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INCREASING THE EFFICIENCY FOR REMOVAL OF EMERGING CONTAMINANTS FROM WATER

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Abstract - *The electrocoagulation process has garnered significant attention as a method to treat wastewater. The technology involves the oxidation of anode, which produces coagulants. This approach serves as a viable alternative to chemical coagulants for pollutant removal and provides an advantage for communities with better access to electricity than such chemicals. In this study, we conducted several electrocoagulation tests using aluminum electrodes to examine various operating parameters, including electric current, initial pollutant concentration, initial water pH, and electrode arrangement. We tested the removal of iron, fluoride and arsenic (V) in single contaminant experiments as well as binary mixtures and ternary mixtures. We determined the evolution of concentration throughout each trial along with total suspended solids and particle size distribution at their conclusion. We found that increasing electrical current improved the removal efficiency for all contaminants. For iron contamination specifically, higher pH values favored its elimination while fluoride and arsenic (V) exhibited opposite trends. Furthermore, during our experience with ternary mixture testing it appeared that the presence of other contaminants facilitated overall elimination results across all pollutants tested.*

Key Words: Electrocoagulation (EC), waterwater treatment, electrolysis, iron, fluoride, arsenic (V)

1.EMERGING CONTAMINANTS

Emerging contaminants in water refer to pollutants that have recently been identified or have become a concern due to their potential impact on human health and the environment. These contaminants can come from various sources, including industrial processes, agricultural runoff, pharmaceuticals, personal care products, and urban runoff. Examples of emerging contaminants include pharmaceuticals, personal care products, pesticides, hormones, perfluoroalkyl substances (PFAS), and microplastics. The presence of emerging contaminants in water bodies poses challenges for water treatment facilities and regulatory agencies. Many of these contaminants are not effectively removed by traditional water treatment methods, leading to potential exposure through drinking water and ecological harm to aquatic ecosystems. Efforts to address emerging contaminants typically involve a combination of monitoring, research, regulation, and technological innovation. Strategies for managing emerging contaminants may include improved wastewater treatment processes, enhanced monitoring programs, regulatory actions to limit the use of certain chemicals, and public education campaigns to promote responsible disposal of pharmaceuticals and personal care products. Addressing emerging contaminants in water requires a multidisciplinary approach involving collaboration between scientists, policymakers, industry stakeholders, and the public to protect human health and the environment.

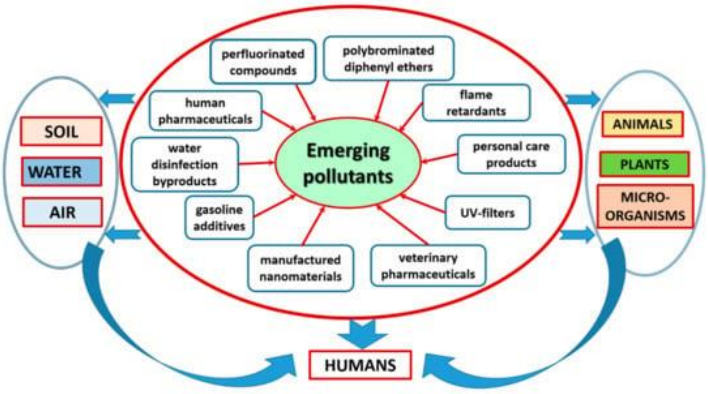

Figure-01: Emerging Contaminants

1.1. CLASSIFICATION OF EMERGING CONTAMINANTS

Emerging contaminants can be classified based on various criteria, including their source, chemical structure, persistence, and potential impact on human health and the environment:

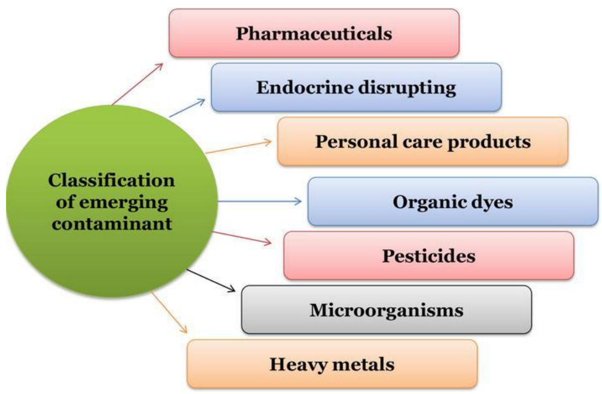

Figure-02: Classification of Emerging Contaminants.

1.1.1.Source-based classification

Industrial chemicals: These include compounds used in various industrial processes, such as flame retardants, plasticizers, and industrial solvents.

Agricultural contaminants: Pesticides, herbicides, and fertilizers can leach into water bodies from agricultural fields, contaminating surface and groundwater.

