Jurnal Teknik dan Keselamatan Transportasi

ISSN: 2622-0105 (print) | 2716-1196 (online)
http://jurnal.poltekbangmakassar.ac.id/

Design and Development of a Solar Water Treatment Plant Prototype as a Learning Media for Water and Pump Systems at the Makassar Aviation Polytechnic

Sheilla Novita[1], Aifa Jelita[2], Ahmad Rossydi[3], KGS. M. Ismail[4]
[1,2,3]Politeknik Penerbangan Makassar, [4]Politeknik Penerbangan Indonesia Curug

***Correspondence:**
sheillanovi@gmail.com

Article info

Received:12-08-2025
Final Revision:12-12-2025
Accepted:23-12-2025
Available online: 24-12-2025

Keywords:

Prototype, Solar Water Treatment Plant, Renewable Energy, Water Treatment, Learning Media

Reccomended Citation:

APA Style

License:

ABSTRACT

This study discusses the development of a prototype Solar Water Treatment Plant (SWTP) as a learning medium for the Water and Pump System at Makassar Aviation Polytechnic. The background of this research stems from the need for a practical tool to help students better understand how clean-water treatment systems operate, particularly those using renewable energy sources such as solar power. The prototype is designed to harness solar energy as an additional power source to drive several components, including a DC motor that operates the coagulation and flocculation processes. The water treatment process in this device comprises five key stages: coagulation, flocculation, sedimentation, filtration, and disinfection. These stages are arranged to replicate the actual clean-water treatment process and to provide students with a clear, easy-to-understand practical learning experience. This research employs the Research and Development (R&D) approach using the Waterfall model, comprising the following phases: planning, design, construction, testing, and maintenance of the prototype. The device was tested to ensure that each component functions correctly and that the water treatment process meets the expected standards. The testing process was supervised by lecturers who are experts in their respective fields. Test results indicate that the SWTP prototype operates effectively and successfully simulates the clean-water treatment process. Parameters such as pH and Total Dissolved Solids (TDS) changed after passing through all stages of the water treatment process. Moreover, this device provides significant educational benefits for students by enabling hands-on learning and enhancing their understanding of the principles underlying solar-powered water treatment systems. Therefore, this prototype is expected to serve as an engaging learning tool and support the introduction of renewable energy technologies at Makassar Aviation Polytechnic.

INTRODUCTION

The aviation industry depends on clean water as a fundamental resource that supports human survival and enables the operation of its industrial processes. The demand for clean water at airports extends beyond basic needs, as it supports multiple functions, including maintaining sanitation facilities, sustaining operational activities, and ensuring safety through firefighting systems. Airport operations require a dependable water system that provides safe drinking water that fulfills all established quality requirements. The vocational education at Makassar Aviation Polytechnic, which serves industry requirements, needs educational materials that combine theoretical knowledge with practical application and direct student involvement. The current market lacks practical learning tools that replicate the clean-water treatment process while using solar power as a renewable energy source. The project addresses this knowledge gap by developing a Solar Water Treatment Plant (SWTP) prototype that replicates clean-water treatment operations at a reduced scale. The prototype serves two purposes: it demonstrates both the operational capabilities of water treatment facilities and their ability to operate on solar power, aligning with global renewable energy adoption.

The research provides a practical educational resource that aligns with industry requirements and helps students understand airport utility systems, with a focus on water and pump system operations. Through this interactive model, students learn by doing, understand all stages of water treatment, and develop knowledge of how renewable energy supports contemporary infrastructure development. The research addresses an existing knowledge gap, as current studies do not link water treatment systems to educational resources that use renewable energy as their power source. The research addresses the need for new learning materials through an integrated study approach. Samudera (2023) presented a Reverse Osmosis Plant design as an educational tool for maritime students. The researcher developed a system that employed reverse osmosis to convert seawater into potable water. The research focused on its educational role, as it served as a training device that taught cadets water treatment methods. The research findings showed that students achieved a better understanding of water treatment operations through the use of prototype-based learning materials. The system operated only for reverse-osmosis ship applications and did not include renewable power systems.

(Karyadi & Suseno, 2020) The authors developed a control system prototype for an Iron Removal Filter (IRF) operating within a clean-water treatment unit, using a Programmable Logic Controller (PLC). The system is designed to reduce iron (Fe) concentrations, a common problem in groundwater supplies. The research benefits from PLC-based automation, which enhances production speed and reduces human involvement in the process. The system operated on a conventional power source but did not incorporate solar power as a renewable energy source. Prastika et al. (2022) developed a solar-powered desalination prototype to provide clean water to coastal communities. The process involved evaporation of seawater using solar power to produce potable water. The results showed that the system operated at high efficiency when sunlight reached its optimal level. The research demonstrates that solar power can serve as the primary energy source for water treatment operations. The system was designed for desalination but failed to meet the requirements of an educational prototype intended to serve as a training tool for vocational education.

