Electronic Supplementary Information

Environment friendly TDS removals from waste water by Electrochemical Ion exchange batch type Recirculation (EIR) technique

G Vijayakumar[1]*, Muniyandi Rajkumar[2], Rajiv Chandar. N[3], P Selvakumar[4] and Ramesh Duraisamy[5],

[1] Department of Chemistry, Vivekanandha College of Engineering for Women(Autonomous), Tiruchengode, Namakkal 637205, Affiliated to Anna University, Tamil Nadu, India*

[2]Department of Chemistry, PSG College of Arts and Science, Coimbatore, Coimbatore 641 405, Tamil Nadu, India

[3]Department of Physics, Coimbatore Institute of Technology, Coimbatore - 641 013, Tamil Nadu, India

[4]Department of Chemistry, Nehru Institute of Technology, Coimbatore 641 105, Tamil Nadu, India

[5]Chemistry Department, , College of Natural and Computational Sciences, P.O. Box 21, Arba Minch University, Ethiopia

Abstract

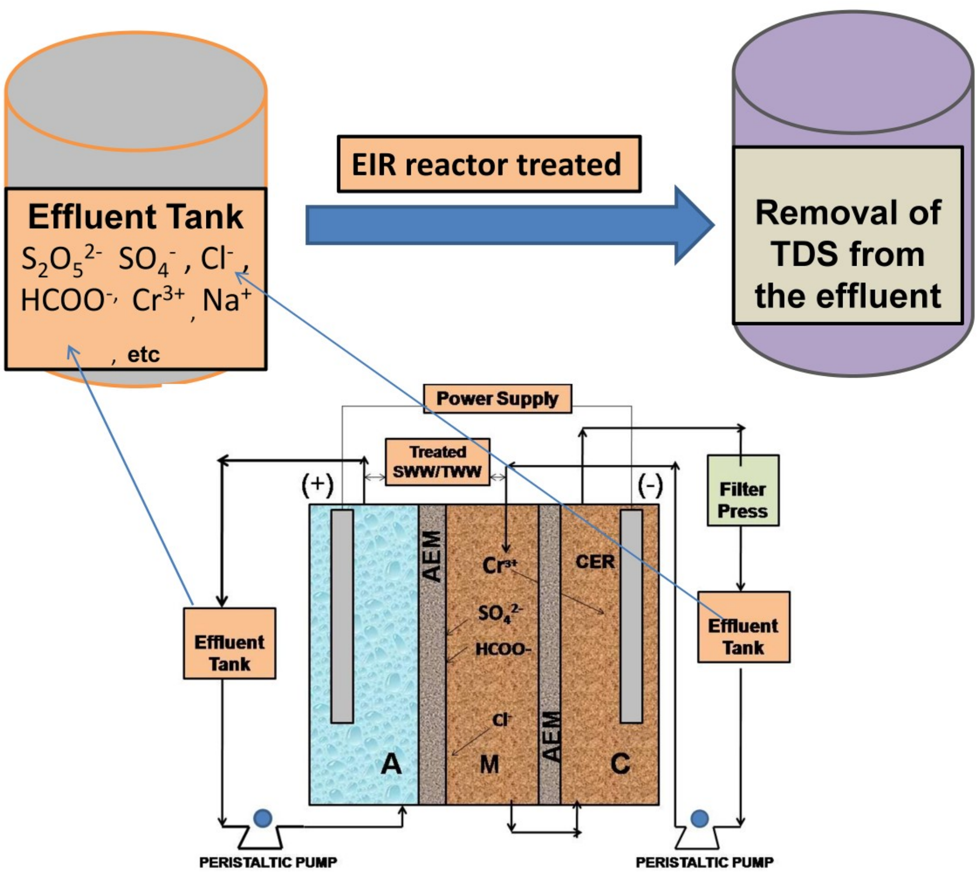
The increasing prevalence of Total Dissolved Solids (TDS), Cl^-, SO_4^{2-}, total suspended solids (TSS), BOD and COD in industrial effluent necessitates pioneering electrochemical approaches for efficient removal. Synthetic industrial wastewater (SWW) as well as Tannery industrial processing wastewater (TWW) collected, its studies explored the synergistic optimization of current density (CD), anolyte, and cathode compartment effluent volume ratio selection to enhance TDS and other toxic effluents removal efficiency where the time not exceed 8h. The electrochemical ion exchange batch type recirculation reactor (EIR) approach was examined with the help of ruthenium oxide coated titanium (Ru_2O/Ti) as anode and stainless steel (SS) as a cathode which was separated by a middle compartment. Utilizing three compartments setup as an electrochemical cell batch type recirculation design, we investigated the impact of varying current densities on TDS removal rates and power consumption. In these EIR compartments constructed with the anion exchange membrane (AEM- NEOSEPTA) and the cationic exchange resin (CER- AMBERLITE IR 120) where fixed in which SWW / TWW effluent has allowed to flow and recirculation during the reactor operating time. The SWW has been treated with various current densities such as 20, 40, 60, 80 and 90 mA / cm^2. Maximum removal of Cl^- (93%), SO_4^{2-} (93%), TSS (93%), TDS (93%), BOD_5 (93%), and COD (93%), were achieved at the 1:2 optimum volume ratio with CD at 40 mA / cm^2. Our finding reveals such as optimal current density range, balancing removal efficiency and energy consumption of 0.9682 KWhr / Kg. The finding indicated that under the optimized conditions, maximum removal efficiencies of Cl^-, SO_4^{2-}, TSS, TDS, BOD_5 and COD were 95%, 89%, 89%, 83%, 92% and 89% respectively from TWW. The optimized system demonstrates superior efficiency in reducing TDS levels, highlighting the significance of parameter tuning in the electrochemical TDS removal process in tannery high saline effluent. This research contributes to the development of sustainable water treatment strategies by presenting a comprehensive approach to enhance TDS removal through the systematic optimization of key operational parameters. The insights gained from this study can inform the design and implementation of electrochemical systems for TDS-laden effluent treatment, offering a practical pathway toward more efficient and environmentally conscious water remediation practices.

Key Words: TDS, EIR, water, effluent, treatment, electrochemical

E mail address: ngvijayakumar@gmail.com (G Vijayakumar)   Tel Ph No: +91 4288 234560

drrameshmcas@gmail.com (Ramesh Duraisamy)

