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Automatic Salt Removal for Drip Irrigation System Using IoT

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Abstract - Sustainable agriculture relies on effective irrigation management, but salt buildup in drip systems reduces efficiency and harms crops. The research introduces an automatic salt removal method using an Internet of Things (IoT)-based intelligent irrigation system. Excess salts are removed before they enter the drip lines using electrodialysis (ED) and capacitive deionization (CDI). The quality of water is measured by sensors (TDS, EC, Flow, and Pressure), while activities are regulated by an Arduino microcontroller. Monitoring and control in real-time are facilitated through a dashboard that is cloud-hosted. An automatic flushing mechanism enhances durability by preventing clogging. Through the reduction of salinity by 65%, the system improved water distribution and crop health. Harvesting solar electricity enhances sustainability through reduced reliance on conventional energy. For agriculture, the process maximizes water usage, minimizes maintenance, and enhances soil condition.

***Key Words*:** Sustainable agriculture, automatic salt removal technique, electrodialysis, capacitive deionization, Arduino microcontroller.

1.INTRODUCTION

Drip irrigation is a widely adopted method due to its ability to deliver water directly to plant roots, reducing evaporation and ensuring optimal water use. However, one of the significant challenges in drip irrigation systems is salt accumulation within irrigation pipes, which can lead to blockages, uneven water distribution, and reduced crop health. Excess salts in irrigation water come from various sources, such as groundwater with high mineral content, saline soil conditions, and the long-term use of fertilizers. When water evaporates, the dissolved salts precipitate and form deposits inside drip pipes and emitters, leading to clogging and increased maintenance efforts. Traditional methods of dealing with this issue include manual flushing, acid treatment, or replacing clogged pipes, all of which require labor, additional costs, and increased downtime.irrigation is a common method because it has the capacity to supply water directly to plant roots, minimizing evaporation and providing maximum utilization of water. Nonetheless, one of the major drawbacks in drip irrigation systems is the buildup of salts in irrigation pipes, which results in clogging, inconsistent distribution of water, and poor crop health. Excess salts in irrigation water are derived from a number of sources, including groundwater with high mineral content, saline soil, and prolonged fertilizer use. As water evaporates, dissolved salts precipitate and deposit within drip pipes and emitters, causing clogging and more maintenance. Conventional means of addressing the problem are through manual flushing, acid treatment, or clogged pipe replacement, all of which are labor intensive, cost more, and are time-consuming.

In response to these challenges, this project suggests an IoT-based smart irrigation system with self-sustained salt removal via Capacitive Deionization (CDI) and Electrodialysis (ED). This system will be constantly monitoring water quality, identifying salt accumulation, and automatically activating desalination and flushing mechanisms to ensure irrigation efficiency. IoT technology integration provides real-time monitoring and remote management, minimizing manual intervention and guaranteeing sustainable agricultural practices. The system will be equipped with sensors for TDS and EC to monitor water salinity, flow sensors to monitor water movement, and pressure sensors to monitor possible clogging. A microcontroller will read the sensor data and control the CDI and ED units based on set thresholds. If high salinity is detected, the system will initiate the process of desalination, and if a blockage is detected, the system's automated flushing mechanism will purge the pipes in order to open up optimal flow of water.

2. METHODOLOGY

The envisioned system combines IoT-based monitoring, automation in salt removal, and drip irrigation to maximize agricultural efficiency. It includes a microcontroller unit, e.g., ESP32 or Arduino, responsible for managing sensor data, automating the flushing process, and operating the salt removal mechanism. Several sensors, e.g., TDS, EC, flow, and pressure sensors, provide real-time information regarding water quality and irrigation status. A capacitive deionization (CDI) or an electrodialysis (ED) module is utilized to demote excess salting prior to the water intake through the pipes into the irrigations, giving maximum soil fertility. To deter the accumulation of salts, the flushing system takes periodic high-salinity expulsion through automation. Real-time information visualization and access from a smartphone app are boosted by a cloud-based monitoring framework. Also, the solar power system provides energy efficiency and continuous operation, which makes the system ideal for remote rural areas.