(Akrim et al., 2024) The research team created a solar-powered wastewater treatment facility that combined aerobic and anaerobic biological treatment methods. The system was designed to process domestic wastewater until it met the required water quality standards. The system became self-sufficient because solar panels enabled it to operate independently in regions without a public electricity supply. The research focused on sustainability and energy self-sufficiency, but concentrated on wastewater treatment rather than clean water production, which a Solar Water Treatment Plant would achieve. The four studies demonstrate that solar energy is an effective power source for water treatment systems. Research studies focus primarily on the functional applications of membrane technology, including water purification and wastewater treatment for public water supply and community wastewater management. The field lacks research demonstrating how Solar Water Treatment Plant technology can be used to develop educational prototypes for teaching Water and Pump System subjects in aviation vocational education programs. The present study aims to fill this research gap.

METHOD

The research employed a Research and Development (R&D) approach that followed the Waterfall development model. The process consists of five stages: Planning to identify learning targets and system needs; Design to create the SWTP prototype layout; and Construction to build the 2-meter-tall prototype with its five treatment stages and solar panel system. The system requires testing to verify the operational performance of all treatment stages and energy generation components. The system requires maintenance to check component reliability and operational simplicity for extended educational purposes.

The requirement analysis stage of the first phase required researchers to determine whether to develop an interactive educational device to demonstrate the complete clean-water treatment process at a reduced scale. At this point, the researcher determined that the prototype must include all essential water treatment plant operations: coagulation, flocculation, sedimentation, filtration, and disinfection. The team chose to add solar power functionality to the prototype because it would enable students to learn about renewable energy through the operation of electrical and mechanical systems.

The system design stage of the second phase involved developing comprehensive mechanical and electrical designs for the prototype. The water treatment section comprised multiple interconnected tanks, serving as separate stages in the treatment process. The coagulation tank enables rapid mixing of raw water with coagulants during the process. The flocculation tank enables slow water mixing, which helps flocs to develop appropriately. The treatment process would start with a sedimentation tank, which allows particles to settle by gravity before moving to a filtration unit containing silica sand, activated carbon, and zeolite for odor and fine-particle removal, and would end with UV disinfection to eliminate microorganisms. The team created two separate designs: the water treatment system and the solar power system layout. The system included a 50 Wp photovoltaic panel, a 10 A solar charge controller, a 12 V 14 Ah battery, and a DC pump. The design allowed for effective solar energy collection, which could be stored and used to operate the system.

The third stage of implementation required the team to build the prototype according to their pre-designed plan. The frame construction used lightweight materials, providing both stability and portability for classroom demonstrations. The tanks followed the water treatment process sequence via PVC pipes, with valves that regulated water distribution. The filtration unit received its media in the correct order, in accordance with standard procedure for water treatment facilities. The solar panel received maximum sunlight exposure due to its strategic placement, while all electrical components met the design requirements for connection to the charge controller and battery.

The testing phase began after prototype assembly, during which the device was operated on unprocessed water samples to assess its operational effectiveness. The testing process evaluated water quality improvements using pH and Total Dissolved Solids (TDS) measurements taken at the start and end of the treatment process. The energy performance of the solar power system was tracked by measuring panel output, battery voltage, and pump operating time under varying sunlight levels. The stage demonstrated that the prototype could perform water treatment operations using solar power alone.

The deployment stage began after testing, during which the prototype was evaluated in classrooms to assess its potential as an educational resource. Students operated the system to observe all water-treatment stages while learning about the integration of solar power with utility systems. The deployment provided essential feedback that guided maintenance and refinement, resulting in minor changes to simplify system use, improve water circulation performance, and maintain consistent water quality.

The black-box testing method was used to validate the prototype's functionality. The method assesses system performance through input-output testing, which does not require component internal inspection (Ambarsari et al., 2021). The testing procedures included: (1) Measuring voltage and current output from the solar panel under varying sunlight conditions. (2) The SCC (solar charge controller) needs testing to verify its ability to control energy transmission. (3) I observed how the battery and DC motors operated during the test. (4) The system requires visual water quality monitoring at all treatment stages to check for turbidity and clarity changes before and after each stage. (5) The UV disinfection stage requires evaluation through pH and TDS measurements, which should be taken before and after the treatment process. The test results were evaluated against the predicted system behavior to verify that the prototype met its dual objectives of educational value and operational water-treatment capabilities.

The prototype validation testing was conducted under the supervision of Mr. Yustin Saranga S.T. M.M., a lecturer specializing in solar cells and a member of the Airport Technology Study Program team. The supervision process verified both the accuracy and reliability of the collected data and assessed whether the prototype met its designed operational goals.