Pharmaceuticals and personal care products (PPCPs): Prescription and over-the-counter drugs, as well as ingredients in personal care products like cosmetics and fragrances, can enter waterways through wastewater effluent or improper disposal.

Urban runoff: Chemicals from roadways, parking lots, and urban areas, including heavy metals, hydrocarbons, and road salts, can be washed into water bodies during rain events.

Landfill leachate: Contaminants from landfills, including organic compounds, heavy metals, and landfill additives, can leach into groundwater and surface water.

1.1.2.Chemical structure-based classification

Organic contaminants: These include compounds containing carbon, such as pharmaceuticals, pesticides, industrial chemicals, and PPCPs.

Inorganic contaminants: Compounds without carbon, such as heavy metals (e.g., lead, mercury, arsenic) and metalloids, can also be emerging contaminants in water.

1.1.3.Persistence-based classification

Persistent organic pollutants (POPs): These are organic compounds that resist degradation in the environment and can persist for long periods. Examples include certain pesticides, industrial chemicals, and some PPCPs.

Non-persistent contaminants: Some emerging contaminants, such as certain pharmaceuticals and personal care products, may degrade relatively quickly in the environment but can still pose risks due to their widespread use and continuous input into water bodies.

1.2.SOURCES AND PATHWAYS OF EMERGING CONTAMINANTS INTO WATER BODIES

Emerging contaminants find their way into water bodies through multiple sources and pathways. Wastewater treatment plants play a significant role, as they receive wastewater from various sources including households, industries, and businesses. While treatment processes remove many contaminants, some persist and are discharged into water bodies. Agricultural runoff contributes pesticides and fertilizers washed from fields by rain or irrigation, while urban runoff carries pollutants like oil and heavy metals from roads and industrial areas into storm drains and water bodies. Landfills produce leachate containing chemicals that can seep into groundwater or surface water. Septic systems and sewage overflows release raw sewage, including pathogens and nutrients, into water bodies if not properly managed. Atmospheric deposition transports contaminants from industrial emissions and agricultural activities to water surfaces. Direct dumping of waste materials into water bodies and natural sources like geological processes also introduce contaminants. Managing these sources and pathways is essential to safeguard water quality and protect ecosystems and public health.

2.IMPORTANCE OF REMOVING EMERGING CONTAMINANTS FROM WATER

Removing emerging contaminants from water is crucial for several reasons:

Protecting Human Health: Many emerging contaminants have been linked to adverse health effects in humans, including developmental disorders, hormonal disruptions, reproductive issues, and increased cancer risk. Removing these contaminants from drinking water helps safeguard public health and reduces the risk of exposure to harmful substances.

Preserving Ecosystem Health: Emerging contaminants can harm aquatic ecosystems by disrupting the balance of natural processes and endangering aquatic life. Some contaminants can bioaccumulate in the food chain, leading to toxicity in higher trophic levels. Removing these contaminants helps maintain the health and biodiversity of aquatic ecosystems, ensuring the survival of fish, plants, and other aquatic organisms.

Ensuring Safe Drinking Water: Access to clean and safe drinking water is essential for human well-being. Removing emerging contaminants from drinking water sources ensures that water meets regulatory standards and is safe for consumption. This is particularly important in regions where surface water or groundwater serves as the primary source of drinking water.

Protecting Agricultural and Irrigation Water: Emerging contaminants can also affect agricultural water sources, potentially contaminating crops and soil through irrigation. Removing these contaminants from water used for agriculture helps protect food safety and agricultural productivity, ensuring the quality of crops and minimizing health risks associated with consumption.

2.1.NEED FOR EFFECTIVE WATER TREATMENT TO SAFEGUARD PUBLIC HEALTH AND THE ENVIRONMENT

Effective water treatment is indispensable for safeguarding public health and the environment. By eliminating harmful pathogens like bacteria and viruses, water treatment prevents the spread of waterborne diseases, ensuring that communities have access to safe drinking water. Additionally, it plays a crucial role in removing chemical contaminants, including heavy metals, pesticides, and emerging pollutants such as pharmaceuticals and personal care products, which can pose significant health risks if left untreated. Moreover, water treatment processes help mitigate the impact of pollution on aquatic ecosystems by reducing the concentration of toxins and pollutants in water bodies, thereby preserving biodiversity and ecosystem health. Furthermore, treated wastewater discharged from treatment plants minimizes environmental pollution, protecting rivers, lakes, and oceans from contamination. Compliance with stringent regulatory standards ensures that water treatment facilities meet quality and safety requirements, maintaining public confidence in the reliability of water supplies and preventing legal and financial penalties for non-compliance. Overall, effective water treatment is essential for ensuring access to clean and safe water, protecting public health, and promoting environmental sustainability.

