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Eco Smart Plasma Systems For The Treatment Of Industrial Effluent

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Abstract: Industrial effluents, often containing organic pollutants, toxic chemicals, and heavy metals, pose a major threat to the environment and public health. When dealing with complex contaminants, traditional wastewater treatment methods can be costly, energy-intensive, and ineffective. For the treatment of industrial wastewater, this initiative offers a novel solution: Eco Smart Plasma Treatment, an environmentally friendly, energy-efficient, and very successful method. Using non-thermal plasma technology, the system generates reactive species that have the potential to break down a range of contaminants, including chemical residues and persistent organic molecules. Intelligent sensors and automated control systems enable the treatment unit to continuously monitor effluent quality, alter operating parameters in real time, and ensure optimal performance with minimal human intervention.

I.INTRODUCTION:

Industrial waste water pollution is a significant environmental challenge, particularly in sectors like paint manufacturing or cooking oil processing, where effluents contain high levels of organic contaminants, heavy metals, oils, and chemical additives. Traditional wastewater treatment methods, such as chemical coagulation, biological treatment, and membrane filtration, often fail to completely remove these pollutants or require expensive operational costs.

Plasma treatment involves the application of high-voltage electric discharge to water, generating reactive species such as hydroxyl radicals (•OH), ozone (O_3), and UV radiation. These highly reactive species break down complex organic molecules, oxidize heavy metals, and eliminate microbial contaminants, making plasma technology an effective Advanced Oxidation Process (AOP). The paint industry effluent contains synthetic dyes, pigments, resins, and heavy metals like lead (Pb) and chromium (Cr), which are toxic and non -bio degradable. Similarly, sunflower oil industry wastewater is rich in fats, fatty acids, organic oils, and emulsifiers, leading to high Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) levels, which severely impact water bodies A if discharged untreated. This project aims to develop a plasma-based water purification system, integrating multi-stage filtration, plasma oxidation, and real-time sensor monitoring. The system will also incorporate TDS, pH, and turbidity sensors, with real-time monitoring displayed on an OLED screen, ensuring continuous assessment of water quality. The final goal is to create an efficient, ecofriendly, and scalable wastewater treatment system that can be implemented in industrial, reducing environmental pollution while promoting sustainable water management.

Plasma technology for water purification represents a cutting-edge approach to water treatment tailored to meet the demands of 21st-century industrial water usage. This technology boasts effectiveness, efficiency, scalability, versatility, and adaptability. It must address several key requirements, including adapting to emerging contaminants, minimizing energy consumption, optimizing power-flow balance, accommodating various flow rates, minimizing infrastructure modification, anticipating regulatory changes, and customizing chemistry to specific site needs. Crucially, any new plasma-based water treatment methods must prioritize public health safety while harnessing the energy and reactive chemical species generated during Non-Thermal Atmospheric Pressure Plasma (NTAPP) processes to effectively eliminate bacteria and microorganisms, thus disinfecting water. One of the technique's major advantages lies in its ability to operate in ambient air at atmospheric pressure, eliminating the need for a vacuum system and avoiding the use of chemical products like chlorine. NTAPP offers three primary water treatment approaches: direct treatment, indirect treatment, and bubbling methods.

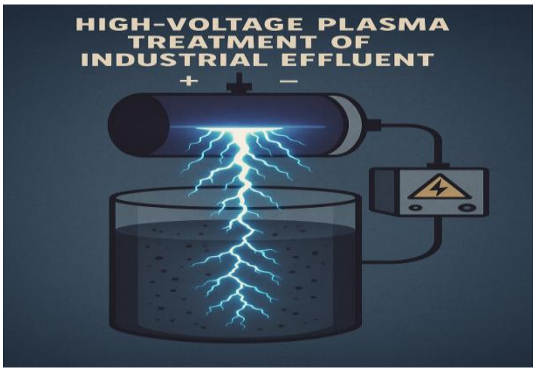

Fig 1 : High voltage plasma treatment for industrial effluent

II.METHODOLOGY:

The proposed water purification system integrates a turbidity sensor, a TDS sensor, a highvoltage generator, UV light source, and an Arduino board. The Arduino serves as the main controller, receiving data from sensors and activating purification components based on user commands. A relay connects the Arduino to the high-voltage generator (Taser module) and UV light, allowing for user-controlled purification.

