

# Community-Based Rainwater Harvesting and Simple Water Treatment System to Improve Domestic Water Security in Rural Indonesia

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**Abstract.** Limited access to clean water remains a major challenge in many rural areas of Indonesia, particularly during dry seasons when groundwater availability decreases and water quality deteriorates. This community service program was conducted in a rural neighborhood community in Palembang to improve household water security through the implementation of a community-based rainwater harvesting system integrated with a simple gravity-driven filtration unit. The program was implemented using participatory methods, including preliminary assessment, technical design, collaborative construction, community training, and post-installation monitoring. A total of 10 households participated in the program. The installed system consisted of rooftop rainwater collection, a first-flush diverter, storage tanks with capacities of 1000–2000 L, and a slow sand filtration unit constructed from locally available materials. Evaluation results indicated increased water availability during dry periods, reduced dependence on shallow groundwater sources by approximately 30–40%, and improved physical water quality, particularly in reducing turbidity and suspended particles. Community members also demonstrated improved understanding of system operation, maintenance procedures, and hygienic water management practices. The findings show that low-cost and appropriate water technology combined with active community participation can effectively improve domestic water resilience and support sustainable water management in rural communities.

**Keywords:** appropriate technology, community empowerment, rainwater harvesting, rural water supply, slow sand filtration, water security.

## 1. Introduction

Access to adequate, safe, and sustainable water resources remains a fundamental challenge in rural development. In many regions of Indonesia, domestic water supply systems are still characterized by high dependency on shallow groundwater, limited infrastructure, and minimal water treatment practices [1]. Seasonal rainfall variability further exacerbates water insecurity, particularly during prolonged dry periods when groundwater tables decline and water availability decreases significantly [2].

In addition to quantity constraints, water quality deterioration presents a parallel concern. Shallow groundwater sources are highly vulnerable to contamination from surface runoff, septic systems, and improper waste disposal, resulting in increased turbidity and reduced suitability for domestic use [3]. Climate variability further intensifies the unpredictability of water availability, where short but intense

rainfall events often lead to rapid surface runoff rather than effective storage, causing significant loss of potential water resources [4].

Rainwater harvesting (RWH) has been widely recognized as a decentralized and environmentally sustainable solution to improve water availability. At the household scale, rooftop catchment systems provide a practical means of converting rainfall into usable domestic water [5]. When combined with appropriate treatment technologies, harvested rainwater can serve as a reliable supplementary water source.

However, technical performance alone does not guarantee long-term sustainability. In many rural communities, water infrastructure projects have faced challenges due to limited technical knowledge, lack of maintenance planning, and insufficient community ownership. Therefore, integrating engineering design with participatory approaches is essential to ensure system sustainability and long-term functionality [6].

The concept of appropriate technology becomes central in this context, where water supply systems must be affordable, simple to operate, energy-efficient, and constructed using locally available materials. Gravity-driven slow sand filtration offers a suitable solution for improving physical water quality without requiring electricity or complex operational procedures.

This community service program was designed as an integrated intervention combining rainwater harvesting, simple gravity filtration, and structured community training [7]. The program emphasizes technical feasibility, economic affordability, environmental sustainability, and community empowerment as key components of rural water security.

The specific objectives of this study are: (1) to increase household water availability during dry periods through rooftop rainwater harvesting, (2) to improve physical water quality using a gravity-based slow sand filtration system, (3) to enhance community capacity in operating and maintaining decentralized water systems, and (4) to promote sustainable water management behavior at the household level. By addressing both technical and social dimensions, this study proposes a replicable model for improving rural domestic water resilience through community-based implementation of appropriate water technology [8].

## **2. Methodology of Implementation**

The community service program was conducted from January to March 2026 in a rural neighborhood area of Palembang involving 10 households experiencing seasonal water scarcity. The community partner was a local RT-level community group that participated actively throughout the program. The implementation team consisted of eight members, including lecturers, students, and technical assistants. Team responsibilities included field assessment, technical design, construction supervision, and community training.

