International Journal of Advanced Research in Physical Science (IJARPS)
Volume 12, Issue 02, 2025, PP 12-19
ISSN (Online)-2349-7882
www.arcjournals.org

Solar-Powered Water Purification System: Innovations in Photovoltaic Filtration Technologies Utilizing Banana (*Musa*) Peel-Derived Activated Carbon

Reginald A. Omboy[1*], Princess Samantha Kaye C. Carias[1], Shammah Glory Q. Sevilleno[1], Ian Jay P. Saldo, Ph.D[2]

[1]*Integrated Basic Education Department, San Isidro College, Malaybalay City, Bukidnon, 8700, Philippines*

[2]*School of Education, San Isidro College, Malaybalay City, Bukidnon, 8700, Philippines*

Corresponding Author:** ***Reginald A. Omboy, *Integrated Basic Education Department, San Isidro College, Malaybalay City, Bukidnon, 8700, Philippines*

Abstract: *Access to clean drinking water remains a critical challenge in remote areas like Cabulohan, Cabanglasan, and Bukidnon. This study aims to develop a solar-powered water purification system utilizing banana peel-derived activated carbon to improve water quality sustainably. The system harnesses photovoltaic (PV) energy to power a filtration process, integrating UV disinfection and activated carbon filtration to remove contaminants. Water samples were tested for turbidity and pH levels before and after purification. Results demonstrated a significant improvement in water quality. Purified water showed a low turbidity level of 0.37 NTU, well below the DENR standard of 1 NTU, compared to untreated river water, which had an average of 6.5 NTU. The pH of purified water was 7.64, within safe drinking limits, while untreated water had an alkaline pH of 9.38. This study highlights the potential of integrating solar energy with sustainable filtration methods to provide safe drinking water in underserved areas. This would offer an eco-friendly and cost-effective alternative to traditional water purification methods.*

Keywords: *filtration, photovoltaic, solar, turbidity, water quality*

1. INTRODUCTION

Water scarcity remains a pressing global issue, with many communities lacking access to clean drinking water due to rapid population growth and climate change [1]. While solar-powered water purification presents a promising solution, challenges such as limited research on its effectiveness across varying environmental conditions [2], economic feasibility in low-income regions and scalability issues remain [3]. Although innovations like low-cost solar filtration systems have shown potential, real-world validation is necessary to ensure their practicality, requiring further research and development [4].

These systems have the potential to provide clean water access to remote and underserved communities while reducing reliance on traditional energy-intensive and environmentally harmful purification methods [5]. Continued advancements in solar panel efficiency, membrane technologies, and system integration can further improve the cost-effectiveness and scalability of these solutions, contributing to the achievement of sustainable development goals related to clean water and affordable energy [6]. Comprehensive studies on the performance, economic feasibility, and user acceptance of solar-powered filtration systems are essential to drive widespread adoption and ensure long-term sustainability.

Implementing solar-powered water purification systems in Bukidnon, Philippines, represents a significant advancement in addressing the local issues of water scarcity and quality. This innovative solution improves access to clean water and promotes sustainability by harnessing renewable energy resources, effectively meeting the community's critical needs. The region, characterized by its agricultural landscape and remote communities, faces challenges in accessing clean drinking water, mainly where traditional purification methods could be more practical [7]. The Ateneo Innovation Center has pioneered a Solar Clean Water System that utilizes cost-effective materials to create sustainable solutions for clean drinking water. This system incorporates solar energy to power filtration processes, ensuring that water is tested for contaminants like E. coli and coliform, enhancing safety and reliability [8]. Additionally, integrating rain catchment systems and community training programs promotes local engagement and empowers residents to maintain these technologies, fostering health improvements and economic opportunities [9].

