

**1. Project proposal reference number**

46S\_M.Tech.\_014

**2. Title of the project**

simultaneous removal of emerging contaminants from multi-component system aqueous using electrochemical oxidation.

**3. Name of the college and department**

M.Tech in Environmental Engineering,  
Department of Civil Engineering,  
B.M.S College of Engineering, Bangalore.

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**5. Keywords**

Electro-chemical oxidation, stainless-steel electrode, emerging contaminants, iron electrode, kinetic study, synergetic index, energy estimation.

## 6. Introduction

The pharmaceuticals and personal care products (PPCPs) are one kind of emerging contaminants which are synthetic or naturally occurring chemicals that are not commonly monitored in the environment but have the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects [1]. Examples of emerging contaminants includes pharmaceuticals, personal care products, micro-plastics, disinfection by-products etc. Emerging contaminants does not have discharge standards. These contaminants are pseudo persistent in nature and the conventional treatment technologies are ineffective in removal of these emerging contaminants[2]. As a result, these pollutants bypass the treatment systems and reaches the surrounding aqueous environment; thereby leading to ecotoxicity[3]. Therefore, it is vital to remove the pollutants from the effluents before reaching into the natural environment. pharmaceuticals and personal care products (PPCPs) include numerous chemical classes[4]. PPCPs are most observed pollutants recently. These products are most produced by the anthropogenic sources such as veterinary medicines, agricultural practices, human health and cosmetics are included in PPCPs these PPCPs enter the environment through various routes like absorption of PPCPs by the body during therapeutic use followed by excretion waste Management and treatment technology sewage systems. Personal care products are products used to improve the quality of daily life by adorning and cleaning our bodies [5]. Personal care products include lotions, fragrances, shampoos, antibacterial soaps, detergents, sunscreens, insect repellents, and cosmetics Pharmaceuticals and personal care products are among the most observed pollutants recently[6]. Another important route for entry of PPCPs into environment is through the discharge of effluent directly into river bodies by the manufacturing plant facility which subsequently enters the surface water, groundwater after leaching through the soil [7].

Most of the studies conducted earlier have reported degradation of PPCPs from mono-component system only. On the other hand, integration of other treatment technologies in order to increase the removal efficiency have not investigated, Moreover, to the finest of our familiarities no work has investigated degradation of PPCPs from mono-component and multi-component systems using electro-chemical stainless steel (SS) iron (Fe) electrodes and photochemical oxidation using visible and UV lights meanwhile very few studies have reported the kinetics of pharmaceuticals and personal care products removal using electro-chemical and photochemical oxidation technique.

## **7. Objectives and scope of the work**

### **Objective**

The main objective of this research is to investigate the simultaneous removal of emerging contaminants using electro-chemical oxidation technique.

Scope of the work includes:

1. Conduct electro-chemical oxidation of emerging contaminants from multi-component system in batch mode using stainless steel (SS) and iron (Fe) electrodes.
2. Investigating effect of operational parameters i.e., reaction time, pollutant concentration, voltage, solution pH, oxidant dose, number of electrodes and spacing between electrodes for removal of emerging contaminants.
3. Determining the rate of removal of emerging contaminants using first order and second order kinetic models.
4. Analysis of synergetic index and energy estimation for simultaneous removal of emerging contaminants.

## **8. Methodology**

Fig. 1 depicts the flowchart of research methodology adopted in this project for removal of emerging contaminants from multi-component aqueous system. This work is divided into 2 phases. In phase 1, electro-chemical oxidation of emerging contaminants removal will be investigated using stainless-steel (SS) electrodes from mono-component and multi-component system. Meanwhile, in phase 2 electro-chemical oxidation of emerging contaminants removal will be investigated using iron (Fe) electrodes. Subsequently, the effect of operational parameters such as treatment time (0-120 min), voltage (5-25 V), effect of concentration (5-50 mg/L), pH (3-11), spacing of electrodes (1-3 cm), number of electrodes (2,4,6) and electrode combination (Fe-SS-Fe-SS and SS-Fe-SS-Fe) are investigated. Meanwhile the rate constants for first order and second order kinetic models, analysis of synergetic index and energy estimation will be elucidated for simultaneous removal of emerging contaminants using SS and Fe electrodes. Fig. 2(a)-(c) depicts the experimental setup of electro-chemical oxidation reactor and electrode configuration for emerging contaminants removal.

