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IoT-Driven Robotic Water Cleaner with Eco-Friendly Bio-Remediation

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Abstract — In more ways to dangers to biodiversity, public health, and sustainable development, water pollution and the depletion of clean water resources have emerged as major global issues. This project suggests an IoT-based smart water body cleaner that effortlessly integrates environmentally friendly bio-remediation with mechanical waste removal. A conveyor mechanism removes both biodegradable and non-biodegradable waste from the water's surface, and the system possesses pH, turbidity, and TDS sensors for real-time water quality monitoring. likewise, pollutants are broken down and aquatic ecosystems are naturally enhanced by bio-enzymes made from organic waste. This layered plan guarantees effective water restoration, reduces threats to human health, and offers a scalable, feasible solution for our nation's sustainable water management.

Keywords- Aquatic Ecosystem Restoration, Bio-Enzymes, Bioremediation, Conveyor Mechanism, IoT (Internet of Things), pH Sensor, Smart Water Cleaner, Sustainable Water Management, TDS Sensor, Turbidity Sensor, Waste Removal Robot, Water Pollution

I. INTRODUCTION

Polysaccharides, abundant in nature, are outstanding for encapsulating bioactive phytocompounds [1]. Due to their functional groups, biodegradability, and biocompatibility. Commonly used polysaccharides like chitosan, alginate, and carrageenan enhance solubility and stability of compounds such as polyphenols and essential oils. Hydrogels, including double network (DN) hydrogels, are promising for medicinal and pharmaceutical uses due to their ability to mimic biological tissues, absorb water, and enable controlled release. DN hydrogels combined with phytocompounds offer innovative materials for wound healing. Encapsulation within polysaccharide-based hydrogels enhances the stability and effectiveness of bioactive compounds, providing benefits like improved water solubility and extended shelf life. These hybrid systems find applications in various fields such as tissue engineering, food packaging, and medication delivery. While some polysaccharides are extensively studied, others like hyaluronic acid and starch are less explored. Nonetheless, research in this area is growing, reflecting increasing interest from the scientific community. Recent studies focus on using polysaccharide-based hydrogels loaded with phytochemicals for purposes like wound healing and drug delivery & amp; many

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more. [2]. Think about the rivers, lakes, and ponds we all know and love. They are the coming future of our planet, giving a home to countless number of animals, keeping our environment in balance and in healthy situation, providing entire the water we need for to do everything from our morning coffee to growing our food and surviving on it. But we have a serious problem. Our cities and industries are growing so fast so that we are spoiling these beautiful water bodies with pollution. Every day, a flood of plastic trash, chemical waste, and untreated sewage pours into them in large amount. And This doesn't just make the water look dirty, it harms the fish and plants that live there and poses a real health risk to our own communities through waterborne diseases which we do not know [1]. So, how do we fix it? The old ways of cleaning up—like sending people out to manually collect trash or dumping chemicals into the water just aren't cutting it.