The methodology combined technical implementation and participatory community engagement through four stages: (1) preliminary assessment, (2) technical design, (3) construction and training, and (4) monitoring and evaluation.

### *2.1. Preliminary Assessment*

The preliminary assessment aimed to identify existing water supply conditions, estimate household water demand, and evaluate the feasibility of rainwater harvesting as a supplementary water source. A field survey was conducted through household observations and semi-structured interviews to collect data on primary water sources, water consumption, seasonal shortages, storage capacity, and community readiness.

Roof type, material, slope, and effective catchment area were also evaluated to determine the suitability for rooftop rainwater harvesting [9]. Basic physical water quality assessment included visual clarity observation, simple turbidity comparison, sedimentation testing, and odor identification.

Community meetings were conducted to discuss local water challenges, implementation plans, and maintenance responsibilities [10]. The assessment showed that households experienced recurring water shortages during dry periods and relied mainly on shallow groundwater sources with declining availability.

## 2.2. Technical Design

The technical design stage translated assessment results into a household-scale rainwater harvesting and filtration system. System sizing considered roof catchment area, rainfall characteristics, and estimated household water demand. Potential rainwater volume was estimated based on rainfall depth, roof area, and runoff efficiency coefficient [11].

The system consisted of rooftop catchment, PVC gutters and downpipes, a first-flush diverter, a 1000–2000 L storage tank, and a gravity-based slow sand filtration unit. The first-flush diverter was used to separate initial runoff containing dust and debris from the roof surface before entering the storage tank.

The filtration unit was designed as a vertical column consisting of gravel, coarse sand, and fine sand layers to improve physical water quality. The system operated entirely under gravity flow without electricity to reduce operational costs and technical complexity [12]. Hydraulic head differences between the storage tank and filter outlet were adjusted to maintain continuous water flow.

## 2.3. Construction and Community Training

Construction activities were carried out collaboratively between the implementation team and local residents to strengthen community participation and system ownership [13]. The activities included installation of gutters and piping systems, assembly of the first-flush diverter, installation of storage tanks, and preparation of sand and gravel filtration media.

The filtration unit was assembled as a gravity-based slow sand filter connected directly to the storage tank outlet. Particular attention was given to leakage prevention, structural stability, and hygienic handling of filter media.

Community training was conducted using a hands-on approach covering rainwater harvesting principles, filtration mechanisms, routine maintenance, media cleaning procedures, and safe water handling practices. Residents also participated directly in several installation activities under team supervision to improve practical understanding and reduce dependency on external technical support.

## 2.4. Monitoring and Evaluation

Monitoring was conducted for three months after installation to evaluate system performance and community adaptation. Evaluation indicators included rainwater storage volume, groundwater use reduction, water clarity improvement, maintenance practices, and user satisfaction.

Water storage conditions were observed using tank level markers, while groundwater use reduction and user responses were assessed through household interviews comparing pre- and post-intervention conditions [14]. Water quality improvement was evaluated through visual turbidity comparison before and after filtration. The evaluation results were documented to support future system improvement and replication.

## 2.5. Participatory Approach Framework

Beyond technical implementation, the methodology emphasized participatory engagement as a core component. Community members were actively involved in identifying local water-related problems, participating in decision-making during system design selection, contributing to collaborative construction activities, and sharing responsibility for routine system maintenance. This participatory approach strengthened local accountability, improved community ownership, and ensured that the implemented system aligned with actual community needs rather than externally imposed solutions [15].