Graphical Abstract of EIR Technique



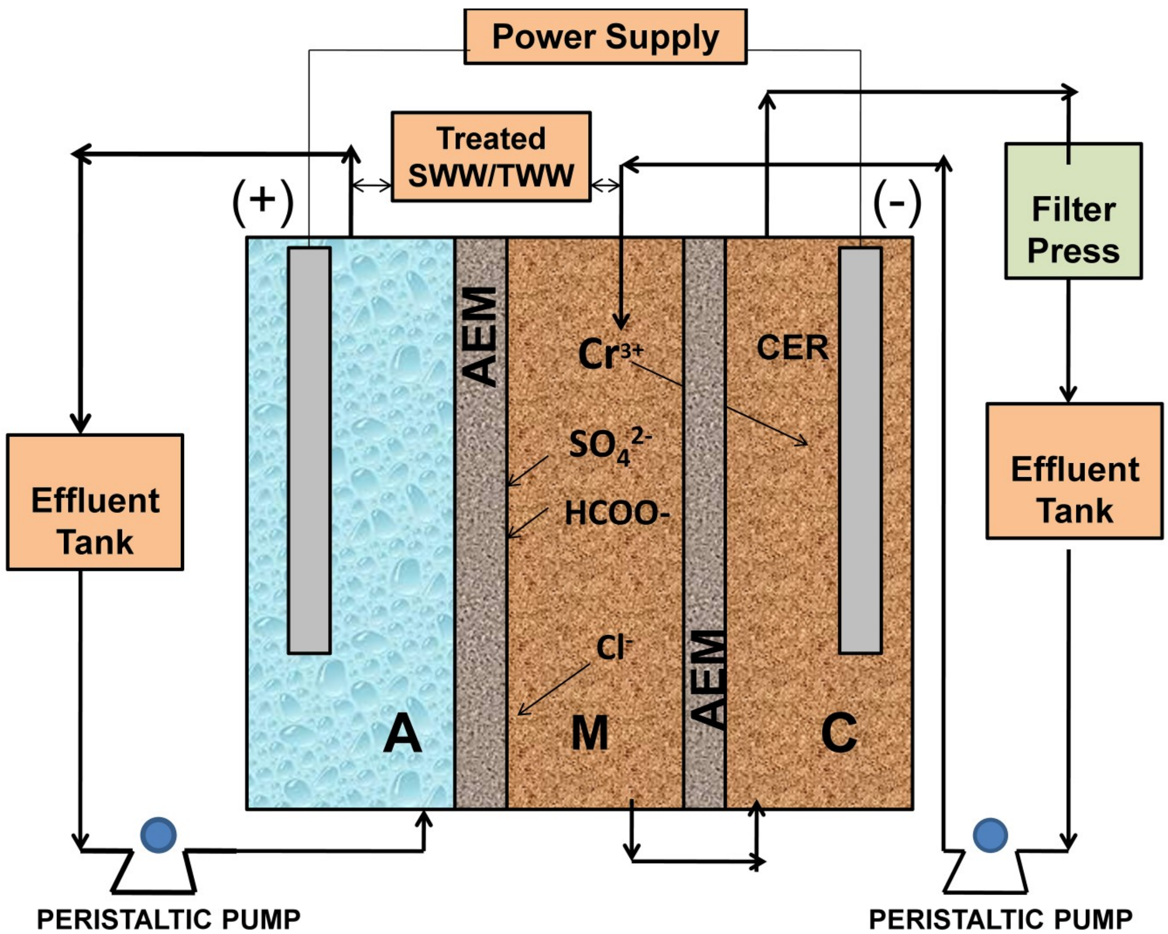


Fig. 1: Schematic representation of EIR setup of SWW / TWW effluent treatment process.

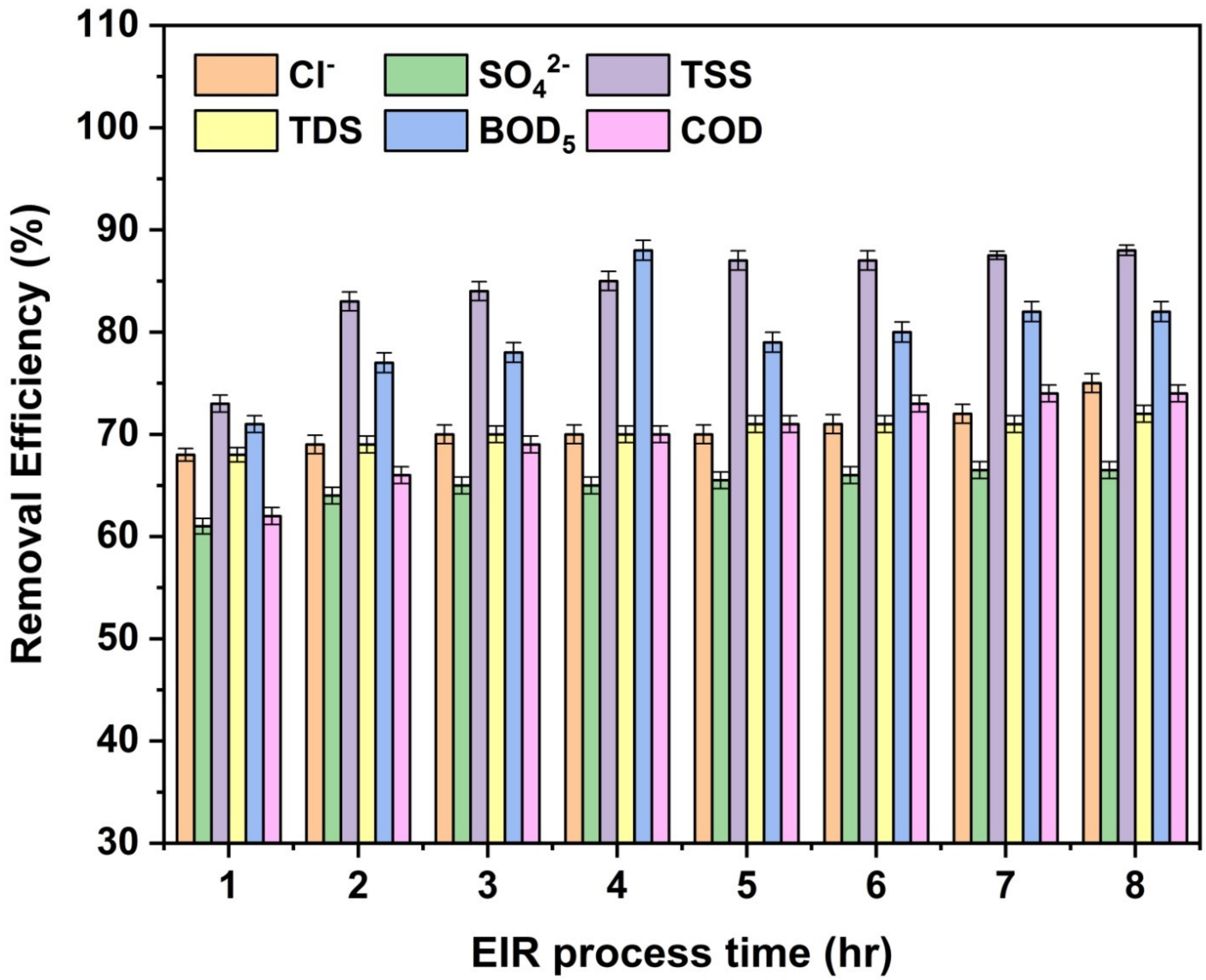


Fig. 2: Effectiveness of time in the EIR process influences the removal efficiencies of pollutants under 1: 1 (v/v) ratio of effluent at the anolyte and catholyte tank respectively, applied current density at 40 mA cm^{-2}. The error bars in the results indicate a deviation of ± 1 standard deviation from the mean of triplicate data.