System Design

The first converts sunlight into electrical energy using solar panels, which serve as the system's primary power source. The generated electricity is directed to a battery via a Solar Charge Controller (SCC), which regulates and stabilizes the current before charging the 12V battery, ensuring safety and efficiency. The stored energy is then used to power two DC motors—one for high-speed mixing and the other for slow-speed mixing—whose speeds are controlled by a Pulse Width Modulation (PWM) system according to the treatment stage. Meanwhile, a 220V AC grid-supplied pump delivers raw water from the source to the coagulation tank.

In the coagulation stage, the first DC motor runs at high speed to mix the water with a coagulant, such as alum, causing fine particles to clump into flocs. The water then flows into the flocculation tank, where the second DC motor rotates slowly to promote floc growth without fragmentation. Next, the water enters the

DOI: http//doi.org/10.46509/ajtk.v8i2.765

sedimentation tank, where the flocs settle at the bottom, and the clear water from the top flows into the filtration stage. During filtration, the water passes through media layers of silica sand, activated carbon, and zeolite stones, which remove remaining impurities and improve its physical and chemical quality. Afterward, the water flows into the disinfection tank, where a 5-Watt UV lamp eliminates bacteria, viruses, and other microorganisms. Finally, the clean water is stored in a reservoir for sanitation, testing, or educational use.

Device Components

In the design of the Solar Water Treatment Plant (SWTP) prototype, various hardware components are used to ensure optimal performance in the water treatment process. Each element has a specific function that is integrated with the others, starting from raw water intake, filtration, and disinfection, to the storage of treated water. The selection of components was based on technical requirements, operational efficiency, and compatibility with the prototype's scale.

The following is a description of the hardware components used, along with their functions: (1) The Sedimentation tank serves as a medium for settling water during the treatment process. (2) PVC Pipes function as water distribution channels between each stage of the treatment process. (3) Pump delivers water to the treatment stages with sufficient pressure. (3) Filter Housing contains the filter media to remove dirt, fine particles, and harmful substances from the water before it is used or consumed. (4) Control Valve Regulates the direction and volume of water entering each treatment stage. (5) Silica Filter, removes larger particles such as silt, sand, and coarse debris from the water. (6) Activated Carbon Filter Adsorbs unpleasant odors, colors, and tastes from the water. (7) Zeolite Filter, removes iron (Fe) and manganese (Mn) content from the water. (8) Reservoir – Stores the treated water before distribution. (9) PVC Pipes (½-inch), the selected size is adequate for water flow in the simulation system. (10) Solar Charge Controller (SCC) regulates the electric current from the solar panel before it is stored in the battery. (11) Battery stores the electrical energy generated by the solar panel for use at night or during cloudy weather. (12) PWM (Pulse Width Modulation) controls the speed of the DC motors according to the process requirements.

Device Design

The first step in designing a Solar Water Treatment Plant (SWTP) prototype is to create a block diagram, which serves as a basic representation of the system. This diagram outlines the main components and their functions, ensuring that the overall design aligns with the research objectives. The block diagram of the system is shown in the image below.

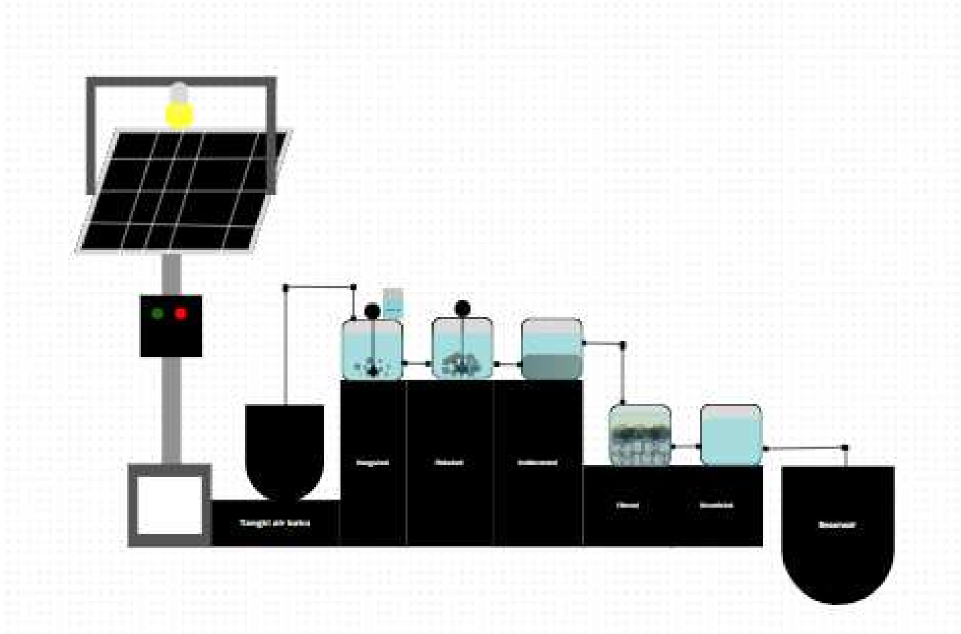

Figure 1 Device Design

The design of the Solar Water Treatment Plant (SWTP) comprises a multistage system that uses solar energy as the primary power source for the water treatment process. The process is arranged sequentially, from raw water intake to the production of clean water for sanitation and educational activities.