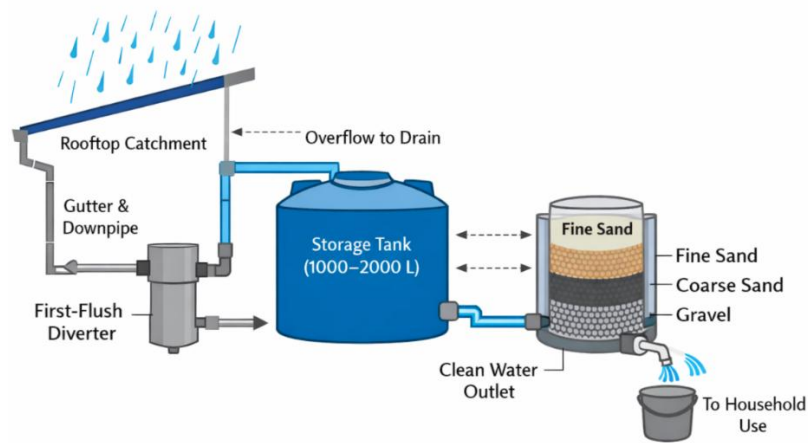
# 3. Results and Discussion

## 3.1. System Performance Improvement

The implementation of the rainwater harvesting system improved household water storage capacity and reduced dependence on shallow groundwater sources during dry periods [16]. Before the intervention, most households relied mainly on shallow wells with limited water availability during peak dry months.

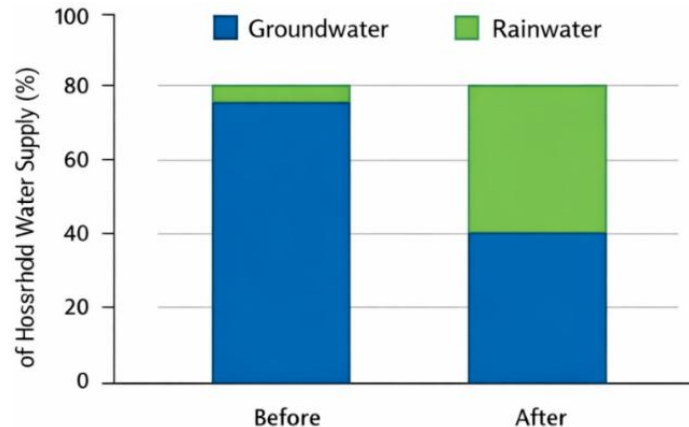
Figure 1 presents the configuration of the implemented household rainwater harvesting and gravity-based filtration system. The system consisted of rooftop rainwater collection, PVC gutters, a first-flush

diverter, a 1000–2000 L storage tank, and a slow sand filtration unit operating under gravity flow without electricity.



**Figure 1.** Schematic diagram of household rainwater harvesting and gravity filtration system.

The installed system was directly utilized by participating households and functioned as a household-scale water supply system rather than a laboratory prototype. Following installation, households obtained an additional water storage capacity of 1000–2000 L, providing approximately 3–7 days of supplementary water supply. Monitoring results showed a reduction in groundwater use by approximately 30–40%. To evaluate changes in household water use, a comparison of water sources before and after implementation is presented in Figure 2.



**Figure 2.** Comparison of household water sources before and after system installation.

Figure 2 indicates increased utilization of harvested rainwater and reduced groundwater dependency after system installation. These results demonstrate that the system effectively improved household water resilience and supported more sustainable local water management.

### 3.2. Water Quality Enhancement

Physical water quality improvement was one of the most observable outcomes of the program. Before filtration, harvested rainwater occasionally contained suspended particles originating from roof surfaces, dust accumulation, and minor organic debris [17]. After passing through the slow sand filtration unit, water clarity improved visibly. Sedimentation tests using transparent containers showed a substantial reduction in suspended solids. The top fine sand layer functioned as the primary filtration barrier, while underlying coarse sand and gravel layers supported hydraulic stability and particle

retention. To provide a direct visual representation of the improvement in physical water quality, a comparison of harvested rainwater samples before and after filtration is presented in Figure 3.