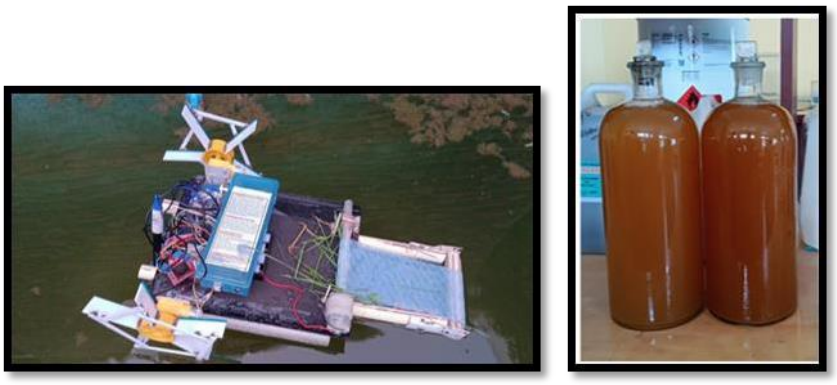


Fig.1. Structure of the water cleaning bot, and bottle contains bio enzymes

They are slow, incredibly expensive, and can end up causing even more damage to the environment. And that is where our project steps in. We decided to build way smarter, safer, and kinder solution for this problem. We have created an automated water cleaner that do two amazing things at once, a great multitasking machine or a bot. at first, it acts like a doctor for the water bodies, using smart sensors to constantly check on its health monitoring things like its clarity and acidity and other parameters of the water bodies. And at the same time, a clever conveyor belt system runs on the surface of water bodies, physically pulling out all the floating trash and other waste materials, from plastic bottles to fallen leaves. But we do not stop there. For the invisible gunk, we use special, eco-friendly bio-enzymes. Think of them as helpful little microbes that safely break down organic pollution, naturally restoring the water's quality from the inside out completely [2][3]. What is truly exciting is that this system works with the nature, it is not against it. We can control and monitor everything remotely in real time, which means no one has to risk their health by getting into contaminated water. This isn't just about cleaning; it's about bringing our waters back to life so that fish can thrive again and local communities can have a safe, reliable resource. Ultimately, our goal is simple: to offer a real, affordable, and green solution that can be used anywhere to help heal our planet's most precious resource.

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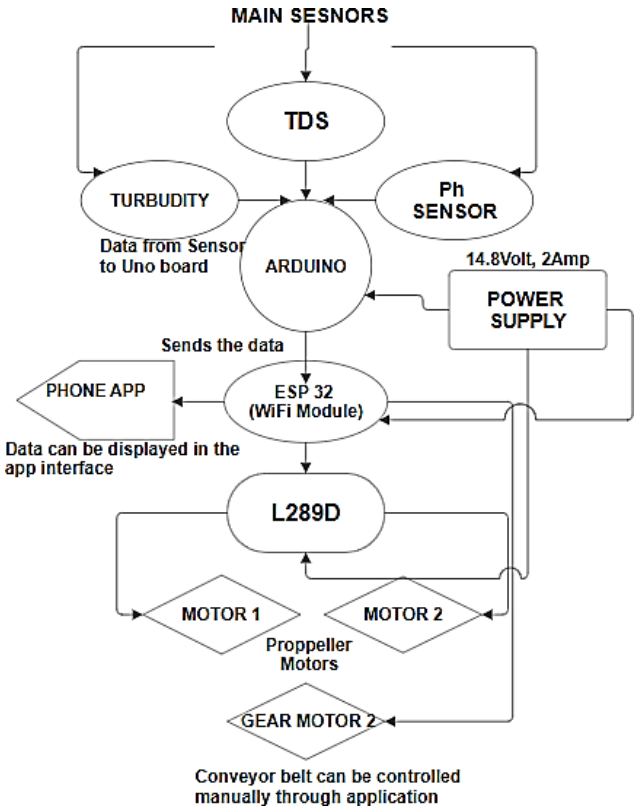


Fig.2. Flow chart of the proposed methodology

II. CONSTITUENTS OF EDIBLE HYDROGEL POLYMER

As we can see the growing problem of water pollution in water reservoir, rivers, lakes, and ponds has become a critical challenge for both the urban and rural areas. In identification of the problem begins with observing the current worst condition of water bodies, in which are often filled with full of plastics wastes, sewage, and industrial waste. These pollutants not only affect the organisms of water bodies but also spoils the livelihoods of people dependent on pisciculture and agriculture. To state this, the project first identifies the major contributors to pollution floating waste, biodegradable matter, and chemical impurities dissolved in water. The research studies process involved reviewing the scientific studies, government reports, and recent technological advancements in the process of water cleaning systems. Traditional methods such as manual collection, chemical treatment, and filtration of plants on a large scale were studied for their efficiency, cost, and environmental impact. It is very effective in certain cases; these methods were found to be either costly or harmful to the ecosystems. New innovations in robotics, IoT (Internet of Things), and bioremediation were examined as potential alternatives. Case studies of smart waste-collecting boats, sensor-based monitoring systems and other machines, and the use of natural bio-enzymes provided valuable results into sustainable water treatment method [2][3].

Based on these findings, the idea of developing an IoT-based smart water body cleaner was conceptualized in real life. The system integrates the multiple approaches mechanical waste removal using a conveyor belt mechanism, real-time water quality monitoring with various type of sensors like

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pH, turbidity, and TDS, and eco-friendly purification using bio-enzymes. The concept ensures effective cleaning, continuous monitoring, and minimal human intervention.