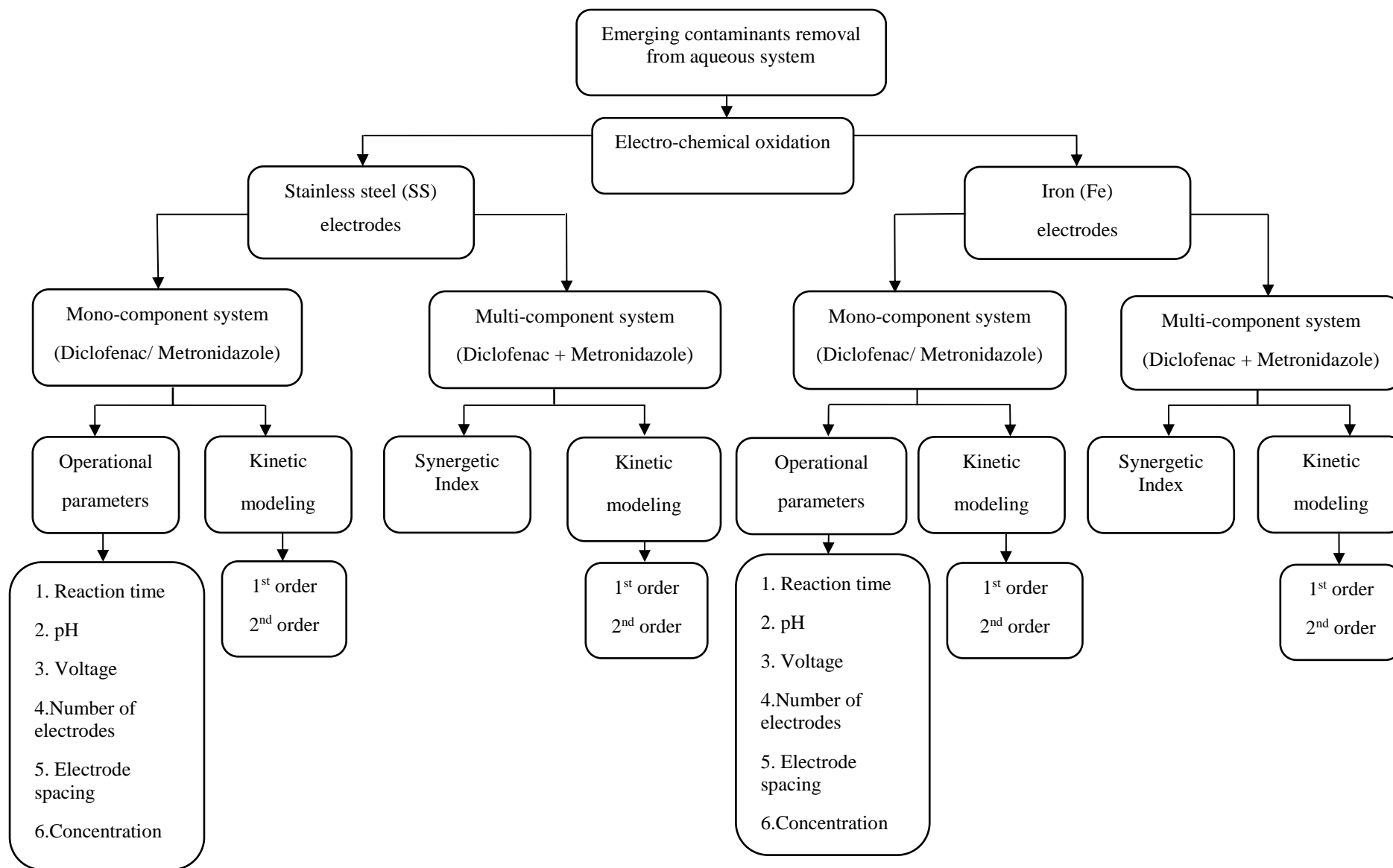
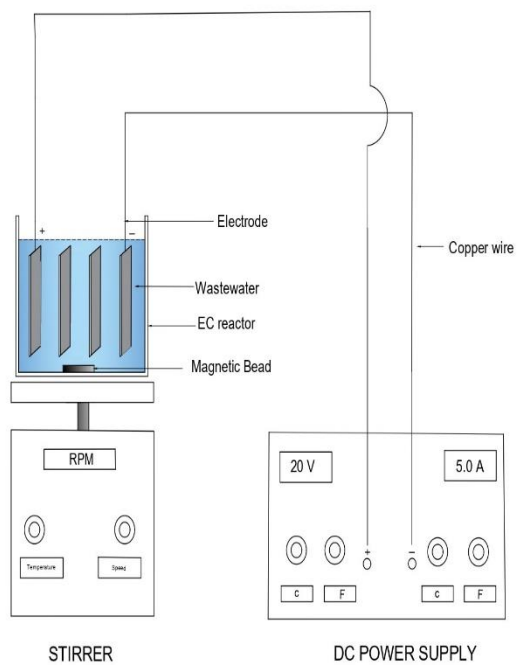