Cabulohan, Cabanglasan, faces challenges in accessing clean drinking water due to its remote agricultural setting and the high cost of solar-powered purification systems dominated by large companies. This research aims to address this gap by developing a sustainable, cost-effective system powered by solar energy. Key objectives include designing a modular, self-sustaining system using photovoltaic technology to drive advanced filtration processes tailored to diverse community needs. The system incorporates locally available materials to reduce costs and ensure feasibility for widespread adoption. Additionally, community training programs will empower residents to operate and maintain the system, fostering local ownership and long-term sustainability. By integrating cutting-edge techniques and reducing reliance on fossil fuels, the study seeks to provide a reliable, clean water source, improve health, promote environmental sustainability, and enhance economic opportunities in off-grid areas.

2. METHODOLOGY

2.1. Research Design

This study utilized a research and development (R&D) approach with a quantitative experimental design to develop and evaluate a solar-powered filtration system. The system was designed, prototyped, and refined using advanced photovoltaic technology, with experiments assessing efficiency, water output, and energy consumption under various conditions. Quantitative data was analyzed and compared to safe drinking water standards set by regulatory bodies like DENR and DOH, demonstrating the system's feasibility and potential for broader application. The experimental design employed controlled experiments to examine the effects of independent variables on dependent outcomes, using random assignment to establish cause-and-effect relationships. Researchers manipulated variables, controlled for external factors, and used statistical analysis to validate findings while ensuring internal and external validity for real-world relevance.

2.2. Entry Protocol

Prior to conducting the study, permission letters were sent to key individuals. These letters outlined the study's objectives, methodologies, and ethical considerations, ensuring transparency and compliance with necessary regulations. Approval was sought to conduct research in designated locations and utilize specific resources. The letters also emphasized that all research procedures would adhere to safety protocols and ethical standards.

2.3. Locale of the Study

This research was conducted at the Bobonawan River in Cabulohan, Cabanglasan, Bukidnon (Figure 1). The Bobonawan River, which flows through this region, is a tributary of the larger Pulangi River. Bobonawan River's location and role as a water source for the surrounding communities made it an ideal site for exploring innovations in photovoltaic-driven filtration technologies. To further analyze water quality, turbidity and pH testing was conducted at the San Isidro College Science Laboratory (Figure 2), ensuring accurate and reliable measurements.

Figure 1. *Bobonawan River, Cabulohan, Cabanglasan, Bukidnon*

Figure 2. *San Isidro College Science Laboratory*

2.4. Research Instruments

The researchers employed several instruments to evaluate the solar-powered water purification system. A solar charge controller measures sunlight intensity, critical for determining available energy to power the system. Portable test kits assessed water quality parameters, including pH and turbidity, providing immediate insights into filtration effectiveness. Additionally, a power analyzer measured the solar panels' electrical output and efficiency, ensuring optimal system performance. Together, these tools ensured comprehensive monitoring and evaluation of the system's functionality.

2.5. Data Gathering Procedures

A solar-powered water purification system was installed according to the electrician's specifications, utilizing photovoltaic technology for effective filtration. Water samples were collected from untreated river water, and water purified by the system. These samples were stored in sterile containers under proper conditions to maintain their quality and sent to the San Isidro College Science Laboratory for physicochemical focusing on pH and turbidity. The pH levels were measured using a calibrated pH meter, ensuring accuracy by accounting for sample temperature. This process provided key insights into the water's acidity or alkalinity. Turbidity was assessed with a calibrated meter, with readings recorded in Nephelometric Turbidity Units (NTU) to evaluate water clarity.

2.6. Statistical Treatment

In this study, researchers collected data on turbidity and pH levels from river water and solar-powered purified water, then used descriptive statistics to summarize the results, calculating measures such as mean, median, and standard deviation. A t-test was applied to assess significant differences between the water sources, particularly in turbidity and pH levels, to evaluate the purification system's effectiveness in reducing contaminants. This comprehensive statistical analysis enables meaningful conclusions about the solar-powered system's performance and supports its potential for improving water quality and access to clean water in regions with limited resources.