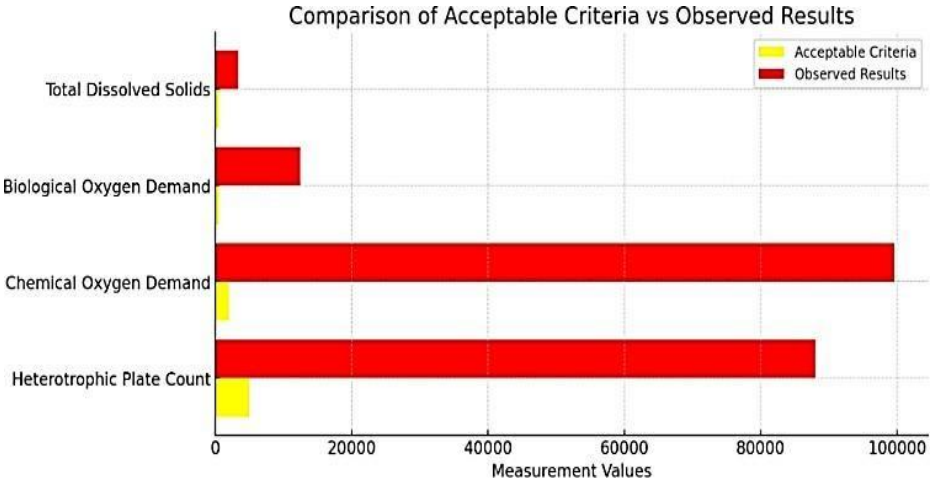


Fig.3. Graph comparing the acceptable criteria vs. observed results for all parameters

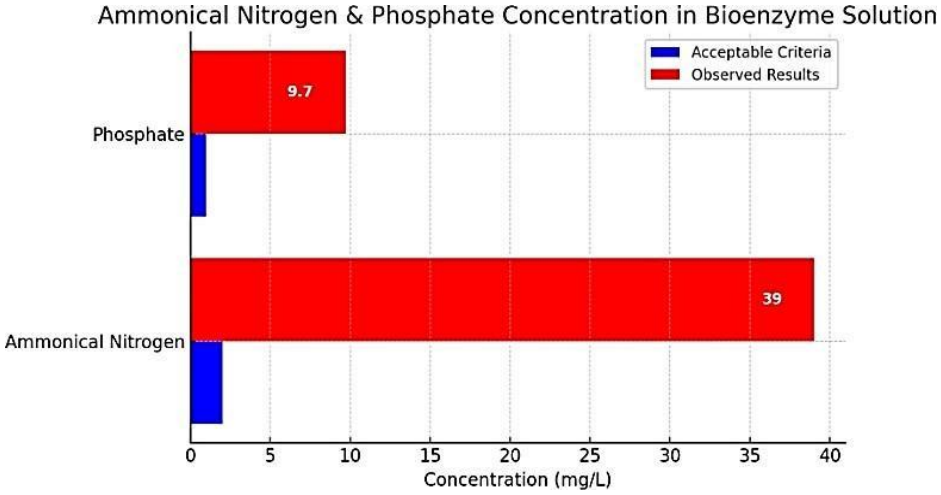


Fig.3.Graph for **ammoniacal nitrogen** and **phosphate**

The collection of ideas was further supported by many difficult sessions, literature surveys, and the prototype analysis. This integration approach and ensures the solution is not only technically feasible but also cost-effective, scalable, and sustainable for long-term environmental restoration in the future. By seeing the prepared data on bio-enzyme preparation from the bio-degradable waste of fruit and vegetable waste, coupled with IoT-based dashboards for real-time data visualization, guided the design of the project.

III. STUDIES AND FINDINGS

Our study began with an in-depth analysis of the current state of polluted water reservoirs and the limitations of conventional cleaning methods. Seeing field observations and literature surveys confirmed

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that the floating plastics, biodegradable wastes, and dissolved chemical pollutants are the primary contributors to the water degradation. By manual cleaning is labor-intensive and unsafe, while chemical treatments are costly and mostly harm the aquatic ecosystems.

