Coupling physicochemical (Electroflocculation) with natural (Constructed wetlands) processes for tertiary effluent treatment

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Summary

Stream rehabilitation in Israel that is based upon discharge of high quality effluent and strict standards for effluent disposal both require economical and efficient treatment alternatives.

The overall goal of the research is to examine the potential of coupling a physicochemical process, Electrocoagulation, with a constructed wetland water treatment facility, for polishing secondary effluents in order to reduce major contaminates.

At the initial stage of this research, chemical and electrochemical modified Jar tests were conducted on the Shafdan secondary effluent, using aluminum or iron. Subsequent experiments were carried out with a continuous flow system injected with artificial wastewater, in order to simulate the treatment efficiency of the individual and combined treatment units. The system consisted of an Electrocoagulation cell, a sand filter, and two horizontal flow constructed wetland. The efficiency parameters examined were: turbidity, particle count, TOC, DOC, residual iron, aluminum and phosphate.

The initial purpose of the Jar tests was to compare the efficiency of alum to that of ferric chloride. Alum has several advantages over ferric: firstly, it performed somewhat better than iron for phosphate removal within the natural pH range of the wastewater, 7-8, thus enabled coagulant saving. Secondly, the same dosage was optimal for particles removal in contrast to iron, which required constant adjustment depending on the removal goal. Thirdly, despite a dominant dependency of phosphate removal ability on pH in both coagulants, the alum improved water turbidity, while ferric did not. The electrocoagulation Jar tests significantly widened the pH range suitable for phosphate removal and lowered the coagulants dose. This implies of the existence of two different mechanisms for chemical and electrochemical phosphate flocculation and probably is related to the common uncertainty in literature about the exact mechanism and the coagulating ion. Surprisingly, it was found that current density had a minimal affect on phosphate removal, thereby allowing a reduction of energy costs by using low currents.

Despite these findings, iron electrodes were chosen due to the health risks and financial costs involved in using aluminum (considerations beyond the scope of this work). In the continuous flow tests conducted with sand filtering, the removal of both turbidity and phosphate was improved. This can be related either to the change in the filtration method (surface filtration versus depth filtration), or to the shortened duration of the tests which prevented the coagulant from aging and forming turbidity. These essential differences disqualify the jar tests as a means to determine the right dose for turbidity removal in direct granular sand filtration.

Separate operation of each unit revealed that the wetland was most successful in removing organic matter, within the range of 25-85%, depending on the concentration and time. In addition, it reduced residual ferric by an order of magnitude and even more, and lowered turbidity to the remarkably low values of 0.3-0.6 NTU. Electrocoagulation treatment was found efficient in removing particles and phosphate, since it removed 50% to 90% and more, by raising the $i \cdot t$ value (which determines the concentrations of the disengaged Fe^{+3} ions in the bulk solution) from 23.5 to 84.6. Reduction by 90% in particle number >2 m from various concentrations of 1500-30000 particles/ml was attained, while using the lowest ferric dose.

The combined treatment can be extremely effective in turbidity and ferric elimination, provided that the wetland functions as a polishing process, due to their complementary treating abilities. Turbidity was reduced by 20% to 50% after Electrocoagulation treatment, excluding extreme events, whereas the wetland improved filtrate turbidity by 25% to 75%. Furthermore, the treatment potential increases even more when the wetland replaces the filtering system, preferably through an indirect process (with an additional intermediate settling stage), especially in view of the potential reduction of the hydraulic conductivity (which wasn’t studied in this work), since it is a horizontal flow system. When considering reverse flow, the combined treatment loses its advantages. It was found that the removal ability of both treatments is strongly dependent on the initial concentrations, since filtrate turbidity (after electrocoagulation) deteriorated whenever raw turbidity was less than ~2 NTU. Filtrate turbidity deteriorated so much, despite a considerable reduction in coagulant dose, to the point that the filter bed had to be replaced with a finer one. The fine grain filter showed better turbidity removal efficiency, while the coarse grain showed a moderate head loss. Evidently, turbidity is a misleading parameter in determining the optimal dose for phosphate removal when using iron as the coagulant agent. It however serves as an aid for filtration optimization in choosing the most appropriate grain size.

The tests described above lead to the conclusion that the Shafdan secondary effluents can be treated in a number of ways:

Electrocoagulation- filtration as pre-treatment, with coarse filter media diameter of 1mm. Coagulant dosage is established by the phosphate concentration in water, since its removal is mostly affected by the cation to- phosphate weight ratio.

Electrocoagulation–filtration as polishing process, with fine filter media diameter of 0.6mm, with reduced coagulant dose than that required with the coarser media.

Electrocoagulation as pre-treatment, without filtering, but an additional intermediate settling stage is required.