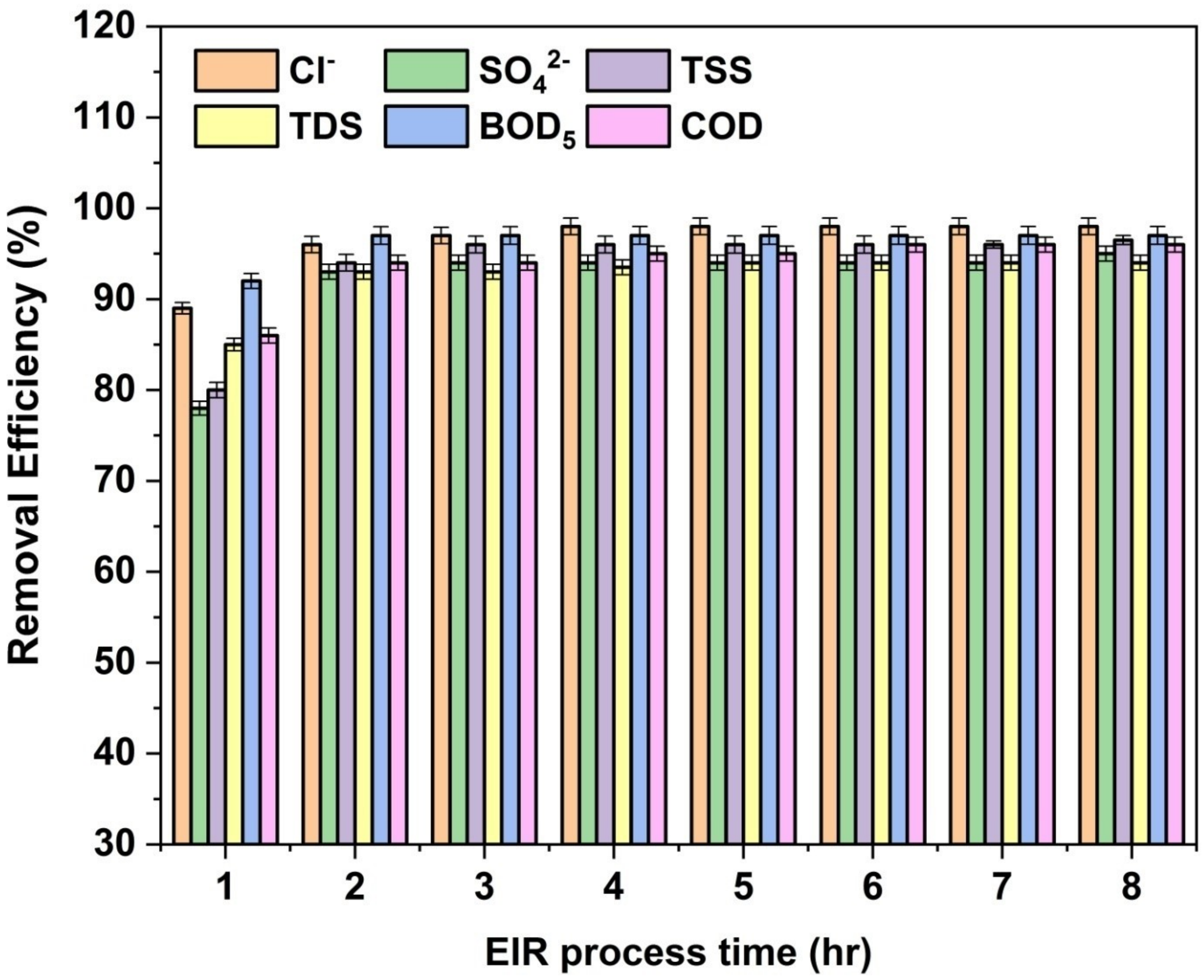


Fig. 3: Effectiveness of time in the EIR process influences the removal efficiencies of pollutants under 1: 2 (v/v) ratio of effluent at the anolyte and catholyte tank respectively, applied current density at 40 mA cm^{-2}. The error bars in the results indicate a deviation of ±1 standard deviation from the mean of triplicate data.

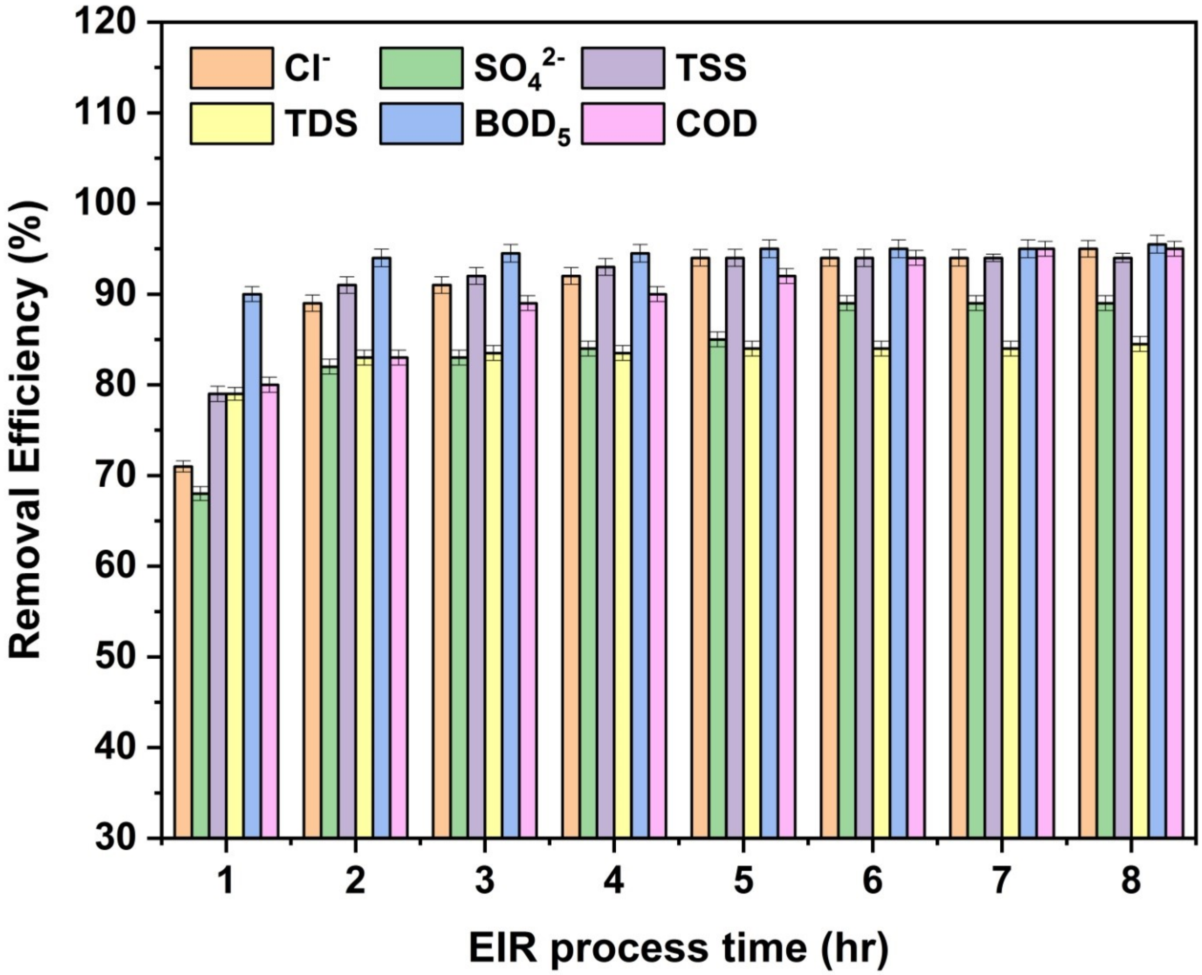


Fig. 4: Effectiveness of time in the EIR process influences the removal efficiencies of pollutants under 1: 3 (v/v) ratio of effluent at the anolyte and catholyte tank respectively, applied current density at 40 mA cm^{-2}. The error bars in the results indicate a deviation of ±1 standard deviation from the mean of triplicate data.