**Figure 3.** Visual comparison of harvested rainwater before and after filtration.

As shown in Figure 3, the filtered sample appears significantly clearer than the unfiltered sample, indicating effective removal of suspended particles and improved physical water quality. This improvement increased community confidence in using harvested rainwater for domestic purposes. Although laboratory-based microbiological testing was not conducted, the observed reduction in turbidity suggests that the filtration system enhanced key physical parameters of water quality. Community feedback further confirmed improved aesthetic acceptability, particularly for washing, bathing, and cleaning activities [18]. The effectiveness of the system is also supported by the use of a first-flush diverter, which minimizes initial roof contaminants entering the storage tank. Overall, the system improved physical water characteristics and user acceptance, supporting its long-term utilization.

### *3.3. Community Capacity Development*

Beyond technical outcomes, the program significantly improved community capacity in understanding and managing the system. Prior to the intervention, knowledge of rainwater harvesting and filtration mechanisms was limited. After training, participants were able to understand system components, operate the first-flush diverter, perform routine inspections, and conduct basic maintenance such as sand layer scraping. Hands-on involvement during construction enhanced learning retention and practical skills. Community members actively participated in system installation, strengthening their understanding and reducing dependency on external assistance.

Maintenance compliance during the monitoring period was satisfactory, with most households following recommended procedures. This indicates that the participatory approach effectively increased community ownership and responsibility. Overall, improved technical capacity contributed to the long-term sustainability of the system.

### *3.4. Sustainability and Replicability*

The implemented system demonstrates strong sustainability characteristics from technical, economic, and social perspectives. From a technical standpoint, the system operates entirely under gravity, eliminating dependence on electricity. This reduces operational costs and ensures functionality even during power interruptions. Economically, construction costs remained relatively affordable due to the use of locally available sand and gravel materials, standard PVC piping components, commercially available polyethylene storage tanks, and simple fabrication methods that did not require specialized equipment or advanced technical expertise.

Maintenance requirements are minimal and do not require specialized skills or external technical support. Environmentally, reduced groundwater abstraction contributes to improved local water balance

management. Rainwater harvesting also reduces surface runoff, potentially decreasing localized erosion and drainage burden during rainfall events.

Socially, the participatory approach enhanced community ownership, increasing the likelihood of long-term adoption and replication. Several households expressed interest in expanding storage capacity or assisting neighboring families in constructing similar systems. Given its affordability, technical simplicity, and adaptability, the model is highly replicable in rural areas with similar climatic conditions and infrastructure limitations. Scaling up through community clusters or village-level programs could amplify water security impacts.

#### 4. Technical Considerations

##### 4.1. Storage Capacity Estimation

Storage tank capacity was determined using a simplified household water balance approach, considering domestic water demand, rainfall characteristics, roof catchment area, and anticipated dry-period duration. Average non-potable water demand was estimated at 50–80 L/person/day. Rainwater harvesting potential was calculated based on catchment area, rainfall, and a runoff coefficient of 0.75–0.85 for metal roofing using Equation (1).

$$V = R \times A \times C \quad (1)$$

Where  $V$  is the estimated harvestable rainwater volume (m<sup>3</sup>),  $R$  is rainfall depth (m),  $A$  is roof catchment area (m<sup>2</sup>), and  $C$  is the runoff coefficient representing collection efficiency. To ensure reliability during dry periods, a storage buffer of 7–14 days was applied. Based on these parameters, a tank capacity of 1000–2000 L per household was considered sufficient while remaining economically feasible. Oversizing was avoided to reduce costs and minimize the risk of water stagnation [19].

##### 4.2. Filtration Media Configuration

The slow sand filtration unit was designed as a vertical gravity-driven column with layered media consisting of fine sand (0.15–0.35 mm; ±40–50 cm), coarse sand (±15–20 cm), and graded gravel (±15–20 cm). The fine sand layer acts as the primary filtration medium, removing suspended solids and supporting the formation of a biological layer (schmutzdecke), while the underlying layers provide structural support, maintain hydraulic conductivity, and prevent clogging. Prior to installation, all media were washed to remove fine particles. The unit was elevated to ensure sufficient hydraulic head for gravity-driven flow, with a low flow rate maintained to enhance contact time and filtration efficiency.