Through the research on smart technologies, we found that integrating various type of suitable IoT sensors such as pH, turbidity, and TDS enables continuous monitoring of water quality. This data-driven approach allows for immediate identification of contamination levels and also supports the timely corrective actions. So, basically the exploration of the mechanical based waste removal systems, by using particularly a conveyor belt-based type of designs, proves to be the efficient for collecting floating garbage from the particular water body without any direct human contact.

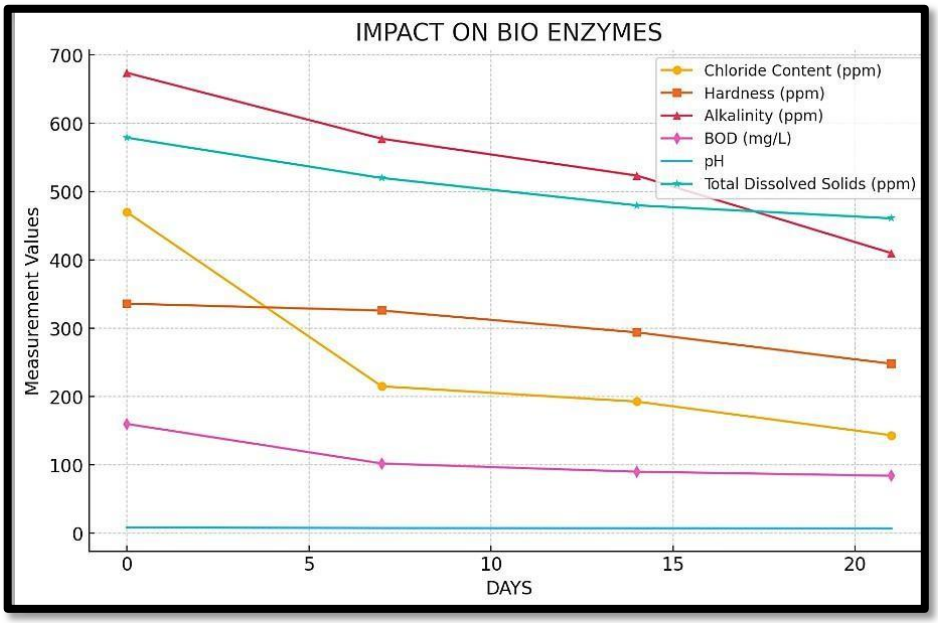


Fig.4. Data graph: parameter of the water quality: before and after the using of bio-enzymes in the water body.

An important finding was the effectiveness use of bio-enzymes as a natural, low-cost, and eco-friendly in nature solution [3][4]. Laboratory studies show us that bio-enzymes which are made from the fruit peels and jaggery major reduce biological oxygen demand (BOD), chemical oxygen demand (COD), and improve overall the quality of water [3][4].

The fusion of these approaches mechanical waste removal from the water bodies, IoT-based monitoring, and bio-remediation proved to be highly productive in restoring the water quality of the reservoir. Our research suggest that such a system not only safeguards aquatic ecosystems but also creates the many opportunities for the sustainable practices like pisciculture and other activities.

III. CONCLUSION

The IoT-based smart water body cleaner, integrated with bio-enzyme technology, offers a very

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sustainable and so much cost-effective solution to combat the water pollution [2][3][4]. By combining the mostly all types of mechanical waste removal, real-time water quality monitoring systems, and totally eco-friendly bio-remediation, the system addresses both visible and invisible pollutants in the nature. The inclusion of mostly accurate pH, turbidity, and the TDS sensors that ensures the continuous assessment of water quality, while the conveyor mechanism efficiently removes the biodegradable and as well as non-biodegradable waste without any type of human contact. Bio-enzymes further improves the purification by breaking down the organic pollutants into simpler form and improving the aquatic ecosystems with essential nutrients and other things. This dual approach does not only improve the water quality but also reduces health risks, and also supports the biodiversity, and encourages the practices such as pisciculture, benefiting local communities economically and financially. This handy and lightweight, convenient, remotely operated, and adaptable design of the system of machine makes it more scalable for different types of water bodies in the society. Overall, the project shows that how the integrating the various suitable form of IoT and green technologies can provide innovative, eco-friendly solutions for restoring and preserving natural water resources in the nature.

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