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האוניברסיטה העברית בירושלים

THE HEBREW UNIVERSITY OF JERUSALEM

THE ROBERT H. SMITH FACULTY OF AGRICULTURE, FOOD AND ENVIRONMENT

M.SC THESIS

BY

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THE USE OF ELECTROCOAGULATION TO REMOVE HUMIC ACID FROM WATER AS PRETREATMENT IN MEMBRANE FILTRATION.

This is an Abstract. Because of HUJI regulations, the complete thesis is in Hebrew. It can be provided upon request.

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Abstract

Natural organic matter is the cause of many problems associated with water treatment such as the presence of disinfection by products and fouling of membrane during water filtration. Today's methods – coagulation, sand and membrane filtration or adsorption on activated carbon – either provide a partial solution or are expensive. Electrocoagulation is a method that can replace chemical coagulation and can act as an alternative in the removal of NOM. In this process the coagulant is introduced to the water by oxidation of metal electrodes (usually iron or aluminum) so that no unnecessary salts are added to the water.

So far, most of the researches examined electrocoagulation as a treatment for industrial sewage or for the removal of particulate colloids from water. This research objective was to examine the efficiency of electrocoagulation in the removal of NOM and the effect of some operative parameters on the process efficiency. In addition, electrocoagulation was tested as a pretreatment for filtration with ultrafiltration membranes in either batch or continuous pilots.

The electrocoagulation was carried out with iron electrodes, and $FeCl_3$ was used in the chemical coagulation. The valence of the ferric ions released from the electrode was determined by comparing the actual iron concentration in the solution to the theoretical concentration according to Faraday's Law. This was done in a jar test system with various pH values and current densities. In all cases the concentration that was measured correlated with bivalent ferric. The different colors of the solution, after adding the iron, suggested different iron species, in different pH values. Sedimentation tests were done in a jar test system in order to examine the removal of humic acid (Leonardite). The parameters examined were TOC and UV_{254} as well as the final pH values and residual iron. The tests demonstrated that electrocoagulation can be used to remove humic acids from water. The UV_{254} fraction showed the highest removal (80-90%) whereas the TOC had a lesser removal (70-80%). This UV_{254} fraction – the aromatic and double bonded – is usually removed easier because of better interaction with the metal coagulant. The optimal pH was pH 8.1 and the removal efficiency decreased with the pH value and increased with the iron concentration to a threshold. These pH values are different from what is recognized in literature as the optimal removal of humic acids with chemical coagulation (pH 4.5–5.5) with trivalent ferric. However, it fits the pH values with bivalent ferric and for the removal of organic substances in waste water with electrocoagulation. The current density did not affect the overall removal; however, lowering it, increased the residual iron concentration after sedimentation. The final pH values changed depending on the initial pH values: acidic pH increased, natural pH did not change and basic pH decreased some what.

There was a decline in absolute value of zeta potential in the two pH values that were tested. In pH 8.1 the potential went down in low iron concentration, whereas in pH 5.3, it went down only when the concentration was high, as was the case in the TOC removal. The main difference between chemical and electrocaogulation was in the floc's character. Using chemical coagulation all the flocs settled and the solution remained clear, while with electrocoagulation, a portion settled and a portion floated. Furthermore, when the conditions were not optimal, a trace of color in the solution was spotted.

Electrocoagulation tests as a pretreatment for ultrafiltraion were carried out in a small laboratory pilot, using membrane with various molecular weight cut off : 4 KDa and 150 KDa made of PES, 50 KDa also made of PES but with a hydrophilic surface and a special 100 KDa membrane (MX50) with a very high surface energy. All experiments were in pH 7 with a constant ferric concentration and two current densities. The purposes of the pretreatment are to improve the humic acid removal and lower the membrane fouling.

The fouling was examined by measuring the flux during filtration in respect to the initial flux of the clean membrane. After filtration, the cake was removed and the flux was measured with distilled water in order to investigate the cake impact. The inner clogging was examined after soaking the membrane in NaOH and measuring the flux. In addition, the tests were carried out with humic acid that was prefiltered with 0.45μm membrane to discover the influence of this fraction on the fouling.

After electrocoagulation all membranes displayed improvement both in the removal of the humic acid and the fouling. The current density did not affect the removal results yet with the 150 KDa membranes it affected the fouling.

The improvement in the TOC and DOC removal after electrocoagulation was 50% higher, but the DOC concentration was much lower. The DOC and TOC concentration after filtration and settling remained the same; so, it can be assumed that this is the fraction that cannot be removed. Only the 4 KDa membranes were able to remove UV_{254} without pretreatment; still, the pretreatment improved its removal by 50%. All other membranes which did not remove UV_{254} exhibited a 70% removal of this fraction after elerctrocoagulation.

The fouling increased with the MWCO of the membranes, except the 100KDa membrane which experienced low fouling. The electrocoagulation reduced the fouling in all membranes especially in the cake formation mechanism which was easier to remove after the pretreatment. The flux after the cake removal went up to 90% of the clean membrane flux, except for the 4 KDa membranes. This membrane

did not experience any flux reduction during filtration, but removing the cake, lowered its flux to 80%. Cleaning the membranes with NaOH improved the flux, especially in the 150 KDa membranes.

Pretreatment with chemical coagulation gave the same results in the humic acid removal, but was not as good in the fouling, and even caused a decline in the flux with the 50 KDa membrane.

A pilot system (ZW-10, Zenon) was built to examine the efficiency of electrocaogulation as a pretreatment in a continuous flow. The filtration was conducted without pretreatment, with electrocoagulation, in two current densities and with chemical coagulation. The results with electro and chemical coagulation were similar and demonstrated an efficient removal of TOC and UV_{254} and a small improvement in the DOC removal, compared to filtration with no pretreatment. In this experiment no fouling was observed during the filtration and therefore, this parameter was not examined.

The results proved that electrocoagulation can be used in the removal from water of humic acid which has similar characteristics as Leonardit and especially as a pretreatment to advanced treatments such as membrane filtration.