2.7. Ethical Consideration

The researchers adhered to ethical guidelines, ensuring compliance with the Data Privacy Act of 2012 to protect personal information. This law establishes data collection, processing, storage, and sharing protocols, requiring security measures to uphold privacy rights. Additionally, the researchers declared no conflicts of interest, maintaining independence throughout the study. By following these ethical standards, the researchers promoted responsible data management and fostered public trust in handling personal information.

2.8. Documentation

The researchers implemented thorough data documentation practices to ensure the accuracy and reliability of water quality analysis, including detailed records of data and sampling methods. Photographs were taken during sample collection, and standardized protocols for handling and storage were followed to prevent contamination and maintain sample integrity. Regular calibration was performed to ensure precise measurements, and all data underwent statistical analysis to validate the findings.

3. RESULTS AND DISCUSSION

3.1. The Design of the Solar-Powered Water Purification System

The Solar-Powered Water Purification System features carefully positioned solar PV panels for optimal energy capture. It uses activated carbon from banana peels for effective impurity removal and includes a UV disinfection unit to eliminate microbial pathogens. The feed pump is optimized for efficient water flow without overloading the system. This design enhances purification, energy efficiency, and system durability, making it a reliable, sustainable solution for water purification using renewable energy.

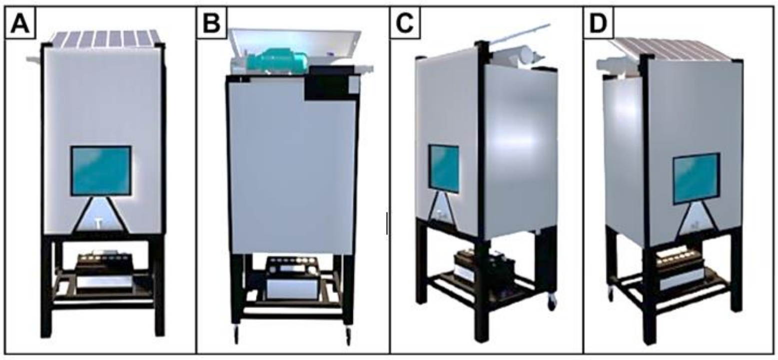

Figure 3. *Digital Sketch of the Solar-Powered Water Purification System.* ***A.*** *Front elevation,* ***B.*** *Rear elevation,* ***C.*** *Right side elevation,* ***D.*** *Left side elevation*