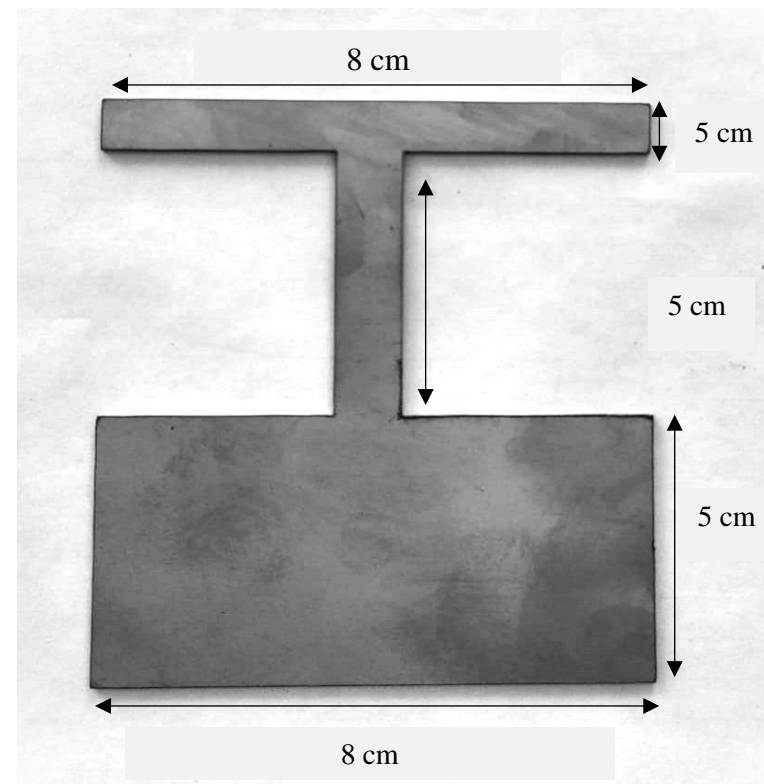
Fig. 1. Methodology for emerging contaminants removal from aqueous system using electrochemical oxidation



(a)



(b)



(c)

