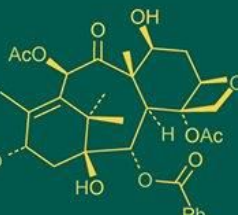
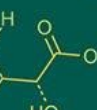
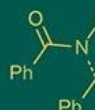


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Study of feasibility of electricity generation at farm field from filtered sewage water

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Abstract

This study explains the design of filters for irrigation field channels carrying sewage water of the Jaganpur Sewage treatment plant (STP), Dayalbagh, and electricity generation from the channel flow using a micro hydro generator device. The water in the field channels of Anupam Upvan, Dayalbagh Educational Institute, Agra, India, coming from the STP plant, was purified to meet the quality standards for irrigation purposes. Through improved irrigation water quality, sustainable health of soil, plant, and human resources can be ensured. The filter system was comprised of activated charcoal, gravel, pebbles, natural sand, and silica sand. Ventury was used to increase the velocity of running water in the channel. Micro-hydro generator devices and water turbine generators were installed to generate electricity. The installed setup could generate voltage in the range of 9V to 48V corresponding to varying flow rates. The installed system is potent to further minimize the ecological impact of sewage irrigation by harnessing the power of flowing water without large-scale dam construction.

Keywords: Filtration, renewable energy, electricity generation, micro-hydro generation device

1. Introduction

The Yamuna River, a major river in India, is super polluted. This pollution comes mostly from untreated sewage, industrial waste, and farm runoff. Even though there's been a lot done to improve how sewage is treated, a big chunk of untreated sewage keeps flowing straight into the river (Keraita *et al.*, 2008; Kiemde *et al.*, 2018) ^[5, 7]. Factories near the Yamuna River send out waste that hasn't been cleaned up, including heavy metals, chemicals, and other nasty stuff. It makes the pollution problem worse (Jiao *et al.*, 2020) ^[4]. Farm runoff involves pesticides, fertilizers, and other chemicals that add to the pollution load. This messes up water quality even more (Kasperek & Wiatkowski, 2014) ^[6]. The pollution in the Yamuna River has caused some serious harm to the environment. It's led to less oxygen in the water, increased toxicity, and even loss of habitats. All of this hurts fish and other creatures living there. On top of that, this pollution also threatens groundwater quality and poses major health risks for people (Sternberg, 2009) ^[11]. To tackle this issue, the Indian government is working with state governments and various groups to kick off several projects like the Yamuna Action Plan and Namami Gange. The projects are geared towards restoring the river to its healthy state. It focuses on appropriate sewage treatment, the establishment of space along the river banks, and public awareness of the protection of our rivers. Still, these efforts face large problems that hamper progressive work: bad infrastructure, not enough money for the projects, weak laws being followed, and rapid urban growth. Fixing pollution in the Yamuna requires teamwork from different areas to make real & lasting changes (Nsengiyumva, 1994; European Small Hydropower Association, 2010) ^[8, 3].

Filtered irrigation water is highly important in maintaining the health of the crops, and ensuring that farming can be conducted sustainably. Filtration systems help a lot by cleaning up irrigation water. Such systems remove impurities in water sources that allow some major perks (Jiao *et al.*, 2020; Keraita *et al.*, 2008) ^[4, 5]. For instance, treated water helps the soil by reducing the presence of harmful compounds that would otherwise inhibit plant growth and fertility. Clean water results in plants having good nutrient absorption. This helps in having stronger roots and increased crop yield. Plus, filtered water helps avoid clogging up irrigation

tools like drip lines and sprinklers. That means farmers are more efficient in the use and distribution of water and cut down on maintenance costs for their applications. Besides, the removal of sediments and pathogens from water by filtration greatly reduces plant infections with waterborne diseases. This ensures the health of crops and reduces chemical usage. Besides, the use of filtered water for irrigation also ensures that the environment is protected from any possible pollution risks to groundwater and surface waters (Rifat & Mahzuba, 2014) [9]. Along the same lines, renewable off-grid energy sources become even more important in the presence of micro-hydro generation devices. For instance, these small-scale hydro systems harness flowing water for electricity and bring many other benefits. Micro-hydro devices provide a reliable renewable energy supply, especially in regions without regular power setups. By using nearby water resources, the system raises energy independence and cuts down reliance on fossil fuels and centralized grids. In addition to that, micro-hydro generation is environmentally friendly since it provides clean electricity with low carbon emissions and little harm to nature (Sternberg, 2009) [11]. Begin this project and lead to many benefits like soil saving, prevent diseases, better livestock health, clean energy, rural electrification, emergency power access, research and innovation opportunities, cost savings, and preservation of the environment (Nsengiyumva, 1994; Jiao *et al.*, 2020) [8, 4]. This combines both filtered irrigation water and micro-hydro generation devices into very comprehensive ways to address agricultural and energy challenges, respectively, with sustainable development and care for the environment.