##### 4.3. Maintenance Strategy

Long-term system performance depends on simple and consistent maintenance that can be independently carried out by households. Routine maintenance includes cleaning the first-flush chamber after rainfall, periodic scraping of the top 1–2 cm sand layer to restore flow, monthly inspection of pipe connections, and storage tank cleaning every 3–6 months to remove sediment [20].

The fine sand layer requires only periodic surface treatment, with full replacement typically after 1–2 years. Maintenance costs remain low, mainly for minor repairs and cleaning. Practical guidelines were provided during training, emphasizing preventive maintenance to ensure system sustainability. The key technical specifications and design parameters of the implemented system are summarized in Table 1.

**Table 1.** Technical design parameters of the system

No.	Design Component	Parameter	Specification	Design Rationale
1	Roof catchment	Runoff coefficient	0.75–0.85	Adjusted for metal roofing to estimate effective harvestable volume

No.	Design Component	Parameter	Specification	Design Rationale
2	Storage tank	Capacity	1000–2000 L	Sized to provide 7–14 days buffering during dry periods
3	Storage tank	Material	Polyethylene (HDPE)	Durable, corrosion-resistant, low-cost
4	First-flush diverter	Function	Initial runoff separation	Prevents roof debris and contaminants from entering tank
5	Filtration unit	Fine sand layer thickness	40–50 cm	Primary sediment retention and turbidity reduction
6	Filtration unit	Fine sand effective size	0.15–0.35 mm	Optimized for slow sand filtration efficiency
7	Filtration unit	Coarse sand thickness	15–20 cm	Supports hydraulic stability
8	Filtration unit	Gravel thickness	15–20 cm	Prevents media washout and supports drainage
9	System operation	Flow mechanism	Gravity-driven	Eliminates need for mechanical pumping
10	Maintenance	Tank cleaning interval	Every 3–6 months	Prevents sediment accumulation
11	Maintenance	Sand surface scraping	Periodic (as needed)	Restores hydraulic conductivity
12	Performance indicator	Estimated groundwater reduction	30–40%	Based on household survey comparison
13	Maintenance	Fine sand replacement	Every 1–2 years	Maintains filtration performance and hydraulic conductivity
14	Maintenance	First-flush cleaning	After major rainfall events	Prevents debris accumulation and contamination
15	Economic aspect	Estimated implementation cost	IDR 2.8–5.6 million/household	Considered affordable for community-scale application

These design considerations ensured that the system remained technically feasible, economically affordable, and operationally sustainable at the household scale. Routine maintenance includes periodic cleaning of the first-flush chamber, storage tank inspection, and surface scraping or replacement of the fine sand layer when needed. The estimated implementation cost of the system is presented in Table 2.

**Table 2.** Estimated cost of system implementation

No	Component	Estimated Cost (IDR)
1	PVC gutter & pipes	500,000 – 800,000
2	First-flush diverter	150,000 – 300,000
3	Storage tank (1000–2000 L)	1,500,000 – 3,000,000
4	Sand & gravel media	100,000 – 250,000
5	Filtration unit container (drum/tank)	300,000 – 600,000
6	Labor (if applicable)	300,000 – 700,000

No	Component	Estimated Cost (IDR)
	Total	2,850,000 – 5,650,000

The total estimated construction cost per household ranged between IDR 2.8 million and 5.6 million, depending on tank capacity, material availability, and local labor costs. The storage tank constitutes the largest cost component, accounting for more than 50% of total investment. Despite this, the system remains economically feasible for rural communities, particularly when implemented through community-based initiatives or partial financial support programs. The use of locally available materials further reduces construction costs and enhances accessibility.

## 5. Acknowledgment

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## 6. Conclusion

The implementation of the community-based rainwater harvesting and gravity-driven filtration system successfully improved household water availability and reduced dependence on shallow groundwater sources during dry periods. The system also improved physical water quality through simple slow sand filtration using locally available materials.

