DEGRADATION OF PHARMACEUTICAL AND PERSONAL CARE PRODUCTS USING ELECTRO-CHEMICAL AND PHOTO-CHEMICAL TECHNIQUE

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Introduction:

Pharmaceuticals are the most important life-saving ones and play a key role in the well-being of human health. However, the unsustainable manufacturing processes along with indiscriminate use have given rise to antibiotic pollution in various environmental matrices. This has led to the emergence of growing global threat of Anti-Microbial Resistance (AMR) genes. Widespread antibiotic pollution violates people’s right to a healthy environment, including their access to clean water. It further threatens their fundamental right to life through long-term exposure to antibiotic residues that are released into the environment. Therefore, the international bodies, including WHO and UNEP have recognized this threat of antibiotic pollution and called for collective efforts to minimize the risks associated with AMR. There are multiple sources of antibiotic release into the environment. Effluents from antibiotic manufacturing, hospitals and municipalities, waste from large-scale animal farms and its use in aquaculture are the major sources of antibiotic pollution in the environment. Antibiotic residues in the environment can have negative effects on biota and human health by consumption of contaminated food and water and by contributing to the development and/or dissemination of AMR in different compartments of the environment. Extremely high pharmaceutical concentrations (in the order of mg/L), have been detected in industrial effluents and recipient streams in different parts of the world including India. India is one of the world’s largest producers and consumers of antibiotics that are widely used for disease treatment in humans and livestock. India is known as the ‘Pharmacy of the World’. However, the lack of strict regulatory and legal actions has accelerated antibiotic pollution in India, damaging the land, water, food, and health. Acetaminophen (ACT) commonly known as paracetamol is the most widely used analgesic and antipyretic pharmaceutical prescribed around the world. The consumption of ACT pharmaceutical has increased greatly in recent times, especially during the Covid-19 pandemic. ACT and its metabolites have been found in surface waters, wastewater and groundwater. On the other hand, ciprofloxacin (CIP), a member of the fluoroquinolones group, has widely been used as an antibacterial agent in recent years. A high concentration of 50 mg/L CIP has been detected in the effluents of pharmaceutical industry. Fluoroquinolones may also cause physiologically teratogenic effects on plants and algae; they are also genotoxic and carcinogenic to organisms. Unfortunately, since these types of antibiotics are less biodegradable, conventional biological wastewater treatment processes are not able to remove these compounds from wastewater effectively. Several studies have reported removal of ACT and CIP from wastewater using conventional technologies such as coagulation, precipitation, filtration, adsorption, ion exchange, and biological techniques. However, these technologies are ineffective in removal of pharmaceutical compounds from wastewater, having limitations such as high operational and maintenance costs, membrane fouling, adsorbent management, longer treatment time and less efficiency. on the other hand, electro-chemical and photo-chemical techniques are highly effective in degrading organic pollutants involving pharmaceutical and personal care products from wastewater, can be operated at neutral pH, is versatile, and environmentally friendly, and requires less land area for setup. As a result, these treatment techniques can be used as an effective and efficient technology for degrading PPCPs including ACT and CIP from wastewater.

Objectives:

The main objective of the project is to remove pharmaceutical and personal care products from wastewater using electrochemical and photochemical techniques.

Scope of the work includes

1. Preparation of electrodes for degradation of PPCPs i.e. ACT and CIP using electro-chemical and photo-chemical techniques.
2. Study the effect of operational parameters (treatment time, pH, voltage, pollutant concentration, number of electrodes, spacing between electrodes) for the removal of select PPCPs using aluminium and stainless-steel electrodes.
3. Study the effect of operational parameters (treatment time, pH, light intensity and catalyst dose) for degradation of select PPCPs by using visible light photo-chemical technique.
4. To determine the rate constant for removal of PPCPs for both electro-chemical and photo-chemical techniques using first-order and second-order kinetic models.

Methodology:

The methodology adopted for carrying out the research is shown in Figure.1 Meanwhile, the experimental setup involving electro-chemical and photo-chemical reactors are shown in Fig. 2 (a) and (b), respectively. ACT ($C_8H_9NO_2$) and CIP ($C_{17}H_{18}FN_3O_3$) compounds were selected as target PPCPs. Meanwhile, the effect of operational parameters viz. treatment time (0-300 mins), voltage (5-25V), electrodes numbers (2-6), type of electrode (Aluminium/stainless steel), electrode spacing (1-2 cm), pH (3-11), and catalyst dose ($FeSO_4$: 0.067-0.67 g/L and H_2O_2: 0.067-0.67mL/L) and light intensity (10-20W) on removal of ACT and CIP compounds will be investigated for both single and multi-component. Subsequently, the rate of removal of select PPCPs will be determined using first-order and second-order kinetic models for both electro-chemical and photo-chemical treatments.

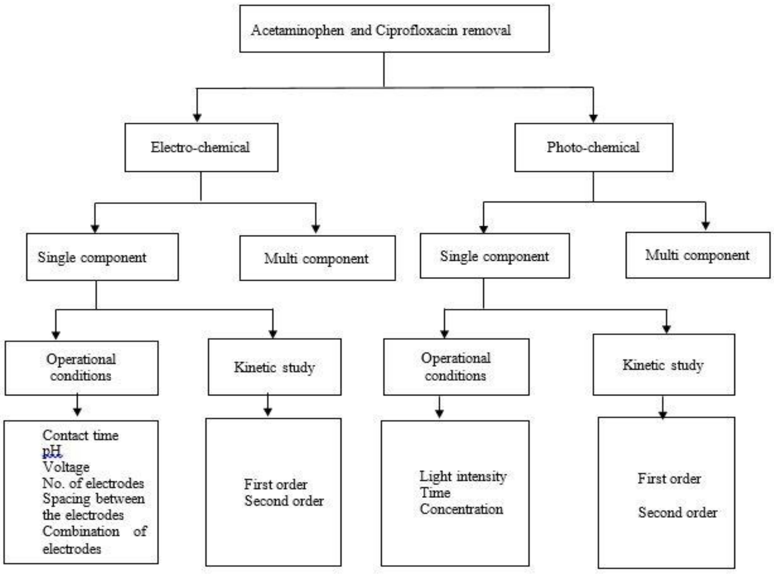

Figure 1: Overview of research methodology for degradation of PPCPs using electro-chemical and photo-chemical techniques.

Figure 2: Experimental set-up: (a) electro-chemical treatment and (b) photo-chemical treatment.

Scope for future work:

1. The efficiency of Al and SS electrodes can be compared with other electrodes such as iron, titanium, and copper electrodes for electro-chemical degradation of PPCPs.
2. The performance of visible light can be compared with other lights such as UV light, xenon lamps, and solar lamps for photo-chemical degradation of PPCPs.
3. The low-cost locally available adsorbents synthesized using agricultural waste or industrial waste can be added to the electro-chemical and photo-chemical reactors and examine the efficiency.
4. Degradation pathways of ACT and CIP using both the treatment techniques can be analyzed using Liquid Chromatography Mass Spectroscopy (LCMS) technique.

5. The performance evaluation of electro-chemical and photo-chemical techniques for removal of PPCPs from real-time wastewater can be investigated.

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