2. Material and Methodology

2.1 Study area

Anupam Upwan is an agroecological research site (78.02070°N latitude, 27.23514° longitude, & elevation of 158.9 m above MSL) of Dayalbagh Educational Institute, Dayalbagh, Agra, Uttar Pradesh, India. The fields have potential for different agricultural and horticultural research. A canal comes to the Anupam Upwan fields directly from the Jaganpur sewage treatment plant. This site is being used for experiments related to various crop and plant developments. In Anupam Upwan, the canal comes from the STP and supplies irrigation for the entire land, and the irrigation water is distributed through small channels. A small stretch of the irrigation channel was selected for the installation of the device (Fig 1).

2.2 Pre-Project Work

The pre-project work of filtration of canal water and production of electricity involves organized steps. A preliminary study was performed to determine how feasible it is to filter water and generate power from the field channel, the water quality, and the power requirement. At the planning stage, detailed planning is done for both systems. This involves choosing the right technology and equipment for the filtering system and electricity generation. Even after the Sewage treatment processes at the STP, flowing water in the canal contains many impurities, which can adversely affect the health and productivity of the plants, because of this many plants couldn't sustain longer and died, and many other plants got affected by many diseases as well. Such diseases can damage the health of humans also. We noticed this and looked into the problem,

and we analyzed the root cause. After the analysis, we found that the problem is in the water and that's why we decided to filter the water. For filtration, we had to install a filtration unit, for which we needed location and required material. For location, we surveyed and inspected for an entirely suitable site. After this, we selected the right filter media for the impurities we had to filter and decided the size of our filtration unit according to the location. In Dayalbagh 80% of the farming is done organically, and new techniques like greenhouse farming, and polyhouse farming, are used in Dayalbagh. Therefore, the quality of irrigation water should be good and impurities-free. Through soil textural analysis, the soil of Anupam Upwan is found as sandy loam. For the micro-hydro generation device, we measured the flow of water at different locations of the canal because for electricity generation we require a high flow of water in the canal.

2.3 Design and Constriction of Sewage Water Filtration System

This section describes the filters to treat agricultural wastewater, the configuration of the filtration medium is shown in Fig 2. The main materials used in filtration media are gravel, pebbles, natural sand, silica sand, activated carbon, and Michelin cloth. Gravel filters are effective at removing sediment and heavy metals from water, even when water levels vary, or the system becomes clogged. Pebbles act as physical boundaries, trapping particles and provide good structural support, and host bacteria beneficial to biological filtering. Natural sand possesses excellent properties for the efficient removal of suspended particles, sediments, and contaminants. It helps in biological filtering with the help of the organism and natural sand is the same as the soil of the fields. Silica sand is known for its effectiveness in removing suspending pollutants due to its uniformity and size. Activated carbon removes organic pollutants and free chlorine, which plays an important role in preparing water for environmental injection or industrial use. Filter media were placed in a plastic drum, and PVC pipes were used for their corrosion resistance. They are compatible with different fittings, providing long service life and clean installation.

The filter system was constructed by the different layers of filter media and all layers of media are fitted into a plastic drum. After each layer, a layer of Michelin cloth was kept to prevent the erodibility of the filter media. The construction method began by pumping the dirt through a PVC pipe into the inlet section. Water first passes through the gravel that catches large objects, and a stone that holds the bulk. Then, the water passes through natural sand/pebbles which removes bacterial salts, then through charcoal, which removes impurities and chemicals, and finally through silica sand, which purifies impurities.