The following is a description of each component: (1) A 50 Wp solar panel is mounted on a vertical frame to capture sunlight and convert it into electrical energy. This energy is directed to a solar charge controller, which regulates and stabilizes the current before storing it in a 12V battery. (2) The raw water is stored in the initial tank before being pumped into the treatment system. (3) Coagulation Tank, a coagulant (such as alum/$Al_2(SO_4)_3$) is added to bind fine impurities into larger clumps. The mixing process is carried out by a high-speed DC motor (rapid mixing). (4) Flocculation Tank, water from the coagulation stage flows into the flocculation tank, which is equipped with a DC motor running at low speed. The purpose is to allow flocs to grow larger without disintegrating. This process is done through gentle stirring (slow mixing). (5) Sedimentation Tank, the water then enters the sedimentation tank, where the formed flocs settle at the bottom. The clear water from the upper layer flows to the next stage. (6) Filtration Unit, clear water is passed through a filter housing that contains three layers of filtration media: silica sand (top layer), activated carbon (middle layer), and zeolite stones (bottom layer). (7) Disinfection Tank: The filtered water enters the disinfection tank, which is equipped with a 5-Watt UV lamp. Ultraviolet light is used to inactivate microorganisms and pathogenic bacteria. (10) Clean Water Reservoir, lean water from the disinfection tank flows into the final reservoir, which serves as the final storage before the water is used or further tested.

Testing Techniques

At this stage, testing is conducted using black-box testing, focusing on individually testing each component of the Solar Water Treatment Plant (SWTP) prototype to ensure that all parts function according to the design. The testing process is conducted under the direct supervision of a lecturer with expertise in the relevant field, ensuring that each evaluation stage is performed accurately and objectively. This method aims to verify the performance of each component without examining the internal circuitry or code, but rather by assessing the output produced in response to the given input.

RESULTS AND DISCUSSION

The author proposes to develop a Solar Water Treatment Plant Prototype that will serve as an educational tool for students at Makassar Aviation Polytechnic to learn about water and pump systems. The educational trainer will help students understand the design and operational aspects of solar-powered water treatment systems, which they will likely encounter during their fieldwork. The research establishes a new practical learning approach which enhances student learning efficiency and effectiveness at the Makassar Aviation Polytechnic. The Solar Water Treatment Plant is a simulation system that models the complete water treatment process, including coagulation and flocculation, sedimentation, filtration, and disinfection, and uses solar power as one of its energy sources.

The research by Aiswarya et al. (2018) demonstrated that photovoltaic-powered pumping systems function properly in rural settings. The research by Tahraoui et al. (2024) demonstrated that solar-based treatment units help decrease the need for fossil fuels. Wibowo & Chang (2020) showed, in their Indonesian study, that the implementation of solar panels for clean water treatment in remote locations reduced operational expenses while enabling local communities to generate their own energy.

The research by Ismail et al. (The research team from 2019) developed a Solar Water Treatment Device (SWAD) prototype. The research followed a design process that began with a CAD-based initial design, then selected aluminum for the frame structure, added a 250 W solar panel, and conducted field tests on the pump and filtration system.

The solar panel generated varying power levels, as shown in Table 1, throughout the day. The highest power output occurs during the midday hours between 12:00 and 14:00, when solar radiation reaches its maximum intensity (Gevorkov et al., 2023). The power output of solar panels typically decreases during the morning and late afternoon hours. The solar panel produces sufficient electrical power to operate the DC motor, as indicated by these measurement results, which show the highest output during peak sunlight. The SCC successfully charged the battery, demonstrating that the power management system operates properly and provides a stable power supply for system operation.

Table 1 Testing of Solar Panel Output Entering the SCC

Waktu	Tegangan (Volt)	Arus (Ampere)	Daya (Watt)
08.00 AM	11.05	0.4	3
09.00 AM	11.95	0.4	3
10.00 AM	12.45	0.4	2
11.00 AM	13.28	0.6	4
12.00 PM	13.37	0.7	6
1.00 PM	13.40	0.7	6
2.00 PM	12.8	0.6	5
3.00 PM	12.91	0.8	6
4.00 PM	13.01	0.6	4

The Solar Charge Controller (SCC) performed effectively, maintaining the battery voltage at 12.65 V and ensuring optimal charging. This result supports the Techno-economical Study of Solar Water Pumping System, which notes that pairing an SCC with appropriately sized batteries maintains continuous system operation.