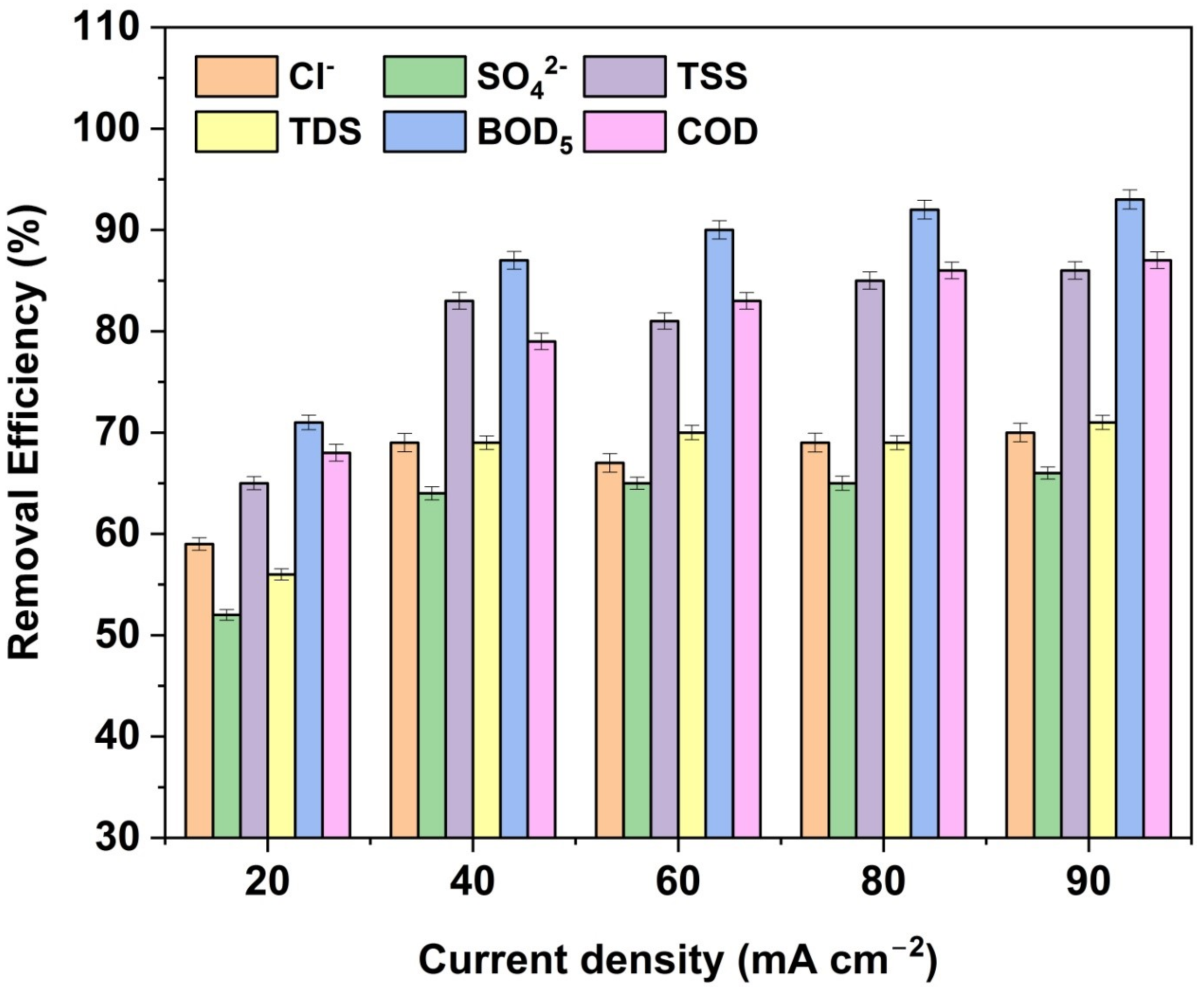


Fig. 5: Varying the CD impacts the efficiency of removing pollutants under 1: 1 (v / v) volume ratio of SWW flow at the anolyte and catholyte tank with respect to optimum time (2hours). The error bars in the results represent a deviation of ±1 standard deviation from the mean of triplicate data.