2.3.1 Laboratory analysis

Water samples from the Anupam Upwan site were collected before and after filtration and were subjected to laboratory analysis to determine pH, total dissolved solids (TDS), and total suspended solids (TSS).

2.4 Design and construction of micro-hydro generation device

This study focused on designing and installing a micro hydro generator device for the farm channel to evaluate its

feasibility for electricity generation from moving irrigation water. The device incorporates components such as PVC pipes, jointers, a dynamo motor, a turbine, a battery, wires, and a DC-DC voltage converter or booster module XL 6009 (Fig 3). For testing and research purposes, two types of motors were used: the RS555, 12-volt DC motor, and a dynamo motor. Site inspections were conducted to verify flow rate, water depth, and stability.

PVC pipe were used because of its low cost, corrosion resistance, and ease of installation. Their lightweight nature makes them particularly suitable for remote areas, while the smooth interior reduces friction losses and improves flow efficiency, providing a flexible approach for micro-hydro generation projects. Connectors play a key role in ensuring safe and efficient connections between pipeline components. These components, acting as connectors, sleeves, tape-fittings, reducers, and adapters, are critical to maintaining the system integrity through proper installation and pressure control. The dynamo motor is an integral part of the device, using electromagnetic induction (EMI) to convert the kinetic energy of water into electrical energy. Connected to a rotor, stator, commutator, and water turbine, the dynamo motor produces voltage and current. Regular maintenance is essential to ensure its efficiency. The turbine itself is essential for converting the kinetic energy of the water into mechanical energy, particularly effective in high head, low flow conditions. Wires are critical for electrical transmission, linking the turbine, dynamo motor, battery, and inverter to ensure efficient power flow. These wires, typically made of copper or aluminum, must be securely connected, insulated, and routed safely. The battery serves as an energy storage unit, capturing electrical energy for later use, thus providing a consistent power supply and load balancing. It is integrated with a charge controller to ensure safe charging and distribution, with regular maintenance and monitoring being crucial for its longevity. Lastly, the DC-DC voltage converter or booster module XL 6009 regulates the output voltage from the dynamo motor, essential for charging or powering devices. These converters, available in Buck, Boost, and Buck-Boost types, ensure efficient power conversion, stability, and protection of electronic components. The module is installed between the motor and the battery or load, connecting the motor output to the devices to maintain a stable and regulated power supply.

The construction of the micro hydrogeneration device involves several key steps to enable low-amount electricity production, contributing to the conservation of natural energy resources. The required materials include a 110-mm T-pipe, two 4-inch pipes, two reducers increasing the velocity (one 110 mm x 63 mm and the other 110 mm x 75 mm), two pipes (75 mm and 63 mm), a 90 mm PVC cap, a 12V DC motor, and a DC-DC voltage converter or booster module XL 6009. To construct the device, 4-inch pipes were jointed to the ends of the T-pipe using an appropriate solution to secure the connections. Next, the reducers were attached to the ends of the 4-inch pipes, and then 75 mm pipe was connected to one end and the 63 mm pipe to the other end of the reducer. The assembly was allowed to dry thoroughly. For the generator assembly, a hole was created in the PVC cap using a soldering gun, and the DC motor was fixed into the cap. Cut turbine blades of 1 x 1 inch were attached to a washer at the top of the motor by soldering. This turbine assembly was inserted into the pipe arrangement. Finally, a battery was connected to store the electricity produced by the micro-hydro generation device.

This construction method demonstrates a practical approach to generating electricity from the flowing irrigation water, utilizing readily available materials and straightforward assembly techniques to harness renewable.

