ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 11 Issue 07 July 2024

Performance Evaluation of Automated Floating Island for Water Quality Treatment in Surface Water Bodies

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Abstract— ***Surface water pollution poses threats to human health and ecosystems. Traditionally, constructed wetlands have been utilized for water treatment, yet they possess drawbacks such as inadequate data collection efficiency and high costs. This research addresses the challenge of surface water treatment by proposing a novel, cost-effective solution: IoT-enabled floating islands utilizing Canna plants for phytoremediation. These floating islands integrate pH, temperature, and TDS sensors to gather real-time water quality data. The central NodeMCU hub transmits this data to IoT platforms for remote monitoring, while an on-site display offers immediate water parameter analysis. This dual-tiered approach empowers stakeholders with comprehensive oversight of water quality, allowing for remote and on-site analysis. Compared to traditional constructed wetlands, these floating islands offer a significantly lower cost (16% of the total expense), making them a sustainable and proactive solution for water resource management.***

Index Terms— ***Canna Plant, Floating Island, Water Contamination, Water Quality Parameters***

I. INTRODUCTION

Water pollution is a significant global challenge, threatening human health, ecosystems, and overall development (Li et al., 2020). Factors like industrialization, urbanization, and climate change exacerbate this issue by introducing various pollutants into water bodies (Bai and Xu, 2021). Traditional water treatment methods are becoming increasingly insufficient due to the growing number and complexity of contaminants (Vymazal, 2011). Consequently, innovative technologies are crucial for addressing water quality concerns.

This research explores the potential of Automated Floating Islands – a sustainable and efficient technology – for water quality improvement. This system utilizes constructed wetlands, with specific plant species playing a vital role in water purification. This study focuses on leveraging the well-established phytoremediation abilities of Canna (Canna spp.) (Rahman and Hasegawa, 2007) while overcoming limitations associated with traditional floating island methods, which can be labor-intensive for installation and water quality monitoring.

This paper also integrates the Internet of Things (IoT) technology for real-time water quality monitoring. This integration utilizes the data transmission and analysis capabilities of IoT, facilitating efficient water resource management. The research investigates the effectiveness of Canna in water remediation and compares its efficiency with potentially suitable alternatives for optimal selection.

The overall objective is to develop a comprehensive and sustainable solution for water quality improvement. This includes evaluating Canna for water purification, designing a system optimized for this plant, and conducting a life-cycle cost analysis to assess its economic viability. By harnessing the power of Canna and IoT technology, this research aims to contribute to environmental conservation and cost effectiveness.

II. MATERIALS AND METHODS

2.1 Study area

The experiment was conducted in Saveetha Engineering College in Kanchipuram, Tamil Nadu, India, with a particular emphasis on a small water storage tank measuring 0.93 meters in length, 2.2 meters in width, and 0.5 meters in height (Fig.1).

Fig. 1. Experimental site in Saveetha Engineering College

2.2 Methodology

2.2.1. Selection of plants

The plants were selected based on research papers to identify their cleaning efficiency and medium growth (Table 1). These plants were chosen primarily for their availability and ability to adapt to our climate conditions. Four plants were selected, primarily based on the type of pollutants they effectively target.

Table 1. Plant species selected for the study

S.NO	PLANT SPECIES	GROWING MEDIUM	HEIGHT & WEIGHT	ROOT DEPTH	CLEANING EFFICIENCY
1	Bulrush (*Scirpoides holoschoens*)	Soil and water	Height- 5 to 10 ft Weight- 28 gm	4.9 ft	30 to 90 % Ni, Zn, Cd, Mg
2	Cattails (*Typha latifolia*)	Soil	Height- 5 to 10 ft Weight- 28 gm	<1.5 ft	48.92% Nitrate, phosphate
3	Vetiver (*Chrysopogn zizanioides*)	Soil	Height- 3 to 6 ft Weight- 1.36 gm	4.9 ft	67.73% TDS
4	Canna (*Canna indica*)	Soil	Height- 8.2 ft Weight- 2000 gm	0.33 ft	98.6% BOD, COD
5	Lemon grass (*Cymbopogn citratus*)	Soil	Height- 3 to 5 ft Weight- <500gm	0.5 ft	80 to 85% TDS, Nitrate, Phosphate, BOD
6	Lotus (*Nelumbo nucifera*)	Water	Height- 4.5 to 5.5 ft Weight -3 to 3.5 gm	0.32 ft	BOD, COD, turbidity, Nitrate reduction

2.2.2. Laboratory testing

This section details the experimental procedures employed to assess water quality and to evaluate the potential of plant-based bioremediation.

Water Sample Collection and Analysis

Water samples were collected from two designated locations: Siruseri farm pond and the college campus. The collected samples were transported to a laboratory for analysis. Standard laboratory procedures were used to measure pH and electrical conductivity (EC) of the water samples. The obtained pH and EC values were compared to established benchmarks for irrigation suitability as given below pH: 6.5-8.4; EC: 1.5-2.5 mS/cm.

Simulating Pollution with Limestone

To investigate the impact of pollutants on water quality, limestone was introduced to both water samples. The amount of limestone added (e.g., 10 grams) should be clearly specified. Following limestone addition, the pH and EC of the water samples were re-measured to assess the changes induced by the simulated pollutant.