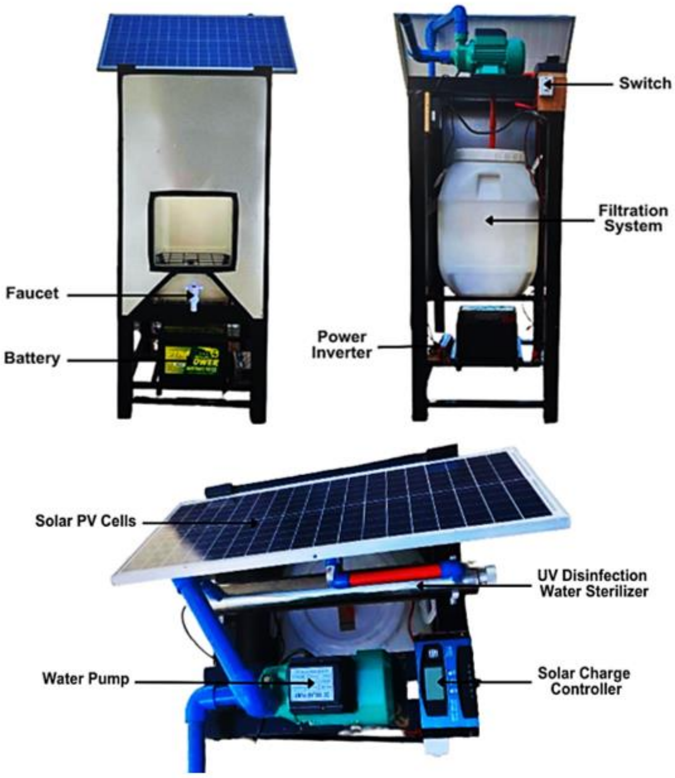

Figure 4. *Model Perspective of the Solar-Powered Water Purification System*

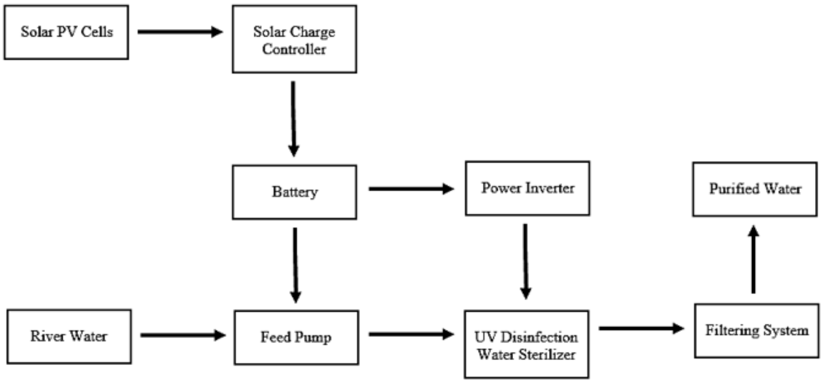

Figure 5. *Flow Diagram of the Solar-Powered Water Purification System*

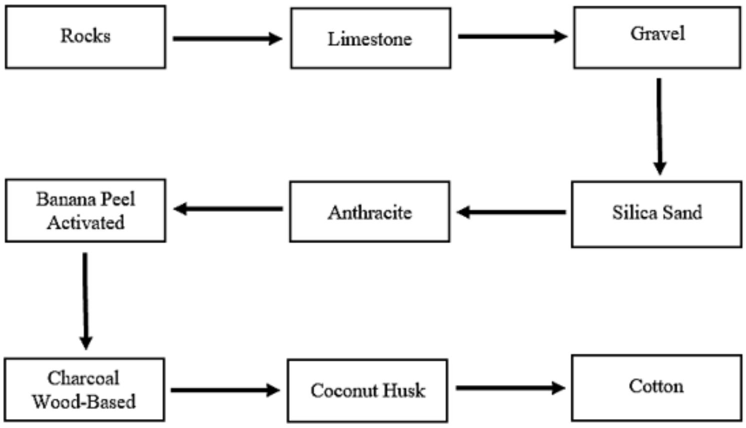

Figure 6. *Flow Diagram of the Filtration System*

The Solar-Powered Water Purification System comprises essential components that work together to ensure efficient water purification. Key elements include a 180-watt water pump [10], 300-watt solar panels [11], a solar charge controller, reliable batteries [12], a 500-watt power inverter, and a 25-watt UV sterilizer. The construction of the system emphasizes structural integrity and operational efficiency. Additionally, PVC pipes transport water between components like pumps and UV sterilizers, while steel provides a durable framework. Plywood serves as a base for mounting key components; the system's electrical functionality is supported by switches for manual control and wires that transfer energy from solar panels to batteries and components; additional features like battery clips and screw nails enhance stability. At the same time, wheels provide mobility for transport to locations. The modular design allows for customization based on specific needs, making it adaptable for various applications. Together, these components create an integrated system capable of delivering safe drinking water effectively while promoting sustainability through renewable energy use.

Moreover, Cotton and coconut husk trap particulates [13], while wood-based charcoal prevents battery issues like overcharging. Banana peel activated carbon stores energy for low sunlight periods [14], and anthracite and silica sand assist in filtration and microbial removal [15]. Gravel, limestone, and rocks balance pH, add minerals, and enhance alkalinity [16]. Together, these components create an efficient system that purifies water, balances pH, and provides safe drinking water.