2.5 Results and Discussion

The filtration system considerably improved the quality and appearance of the irrigation water (Fig. 4-5). The TDS and TSS values were significantly reduced, indicating its efficiency in removing dissolved and particulate matter from the water. TDS levels in the incoming sewage water samples were between 895.08 mg l⁻¹ to 960.06 mg l⁻¹ against the maximum limit of 960 mg l⁻¹, as specified by the standards for irrigation water. On the contrary, post-filtration values of TDS were much reduced TDS to the range of 41 mg/l to 49 mg/l (Fig 6), showing that a large amount of dissolved inorganic salts and other compounds have been removed. This could mean that the filtration system is highly effective in removing dissolved impurities, maintaining the safe consumption limit of the filtered water for irrigation purpose. The TSS values (Fig 7) in the raw water samples were between 51.1 mg l⁻¹ and 62.54 mg l⁻¹, which exceeded the recommended limit of 50 mg l⁻¹ for irrigation water. The TSS levels reduced to the range of 41.34 mg l⁻¹ to 44.87 mg l⁻¹ after filtration, indicating high capacity of the filter in the removal of suspended particles such as silt, clay, organic matter, and other impurities. This high improvement indicates that the filtration process is effective in producing clear water by the reduction of particulate matter. The pH levels (Fig 8) in both the water samples were within permissible limits for irrigation. The standard pH range for irrigation water is between 6.5 - 8.4. The pH levels of unfiltered or raw water samples ranged from 7.7 to 8.45, but after filtration (Fig 8), we got the pH levels dropped to between 6.7 and 6.73. It means that the process of filtration hardly affected to keep the chemical stability of the filtered water at suitable conditions for irrigation to the plants. This could probably be because of the removal of some alkaline compounds during the filtration process; this range, however, is within the right scale for domestic purposes as well. Generally, the results of this study highlighted the capability of the filtration system to enhance water quality by significantly reducing dangerously high levels of TDS and TSS, while at the same time maintaining the pH within the safety limits of drinking water.

Despite many attempts to electrify a micro-hydro generator, several challenges were encountered, especially damage of the motor due to water residues and limited space in the channel. The experimental program involved several tests to make the device work well. At the highest speed, the system generated a voltage of 14V, while the average output was recorded at 5.6V. Two different devices were used to achieve these results: an RS555 12V DC motor and a dynamo motor. Each device offered unique advantages and limitations and required further testing and modifications. A DC-DC voltage converter or booster module was added to the system to further increase the voltage output. This module played a key role in increasing the output voltage of the device, significantly from an initial 9V to 48V. This increase was necessary to ensure the reliability and efficiency of micro-hydro generation devices to meet the power demands of various applications. The experiment emphasized the importance of flexibility and innovation in developing sustainable energy solutions at the farm.