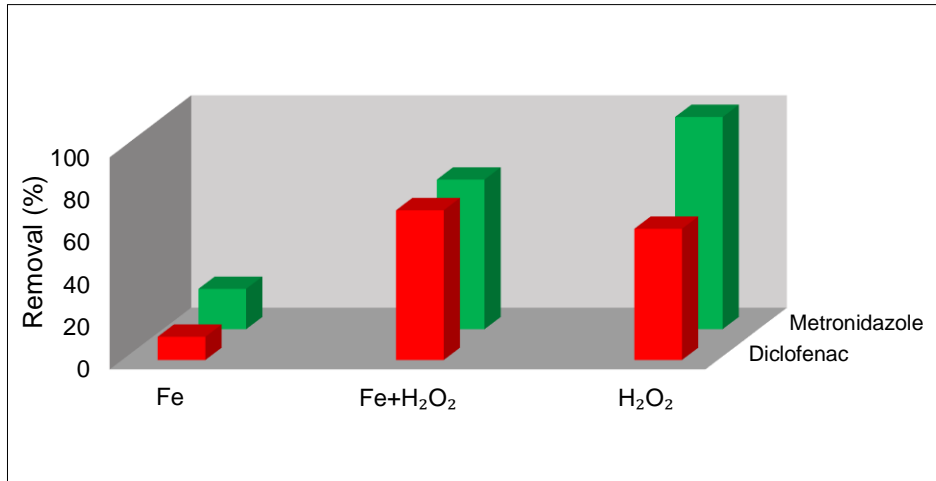
Fig. 2. Experimental set-up: (a) line diagram for electrochemical oxidation reactor set-up; (b) laboratory scale diagram for electrochemical oxidation reactor set-up and (c) electrodes configuration

## 9. Results and discussion

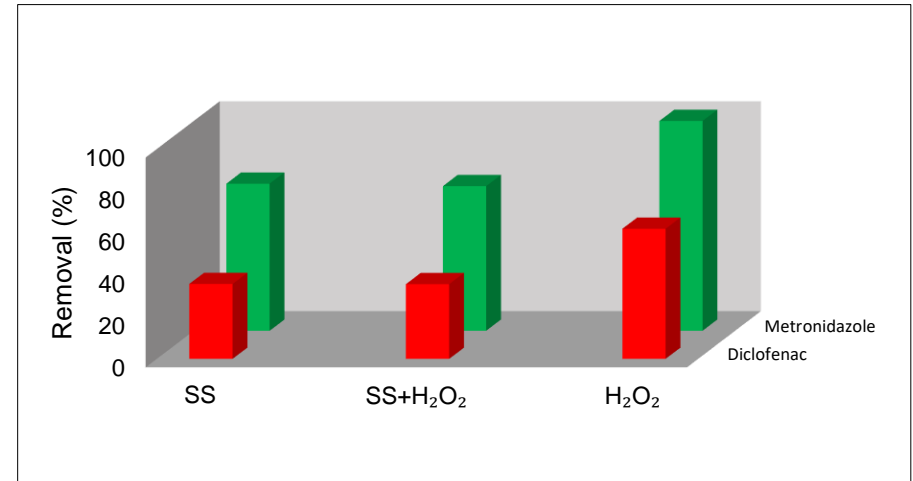
In this research work Diclofenac (DIC) and metronidazole (MET) are degraded using stainless steel (SS) and iron (Fe) electrodes with H<sub>2</sub>O<sub>2</sub>. to evaluate the performance of ECS techniques for degradation of DIC/MNZ from aqueous solution. In the meantime, investigate the operating factors like reaction time (0-120 min), concentration (5-50 mg/L), voltage (5-25 V), electrode materials (iron; Fe and Stainless steel: SS). Subsequently, kinetic study was performed to elucidate rate of PPCPs degradation using first-order and second-order kinetic models for both PPCP in both techniques. Furthermore, energy required for degradation of PPCPs from one cubic meter of effluent using Fe, SS electrodes in ECS The degradation is carried with treatment time of 120, with four electrodes and spacing of electrodes of 1 cm and maintained voltage was 15 V. From results, it is observed that optimum operating conditions were found to be 30 min, 15 V, 4 electrodes and 1 cm electrode. At optimized conditions, multi-component systems are carried out for of different combinations techniques and also rate constants were determined using first-order and second-order kinetic models. At optimized conditions.

