Electrocoagulation process in wastewater treatment

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Abstract. Nutrients are an important component in the composition of urban wastewater. The most common representatives are nitrogen and phosphorus, which are required to be removed in wastewater treatment plants. High concentrations of nutrients discharged into the water bodies can lead to oxygen depletion and eutrophication, which has a negative impact on the ecosystem. The level of nutrient reduction must comply with the national or local legal requirements. Nutrient removal can be achieved by the electrocoagulation process, a modern electrochemical method, within the tertiary level of treatment.

Keywords: wastewater, electrocoagulation process, nutrients, sustainable development

1. Introduction

Wastewater refers to any water that has been contaminated by human activities and is no longer suitable for its original intended use. It is often generated as a byproduct of various processes, including domestic, industrial, commercial, and agricultural activities. With the rapid growth in urbanization and industrialization, environmental contamination has worsened due to the incessant discharge of toxic substances into water bodies, which has become a worldwide problem [1]. Various substances make up the composition of wastewater:

- various particles (inert, dissolved, suspended, settleable),
- biodegradable matter (organic matter),
- non-biodegradable substances (salts, acids, bases, xenobiotic substances),
- nutrients (nitrogen, phosphorus, potassium, etc.),
- toxic substances (metals, pesticides, carcinogenic materials),
- radioactive substances and
- pathogenic organisms.

Water pollution and wasteful use of freshwater threaten development projects and make water treatment essential to produce safe drinking water [2]. Wastewater treatment processes aim to remove or reduce contaminants, making the water safe for discharge into natural bodies of water or, in some cases, for reuse in various applications. Wastewater treatment techniques cover a wide range of processes: biological, physico-chemical, and electrochemical ones [3].

2. Problem background

Electrocoagulation (EC) is one of the electrochemical procedures for wastewater treatment. Electrocoagulation technology is an electrochemical process based on the application of an electric field in an electrolysis reactor flowing through a stream of contaminated solution (usually wastewater) for the treatment and flocculation of contaminants without the addition of chemical coagulants [3]. During the electrocoagulation process, wastewater is separated into two phases, a clear, liquid phase, and a precipitated, solid phase. Of the key factors that influence electrocoagulation, the factors that are important for the optimization of the electrocoagulation process are particularly different, especially the factors that represent the key characteristics of the water to which the electrocoagulation process is applied. The following are important for the electrocoagulation process: current density, the temperature at which [1]the process takes place, type of material from which the electrodes are made [4].

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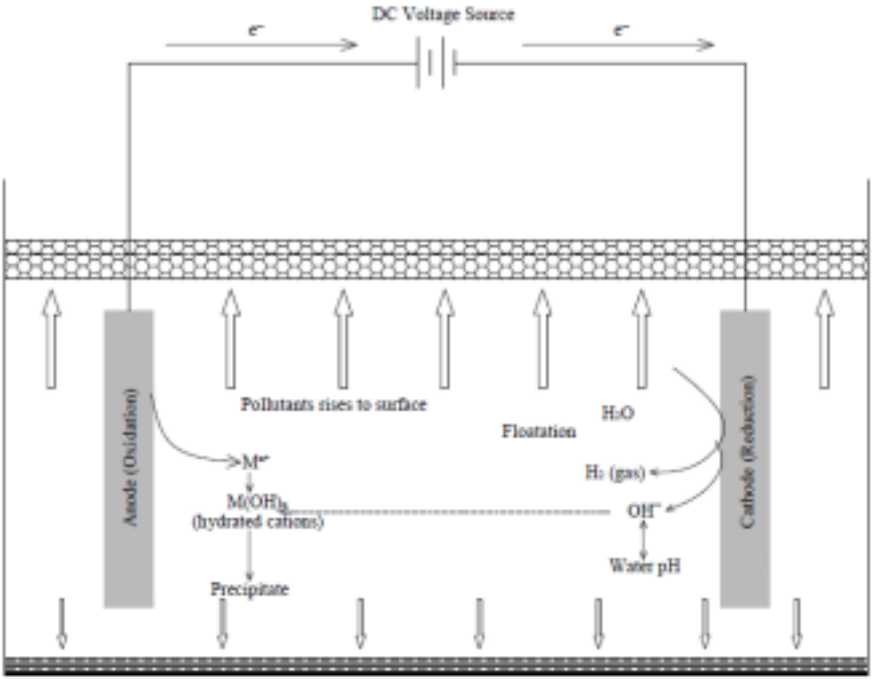

Figure 1. Diagram of a bench-scale EC reactor; *Source: Bharath, M., Krishna, B.M., Manoj Kumor B, 2018, A Review of Electrocoagulation Process for Wastewater Treatment, International Journal of ChemTech Research, Vol.11, No.03, pp. 289-302., page 4*

One of the disadvantages of the Electrocoagulation Process is that sacrificial anodes are dissolved into the solution due to oxidation and need regular replacement, and it requires high conductivity of the wastewater suspension, which can result in the solubilization of viscous hydroxide in some cases, might be limited by the availability and cost of electricity in certain areas, and efficiency may decrease due to the formation of an impervious oxide film on the cathode [5].

3. Methodology

The electrocoagulation process, within this research's framework, primarily refers to the removal of phosphorus from municipal wastewater. However, as this process in the area of wastewater treatment is still insufficiently researched, and due to the small amount of data in this area, tests were performed on different samples.