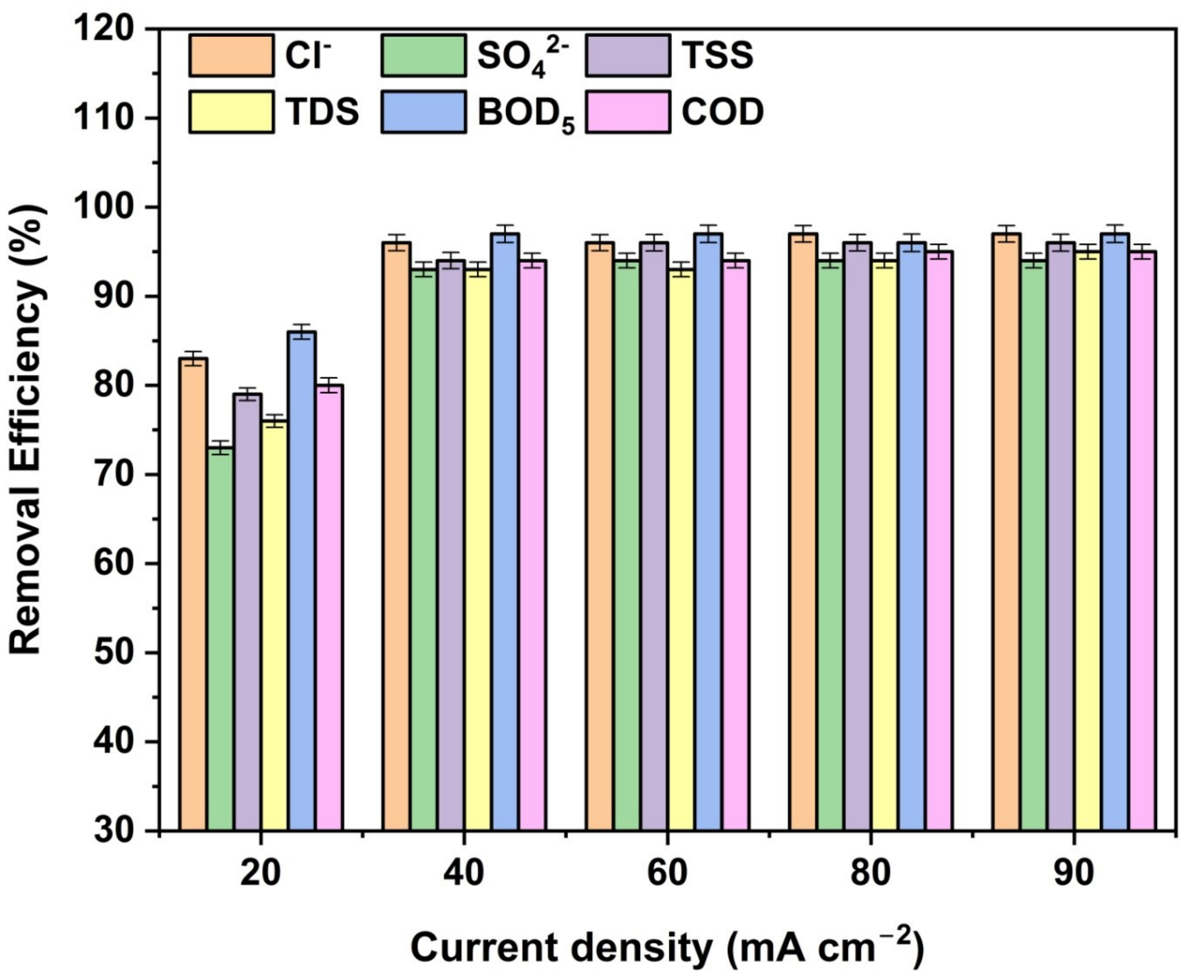


Fig. 6: Varying the CD impacts the efficiency of removing pollutants under 1: 2 (v / v) volume ratio of SWW flow at the anolyte and catholyte tank with respect to optimum time (2hours). The error bars in the results represent a deviation of ±1 standard deviation from the mean of triplicate data.

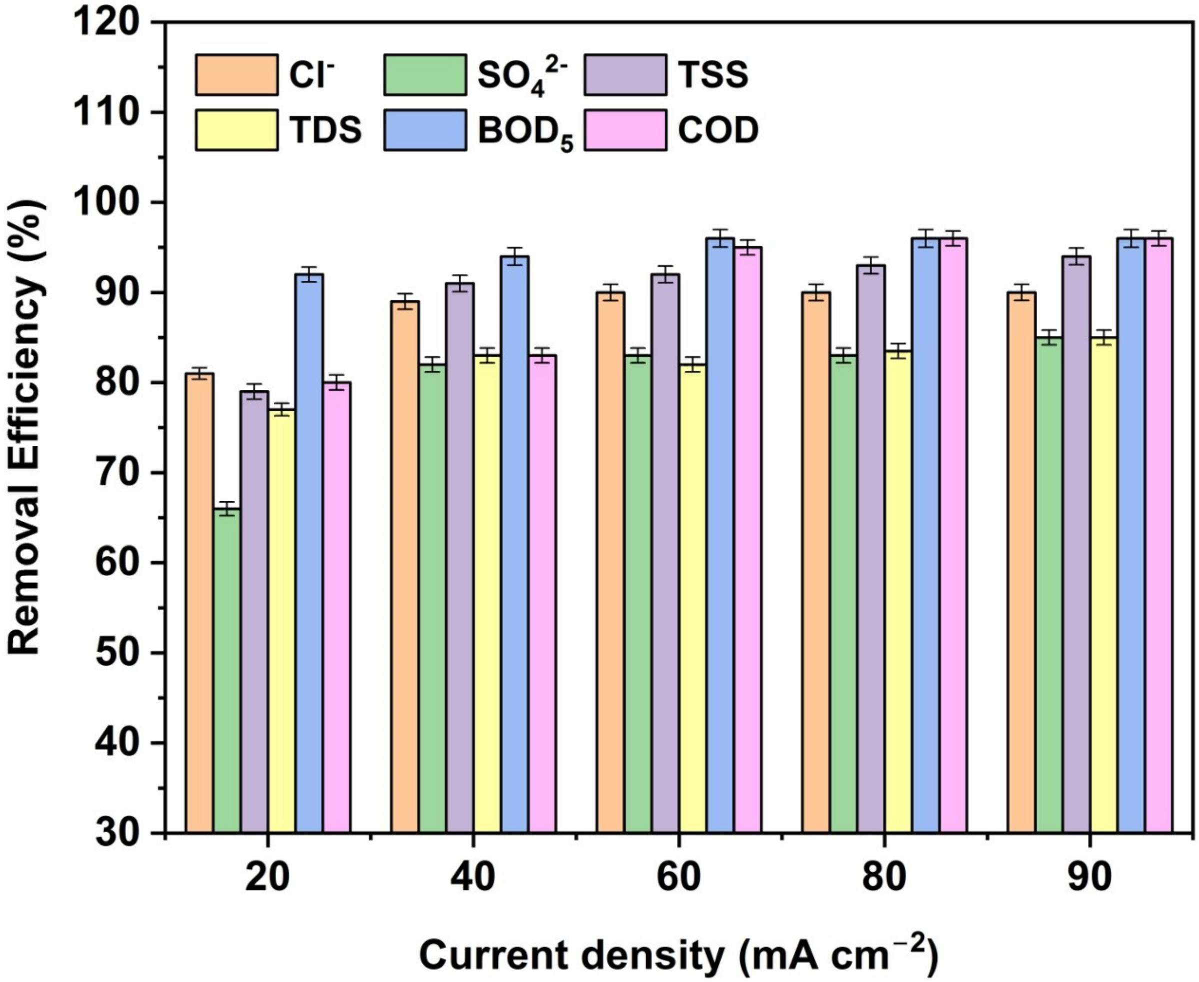


Fig. 7: Varying the current density (CD) impacts the efficiency of removing pollutants under 1: 3 (v / v) ratio of effluent flow at the anolyte and catholyte tank with respect to optimum time (2hours). The error bars in the results represent a deviation of ± 1 standard deviation from the mean of triplicate data.