The participatory approach enhanced community understanding, ownership, and maintenance capacity, supporting long-term system sustainability. Due to its low-cost, electricity-free operation, and technical simplicity, the system demonstrates strong potential for wider application in rural communities facing similar water supply challenges.

## 7. Referensi

- [1] Taus, M. N. P. (2025). Transformasi Pendidikan Melalui Teknologi Deep Learning: Peluang dan Tantangan di Dunia Pendidikan Indonesia. SEMNASFIP, 2(2), 2360-2370.. Available: <https://jurnal.umj.ac.id/index.php/SEMNASFIP/article/view/28563>
- [2] M. H. S. Putra, "Analisa Komposisi Sampah yang Dihasilkan Berdasarkan Sifat dan Karakternya di Kampus Institut Teknologi Sumatera 2023," *CIVeng: Jurnal Teknik Sipil dan Lingkungan*, vol. 6, no. 1, pp. 13–18, Jan. 2025, doi: 10.30595/CIVENG.V6I1.24156.
- [3] Westari, N., & Sumarsono, R. B. (2025). Tantangan dan Peluang Transformasi Manajemen Pendidikan di Era Digital (Tinjauan Literatur Sistematis). Proceedings Series of Educational Studies.. Available: <http://conference.um.ac.id/index.php/pses/article/view/10270>
- [4] P. Mesara Averoes and U. Sultan Ageng Tirtayasa, "Analisis Tantangan dan Peluang Transformasi Pendidikan Inklusi Sains dan Teknologi untuk Mencapai Sustainable Development Goals (SDGs) 2030," *prosiding.unipar.ac.id*, Accessed: Dec. 31, 2025. [Online]. Available: <https://prosiding.unipar.ac.id/index.php/seminalu/article/view/54>
- [5] M. Hakiem and S. Putra, "Analisis Kebutuhan Air Irigasi Menggunakan Software Cropwat 8.0 (Studi Kasus: Daerah Irigasi Sekampung Batanghari)," *MEDIA KOMUNIKASI TEKNIK SIPIL*, vol. 30, no. 2, pp. 246–255, Mar. 2025, doi: 10.14710/MKTS.V30I2.66772.