2.2.ECONOMIC AND SOCIAL IMPLICATIONS OF CONTAMINATED WATER SUPPLIES

Contaminated water supplies present significant economic and social challenges for communities worldwide. The health implications of waterborne diseases strain healthcare systems and impose financial burdens on individuals and governments through medical expenses and lost productivity. Moreover, contaminated water jeopardizes livelihoods, particularly in rural areas reliant on agriculture and tourism, leading to economic losses and hindering social development. Environmental degradation stemming from water pollution exacerbates these challenges, threatening ecosystems, biodiversity, and natural resources essential for human well-being. Furthermore, contaminated water disproportionately affects vulnerable populations, perpetuating social inequities and marginalization. The financial costs of treating contaminated water and upgrading infrastructure further strain budgets and may result in increased water bills for consumers. Additionally, persistent water contamination can disrupt social cohesion, contribute to population displacement, and exacerbate conflicts over scarce water resources. Addressing the economic and social ramifications of contaminated water supplies necessitates comprehensive strategies that prioritize investments in water infrastructure, sustainable management practices, and equitable access to clean and safe water for all members of society.

3.INCREASING CONCERN OVER THE PRESENCE OF EMERGING CONTAMINANTS IN WATER SOURCES

The presence of emerging contaminants in water sources has become a matter of increasing concern globally. These contaminants, ranging from pharmaceuticals and personal care products to industrial chemicals and pesticides, have garnered attention due to their potential adverse effects on human health and the environment. Unlike traditional pollutants, emerging contaminants often persist in the environment and are not effectively removed by conventional water treatment methods, posing challenges for water management and public health protection. The proliferation of these contaminants in water bodies is attributed to factors such as their widespread use, improper disposal practices, and limitations in existing wastewater treatment infrastructure. Concerns arise regarding the chronic exposure to low levels of these contaminants through drinking water and the ecological consequences for aquatic ecosystems and wildlife. Addressing this issue requires concerted efforts from policymakers, regulatory agencies, water utilities, and the public to enhance monitoring, research, and mitigation measures aimed at safeguarding water quality and ensuring the sustainability of water resources. Moreover, raising public awareness and promoting responsible consumption and disposal practices are crucial steps in minimizing the presence of emerging contaminants in water sources and protecting human health and the environment.

4.INCOMPLETE REMOVAL EFFICIENCY FOR CERTAIN CONTAMINANTS

Incomplete removal efficiency for certain contaminants poses a significant challenge in water treatment processes. While traditional methods effectively eliminate many pollutants like bacteria and larger particles, emerging contaminants such as pharmaceuticals, personal care products, and industrial chemicals often evade complete removal. Their persistence in water post-treatment raises concerns regarding potential health risks and environmental impacts. This incomplete removal can be attributed to factors such as complex chemical structures, low concentrations, and the limitations of existing treatment technologies. Advanced treatment processes like advanced oxidation and membrane filtration are sometimes required but can be costly and inaccessible for smaller treatment facilities. Moreover, the constant introduction of new chemicals complicates the scenario, demanding continuous adaptation of treatment strategies. Regulatory efforts are underway to address emerging contaminants, yet gaps in understanding and monitoring persist. To tackle this issue effectively, collaboration among stakeholders is crucial, alongside investment in research, technology development, and public education to promote responsible chemical use and disposal practices. By addressing incomplete removal challenges, we can enhance water treatment processes and ensure the safety and sustainability of water resources.

5.PROCEDURE FOR WATER TREATMENT

5.1.Water Sample

Two samples of water were taken, one being 3 liters of deionized water and the other filtered water. Deionized water has its mineral ions removed through deionization, often used in laboratories, medical settings, and industrial applications. Filtered water goes through a filtration system to remove impurities like sediment, chlorine, bacteria, and other contaminants. Combining deionization and filtration ensures exceptionally pure water, suitable for applications where even trace contaminants could cause issues, such as scientific experiments, medical procedures, or sensitive industrial processes.

5.2.EC Reactor

An EC Reactor is a tool utilized for gauging or managing the electrical conductivity of a solution or substance. Electrical conductivity, an inherent characteristic of materials, reflects their capacity to conduct an electric current. In the context of reactor operations, monitoring and regulating electrical conductivity are critical components in numerous industrial processes, particularly those that require solutions or liquids.

Figure-03: EC Reactor.

6.RESULT AND ANALYSIS

In this research work, we have chooses three main parameter for the removal of the emerging contaminants from water by using the electrocoagulation technique. These three parameter is given below:

1. Iron
2. Fluoride
3. Arsenic

6.1.Influence of Electric Current on Iron

In order to ascertain the impact of the administered electrical current (I) on iron elimination during electrocoagulation (EC), all trials were performed with a starting concentration of 25 mg·L^{-1} and pH level at 6. Three distinct electric currents, namely 40 mA, 100 mA, and 190 mA, were tested while maintaining a total anodic surface area of 0.0076 m^2.