In the coagulation–flocculation stage, jar tests using alum (aluminum sulfate) identified an optimal dose of 25 g/L, producing stable, well-formed flocs that settled effectively. This dosage is consistent with findings by Tahraoui et al. (2024) and Husaini et al. (2020), which note that coagulation effectiveness depends heavily on coagulant concentration and the raw water's initial characteristics. The pH drop from 6.68 to 3.83 upon alum addition indicates its acidic nature and warns that low pH can degrade water quality for direct consumption. Total Dissolved Solids (TDS) increased from 196 ppm to 980 ppm, consistent with the theory that coagulant addition increases dissolved ion concentrations.

The raw water is mixed with a coagulant, aluminum sulfate (alum), dissolved in water. An appropriate coagulant dosage is required for effective coagulation. If the added dosage is too low, flocs will not form. Conversely, if the dosage is excessive, the flocs formed may be imperfect due to changes in the solution's pH(Mayasari et al., 2019).

In line with Haghiri et al. (2018), the alum dosage was determined using a jar test to identify the most effective Aluminum Sulfate (alum) dosage for floc formation. This test was conducted by preparing sample variations at different alum dosages, each mixed with 1 liter of clean water.

Table 2 Testing of Samples

No.	Sample	Dosage (grams/liter)	Visual Observation Results
1.	Sample 1	15	No floc formation
2.	Sample 2	16	No floc formation
3.	Sample 3	20	No floc formation
4.	Sample 4	25	Small flocs began to appear
5.	Sample 5	33	No floc formation

The jar test results showed that sample 4, with 25 grams of alum, achieved the best coagulation performance. Floc formation at this dosage rate produced a uniform distribution across the water column, while the supernatant showed a significant improvement in clarity, with only small amounts of sediment remaining. The treatment process produced insufficient coagulation at lower dosages because it produced unstable flocs that were smaller. Sedimentation became excessive at high dosages, potentially causing adverse effects on subsequent treatment stages. The researchers determined that 25 grams was the optimal dose for subsequent treatment phases.

The coagulation process began after dosage optimization, when 25 g of alum dissolved in 1 L of water was added to 5 L of raw water. The rapid mixing process was operated for 5 minutes to achieve complete distribution of the coagulant throughout the solution and to break down suspended particles in the water. The stage showed the first signs of fine floc formation, indicating that particles had begun to collide and form their first aggregates. The methodical treatment method follows automation-based system design principles, which require consistent, repeatable operations to produce dependable results, according to Muhammad Fikri, Rossydi, and Risal (2024) in their research on IoT-based learning media systems.

The research findings from Putri et al. (The flocculation stage required slow stirring for 10 minutes to enable fine flocs from coagulation to merge into bigger settleable aggregates, 2024). The stage required no additional chemical reagents; therefore, the pH remained at 3.83 and the TDS at 975 ppm. The stable water composition indicates that flocculation primarily altered particle dimensions rather than altering the water's chemical properties.

The flocs settled effectively during the sedimentation stage, resulting in a transparent water layer above the sediment after 30 minutes. The rapid settling pattern indicates that the coagulation–flocculation process produced flocs that reached appropriate dimensions and weight, according to Putri et al. (2024). The sedimentation process must operate at maximum efficiency because it reduces the number of particles that reach the filtration stage, thereby enhancing the overall performance of the treatment system.

Water quality improved after filtration using a three-layer media system comprising silica sand, activated carbon, and zeolite. The TDS level after coagulation decreased from 980 ppm to 116 ppm, and the solution became more transparent. The research results align with those of Kustanto et al. (2025), who demonstrated that this filtration system, employing multiple media, effectively removed suspended particles, organic compounds, and specific metal contaminants.

The first filtration layer consists of silica sand, which removes both residual turbidity and particulate matter. Farras Fadillah et al. (2025) showed that silica sand filtration reduces water turbidity and removes heavy metals, including iron (Fe) and manganese (Mn), from river water using a system that begins with coarse filters followed by fine filters.

The second treatment layer consists of activated carbon, which improves process efficiency by adsorbing contaminants. Activated carbon serves as a well-documented material that effectively removes organic compounds, odors, color, and heavy metals from water. Research using coconut shell-based activated carbon has demonstrated that this material is effective for treating acidic water and removing organic contaminants. Activated carbon enhances both taste and odor quality, which are essential sensory characteristics of safe drinking water. The research findings from Dina Devy et al. (The research by Wang et al. (2024)) show that activated carbon functions as a surface adsorption material, which helps eliminate heavy metals from water.