- [6] M. Hakiem and S. Putra, "Penerapan pemanenan air hujan dalam menyediakan air domestik dan mengurangi debit drainase di daerah perkotaan," *REKAYASA: Jurnal Ilmiah Fakultas Teknik Universitas Lampung*, vol. 25, no. 2, pp. 42–45, Aug. 2021, doi: 10.23960/REKRJITS.V25I2.38.
- [7] Jaya, H., Hambali, M. and Fakhurrozi, F., 2023. Transformasi pendidikan: peran pendidikan berkelanjutan dalam menghadapi tantangan abad ke-21. *Jurnal Review Pendidikan Dan Pengajaran*, 6(4), pp.2416-2422.. Available: <http://repository.uin-malang.ac.id/17431/>
- [8] M. H. S. Putra, "Potensi Metode Rainwater Harvesting dalam Pemenuhan Kebutuhan Air Domestik di SD Negeri 02 Gunung Terang Bandar Lampung," *Jurnal Teknik Sipil*, vol. 19, no. 1, pp. 01–11, Apr. 2023, doi: 10.28932/JTS.V19I1.5112).
- [9] Kudriani, N., Murdana, F., & Muriati, L. (2023). Transformasi digital dalam pendidikan: Tantangan dan peluang penerapan kecerdasan buatan dalam proses pembelajaran. *Jurnal Literasi Digital*, 3(3), 129-139. Available: <https://www.pusdig.my.id/literasi/article/view/596>
- [10] Hafid, A. and Mujrimin, B, 2023, "Transformasi Pendidikan Islam Dalam Konteks Masyarakat Adat Di Batam: Tantangan Dan Peluang," *jurnalstaiibnusina.ac.id*, Accessed: Dec. 31, 2025. [Online]. Available: <https://jurnalstaiibnusina.ac.id/index.php/ary/article/view/154>
- [11] T. Pendidikan *et al.*, "Transformasi Pendidikan di Era Digital Peluang dan Tantangan bagi Generasi Muda," *risetkendikia.com*, Accessed: Dec. 31, 2025. [Online]. Available: <https://www.risetkendikia.com/index.php/journal-luxfia/article/view/21>
- [12] "PELUANG, TANTANGAN, DAN TRANSFORMASI PENDIDIKAN - Google Scholar." Accessed: Dec. 31, 2025. [Online]. Available: [https://scholar.google.com/scholar?hl=en&as\\_sdt=0%2C5&as\\_ylo=2020&as\\_yhi=2025&q=P+ELUANG%2C+TANTANGAN%2C+DAN+TRANSFORMASI+PENDIDIKAN&btnG=](https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&as_ylo=2020&as_yhi=2025&q=P+ELUANG%2C+TANTANGAN%2C+DAN+TRANSFORMASI+PENDIDIKAN&btnG=)
- [13] M. H. S. Putra, "Analisa Komposisi Sampah yang Dihasilkan Berdasarkan Sifat dan Karakternya di Kampus Institut Teknologi Sumatera 2023," *CIVeng: Jurnal Teknik Sipil dan Lingkungan*, vol. 6, no. 1, pp. 13–18, Jan. 2025, doi: 10.30595/CIVENG.V6I1.24156.
- [14] M. H. S. Putra and S. Syuhada, "Analisa Indeks Kekeringan Kota Bengkulu Menggunakan Metode Thornthwaite-Mather," *CIVeng: Jurnal Teknik Sipil dan Lingkungan*, vol. 6, no. 2, pp. 103–108, Aug. 2025, doi: 10.30595/CIVENG.V6I2.24651.
- [15] Frisnoiry, S., 2024. Transformasi pendidikan menuju literasi dalam era globalisasi: Tantangan dan peluang. *Jurnal Pendidikan Matematika Malikussaleh*, 4(1), pp.53-63. [Online]. Available: <https://ojs.unimal.ac.id/jpmm/article/view/13860>
- [16] M. Hakiem Sedo Putra *et al.*, "PEMILIHAN SAMPAH DI ITERA 2023: MEMBANGUN BUDAYA LINGKUNGAN BERSIH DAN BERKELANJUTAN," *TeknoKreatif: Jurnal Pengabdian kepada Masyarakat*, vol. 5, no. 1, pp. 13–21, Jun. 2025, doi: 10.35472/TEKNOKREATIF.V5I1.2118.
- [17] A. Ruffell, J. K. Pringle, N. Powell, A. O'Keefe, K. D. Wisniewski, and L. Hobson, "Forensic geoscience on, and in, water," *Wiley Online Library*, vol. 40, no. 4, pp. 153–158, Jul. 2024, doi: 10.1111/GTO.12486.

- [18] Romashchenko, M.I., Husyev, Y.V., Shatkovskiy, A.P., Saidak, R.V., Yatsyuk, M.V., Shevchenko, A.M. and Matiash, T.V., 2020. Impact of climate change on water resources and agricultural production. *Land Reclamation and Water Management*, (1), pp.5-22. [Online]. Available: <http://mivg.iwpim.com.ua/index.php/mivg/article/view/235>
- [19] D. E. N. Siagian and M. H. S. Putra, "SERAT ALAM SEBAGAI BAHAN KOMPOSIT RAMAH LINGKUNGAN," *CIVeng: Jurnal Teknik Sipil dan Lingkungan*, vol. 5, no. 1, pp. 55–60, Jan. 2024, doi: 10.30595/CIVENG.V5I1.17879.
- [20] M. Hakiem, S. Putra, and E. Kurnianingtyas, *AIR*.