ABSTRACT

Electrocoagulation (EC) process is one of the promising, ecofriendly and unpretentious technique. The conventional electrocoagulation (CEC) process is applied globally for physical, chemical and heavy metals removal from wastewater. In current research work, integrated hybrid modified electrocoagulation (MEC) approach for the simultaneous treatment of microbiological and chemical contaminations including toxic metals has been developed. The CEC process removed contaminants like fluoride, phosphate, nitrate and arsenic but could not remove microbial contamination completely. The CEC process was amended by using various anode composition using copper, zinc, aluminum and silver metals with conventional iron anode to optimize the EC process for simultaneous removal of chemical and microbial contaminants from drinking water.

The modified anodes sequence of metal removal effectiveness was of the order as Fe-Zn≥ Fe-Cu >Fe-Al >Fe-Ag as established during screening and optimization process. Artificially contaminated water samples having bacterial ATCC cultures and heavy metals from certified reference materials (CRMs) were subjected to CEC & MEC process for comparative efficiency evaluation. The 100% of trace metals (As, Cd, Cr, Pb, Ni and Mn) removal was achieved from 200 µg/L spiked sample (GWS-1) by MEC treatments. The artificial contamination of *Staphylococcus aureus* and *Escherichia coli* (ATCC) cultures in drinking water was disinfected completely from 430 & 350 MPN/100 mL respectively to not detected. The order of efficiency of MEC was established as Fe-Cu> Fe-Zn>Fe-Ag>Fe-Al.

Based on the optimization comparison, Fe-Zn & Fe-Cu anode combinations were selected and applied on two potable water samples to verify and validate the MEC process efficiency. In first case, water sample (DWS-1) having TDS of 343.6 mg/L, was treated with above anodes and evaluated for chemical, heavy metals and microbiological contaminants removal. The contamination of nitrates, fluorides, phosphates and manganese, arsenic removed 100% within 5 minutes' treatment time. The bacterial load count of 94, 43 and 12 MPN/100mL of total coliform, fecal coliform and *Escherichia coli* respectively decreased to ND with MEC process quite efficiently as compared to CEC process. The Fe-Zn and Fe-Cu anodes also successfully removed the microbial contamination from suspension, filtrate and flocs suspension. For artificially contaminated water sample using multi-element standard, MEC process with Fe-Zn

anode removed remarkably most of the metals including As, Be, Cd, Co, Cr, Mn, Cu, V, Ni, P, Pb and Hg. The similar findings were observed for the other water sample (DWS-2) having comparatively higher pre-treatment TDS of 462 mg/L. The DWS-1 was artificially contaminated with ATCC cultures of *Escherichia coli* (540 MPN/100 mL), *Pseudomonas aeruginosa* (350 MPN/100 mL) and *Staphylococcus aureus* (7.57-$\log_{10}$) and subjected to Fe-Zn MEC treatment process. The Fe-Zn anode removed the 7 logs of gram positive and gram negative bacteria within 5 minutes.

The heavy metals uptake and adsorption by the flocs has also been studied and verified by various techniques like SEM, EDX and ICP-OES analysis. The analysis of the recovered flocs after dissolution in acidified medium shown presence of all metals of the contaminated sample. The iron was the major component of the flocs (86%) whereas, remaining 14% composition of flocs constituted by up taken metals from sample as K, Na, Mg, Ca, P, Al, As and Se respectively. The iron was the major component of the flocs while other elements included in the flocs EDX analysis were carbon, oxygen, sodium, magnesium, aluminum, silicon, phosphorus, sulphur, chloride, potassium, calcium, copper and cadmium.

The SEM morphological analysis of the gram negative (*Escherichia Coli*) and gram positive (*S. aureus*) having 0.5 O.D. suspension has also established the complete bacterial cellular disintegration with Fe-Zn anode treatment. The said anode combination exhibited marvelous antiviral activity for influenza virus in embryonated poultry eggs. The FTIR analysis of the flocs did not show any significant peak for sludge samples. FTIR analysis of the sodium naphthalene sulphonate also shown no critical changes in structure after CEC and MEC process.

With the experimental analysis results, verification and validation data, the novelty of the MEC process has been successfully established. The Fe-Zn anode combination efficiency for simultaneous removal of major target contaminants along with viral contamination is verified from detailed screening and validation experimental results. Thus making water safe for human consumption after MEC treatment within the regulatory guidelines. The application and adoption of this ecofriendly electrocoagulation process at community level will enhance the safe water supply and improve the general public health.