

SOLAR-POWERED RAINWATER AND WELL WATER TREATMENT FOR SUSTAINABLE SCHOOL WATER

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ABSTRACT

Purpose: This study evaluates the implementation of an integrated solar-powered rainwater harvesting, well water, and treatment system at SMAN 12 Padang as an alternative source of non-potable clean water and a green-school technology. **Design/methods/approach:** The intervention integrated rooftop rainwater collection, well water, staged filtration, photovoltaic power, and IoT-based monitoring. Water quality was evaluated before and after filtration using temperature, pH, total dissolved solids (TDS), turbidity, iron (Fe), and zinc (Zn). System implementation also included a 600 Wp photovoltaic array, water filtration units, and real-time monitoring. **Findings/results:** Before treatment, two source samples showed acidic pH (5.60 and 5.19), TDS of 408 and 320 ppm, and high turbidity of 209 and 281 NTU. After filtration, the measured water quality improved to 28 °C, pH 6.9, TDS 198 ppm, turbidity 4 NTU, Fe 0.110 ppm, and Zn below the limit of detection. The IoT dashboard also recorded post-treatment values of 25.1 °C, pH 6.14, and TDS 182 ppm during system operation. **Conclusions:** The integrated system substantially improved the measured physicochemical quality of the available water and demonstrates the feasibility of combining rainwater and well water utilization, filtration, solar energy, and digital monitoring for sustainable school water management. Further routine microbiological testing and long-term performance monitoring are required before making drinking-water claims.

Keywords: Rainwater harvesting; Solar energy; Water filtration; IoT monitoring; Green school

INTRODUCTION

Water availability, sanitation, and energy efficiency are closely connected challenges in educational facilities. Schools with large student populations require reliable water supplies for toilets, cleaning, canteens, landscaping, and other non-consumptive uses. At the same time, dependence on conventional water and grid electricity can increase operational costs and reduce resilience when supply disruptions occur.

SMAN 12 Padang has approximately 1,230 students and a large roof area that can function as a rainwater catchment. The source report identifies recurring water-quality problems, including turbid groundwater, while the local climatic context provides substantial rainfall and solar-energy potential. These conditions create an opportunity to integrate rainwater harvesting with renewable energy and water-treatment technologies.

Rainwater harvesting has been widely studied as a strategy for sustainable water management, while solar-powered pumping and treatment technologies can reduce dependence on conventional electricity. However, the practical integration of rainwater harvesting, well water, multistage filtration, photovoltaic power, and IoT-based water-quality monitoring in a school environment remains an important applied research area. The present work therefore focuses on the performance and implementation of an

integrated Rainwater Harvesting, well water, and Processing–Solar (RWHP-Solar) system in a secondary-school setting.

The novelty of this study lies in the school-scale integration of four components within one operational intervention: rainwater capture and well water, staged water treatment, photovoltaic energy supply, and real-time IoT monitoring. The study aims to describe the system configuration, compare selected water-quality parameters before and after filtration, and assess its potential contribution to sustainable water and energy management at SMAN 12 Padang

MATERIALS AND METHODS

2.1 Study Site and System Design

The study was conducted at SMAN 12 Padang, Gurun Laweh, Nanggalo District, Padang City, West Sumatra, Indonesia. The school has approximately 1,230 students and provides a relevant setting for an applied water-conservation intervention.

The implemented technology was an integrated RWHP-Solar system. Rainwater from rooftop catchment areas and well water are conveyed through piping and filtration units, collected, and distributed to meet the school's water needs.

The broader system design included a first-flush concept, multimedia filtration, solar-powered pumping, and IoT monitoring of selected operational and water-quality parameters. The installed renewable-energy component reported in the implementation stage consisted of a 600 W on-grid tie inverter and approximately 600 Wp of photovoltaic modules. The monitoring architecture used sensors for parameters such as pH and TDS and was designed to support real-time observation by school operators.

2.2 Water Quality Measurement

Water samples were evaluated before and after filtration. The reported parameters were temperature, pH, total dissolved solids (TDS), turbidity, Fe, and Zn. The source report identifies turbidimetry, a pH meter, and atomic absorption spectrometry (AAS) among the analytical equipment. Two source-water samples were characterized before treatment, while a post-filtration sample was analyzed after the treatment process.