Fe electrodes were found to be more efficient in oxidation of MET and DIC removal by Fe (11%) and (19.04%) and Fe+H<sub>2</sub>O<sub>2</sub> (70.7%) and (70.55%) from mono-component system, Similarly for SS (35.7%) and (70.1%) and SS+H<sub>2</sub>O<sub>2</sub> (35.6%) and (68.93%) from mono-component system. Subsequently for MET and DIC removal by Fe (14.7%) and (20.2%) and Fe+H<sub>2</sub>O<sub>2</sub> (48.4%) and (29.1%) from multi-component system and also for MET and DIC removal by Fe (19.5%) and (25.3%) and Fe+H<sub>2</sub>O<sub>2</sub> (49.8%) and (29.9%) from multi-component system. depicted in Figure 3.

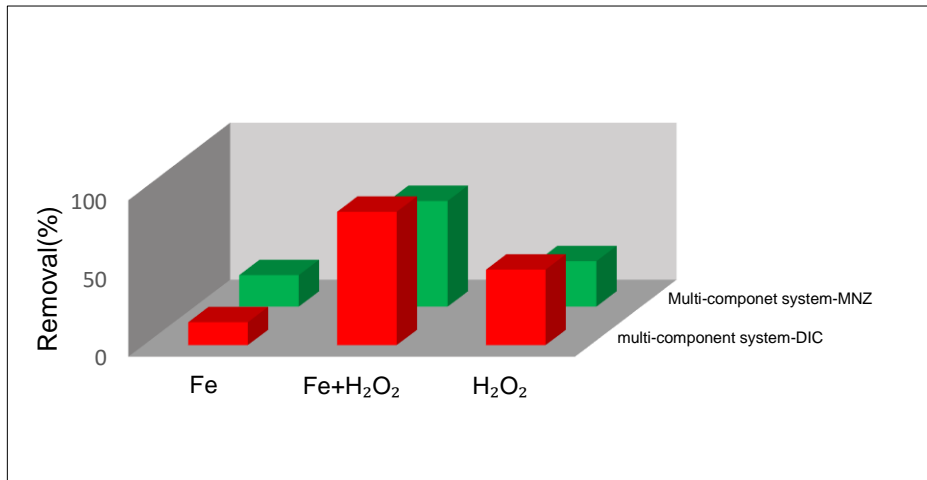
Subsequently, second order kinetics was comparatively more with first order kinetics for both multi-component and mono -component system for both MET and DIC. Meanwhile, K<sub>2</sub> for mono-component system Fe-DIC > (1.1x10<sup>-2</sup> min<sup>-1</sup>) >Fe+H<sub>2</sub>O<sub>2</sub>-DIC (1.5x10<sup>-3</sup> min<sup>-1</sup>) > H<sub>2</sub>O<sub>2</sub>-DIC (2.5x10<sup>-4</sup> min<sup>-1</sup>), Fe-MNZ > (2x10<sup>-5</sup> min<sup>-1</sup>) >Fe+H<sub>2</sub>O<sub>2</sub>-MNZ (1.0x10<sup>-3</sup> min<sup>-1</sup>) > H<sub>2</sub>O<sub>2</sub>-MNZ (9x10<sup>-5</sup> min<sup>-1</sup>), SS-DIC > (2x10<sup>-4</sup> min<sup>-1</sup>) >SS+H<sub>2</sub>O<sub>2</sub>-DIC (3.8x10<sup>-4</sup> min<sup>-1</sup>) > H<sub>2</sub>O<sub>2</sub>-DIC (5x10<sup>-5</sup> min<sup>-1</sup>), SS-MNZ > (1.5x10<sup>-3</sup> min<sup>-1</sup>) >SS+H<sub>2</sub>O<sub>2</sub>-MNZ (9x10<sup>-5</sup>min<sup>-1</sup>) > H<sub>2</sub>O<sub>2</sub>-MNZ (9x10<sup>-5</sup>min<sup>-1</sup>) Similarly, K<sub>2</sub> for multi-component system Fe-DIC > (2x10<sup>-5</sup> min<sup>-1</sup>) >Fe+H<sub>2</sub>O<sub>2</sub>-DIC (1.3x10<sup>-4</sup>x10<sup>-3</sup> min<sup>-1</sup>), Fe-MNZ > ( 2x10<sup>-5</sup>min<sup>-1</sup>) >Fe+H<sub>2</sub>O<sub>2</sub>-MNZ (1.9x10<sup>-4</sup> min<sup>-1</sup>), SS-DIC > (1.3x10<sup>-4</sup> min<sup>-1</sup>) >SS+H<sub>2</sub>O<sub>2</sub>-DIC (1x10<sup>-4</sup> min<sup>-1</sup>), SS-MNZ > (1x10<sup>-5</sup> min<sup>-1</sup>) >SS+H<sub>2</sub>O<sub>2</sub>-MNZ (3x10<sup>-5</sup>min<sup>-1</sup>) respectively.