The zeolite filtration layer operates via ion-exchange processes, thereby effectively removing dissolved metal ions from water. The research conducted by Khimayah (2021) in Sidoarjo showed that zeolite media reduced iron concentrations in clean water sources by 87%, depending on particle size. The three filtration media work together to achieve optimal treatment performance following sedimentation in conventional and decentralized water treatment systems employing this configuration.

The final treatment phase employed UV disinfection to eliminate all pathogenic microorganisms. The pH rose to 7.3 after UV exposure, bringing the solution near neutral, but TDS measurements remained stable, indicating that UV treatment primarily affects biological components rather than chemical substances. The study did not perform microbiological analysis, but its disinfection method follows the principles demonstrated by MacIsaac et al. (2024), who showed that UV disinfection system performance depends on three main factors: radiation dose, exposure time, and water turbidity. The initial turbidity reduction improved UV light transmission through the water, thereby increasing the treatment process's effectiveness.

The treated water met all essential quality standards required for sanitation. The Indonesian standards require water used for sanitation to maintain pH levels between 6.5 and 8.5 while keeping TDS concentrations at or below 500 mg/L. The treated water met all requirements, demonstrating its readiness for use in sanitation and hygiene operations. The Kementerian Kesehatan Republik Indonesia (2023) requires sanitation and hygiene facilities to meet water quality standards, necessitating proper management of these parameters to protect public health and environmental sanitation.

Table 3 Indicators of Success

Testing Activity	Expected Outcome	Test result	Conclusion
Solar Panel Testing	Generate voltage and current	The solar panel operated optimally, activating both DC motors	The solar panel works well
Solar Charge Controller (SCC) Testing	Able to regulate incoming voltage and current	Successfully regulated voltage and current and charged the battery	The solar charge controller works well
Battery Testing	Charges according to specifications	When comparing the measured voltage value with the battery specifications, the battery specification shows 12 V, and the measurement result is 12.65 V	The battery is in good condition
Coagulation Process Testing	Formation of flocs	Flocs formed after the addition of coagulant	Rapid mixing and coagulant addition worked well
Flocculation Proces	Flocs enlarge and do not break apart	Flocs did not break apart	Slow mixing kept the flocs intact
Sedimentation Process	Flocs settle and clear water begins to appear	Flocs settled after a while, and clear water began to appear on top	The sedimentation process worked well in separating flocs from clear water
Water Flow to Filtration Tube	Water becomes clearer than before	Water became clear	The filter media worked well
Disinfection Process using UV Sterilizer	Water pH and TDS values change	pH and TDS values changed	The disinfection process worked well

The research resulted in a small-scale Solar Water Treatment Plant (SWTP) prototype that functions as a learning medium for the Water and Pump System course at the Makassar Aviation Polytechnic. The prototype was designed to simulate the clean-water treatment process, using solar energy as the primary power source. In addition to serving as an educational tool, it introduces the concept of renewable energy utilization in water treatment technology.

The development process began with the identification of classroom learning needs, followed by system design, component selection, assembly, and testing. The main components include a 50 Wp solar panel, a solar charge controller (SCC), a 12V 14Ah battery, 12V DC motors, a water pump, process tanks, a 5W UV lamp, and a filtration system comprising silica sand, activated carbon, and zeolite. All components were mounted on a wooden frame, with ½-inch PVC piping and vertically arranged tanks to utilize gravity-assisted flow.

The prototype operates by capturing solar energy through the panel, which is then routed via the SCC to the battery for energy storage. Raw water is pumped into the coagulation tank, where a coagulant, such as alum, is added and stirred by a high-speed DC motor. The water then flows into the flocculation tank, where it is stirred at a slower speed to form larger flocs. The next stage is sedimentation, in which flocs settle to the bottom of the tank, while the clear water on top flows into the filtration unit containing silica sand, activated carbon, and zeolite layers. After filtration, the water enters the disinfection tank, where it is exposed to UV light before being collected in the final reservoir.

Functional testing using the black-box method demonstrated that all components functioned as intended. The solar panel generated stable voltage and current from 08:00 to 16:00; the SCC effectively regulated power flow to the battery, and the battery was able to store up to 12.65V, exceeding its nominal capacity. The DC motors operated effectively during coagulation and flocculation, while the pump delivered consistent water flow. The filtration stage produced visibly clear water, and UV disinfection resulted in significant changes in pH and TDS values.