2.3 Data Analysis

The analysis was descriptive and comparative. Pre-treatment and post-treatment values were tabulated and percentage reductions were calculated where the same parameter was available. Because the source report does not provide replicate measurements, standard deviations, inferential statistics, or microbiological data, the results are interpreted as implementation-performance observations rather than a controlled efficacy trial.

RESULT

3.1 Baseline Water Quality

The untreated source-water samples showed acidic conditions and substantial turbidity. Sample 1 had pH 5.60, TDS 408 ppm, and turbidity 209 NTU, while Sample 2 had pH 5.19, TDS 320 ppm, and turbidity 281 NTU. These results indicate that treatment was necessary before the water could be considered suitable for routine clean-water applications.

Table 1. Water-quality measurements before and after filtration.

Sample	Temp. (°C)	pH	TDS (ppm)	Turbidity (NTU)	Fe (ppm)	Zn (ppm)
Before 1	29.3	5.60	408	209	Not reported	Not reported
Before 2	29.7	5.19	320	281	Not reported	Not reported
After filtration	28.0	6.90	198	4	0.110	<LOD

3.2 Post-Filtration Performance

After filtration, the water sample showed pH 6.9, TDS 198 ppm, turbidity 4 NTU, Fe 0.110 ppm, and Zn below the analytical limit of detection. Relative to the two untreated samples, the post-treatment turbidity value represents a reduction of approximately 98.1% compared with Sample 1 and 98.6% compared with Sample 2. TDS decreased by approximately 51.5% and 38.1%, respectively. The shift in pH toward neutral conditions is also operationally important because acidic source water can increase corrosion risks in distribution components.

The IoT dashboard provided an additional operational snapshot after treatment, recording a temperature of 25.1 °C, pH 6.14, and TDS 182 ppm. The difference between laboratory and dashboard readings should not be interpreted as disagreement without synchronized sampling and calibration information; instead, it demonstrates the role of continuous sensing as a complementary operational tool.

3.3 Integration Of Solar Energy And Digital Monitoring

The 600 Wp photovoltaic installation and 600 W grid-tie inverter provide a renewable-energy component for the school water-management intervention. Combining water conservation with renewable energy is relevant to SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The IoT layer further supports preventive maintenance and operational awareness by making selected parameters visible to school operators.

From an educational perspective, the system can also function as a living laboratory. Students can observe the relationship among rainfall, water quality, filtration, energy generation, and resource efficiency. This creates an applied environmental-learning context beyond the immediate infrastructure benefit.

3.4 Potential Water Availability And School Application

The source report estimates a roof catchment area of approximately 1,500 m² and describes Padang as having high annual rainfall. Using the program's design assumptions, the system has substantial theoretical rainwater-harvesting potential, while the operational target is at least 500 L/day of treated water for non-consumptive uses. Such water can support toilets, cleaning, and other school functions, thereby reducing pressure on conventional supply sources.

The intervention is particularly relevant for school resilience because it combines decentralized water storage with local energy generation. Nevertheless, actual annual yield depends on rainfall distribution, runoff losses, storage capacity, system downtime, maintenance, and user demand. Long-term metering is therefore necessary to quantify real water savings and energy performance.

3.5 Limitations

This study is based on implementation data from a community-service program. The available dataset does not include repeated laboratory measurements, microbiological testing, synchronized sensor validation, long-term energy-production records, or a control site. Consequently, the findings support the technical feasibility and observed improvement of measured physicochemical parameters, but they do not establish drinking-water safety or long-term treatment efficacy. Future work should include microbial indicators, replicated sampling across seasons, sensor calibration, energy-yield analysis, maintenance-cost evaluation, and user acceptance.

CONCLUSION

The integrated RWHP-Solar system at SMAN 12 Padang demonstrates a practical approach to sustainable school water management by combining rainwater and well water utilization, filtration, photovoltaic energy, and IoT monitoring. The available measurements show substantial improvement after filtration, particularly in turbidity, TDS, and pH, with post-treatment values of pH 6.9, TDS 198 ppm, turbidity 4 NTU, Fe 0.110 ppm, and Zn below the limit of detection. The system also creates opportunities for resource conservation and environmental learning. Continued laboratory monitoring, especially microbiological analysis, together with long-term water-volume and energy measurements, is needed to validate performance and guide replication in other schools.

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