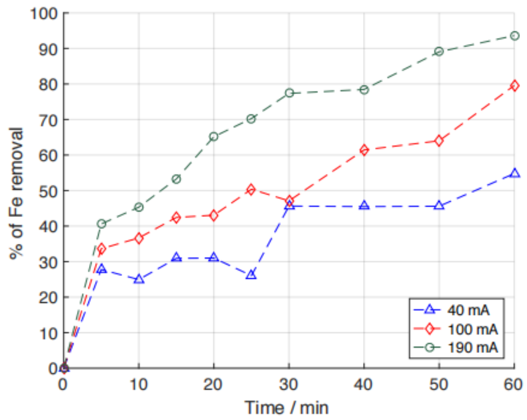

Figure-04: Effect of electric current on the removal of iron.

6.2.Influence of the Electric Current on Fluoride

The impact of the applied electric current on the elimination of fluoride through EC treatment was evaluated. The experiments were performed under uniform conditions, with an initial fluoride concentration of 15 mg·L-1 and pH 6. Three distinct currents (40 mA, 100 mA, 190 mA) were examined to determine their efficacy. The total anodic area utilized in these trials was measured at 0.0076 m2.

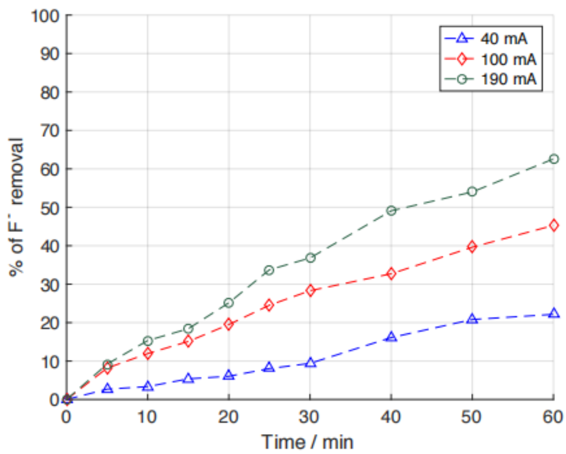

Figure-05: Electric current can remove fluoride. Starting conditions: 15 mg/L fluoride concentration and pH 6.

6.3.Influence of electric current on Arsenic

To ascertain the impact of the administered electrical current on arsenic (V) elimination through EC experiments, three distinct electric currents were utilized - 40 mA, 100 mA and 190 mA. The tests were conducted under a pH level of 6 with an initial concentration of arsenic (V) at 3 mg·L-1. The total anodic area was measured to be approximately 0.0076 m2.

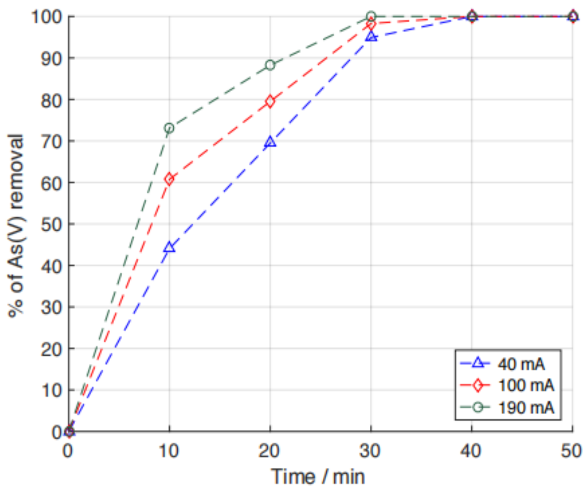

Figure-06:Effect of electric current on the removal of arsenic (V). Operating conditions – initial concentration of arsenic (V): 3 mg·L-1 , initial water pH: 6.

In the first 10 minutes the arsenic removal was proportional to the electric current. However, that difference faded over time and every experiment achieved total arsenic removal at around the same time.

7.CONCLUSION

The rate of contaminant removal is influenced by the electric current applied, with higher currents leading to more flocs produced. For arsenic (V) removal, all experiments reached complete removal simultaneously. Initial contaminant concentration did not affect iron and arsenic (V) removal, but negatively impacted fluoride removal. Different initial water pH levels affected contaminant removal differently. Iron removal increased with higher pH, but in an alkaline medium, iron precipitated before the removal process. For fluoride and arsenic (V), higher initial pH interfered with removal due to increased OH- concentration. The number and arrangement of electrodes did not significantly impact iron and fluoride removal but led to quicker arsenic (V) removal. Despite using the same electric current, the anodic area in tests with four electrodes affected the removal process. Testing the size of flocs formed with different arrangements could provide insight into observed differences.

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