Visual observation revealed a clear transformation from start to finish. Before treatment, the water appeared turbid due to suspended particles; after coagulation, white flocs formed; after flocculation and sedimentation, the water became clearer, with sediment at the bottom; filtration produced clear, odorless water; and following UV disinfection, water quality improved and became suitable for sanitation or educational purposes.

In terms of advantages, this prototype can operate on solar power, has a simple and easy-to-understand system, and allows students to interact directly with the water treatment process. However, it also has limitations, including the absence of automatic sensors or microcontroller-based controls, limited treatment capacity, and the absence of microbiological laboratory testing.

Based on these findings, the SWTP prototype accurately represents the operational principles of a small-scale clean-water treatment installation powered by renewable energy. Moreover, it is effective as an interactive learning tool, providing students with hands-on experiences that align with prior research emphasizing the importance of prototypes in technical education for enhancing students' practical understanding.

CONCLUSION

The device's design began with a thorough collection of information on the tool's requirements and specifications. After gathering the necessary data, a systematic plan was developed to cover the design, materials, and processes for building the prototype. The prototype was then constructed according to the established design. The next stage involved component-level testing to ensure that each part functioned properly. Testing was conducted comprehensively until the entire system operated optimally and met the intended objectives. The development of the device began with a comprehensive needs assessment to identify all necessary system functions, technical specifications, and educational learning objectives. The first stage required gathering data on water treatment methods, equipment supply, and system limitations to confirm that the tool would function as both a practical solution and an educational resource. The collected data enabled the development of a systematic design plan that included system architecture, material selection, component arrangement, and construction methods. The design phase ended when the team built the prototype based on the specifications that they had created during the design phase. The system underwent component-level testing to confirm that all system parts, including mixing units, filtration media, and disinfection components, operated correctly and reliably. The evaluation of each system component was conducted before the components were integrated into the complete system. The system underwent sequential testing, enabling engineers to detect failures at their first occurrence to improve system operation and reliability. The testing process followed an iterative pattern until the complete system achieved the specified performance level and met all specified requirements.

The prototype underwent complete operational testing after successful component validation, during which the full water treatment process was executed through its five stages: coagulation, flocculation, sedimentation, filtration, and disinfection. The students operated these processes manually to observe the physical and chemical changes that occurred during each treatment step. The learners observed floc formation, sediment settling, and changes in water clarity using visual methods, which helped them link classroom theories to real-world environmental processes. The developed prototype functions as both a technical simulation of solar-powered water treatment systems and an educational tool that enables students to learn through direct experience. Students who participate in treatment process activities develop a better understanding of system mechanics, operational principles, and process interaction patterns. The research results demonstrate that the developed prototype functions as an educational simulation tool that provides practical learning experiences to students at Makassar Aviation Polytechnic through interactive technology-based education.

REFERENCES

Aiswarya, L., Arunadevi, K., Lalitha, R., & Vallalkannan, S. (2018). Performance Evaluation of Solar Photovoltaic Water Pumping System. *International Journal of Current Microbiology and Applied Sciences*, *7*(12), 2627–2632. https://doi.org/10.20546/ijcmas.2018.712.298

Akrim, D., Swandi, A., Buraerah, M. F., Irwandi, A., Sariman, S., & Hamsina. (2024). Design of Prototype of Solar Power Based Waste Water Treatment Plant. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3072–3079. https://doi.org/10.29303/jppipa.v10i6.6895

Ambarsari, L. S., Puspitasari, W., & Syahrina, A. (2021). Perancangan Modul Landing Page Dan Pembayaran Pada Website Pahamee Tentang Kesehatan Mental Menggunakan Metode Extreme Programming. *E-Proceeding of Engineering*, *8*(5), 9639.

Dina Devy, S., Miranda, V., Nugroho, W., Magdalena, H., & Hasan, H. (2024). Pemanfaatan karbon aktif tempurung kelapa untuk pemenuhan baku mutu air tanah untuk pH, Mn dan Fe di Muara Badak, Kutai Kertanegara Kalimantan Timur. *ANDIL Mulawarman Journal of Community Engagement*, *1*(2), 30–34. https://doi.org/10.30872/andil.v1i2.1226

Farras Fadillah, R., Endah Badriani, R., & Almas Fildzah, C. (2025). Efektivitas Media Filter Pasir Silika dan Arang Ampas Tebu untuk Menurunkan Warna Menggunakan Filtrasi Upflow. *Rekayasa*, *18*(1), 9–19. https://doi.org/10.21107/rekayasa.v18i1.24483

Gevorkov, L., Domínguez-García, J. L., & Romero, L. T. (2023). Review on Solar Photovoltaic-Powered Pumping Systems. *Energies*, *16*(1). https://doi.org/10.3390/en16010094