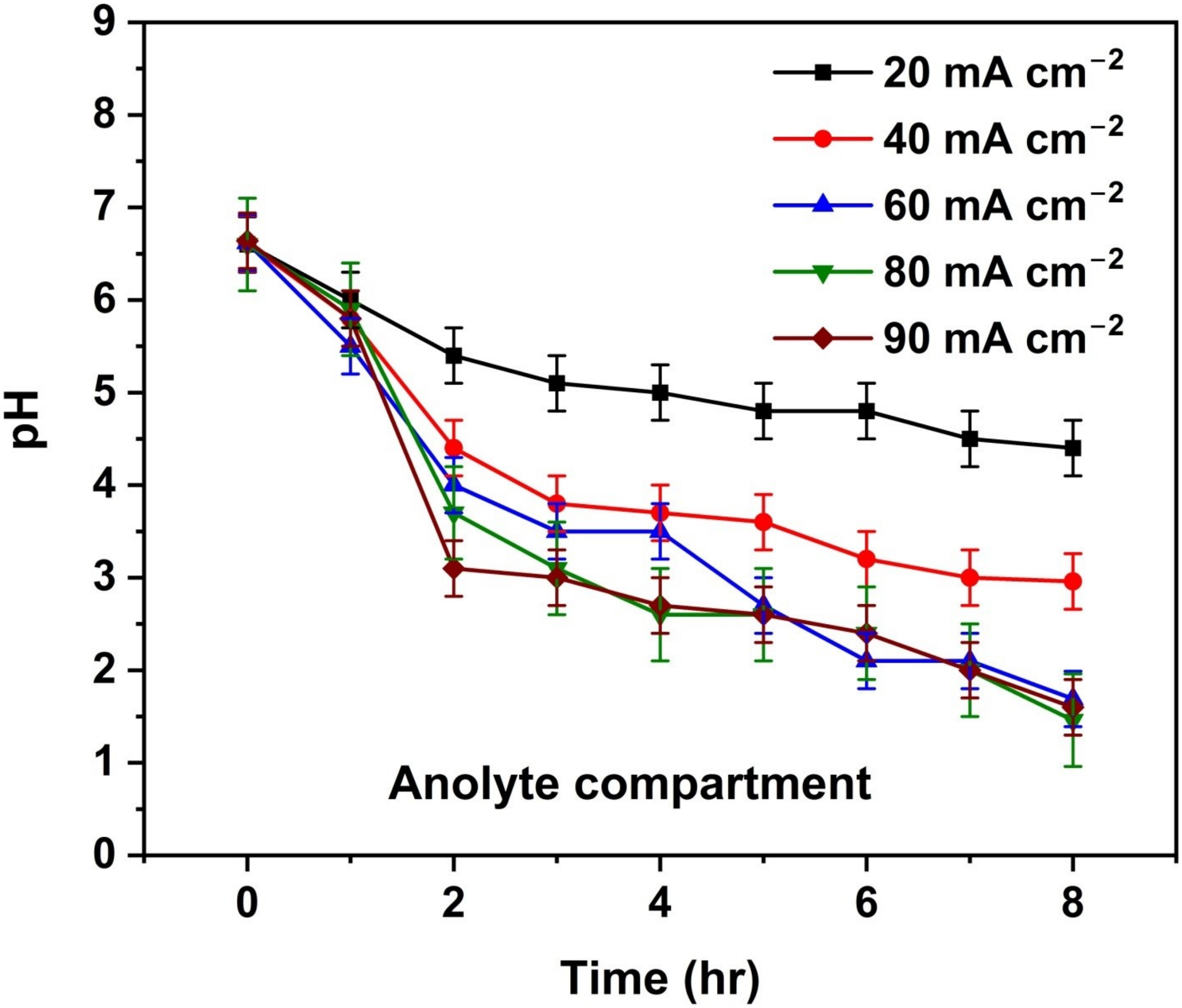


Fig. 8 (a). pH value of SWW at AE tank

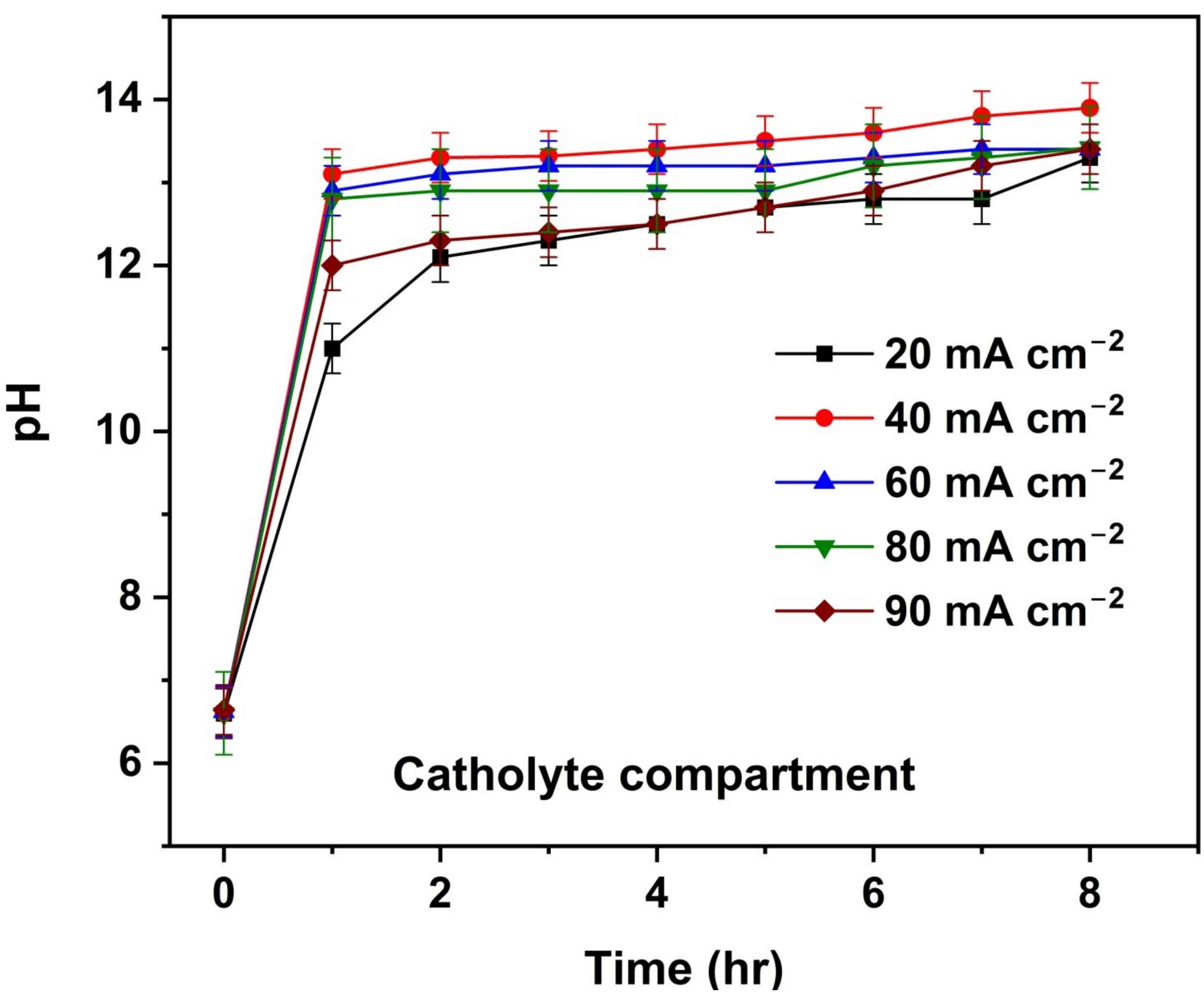


Fig. 8 (b) pH value of SWW at CE tank

Fig. 8 (a). pH value of SWW at AE tank and (b) pH value of SWW at CE tank : optimum SWW volume ratio (1:2) and varying applied CDs (mA cm^{-2})