Experiment on treatment efficiency of selected plants

A literature review was conducted to identify plant species with potential for mitigating water pollutants. Individual containers were prepared for each plant species. Each container was filled with a designated volume of water (e.g., 6 litres) and supplemented with a standardized amount of limestone (e.g. 10 grams). The plant specimens were introduced into their respective containers. The entire experiment was conducted under controlled laboratory conditions for a predetermined period from December 22, 2023 – January 4, 2024). Daily measurements of pH and EC were taken throughout the experimental duration to monitor the impact of plants on water quality.

Data Analysis

The collected data on pH and EC measured before and after limestone introduction and throughout the plant experiment, were compiled and analysed. Statistical methods (if applicable) were employed to evaluate the significance of changes observed in water quality parameters due to the presence of plants.

2.2.3. CONSTRUCTION OF FLOATING ISLAND

The construction of the floating island involves assembling a robust base frame by connecting four pipes, each measuring 1.5 meters in length and 75 millimetres in diameter (Fig 2). These pipes are joined together using elbow connectors to form a rectangular structure. At the base of this pipe setup, a mesh is installed to facilitate root growth through it.

To ensure buoyancy, empty bottles are affixed to the base of the pipes, providing the necessary flotation. Central to the frame is a tray that houses all the essential sensor components. This tray is strategically placed at the centre to ensure balanced weight distribution and optimal functionality. The sensors are designed to monitor various parameters of the water in the storage tank, including pH, temperature, and total dissolved solids (TDS).

These measurements are crucial for maintaining the health of the plants and the overall ecosystem. The mesh base is covered with a coir medium, which serves as a growing substrate for the plants. The selected plants based on the results of the section 2.2.2 are carefully planted in this medium, leveraging its properties to support healthy growth.

The coir medium not only anchors the plants but also aids in nutrient absorption and root development. The quality of the water will be displayed on a small LED screen connected to the sensors, providing an immediate visual reference. Furthermore, the data is also transmitted to a Google Sheet, updating every 10 seconds. This setup ensures continuous monitoring and allows for remote access to the data, enabling timely interventions if any of the water parameters deviate from the optimal range.

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Fig.2 Construction of Automated Floating Island

2.3 Life Cycle Cost Analysis

DESCRIPTION	MANUAL	IoT
PH , Temperature , TDS	Rs.1,000(per sample)	Rs.25000(Once Investment of sensors)
Travel Expense	Rs.5,000(per Year)	1000
Maintenance	Rs.1,000(per Year)	5000(per year)
Duration of Sampling	4 Days Once	2 Hours Once
Total (Avg. of 200 Samples per year)	200*1,000+5,000+1,000=Rs. 2,06,000	Rs.31,000 – Rs.35,000

Utilizing IoT-enabled floating islands reduces costs to just 16% of the total expenses of traditional constructed wetlands, offering a more economical option for managing water quality.

III. RESULT AND DISCUSSION

3.1. Results of the laboratory test

Table 1a and 1b show the water quality parameters before and after the treatment of the spiked water.

Table 1a. Quality parameters of the spiked water before the treatment

PARAMETERS	IRRIGATION WATER QUALITY STANDARDS	SPIKED WATER
pH	6.5- 8.5	11.35
EC(mS/cm)	<0.7	5.39

Table 1b. Quality parameters of the spiked water after treatment

PLANTS	pH	Treatment Efficiency (%)	EC(mS/cm)	Treatment Efficiency (%)
Cattails	8.1	28.63	0.78	85.52
Canna	8.22	27.57	0.43	92.02
Vetiver	8.34	26.51	0.49	90.9
Lemon grass	8.56	24.58	0.48	91

The results indicate that the Canna plants help the spiked water to meet the Irrigation Water Quality Standards.

3.2. Water treatment using Automated Floating Island

The experiment using floating islands with Canna plants integrates pH, temperature, and TDS sensors for immediate water quality assessment and remote monitoring.

PARAMETERS	INITIAL VALUE (8th Apr 2024)	FINAL VALUE (21st May 2024)	Treatment Efficiency (%)
pH	13.3	8.03	39.62
TDS (mg/l)	2154	625	70.98
EC (mS)	6.39	0.52	91.86

Canna plants have effectively reduced pH, EC, and TDS levels to 39.62%, 70.98%, and 91.86% respectively from their initial values.

IV. CONCLUSIONS

This study investigated the potential of Canna plants integrated into floating islands for water remediation. The Canna *(Canna indica)* plants effectively reduced pH and EC in spiked water samples (27.57% and 92.02%) respectively, demonstrating their suitability for water purification. The IoT-enabled system facilitated real-time water quality monitoring and remote data access (pH - 39.62%, TDS - 70.98%, EC - 91.86%).

Compared to traditional constructed wetlands, floating islands offer a significantly lower cost 16% of the total expense which lies in the reduction of travel expenses, maintenance and duration of sampling, making them a sustainable and cost-effective solution for water resource management. The Canna-based floating island system presents a promising approach for water quality improvement, combining ecological principles with technological advancements for efficient and sustainable water resource management.

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