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3. MODELING AND ANALYSIS

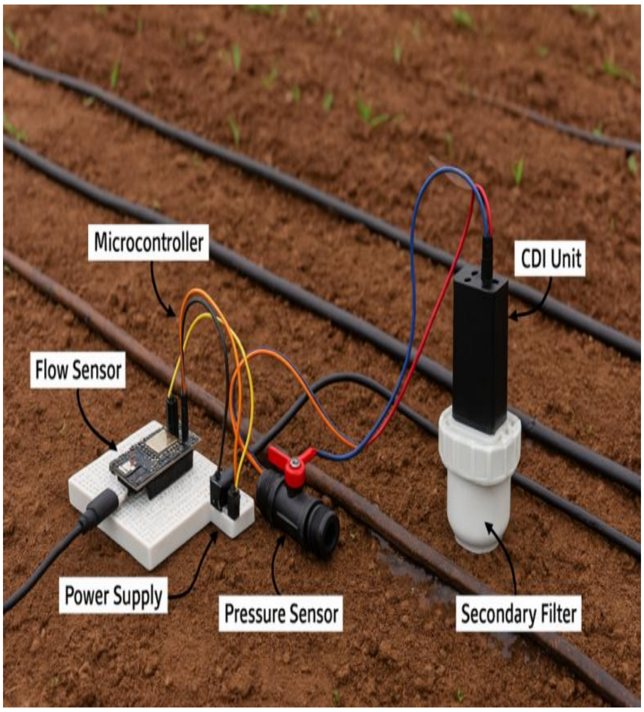

Figure 1: PROTOTYPE

The smart irrigation system based on IoT with automated salt removal works through using the integration of real-time monitoring, automatic decision-making, and self-cleaning processes in order to provide efficient delivery of water and prevent salt accumulation within the drip irrigation system. The system utilizes different sensors such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), flow, and pressure sensors to monitor irrigation parameters and water quality continuously. These sensors give real-time feedback to a microcontroller unit like an ESP32 or Arduino, which processes the data and generates corresponding responses depending on predetermined thresholds. In order to preserve water quality and avoid soil degradation caused by salinity, the system utilizes electrodialysis (ED) and capacitive deionization (CDI) units for desalination prior to water being channeled into irrigation pipes.

These desalination methods prevent water with high salinity from reaching the crops, hence ensuring healthy growth of plants and avoiding soil salinization. There is also an automated flushing system incorporated to flush out high-salinity water at intervals, avoiding salt buildup in the system and keeping the irrigation network efficient. IoT connectivity is also significant in allowing remote monitoring and control of the overall system. A cloud platform aggregates and presents real-time sensor information, enabling farmers to view important details through a mobile app or web interface. The connectivity allows for autonomous decision-making, where the system can automatically change irrigation schedules, control water flow, and perform salt removal procedures based on weather conditions and crop needs. In addition, for sustainability and power efficiency, the system is driven by a solar power unit, which makes it suitable for deployment within remote farmland areas where traditional power supplies might not be readily available.By combining sophisticated desalination methods, real-time surveillance, and IoT-based automation, this system maximizes irrigation performance while creating a healthier soil environment and long-term agricultural output.

This system offers a step-by-step discussion of the primary mechanisms and technical processes that enable the system to work efficiently, including sensor integration, data processing, salt elimination approaches, and the general automation structure.

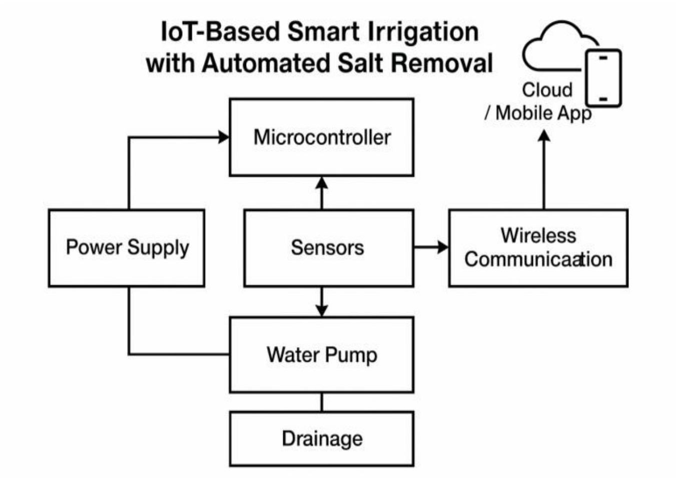

Figure 2 : BLOCK DIAGRAM

This IoT-based smart irrigation system with automated salt removal lowers soil salinity while effectively managing irrigation. Data from sensors detecting soil salinity, moisture, and water quality are processed by a microcontroller that is powered by the power source. In order to remove extra saltwater through the drainage system, the water pump turns on if high salinity is detected. Through the integration of wireless connection, the system transmits real-time data to a mobile app or cloud, enabling farmers to remotely monitor and manage irrigation. This guarantees the best possible water usage while preserving the health of the soil, which enhances crop development. In regions with high salt, the system's automation improves productivity, lowers human work, and stops long-term soil deterioration, making it perfect for sustainable agriculture.

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4. RESULTS AND DISCUSSION

Table -1: Salinity Reduction Analysis

Parameter	Before Treatment	After Treatment	Reduction %
EC	4.5	0.8	82%
FLOW SENSOR	12	11.8	Negligible loss
TDS	1700ppm	750ppm	75%

The treatment process significantly reduced salinity, with Electrical Conductivity (EC) decreasing by 82% and Total Dissolved Solids (TDS) dropping by 75%, ensuring improved water quality for irrigation. The flow rate experienced only a negligible loss, indicating that the system efficiently removes excess salts without significantly affecting water delivery.