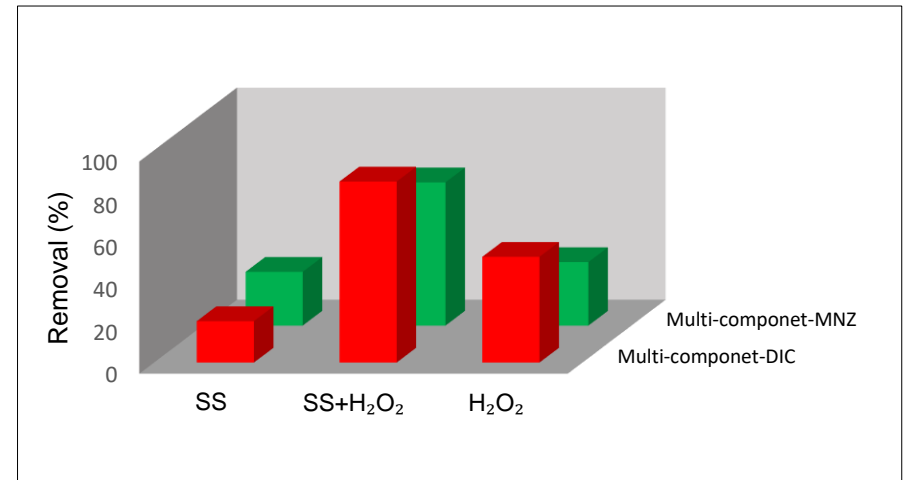
(a)



(b)



(c)



(d)

Fig.3. (a) MET and DIC removal by Fe and Fe+H<sub>2</sub>O<sub>2</sub> from mono-component system (b) MET and DIC removal by SS and SS+H<sub>2</sub>O<sub>2</sub> from mono-component system (C) MET and DIC removal by Fe and Fe+H<sub>2</sub>O<sub>2</sub> from multi-component system (D) MET and DIC removal by SS and SS+H<sub>2</sub>O<sub>2</sub> from multi-component system

Table 1: Kinetic constants for removal of MNZ and DIC using electrochemical oxidation.