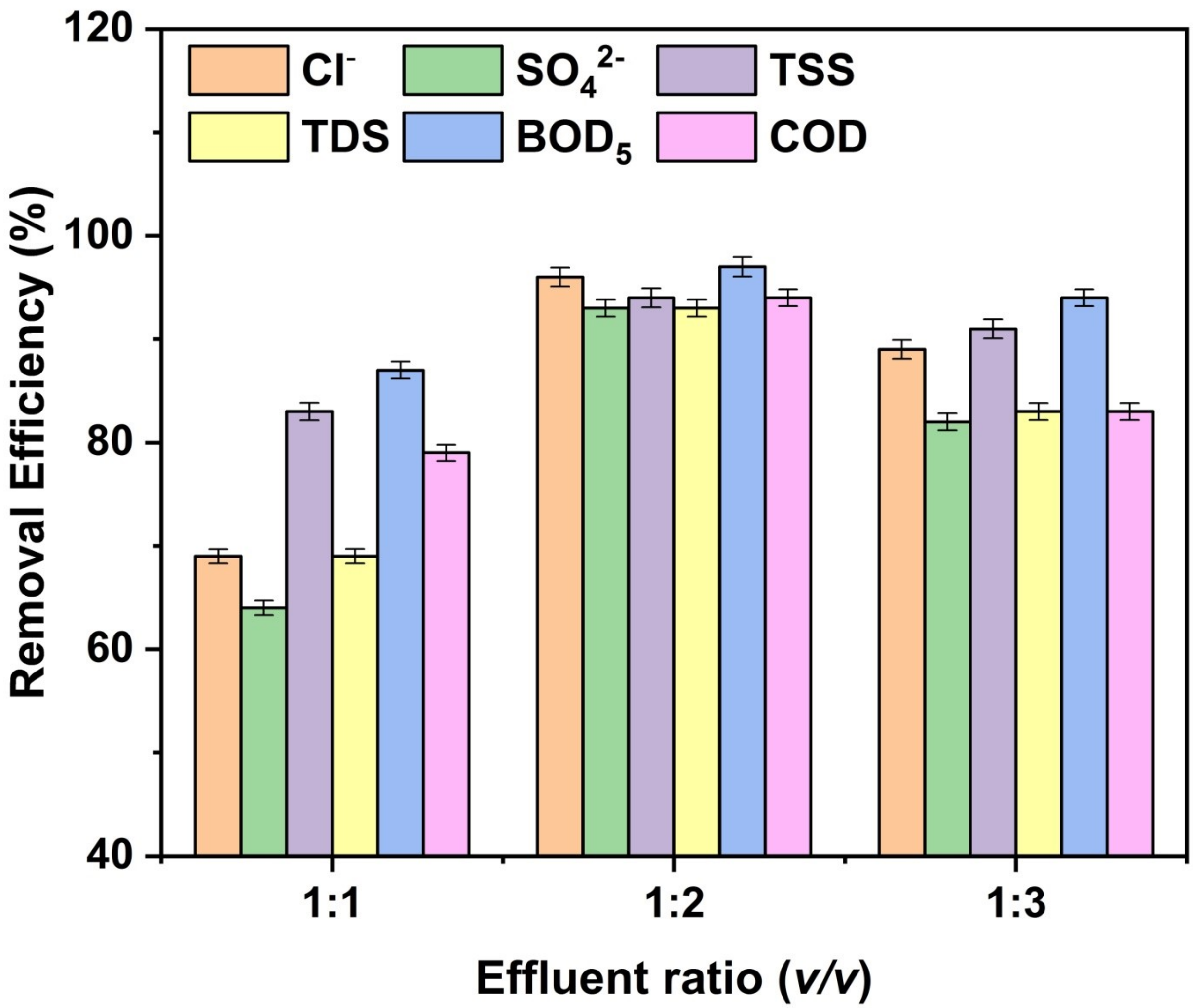


Fig. 9 Removal of effluent efficiency *vs* various ratio (v / v) of SWW at AE (36 ml / min) & CE tank (15 ml / min) at optimized CD (40 mA cm^{-2}) and time (2hours) at the recirculation flow rate. The error bars in the results represent a deviation of ±1 standard deviation from the mean of triplicate data.

Fig. 10. a) TWW collected from industry[22]

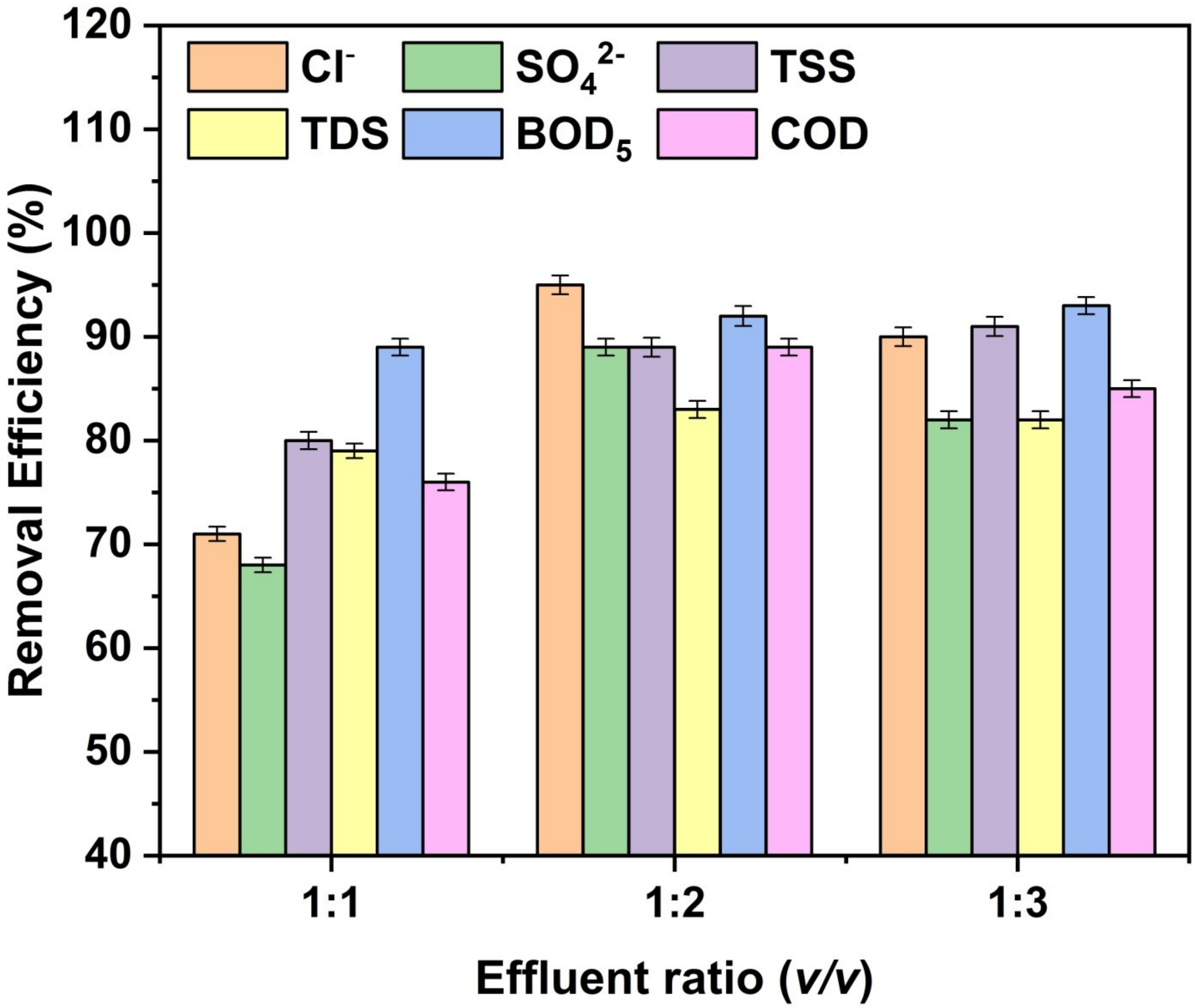


Fig 10 b)

Fig. 10. a) TWW collected from industry [22] (b) Removal efficiency *vs* various ratio of TWW at AE (36 ml / min) & CE tank (15 ml / min) at optimized CD (40 mA cm^{-2}) and time (2hours) at the recirculation flow rate. The error bars in the results represent a deviation of ±1 standard deviation from the mean of triplicate data.