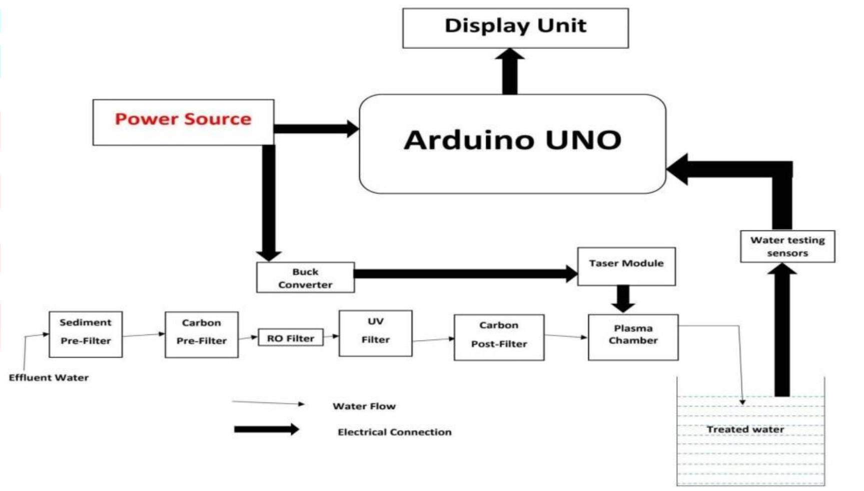

Fig. 2 Block Diagram of Eco smart plasma system

The diagram illustrates a smart water purification and monitoring system powered by an Arduino UNO microcontroller. The process begins with effluent (untreated) water passing through a series of filtration stages. First, it goes through a sedimentation pre-filter that removes large particles, followed by a carbon pre-filter which eliminates chlorine and organic compounds to enhance taste and odor. The water then enters a UV filter that uses ultraviolet light to disinfect by killing bacteria and viruses. It flows to electrodes powered by a high voltage (HV) circuit to generate plasma for advanced purification. The treated water then passes through a carbon post-filter for final polishing before being collected. The entire purification process is controlled and monitored using an Arduino UNO. A power source provides the necessary electrical supply to the system. The Arduino controls the filtration process via a relay module and a control circuit. It also operates the HV circuit that powers the plasma electrodes. Water quality is monitored using sensors that feed real-time data to the Arduino, which can then display the information on a display unit. Additionally, a communication module allows for remote data access or system control. Electrical connections are represented with thick arrows, while water flow is indicated by thin arrows in the diagram.

2.1 COMPONENTS:

2.1.1 HARDWARE REQUIREMENTS

- Sediment Pre-Filter
- Carbon Pre-Filter
- Uv Filter
- Carbon Post –Filter
- Electrodes For Plasma
- Treated Water Tank
- Arduino Uno
- Power Source
- Relay Module
- Control Circuit
- High Voltage Generator Or Buck Converter
- Switch Mode Power Supply (Smps),

2.1.2 WATER TESTING SENSORS

- Turbidity Sensor
- PH Sensor
- Display Unit (OLED)
- Communication Module
- TDS Sensor

The system works as follows:

- The turbidity sensor measures the amount of suspended solids in the water.
- The Arduino Uno reads the data from the turbidity sensor.
- If the turbidity level is too high, the Arduino Uno will turn on the UV light module.
- The UV light will kill bacteria and other microorganisms in the water.
- The relay is used to control the power to the UV light module.
- The power adapter provides power to the Arduino Uno and the UV light module.