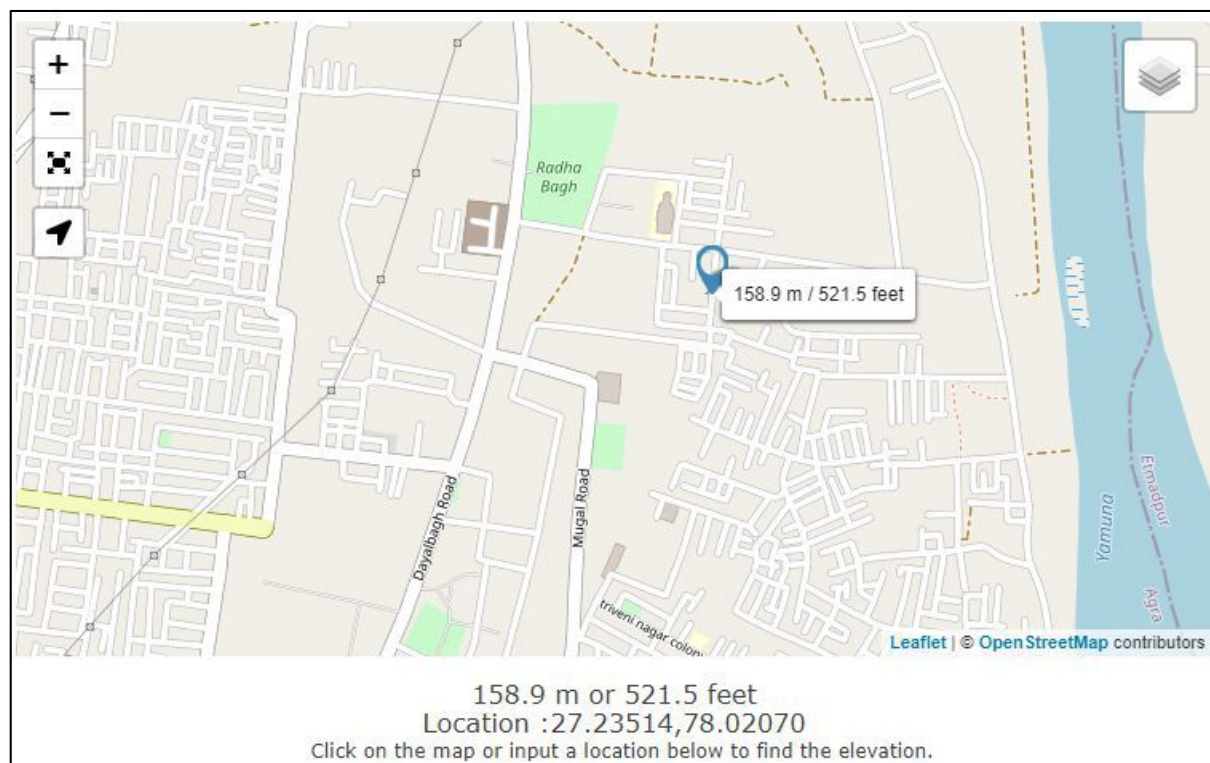
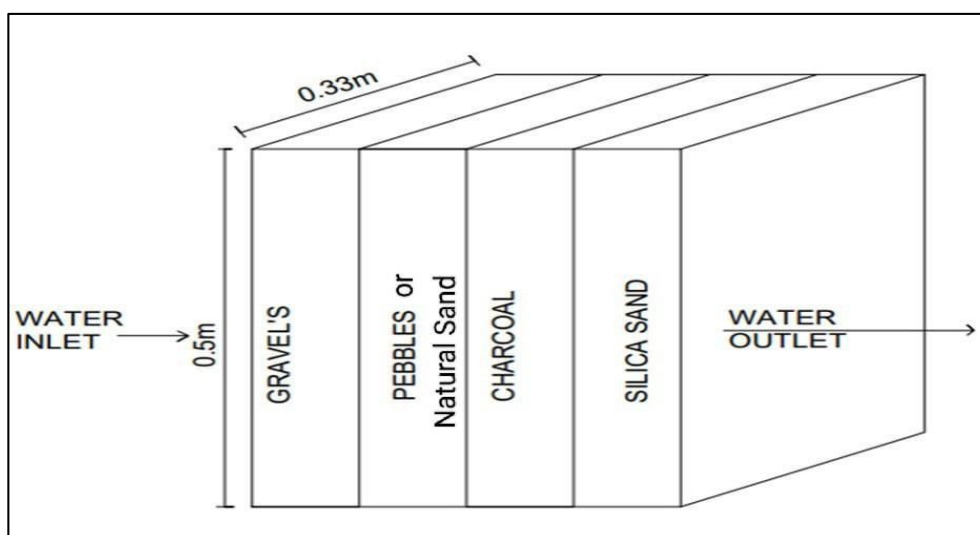
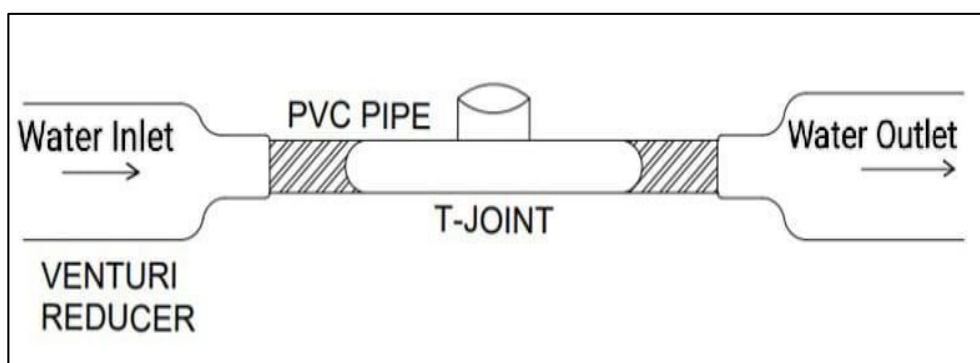
**Fig 1: Study Site****Fig 2: Design of filter media****Fig 3: Design of micro-hydro generation device**