This choice, for several experiments and several types of water, was made to obtain a larger number of results for the examined parameters, to perform a comparison of the results and a comparison of the efficiency of electrocoagulation. Tap water and a sample of real municipal wastewater were chosen for the samples. Each electrocoagulation experiment lasted one hour (1h). No parameters were changed during the experiment. The process was tested at approximately maximum values of voltage and electric current. The electrocoagulation process was tested on the sample:

1. tap water with aluminum electrodes,
2. municipal wastewater with aluminum electrodes,
3. tap water with iron electrodes, i
4. municipal wastewater with iron electrodes.

The experiment examined the removal of nutrients from municipal wastewater by the processes of electrocoagulation and chemical coagulation. Tests were done for nitrogen and phosphorus, as the most abundant nutrients. The nitrogen removal efficiency is approximately 1%, so it was not relevant to further consider nitrogen compounds in this experiment. We will introduce the following notations to help you follow the process change, and note the differences between the electrocoagulation and chemical coagulation processes for comparison. The tags are:

• Experiment 1 – Electrocoagulation process on a municipal wastewater sample using aluminum electrodes • Experiment 2 - Process of chemical coagulation on a municipal wastewater sample using a coagulant with aluminum
• Experiment 3 - Electrocoagulation process on a municipal wastewater sample using iron electrodes • Experiment 4 - Process of chemical coagulation on a sample of municipal wastewater using a coagulant with iron

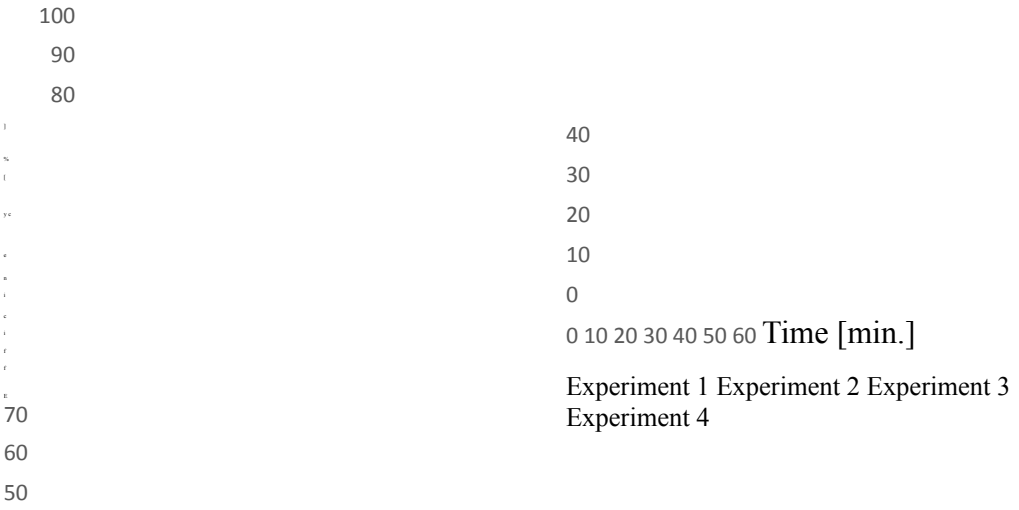

Figure 1. Graphic representation of the efficiency of phosphorus removal during the duration of the experiment

Based on Figure 1, the following can be concluded:

- Experiment 1 – shows significant effectiveness during the beginning, and reaches its maximum at the 30th minute, where it gradually begins to decline,
- Experiment 1– shows worse efficiency after the process is completed
- Experiment 2 - showed lower efficiency, which is not of great importance for application, other experiments have achieved significant efficiency, which goes above 80%,
- Experiment 3 – achieves solid efficiency, where there is a significant increase at the beginning, • Experiment 4 - achieves the best efficiency, at the end of the process.

4. Conclusion and further work

This experiment aims to remove phosphorus and nitrogen, the main representatives of nutrients from municipal wastewater. A laboratory experiment, which examined the process of electrocoagulation, showed that phosphorus is effectively removed, while there was no efficiency in nitrogen removal. The results show that the phosphorus values meet the legal requirements for the recipient. This has shown that the electrocoagulation process can be used to remove phosphorus in wastewater treatment plants, as part of tertiary treatment.

Both iron and aluminum electrodes can be used during the process. Aluminum electrodes achieve greater efficiency in a shorter time, but their application is more expensive than iron electrodes. The process itself requires simple equipment and is very easy to perform, which is an important advantage if it were to be applied in plants. Sludge production is a consequent factor of the electrocoagulation process, and it significantly affects the dimensions of the facility and the dimensioning of the sludge pipeline, which schematically represents the sludge line within the wastewater treatment plant. The quantities of sludge production obtained by laboratory tests represent very large values.

As a result of the overall research, a high percentage of the successful application of the electrocoagulation process method in the removal of phosphorus from municipal wastewater has been established. Based on the calculation, it is recommended that electrocoagulation be applied as a higher level of purification, i.e. advanced treatment, where after previous treatments, the quality of the effluent must be under legal regulations. Through the analysis of the obtained results, a significant contribution was made to research for environmental protection and

wastewater treatment, where the electrocoagulation process can be used. The application of the electrocoagulation process, which is only in its initial phase, is represented in our areas.

In future work, there are plans to continue further investigations into the removal of nutrients, specifically nitrogen and phosphorus, using the electrocoagulation process. The previous experiment did not achieve the desired efficiency in nitrogen removal, and it is necessary to explore how to attain effective nitrogen removal within the electrocoagulation process and whether this is achievable. Regarding the study on phosphorus removal, it is essential to pay attention to the quantities of generated sludge as this is a critical factor in designing wastewater treatment plants.

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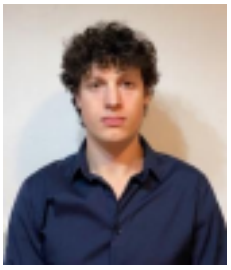

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