3.2. Results of the physical properties of water based on the obtained samples

Table1. *Turbidity*

Water Type	**Test 1 (NTU)**	**Test 2 (NTU)**	**Test 3 (NTU)**	**Average**
Purified Water	0.3	0.3	0.5	0.37
Untreated River Water	6.3	6.5	6.7	6.5

Table 1 shows purified and untreated river water turbidity levels across three tests. Purified water had low turbidity values of 0.3 NTU (Tests 1 and 2) and 0.5 NTU (Test 3), averaging 0.37 NTU—well below the DENR standard of 1 NTU. Untreated river water had significantly higher turbidity, averaging 6.5 NTU, indicating harmful particles. This demonstrates the importance of water treatment to ensure safety, as untreated water poses serious health risks. In addition, turbid waters may harbor pathogens or pollutants, posing health risks to humans and wildlife alike [17].

In the study of [18], turbidity is a key parameter in assessing water quality. It is defined as the cloudiness or haziness of a fluid caused by suspended particles that are generally invisible to the naked eye. These particles can include sediments, plankton, and organic matter, which scatter and absorb light, reducing clarity in water bodies.

The results of the physical properties of water, as shown in Table 1, highlight the effectiveness of the Solar-Powered Water Purification System in improving water quality. Table 1 presents turbidity levels measured across three purified and untreated river water tests. The purified water recorded turbidity values of 0.3 NTU in Tests 1 and 2 and 0.5 NTU in Test 3, resulting in an average turbidity of 0.37 NTU. This average is significantly below the DENR standard of 1 NTU for safe drinking water, indicating that the purified water is clear and free from harmful particles. In contrast, untreated river water exhibited much higher turbidity levels with values of 6.3 NTU, 6.5 NTU, and 6.7 NTU across the tests, leading to an average turbidity of 6.5 NTU. This high turbidity suggests a substantial presence of suspended solids and impurities that can pose health risks if consumed.

The findings emphasize the critical importance of adequate water treatment systems in ensuring safe drinking water. The stark contrast between the purified and untreated water highlights how the Solar-Powered Water Purification System successfully addresses water quality issues in remote areas like Cabulohan. The results demonstrate that purified water meets safety standards for turbidity, providing a reliable source of clean drinking water while protecting public health.

3.3. Results of the chemical properties of water based on the obtained samples

Table2. *pH*

Water Type	**Test 1 (pH)**	**Test 2 (pH)**	**Test 3 (pH)**	**Average**
Purified Water	7.65	7.64	7.64	7.64
Untreated River Water	9.39	9.35	9.4	9.38

The results of the pH levels measured in three separate tests for both purified water and untreated river water are presented in Table 2. The purified water recorded 7.65, 7.64, and 7.64 across the tests, resulting in an average pH of 7.64. This average falls within the acceptable range for drinking water as set by the Department of Health (DOH) and DENR, typically between 6.5 and 8.5. These findings indicate that the purified water is safe for everyday consumption and meets health standards. For safety and taste, most drinking water should have a pH between 6.5 and 8.5, and pH can also indicate other contaminants or bacterial growth [20].

In contrast, the untreated river water exhibited higher pH levels of 9.39, 9.35, and 9.40, leading to an average pH of 9.38. This average exceeds the recommended limits for safe drinking water, indicating potential safety concerns for consumption. The elevated pH levels in untreated river water suggest that it may affect taste and pose health risks if consumed over time. The pH scale, ranging from 0 to 14, is a logarithmic measure of the acidity or basicity of water-based solutions, with 7 representing neutrality [21]. Solutions with pH values below seven are considered acidic, with lower numbers indicating higher acidity, while those above 7 are basic or alkaline, with higher numbers signifying increased basicity [22].

The significant difference in pH levels between the two water sources underscores the effectiveness of the Solar-Powered Water Purification System in providing safe drinking water. The purified water's pH levels indicate that it is well within a safe range, while the untreated river water's high pH highlights the necessity of treatment processes to ensure water safety. This disparity emphasizes the importance of utilizing effective purification systems to mitigate risks associated with consuming untreated water, ensuring communities can access clean and safe drinking water.

4. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study successfully developed a Solar-Powered Water Purification System that utilizes banana peel-derived activated carbon to improve water quality. The system is designed with solar photovoltaic (PV) panels that efficiently capture sunlight to provide a reliable power source. It includes a filtration process employing activated carbon specifically designed to remove various impurities and a UV disinfection unit that effectively eliminates harmful microorganisms. This innovative design ensures effective water purification and highlights the potential for sustainable solutions to address water quality challenges.

The Solar-Powered Water Purification System was completed for 10,139 and was built in approximately two weeks. This efficient timeline and cost demonstrate the system's practicality and feasibility as a sustainable water purification solution.

The water quality analysis before and after using the Solar-Powered Water Purification System shows significant improvements in physical and chemical properties. The purified water demonstrated low turbidity levels well below the DENR standard for safe drinking water, while untreated river water exhibited high turbidity, indicating a concentration of harmful particles. Chemical assessments revealed that the average pH of purified water falls within the acceptable range for drinking, whereas untreated river water had a higher pH that exceeds recommended limits.

Significant differences in water properties exist before and after using the solar-powered water purification system. The study confirms substantial reductions in turbidity levels and pH levels in purified water compared to untreated river water. These differences highlight the system's effectiveness in providing safe drinking water that meets health standards. Overall, this research illustrates how combining renewable energy with innovative filtration methods can lead to sustainable solutions for improving community access to clean drinking water while protecting public health through effective treatment systems.

Recommendations include conducting regular assessments and updates to the design of the Solar-Powered Water Purification System to ensure it remains efficient and effective under various environmental conditions; implementing a routine monitoring program to evaluate physical properties such as turbidity and load regularly; expanding chemical property analyses beyond pH levels to include testing for heavy metals and other contaminants; and encouraging further research on the long-term impacts of using the purification system on water quality.

REFERENCES

[1] Salehi, M. (2021). Global water shortage and potable water safety; Today’s concern and tomorrow’s crisis. Environment International, 158, 106936. https://doi.org/10.1016/j.envint.2021.106936

[2] Ukoba, K., Yoro, K. O., Eterigho-Ikelegbe, O., Ibegbulam, C., & Jen, T. (2024). Adaptation of solar energy in the Global South: Prospects, challenges and opportunities. Heliyon, 10(7), e28009. https://doi.org/10.1016/j.heliyon.2024.e28009

[3] Singal, S. K., Goel, V., Nautiyal, H., & Papantonis, D. E. (2023). Economic and financial aspects of small hydropower. In Elsevier eBooks (pp. 245–257). https://doi.org/10.1016/b978-0-323-91757-5.00001-4

[4] Kamyab, H., Khademi, T., Chelliapan, S., SaberiKamarposhti, M., Rezania, S., Yusuf, M., Farajnezhad, M., Abbas, M., Jeon, B. H., & Ahn, Y. (2023). The latest innovative avenues for the utilization of artificial Intelligence and big data analytics in water resource management. Results in Engineering, 20, 101566. https://doi.org/10.1016/j.rineng.2023.101566

[5] NuWater. (2023). The advantages of solar-powered water treatment solutions. NuWater Water Treatment Solutions South Africa. https://nuwater.com/advantages-of- solar-powered-water-treatment-solutions/

[6] Yousef, B. A., Obaideen, K., AlMallahi, M. N., Alajmi, N., Radwan, A., Al-Shihabi, S., & Elgendi, M. (2024). On the contribution of concentrated solar power (CSP) to the sustainable development goals (SDGs): A bibliometric analysis. Energy Strategy Reviews, 52, 101356. https://doi.org/10.1016/j.esr.2024.101356

[7] K. Dikgale, D.F. Ntobela, B.G.V. Mendes, L.K. Tartibu, T.J. Kunene, E. Bakaya-Kyahurwa. 2020. Development of solar-powered water purification systems. 9th International Conference on Appropriate Technology. November 2020. Tshwane University of Technology, Pretoria. pp. 900-919.