III.IMPLEMENTATION

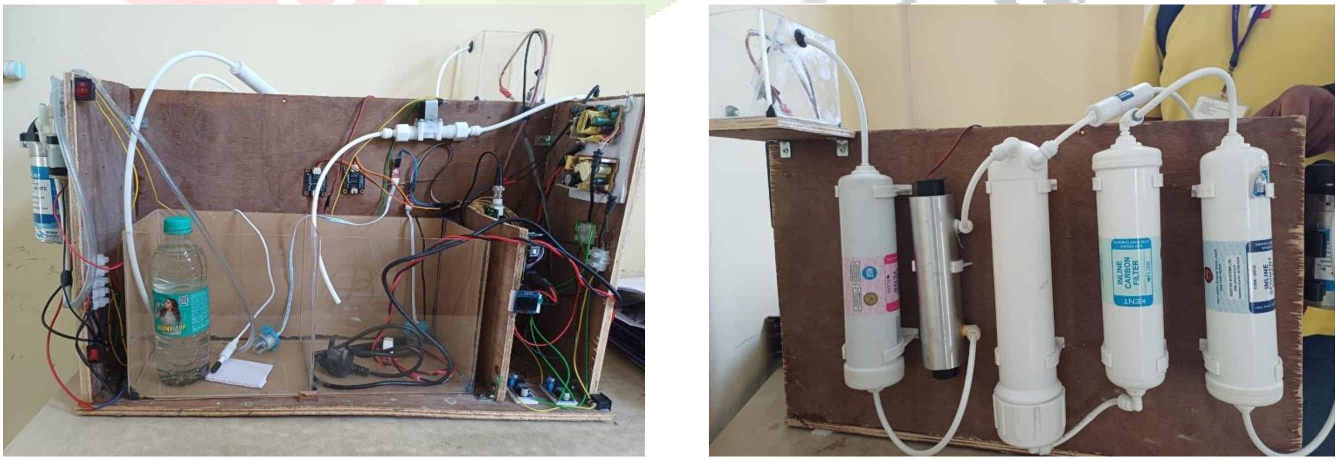

Fig 3: Eco smart plasma system

The Eco Smart Plasma System combines state-of-the-art plasma technology with traditional filtering techniques to treat industrial wastewater in a sophisticated manner. After removing suspended particles with a sedimentation filter, organic contaminants and smells are removed with a carbon pre-filter. After that, the water is run through a reverse osmosis (RO) filter, which drastically lowers the levels of chemical pollutants.

Targeting any leftover organic chemicals and microbiological pathogens, a carbon post-filter and a UV filter are used for additional polishing. The core innovation lies in the plasma filtration unit, where non-thermal plasma is generated to break down complex chemical compounds, neutralize harmful gases, and disinfect the water at a molecular level without adding any chemicals.

Sensors are embedded to monitor pH, TDS, and turbidity, ensuring the treated water meets environmental discharge standards. A microcontroller-based electronics unit, which automates processes and gives real-time feedback, controls the entire system. This sustainable, modular design ensures efficient treatment of industrial effluent, promoting eco-friendly water reuse and compliance with pollution control norms.

IV.RESULT

- Significant reduction in COD, BOD, oil content, and heavy metals in wastewater.
- Improved water clarity and pH balance for safer disposal or reuse.
- Validation of plasma oxidation as an effective alternative for industrial effluent treatment.
- Demonstration of real-time water quality monitoring for automated control and analysis.

V.CONCLUSION:

In conclusion, Eco smart plasma systems present an innovative and sustainable solution for the treatment of industrial effluent. By harnessing the power of non thermal plasma technology, these systems can effectively break down harmful contaminants, including complex organic compounds and toxic gases, without the need for excessive chemicals or high energy input. Compared to conventional treatment methods, plasma-based treatment offers several advantages—such as at high efficiency, reduced environmental impact, and potential for on-site application—making it especially suitable for industries with stringent wastewater discharge standards. As industries continue to face growing pressure to adopt eco-friendly practices, Eco smart plasma systems represent a promising direction for the future of effluent management. With further research and scaling, this technology could become a mainstream choice for cleaner and smarter wastewater treatment.

VI.FUTURE SCOPE :

The future scope of this project includes:

- Develop a plasma-based treatment system for removing pollutants from paint or sunflower oil industry effluents.
- Design and fabricate the system using stainless steel (SS) and PVC transparent pipes for long-term industrial use.
- Integrate real-time water quality monitoring with pH, TDS, and turbidity sensors and display data on an OLED screen.
- Ensure compliance with environmental regulations by significantly reducing COD, BOD, and heavy metal content.
- Investigate the chemical breakdown process of contaminants using plasma generated hydroxyl radicals and ozone.
- Optimize energy consumption and cost-effectiveness to make the system suitable for large-scale industrial applications.

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