System	Experimental conditions	MNZ removal				DIC removal			
		First order		Second order		First order		Second order	
		$K_1$ ( $\text{min}^{-1}$ )	$R^2$	$K_2$ ( $\text{min}^{-1}$ )	$R^2$	$K_1$ ( $\text{min}^{-1}$ )	$R^2$	$K_2$ ( $\text{min}^{-1}$ )	$R^2$
Mono-component	Fe	$1.9 \times 10^{-4}$	0.927	$2 \times 10^{-5}$	0.922	$1.1 \times 10^{-2}$	0.958	$8 \times 10^{-5}$	0.973
	Fe +H <sub>2</sub> O <sub>2</sub>	$1.07 \times 10^{-3}$	0.991	$1.0 \times 10^{-3}$	0.991	$1.5 \times 10^{-3}$	0.991	$3.7 \times 10^{-4}$	0.991
	SS	$2.9 \times 10^{-4}$	0.994	$1.5 \times 10^{-3}$	0.979	$4 \times 10^{-5}$	0.978	$2 \times 10^{-4}$	0.993
	SS +H <sub>2</sub> O <sub>2</sub>	$4 \times 10^{-4}$	0.978	$9 \times 10^{-5}$	0.997	$4 \times 10^{-5}$	0.982	$3.8 \times 10^{-4}$	0.976
	H <sub>2</sub> O <sub>2</sub>	$8 \times 10^{-5}$	0.991	$9 \times 10^{-5}$	0.997	$2.5 \times 10^{-4}$	0.992	$5 \times 10^{-5}$	0.991
Multicomponent	Fe	$1.8 \times 10^{-4}$	0.992	$2 \times 10^{-5}$	0.998	$2.2 \times 10^{-4}$	0.994	$2 \times 10^{-5}$	0.991
	Fe +H <sub>2</sub> O <sub>2</sub>	$9.3 \times 10^{-4}$	0.995	$1.9 \times 10^{-4}$	0.997	$9.4 \times 10^{-4}$	0.992	$1.3 \times 10^{-4}$	0.995
	SS	$8 \times 10^{-5}$	0.994	$1 \times 10^{-5}$	0.990	$1 \times 10^{-5}$	0.990	$1 \times 10^{-4}$	0.996
	SS +H <sub>2</sub> O <sub>2</sub>	$1.2 \times 10^{-4}$	0.986	$3 \times 10^{-5}$	0.989	$3.9 \times 10^{-4}$	0.923	$5 \times 10^{-5}$	0.974



## 10 Conclusions

In this research, degradation of dyes DIC and MNZ was examined using techniques, electrochemical oxidation technique. The influence of operational parameters i.e., treatment time, voltage, concentration is determined. From results, it was observed that ECS Fe electrodes were found to be more efficient in oxidation of MET and DIC removal by Fe (11%) and (19.04%) and Fe+H<sub>2</sub>O<sub>2</sub> (70.7%) and (70.55%) from mono-component system, Similarly for SS (35.7%) and (70.1%) and SS+H<sub>2</sub>O<sub>2</sub> (35.6%) and (68.93%) from mono-component system. Subsequently for MET and DIC removal by Fe (14.7%) and (20.2%) and Fe+H<sub>2</sub>O<sub>2</sub> (48.4%) and (29.1%) from multi-component system and also for MET and DIC removal by Fe (19.5%) and (25.3%) and Fe+H<sub>2</sub>O<sub>2</sub> (49.8%) and (29.9%) from multi-component system.

## 11 Scope of the work

- The electro-chemical degradation of SS and Fe can be compared with other electrodes such as aluminium, titanium and copper, platinum, boron doped diamond electrodes.
- Locally available materials viz. agricultural and industrial waste can be adopted for synthesizing activated carbon and coated with zinc or iron oxide nanoparticles can be used as catalyst for the electro-chemical oxidation technique.
- The degradation of DIC and MNZ using electro-chemical treatment technique can be analysed using liquid chromatography mass spectroscopy (LCMS) technique.
- The performance evaluation of electro-chemical technique for removal of PPCPs from real-time wastewater can be investigated.

## 12 Innovation of the work

- Most of studies in the past focused on removal of single PPCP from aqueous solutions. Meanwhile, in real-time situation, multiple pollutants are present in wastewater. Therefore, in this study simultaneous removal of multiple PPCPs (ACT+CIP) multi-component system.
- Most of the researches are carried out on the removal of PPCPs in mono-component system using electrochemical oxidation technique using single electrode material, however, in this study performance evaluation of two different low-cost electrode materials i.e., Fe and SS are compared for simultaneous degradation of PPCPs from multicomponent system in the presences of H<sub>2</sub>O<sub>2</sub> as oxidant.

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