

Introduction

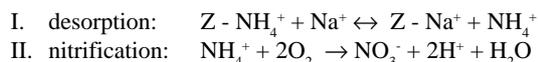
A new process for ammonium removal from wastewater has been developed at the Technion. The process uses chabazite, an ion-exchange mineral of the zeolite group, to remove ammonium from wastewater effluents. The zeolite also serves the dual purpose of a physical carrier for nitrifying bacteria which bio-regenerate the ammonium-saturated mineral. By removing the nitrogen from the whole treatment plant flow, a more efficient and flexible wastewater treatment scheme is facilitated. The process has the advantages of the ion-exchange process (high reaction rate, good control of effluent quality, no sensitivity to fluctuations in NH_4^+ influent concentrations), while overcoming its main drawback, the costs involved in the chemical regeneration by employing biological regeneration of the ion exchanger.

The process is carried out in a single, compact reactor and takes place in two phases:

Ion-exchange mode (NH_4^+ separation stage): A column filled with zeolite (chabazite) is used for ammonium ion exchange from secondary or primary effluents. When NH_4^+ concentration breakthrough occurs the system switches to the bioregeneration mode.

Bioregeneration mode (nitrification stage): The same column containing the ammonium-rich chabazite is used during the bioregeneration mode as a fluidised bed reactor for biological nitrification with the chabazite acting as the carrier for the biofilm. A cation containing regenerant solution is recirculated through the bed in order to desorb NH_4^+ . The amount of the NH_4^+ desorbed and its concentration in the regenerant solution is a function of the total cation concentration in the solution and the recirculated solution

volume. After a short time, the solution reaches an apparent equilibrium concentration of ammonium (Reaction I), while simultaneously, the biomass starts to oxidise ammonia (Reaction II).



The oxidation of the liberated ammonia to the nitrate anion in the second reaction, shifts the equilibrium in the first reaction to the right and desorption continues until the ammonium concentration in the solution drops to negligible values. At this point, the amount of NH_4^+ remaining in the chabazite to the next adsorption phase is a function of the cation composition and concentration of the recirculated regenerant solution.

During the regeneration mode, the reactor operates in an almost batch mode (no outflow and minimal inflow) and pressurised oxygen is supplied for the nitrification process together with bicarbonate to maintain constant pH. The oxidation of the desorbed ammonium to nitrate anions allows for the reuse of the regenerant during many cycles of nitrification. The addition of external cations is limited only to the amount of sodium bicarbonate buffer added. At the end of both adsorption and regeneration modes, backwash is practiced. After the adsorption mode, backwash removes suspended solids thus preventing bed clogging and heterotroph bacteria accumulation in the bed which might compete with the nitrifier population. At the end of the bioregeneration mode, backwash removes the remaining regenerant solution from the bed which may deteriorate ion exchange efficiency at the beginning of the next adsorption phase. This nitrate-rich backwash water is considered a product rather than a pollutant and therefore denitrification is not necessary. A schematic description of the system is shown in Fig. 1.

Results from experiments with either simulated, secondary, or primary effluents showed that the process is capable of high-rate ammonium removal and stable performance (an average nitrification rate of 7.2 g $\text{NH}_4\text{-N}/(\ell \text{ reactor-d})$ was obtained during the

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