[8] Department of Agriculture (Director). (2021). Water Purification with Solar Energy. https://aim2flourish.com/innovations/water-purification-with-solar-energy

[9] Chandak, P. (2023). Philippines: Solar-powered water Systems enhance water access in Barangay Domoit. SolarQuarter. https://solarquarter.com/2023/12/22/philippines-solar-powered-water-systems-enhance-water-access-in-barangay-domoit/

[10] Sinaga, R., Tanesab, J., Beily, M., & Sampeallo, A. (2021). Design and construction of a portable solar water pump 3000 litter per hour. *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science*, 1210–1216. https://doi.org/10.5220/0010962500003260

[11] Kinally, C., Antonanzas-Torres, F., Podd, F., & Gallego-Schmid, A. (2024). Life cycle assessment of solar home system informal waste management practices in Malawi. Applied Energy, 364, 123190. https://doi.org/10.1016/j.apenergy.2024.123190

[12] Hussain, Akhtar & Arif, Syed & Muhammad, Aslam. (2017). Emerging renewable and sustainable energy technologies: State of the art. Renewable and Sustainable Energy Reviews. 71. 12-28. 10.1016/j.rser.2016.12.033.

[13] Katsanou, K., & Karapanagioti, H. (2016). Water supplies: Water analysis. In Elsevier eBooks (pp. 463–469). https://doi.org/10.1016/b978-0-12-384947-2.00742-x

[14] Khalid, M. (2024). Smart grids and renewable energy systems: Perspectives and grid integration challenges. Energy Strategy Reviews, 51, 101299. https://doi.org/10.1016/j.esr.2024.101299

[15] Lakshminarasimhan, R. (2022). Solar-driven water treatment: the path forward for the energy–water nexus. In Elsevier eBooks (pp. 337–362). https://doi.org/10.1016/b978-0-323-90991-4.00008-6

[16] Mattson, M. D. (2021). Acid lakes and rivers. In Kluwer Academic Publishers eBooks (pp. 6–9). https://doi.org/10.1007/1-4020-4494-1_4

[17] Patil, P. & Sawant, D.V. & Deshmukh, R.N.. (2020). Physico-chemical parameters for testing of water - a review. Int. J. Environ. Sci.. 3. 1194-1207.

[18] Ritchie, H., Roser, M., & Rosado, P. (2024). Access to water. Our World in Data. https://ourworldindata.org/water-access River Sediment Dynamics | U.S. Geological Survey. (2019). https://www.usgs.gov/centers/southwest-biological-science-center/science /river-sediment-dynamics

[19] Musie, W., & Gonfa, G. (2023). Fresh water resource, scarcity, water salinity challenges and possible remedies: A review. Heliyon, 9(8), e18685. https://doi.org/10.1016/j.heliyon.2023.e18685

[20] Tantray, J. A., Mansoor, S., Wani, R. F. C., & Nissa, N. U. (2023). pH meter. In Elsevier eBooks (pp. 9–10). https://doi.org/10.1016/b978-0-443-19174-9.00003-9

[21] Du Plessis, A. (2022). Persistent degradation: Global water quality challenges and required actions. One Earth, 5(2), 129–131. https://doi.org/10.1016/j.oneear.2022.01.005

[22] Jones, C., Williams, D. R., & Marsicano, F. (2019). Surface water pH measurements — theory and practice. The Science of the Total Environment, 64(1–2), 211–230. https://doi.org/10.1016/0048-9697(87)90132-x

Citation: *Reginald A. Omboy, et.al., " Solar-Powered Water Purification System: Innovations in Photovoltaic Filtration Technologies Utilizing Banana (Musa) Peel-Derived Activated Carbon " International Journal of Advanced Research in Physical Science (IJARPS), vol 12, no. 02, pp. 12-19, 2025.*