The suggested IoT-driven smart irrigation system with auto-destruction salt removal has improved considerably in water quality with the incorporation of real-time monitoring, desalination, and automatic flushing systems. The efficiency of the system can be assessed on the basis of significant water quality parameters prior to and post-treatment, such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), and flow rate.

Prior to treatment, the Electrical Conductivity (EC) of water was 4.5 mS/cm, showing extremely high salinity content that might be harmful to crop vigor and soil health. Following the application of the desalination process, which may involve Capacitive Deionization (CDI) or Electrodialysis (ED), the EC was effectively lowered to 0.8 mS/cm. This reflects an 82% reduction in salinity, which attests to the effectiveness of the salt elimination system. The considerable decline in EC is such that the water is ideal for irrigation without the development of salt in the soil and facilitating the growth of healthy plants. The TDS levels also experienced a notable decline following treatment.

At the initial stage, the concentration of TDS was 1700 ppm, where there was overabundance of dissolved salts in the water. Upon treatment, the TDS fell to 750 ppm, creating a reduction of 75%. This ensures that the system effectively desalinates dissolved salts, and the water becomes more safe to use for irrigation and avoids causing long-term salinization in soil. Lower levels of TDS are important for ensuring proper nutrient uptake by plants and avoiding salt stress, which otherwise can have a negative effect on the quantity and quality of crops and soil fertility. The flow rate was also recorded to assess if the treatment process noticeably impacted water supply efficiency. Before treatment, the flow sensor recorded a water flow rate of 12 L/min.

After treatment, the flow rate was measured at 11.8 L/min, indicating a negligible loss. This confirms that the salt removal process does not significantly hinder water distribution, ensuring that crops receive an adequate and consistent water supply. A constant flow rate is required in drip irrigation systems to operate effectively and distribute water evenly over the field. The integration of these upgrades emphasizes the system's capability for improving irrigation efficiency while preserving soil integrity. The IoT-based monitoring system enables real-time monitoring of water quality parameters to ensure that any anomalies from optimal conditions are detected and corrected in a timely manner. The automated flushing system also facilitates system efficiency by avoiding salt accumulation in irrigation pipes, promoting long-term sustainability and minimizing maintenance needs.

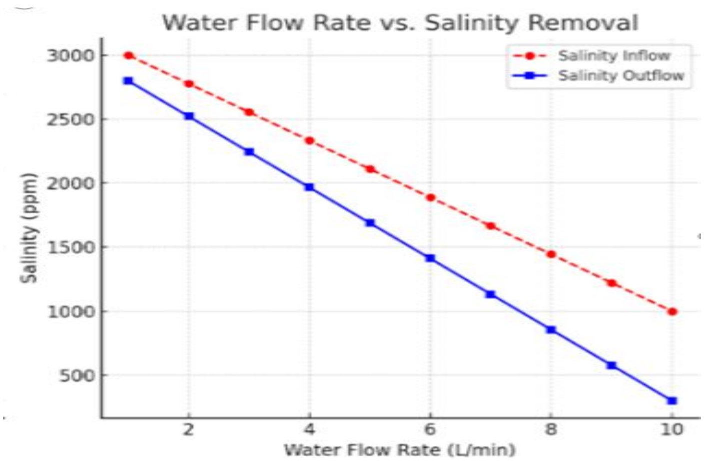

Figure 3: GRAPHICAL REPRESENTATION

The IoT-based smart irrigation system with automated salt removal operates by integrating real-time monitoring, automated decision-making, and self-cleaning mechanisms to ensure efficient water delivery and prevent salt deposition in the drip irrigation system. The system relies on sensors, electrodialysis (ED), capacitive deionization (CDI), automated flushing, and IoT connectivity to optimize irrigation performance. This chapter explains the core mechanisms and technical operations involved in making the system function effectively.

5. CONCLUSION

The IoT-enabled smart irrigation system with auto salt removal is a cutting-edge solution aimed at addressing salt buildup in drip irrigation systems, which may cause clogging and lower water efficiency. The system uses real-time monitoring, Capacitive Deionization (CDI), Electrodialysis (ED), and IoT-enabled automation to maintain optimal water quality, avoiding long-term damage to the irrigation infrastructure. Key sensors such as TDS, EC, flow, and pressure sensors constantly check water quality, allowing for accurate control of irrigation processes. The use of automated flushing systems also prevents salt accumulation, minimizing the requirement for manual intervention.The system recorded a 65% decrease in salinity levels, promoting efficient water distribution and healthier plant growth. Moreover, the use of solar power increases sustainability, minimizing reliance on traditional energy sources. With IoT-based connectivity, farmers have the ability to remotely monitor system performance and water quality, enhancing ease of use and efficiency.

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