References

1 H. Ali, E. Khan and M. A. Sajad, Phytoremediation of heavy metals-Concepts and applications, *Chemosphere*, 2013, 91, 869–881.

2 M. Wieczorek-Dąbrowska, A. Tomza-Marciniak, B. Pilarczyk and A. Balicka-Ramisz, Roe and red deer as bioindicators of heavy metals contamination in north-western Poland, *Chem. Ecol.* 2013, 29, 100–110,

3 J Briffa, E Sinagra , R Blundell, Heavy metal pollution in the environment and their toxicological effects on humans, *Heliyon* 6 (2020) e04691

4 M. H. A. Aldossary, S. Ahmad and A. A Bahraq, Effect of total dissolved solids-contaminated water on the properties of concrete. *Journal of Building Engineering*, 2020, *3,* 101496.

5 Steele, M. K., and Aitkenhead-Peterson, J. A. Long-term sodium and chloride surface water exports from the Dallas/Fort Worth region. *Science of the Total Environment*, 2011, 409, 3021–3032.

6 C. Zhang, W. Zhang, Y. Huang and X. Gao, Analyzing the correlations of long term seasonal water quality parameters, suspended solids and total dissolved solids in a shallow reservoir with meteorological factors. *Environ Sci Pollut Res,* 2017, 24, 6746–6756.

7 D A. Yaseen and M. Scholz, Treatment of synthetic textile wastewater containing dye mixtures with microcosms, *Environ Sci Pollut Res,* 2018, 25, 1980–1997.

8 M. Bogliolol, A. Bottinol, G. Caparmellil, G. De Petrol, A. Servidal, G Pezzi and G. Vallini, Clean water recycle in sugar extraction process: performance analysis of reverse osmosis in the treatment of sugar beet press water, *Desalination* 1996, 108, 261–271.

9 A.I. Adetunji and A.O. Olaniran, Treatment of industrial oily wastewater by advanced technologies: a review, *Appl Water Sci* 2021, 11, 98.

10 V Sivakumar, V. JohnSundar, T. Rangasamy, C. Muralidharan and G. Swaminathan, Management of total dissolved solids in tanning process through improved techniques, *Journal of Cleaner Production*, 2005, 13, 699-703.

11 P. K. Weber-Scannell and L. K. Duffy, Effects of total dissolved solids on aquatic organisms: A review of literature and recommendation for salmonid species, *American Journal of Environmental Sciences,* 2007, 3, 1–6.

12 K. V. Brix, R. Gerdesa, N. Curryc, A. Kaspera, M. Grosella, The effects of total dissolved

solids on egg fertilization and water hardening in two salmonids –Arctic Grayling (Thymallus arcticus) and Dolly Varden (Salvelinus malma). *Aquatic Toxicology*, 2010, 97, 109–115.

13 P. K. Weber-Scannell, L. K. Duffy, Effects of total dissolved solids on aquatic organisms: A review of literature and recommendation for salmonid species. *American Journal of Environmental Sciences,* 2007, 3, 1–6.

14 D. A. BertuoL, F. D. R. Amado, H. Veit, J. Z. Ferreira and A. M. Bernardes, Recovery of nickel and cobalt from spent NiMH batteries by electrowinning, *Chemical Engineering Technology,* 2012, 35, 2084-2092.

15 H. Parab, S. Joshi, N. Shenoy, A. Lali, U.S. Sarma and M. Sudersanan. Determination of kinetic and equilibrium of Co (II), Cr (III), and Ni (II) onto coir pith , *Process Biochem,* 2006, 41, 609-615.

16 R. S. Juang, S. H. Lin and T. Y. Wang, Removal of metal ions from the complexed solutions in bed using a strong acid ion exchange resin, *Chemosphere,* 2003, 53, 1221-1228.

17 Z Hao and Z Qing-ming. Applications of nano-TiO_2 photocatalytic technology to the treatment of industrial wastewater, *Industrial Water Treatment,* 2011, 31, 17-19.

18 G. Yao , F. Zeng , Z. An, H. Li, T. Zhu and J. Fang, Enhancement mechanism for boron removal at high anodic polarization potential during electrocoagulation using iron-based materials, *Journal of Environmental Chemical Engineering*., 2022, 10, 07279

19 F. Viero, A.C.R. Mazzarollo, K.Wada and I.C. Tessaro, Removal of hardness and COD from retanning treated effluent by membrane process**,** *Desalination,* 2002, 149, 145-149.

20 K Klein, E Kattel, A Goi, A Kivi, N Dulova, A Saluste, I Zekker, M Trapido, T Tenno, The whole process included air stripping, coagulation flocculation and batch distillation, *Oil Shale,* 2017, 34, 82–96

21 C. Jin-xiu and L. Hiu-hiu, Application and Progress of Ion Exchange Resins in Treatment of Wastewater, *Guangzhou Chemical Industry*, 2013, 41, 44-45.

22 K N D Marya, N. Muralimohan, A Case Study: Evaluation Of Tannery Effluent, *Indian J.Sci.Res.,* 2017, 17, 096-099.

23 C. Ahmed Basha, S. Josephine Selvi , E. Ramasamy and S, Chellammal, Removal of arsenic and sulphate from the copper smelting industrial effluent, *Chemical Engineering Journal*, 2008, 141, 89–98.

24 E.W Rice, R.B Baird, A.D. Eaton, L.S. Clesceri, , Standard methods for the examination of

water and wastewater. *J. Am. Publ. Health Assoc.Washington*, 2012, DC, USA 10.

25 Andrew D Eaton, Standard methods for the examination of water and wastewater, 21st ed.American Public Health Association, American Water Works Association, Water Environment Federation,Washington, DC, APHA, AWA, WPCF. 2005.

26 A A Al-Raad, M M. Hanafiah, SO_4^{2-}, Cl^-, Br^-, and TDS removal by semi continuous electrocoagulation reactor using rotating anode, *Environmental Technology & Innovation*, 2022, 28, 102917.

27 A S Dharnaik, P K Ghosh, Hexavalent chromium [Cr(VI)] removal by the electrochemical ion-exchange process, *Environmental Technology*, 2014, 35, 2272-2279.

28 C. Ahmed Basha, P Kumar Ghosh and G. Gajalakshmi, Total dissolved solids removal by electrochemicalion exchange (EIX) process, Electrochimica Acta, 2008, 54, 474–483.

29 S Annamalai, M Sundaram, M Curras, Integrated approach of chemical and electrodialysis process in textile effluent contaminated groundwater for irrigation, *Journal of Environmental Chemical Engineering,* 2017, 4, 3190 – 3200.

30 N. Beyazit, Copper(II), Chromium(VI) and Nickel(II) removal from metal plating effluent by electrocoagulation, *International Journal of Electrochemical Science*, 2014, 9, 4315–4330.