Fig 4-5: STP Water Sample, before and after filtration

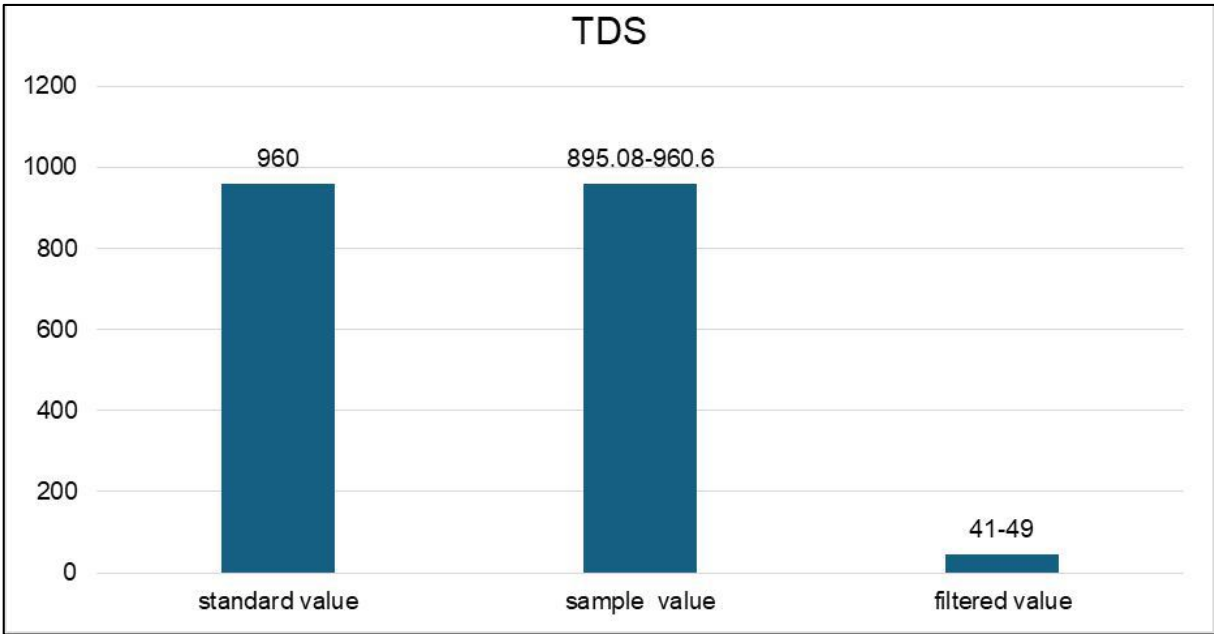


Fig 6: TDS values and Result

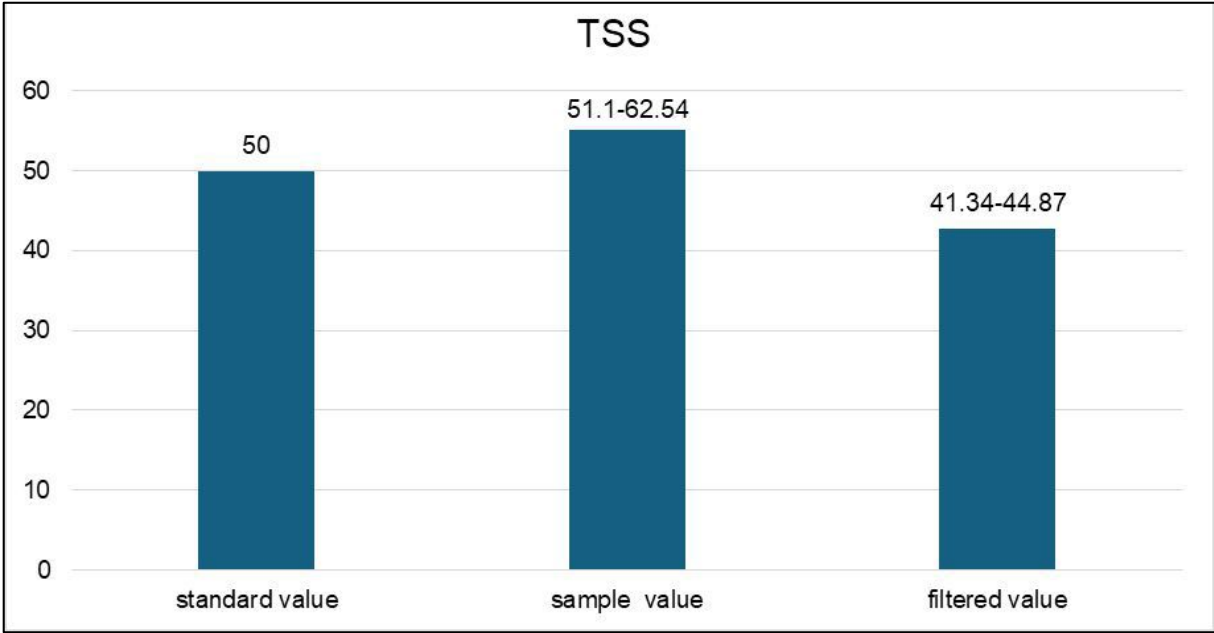


Fig 7: TSS values and Result
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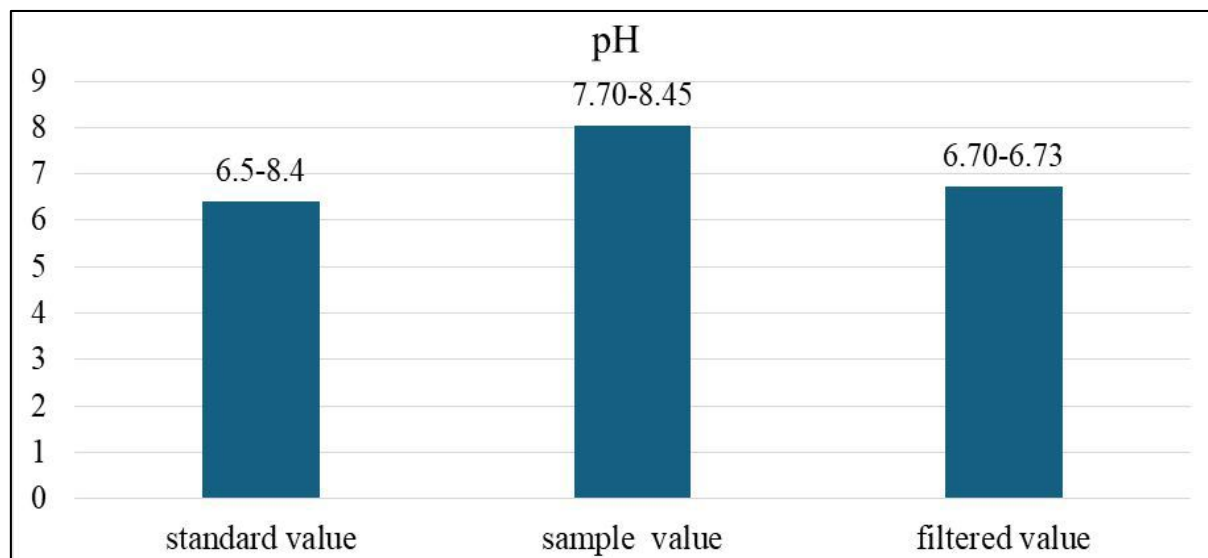


Fig 8: pH Values and Result

3. Conclusion

In conclusion, our findings highlight the significant value of innovative methods and experiments on the optimization of sewage water for irrigation and electricity generation from the same. The implementation of dual separation technologies showed great promise in reducing waste issues, while advances in electricity technologies showed potential for sustainable energy generation from the field channels. Future research and developments are necessary to adapt these technologies for better use in sustainable farm ecosystems. Our research on electricity generation has highlighted the opportunities and limitations of renewable energy use. Despite the initial setbacks, especially water damage to the motor during the first test, the device performance improved dramatically through modifications. We successfully determined the voltage from the motor, and it peaked at 14 volts during the tests and obtained a voltage of 5.6 volts. Furthermore, the addition of DC-DC voltage converters increased the output voltage, laying the foundation for more efficient energy production looking forward, continued research works are very important to modify this technology due to its key role in environmental sustainability. Multi-sectoral development will be essential to achieve greater innovation and success in wastewater treatment and renewable energy. By continuing to explore new ways and overcome challenges, we can pave the way for a cleaner and more sustainable future.

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