Haghiri, S., Daghighi, A., & Moharramzadeh, S. (2018). Optimum coagulant forecasting by modeling jar test experiments using ANNs. *Drinking Water Engineering and Science*, *11*(1). https://doi.org/10.5194/dwes-11-1-2018

Husaini, A., Yenni, M., & Wuni, C. (2020). Efektivitas Metode Filtrasi Dan Adsorpsi Dalam Menurunkan Kesadahan Air Sumur Di Kecamatan Kota Baru Kota Jambi. *Jurnal Formil (Forum Ilmiah) Kesmas Respati*, *5*(2), 91. https://doi.org/10.35842/formil.v5i2.323

Ismail, I. N. Bin, Khean, F. F., Zawawi, M. H., Zahari, N. M., Abidin, S. Z., Yusairah, W. N., Zuhdi, A. W. M., Eqwan, M. R., Mohamed, H., Ramli, M. Z., Mansor, M. H., Syaifoelida, F., Zakaria, A. A., Isa, M. R., Mohamad, D., Jaafar, M. F., Rahmat, N. A., & Rahman, M. S. A. (2019). Development of solar powered water treatment device (SWAD) prototype. *AIP Conference Proceedings*, *2129*. https://doi.org/10.1063/1.5118027

Karyadi, K., & Suseno, J. E. (2020). Rancang Bangun Prototipe Sistem Kendali Iron Removal Filter (IRF) pada Unit Pengolahan Air Bersih Berbasis PLC. *Gema Teknologi*. https://doi.org/10.14710/gt.v20i2.23100

Kementerian Kesehatan. (2023). Permenkes No. 2 Tahun 2023. *Kemenkes Republik Indonesia*, *55*, 1–175.

Khimayah. (2021). *Variasi Diameter Zeolit Untuk MEenurunkan Kadar Besi (Fe) Pada Air Sumur Gali*. *3*.

Kustanto, P., Ramadhan, B. K., & Noe, A. (2025). *Penerapan Metode Prototype dalam Perancangan Media Pembelajaran Interaktif*. *5*(1), 83–94.

MacIsaac, S. A., Reid, B., Ontiveros, C., Linden, K. G., Stoddart, A. K., & Gagnon, G. A. (2024). UV LED wastewater disinfection: The future is upon us. *Water Research X*, *24*(June), 100236. https://doi.org/10.1016/j.wroa.2024.100236

Mayasari, R., Hastarina, M., & Apriyani, E. (2019). Analisis turbidity terhadap dosis koagulan dengan metode regresi linear (studi kasus di PDAM Tirta Musi Palembang). *Jurnal Integrasi Sistem Industri*, *6*(2).

Muhammad Fikri, Rossydi, A., & Risal, A. (2024). Design of a Security Cameras for Smart Rooms Based on Internet of Things (IoT) as an Automation Learning Media at Makassar Aviation Polytechnic. Airman: Jurnal Teknik Dan Keselamatan Transportasi, 7(2), 14–29. https://doi.org/10.46509/ajtk.v7i2.510

Prastika, J., Mutia, E., & Lydia, E. N. (2022). Rancang Bangun Prototipe Desalinator Untuk Memenuhi Kebutuhan Air Bersih Pada Desa Meurandeh Kecamatan Manyak Payed. *Teras Jurnal : Jurnal Teknik Sipil*, *12*(1), 307. https://doi.org/10.29103/tj.v12i1.734

Putri, E. A., Rahayu, R. D., Maryanty, Y., & Hidayat, V. (2024). Analisis Penggunaan Koagulan Pada Pengolahan Hard Water Dengan Metode Koagulasi Flokulasi Di Pt Petrokimia Gresik. *DISTILAT: Jurnal Teknologi Separasi*, *10*(3), 542–553. https://doi.org/10.33795/distilat.v10i3.6228

Samudera, G. A. (2023). *Program studi teknika diploma iv politeknik ilmu pelayaran semarang 2023*.

Tahraoui, H., Toumi, S., Boudoukhani, M., Touzout, N., Sid, A. N. E. H., Amrane, A., Belhadj, A. E., Hadjadj, M., Laichi, Y., Aboumustapha, M., Kebir, M., Bouguettoucha, A., Chebli, D., Assadi, A. A., & Zhang, J. (2024). Evaluating the Effectiveness of Coagulation–Flocculation Treatment Using Aluminum Sulfate on a Polluted Surface Water Source: A Year-Long Study. *Water (Switzerland)*, *16*(3). https://doi.org/10.3390/w16030400

Wibowo, A. I., & Chang, K. C. (2020). Solar energy-based water treatment system applicable to the remote areas: Case of Indonesia, Arsanto Ishadi Wibowo and Keh-Chin Chang. *Journal of Water, Sanitation and Hygiene for Development*, *10*(2), 347–356. https://doi.org/10.2166/washdev.2020.003