VOLUME 4 NUMBER 3, NOVEMBER 2026

UNIVERSITAS AMIKOM YOGYAKARTA, INDONESIA

SWAGATI: Journal of Community Service

Journal homepage: https://jurnal.amikom.ac.id/index.php/swagati

P-ISSN 2986-7940 | E-ISSN 2986-7339

Community Based Circular Waste Management through Soap Production and IoT Assisted Pyrolysis in Triharjo

Windha Mega Pradnya Dhuhita [1], Sukamta [2], Rivga Agusta [3], Chandra Wahyu Purnomo [4]

[1, 3] Universitas Amikom Yogyakarta, Jl. Ringroad Utara Condongcatur, Yogyakarta 5581, Indonesia

[2] Universitas Muhammadiyah Yogyakarta, Jl. Brawijaya, Geblagan, Tamantirto, Yogyakarta 55183, Indonesia

[4] Universitas Gadjah Mada, Bulaksumur, Caturtunggal, Depok, Yogyakarta and 55281, Indonesia

Keywords:

Maximum 5 keyword

Community empowerment,
Circular economy,
Internet of Things
Plastic pyrolysis
Waste cooking oil

ABSTRACT

Community-based waste management requires not only waste collection but also the capacity to transform waste into valuable products and independently manage supporting technologies. This third-year community empowerment program strengthened ATRAS Waste Bank and AMOR Waste Management Group in Triharjo, Sleman, through participatory training, technology implementation, mentoring, and empowerment evaluation. ATRAS received a 60-liter soap-processing unit and training in waste cooking oil processing, packaging, business management, branding, and promotion. Current operation processes 10 liters of waste cooking oil every two weeks into 180 bars of 50-g soap, equivalent to 16.67% equipment utilization and a potential gross sales value of IDR 1.08 million per month. AMOR strengthened plastic-waste processing through pyrolysis, distillation, and IoT-based monitoring; one seven-hour cycle processes approximately 50 kg of plastic into 40 liters of liquid pyrolysis product, or about 320 liters per four weeks at two cycles per week. Across four assessed empowerment dimensions, all improved by one to three levels: ATRAS production 0-3, ATRAS product management 2-3, AMOR production 3-4, and AMOR IoT-based management 0-3. The program established measurable pathways for circular waste valorization and partner independence.

*Corresponding author: **windha@amikom.ac.id**

Peer review under responsibility of Lembaga Penelitian & Pengabdian Masyarakat Univ. Amikom Yogyakarta.

©2026 Hosting by Universitas Amikom Yogyakarta. All rights reserved.

https://doi.org/10.24076/swagati.2026v4i3.3001

1. Introduction

Waste management remains a major environmental challenge in Indonesia. The National Waste Management Information System (Sistem Informasi Pengelolaan Sampah Nasional—SIPSN) reported approximately 33.19 million tons of annual waste generation in 2025 based on data submitted by 303 regencies and cities [1]. This figure highlights the need for waste-management strategies that go beyond collection and final disposal toward reduction, reuse, recycling, and recovery of value from materials that can still be utilized.

Law of the Republic of Indonesia Number 18 of 2008 concerning Waste Management emphasizes waste reduction and handling as important components of an integrated waste-management system [2]. At the community level, waste banks can play a strategic role not only in collecting recyclable materials but also in promoting behavioral change, community participation, environmental awareness, and local economic empowerment [3].

ATRAS Waste Bank (Angudi Triharjo Resik Apik lan Sehat) and AMOR Waste Management Group in Murangan, Triharjo, Sleman, are two community partners with different but complementary roles. ATRAS focuses on household waste collection, sorting, savings administration, and community participation, while AMOR handles waste fractions that have limited value through conventional recycling pathways.

The community empowerment program has been implemented progressively over three years. The initial stage focused on strengthening ATRAS administration through the SIMBATRAS information system and introducing plastic pyrolysis technology to AMOR. The second stage strengthened financial administration, organic and residual waste processing, and technical capacity. In the third year, the program focused on increasing product value, technological sustainability, and partner independence.

One of the opportunities identified at ATRAS was the utilization of waste cooking oil. Improper disposal of waste cooking oil may contribute to environmental pollution, whereas saponification provides an alternative pathway for converting it into useful products. Previous studies have demonstrated that converting waste cooking oil into soap through community-based activities can increase environmental awareness, practical skills, and opportunities for economic value creation [4], [5].

Therefore, the third-year intervention at ATRAS was not limited to soap-production skills. It also included product packaging, business management, branding, promotion, and digital communication to support the transformation of recycled products into marketable community products.

AMOR faced a different challenge. Some plastic waste fractions are difficult to utilize through conventional recycling and therefore require alternative treatment. Pyrolysis thermally decomposes plastic polymers under limited-oxygen conditions, producing liquid, gaseous, and solid fractions. The yield and characteristics of pyrolysis products depend on plastic type, processing temperature, reactor design, residence time, and other operating parameters [6].

Although AMOR had already operated a pyrolysis system, technological sustainability required further improvement. The third-year program therefore introduced a distillation unit and an Internet of Things (IoT)-based monitoring system. Monitoring is particularly relevant to pyrolysis because operating temperature is closely related to thermal decomposition and product formation [7]. IoT-based systems can provide real-time information on process parameters, while sensor-based condition monitoring can also support early fault detection and preventive maintenance [8], [9].

Accordingly, the third-year program was designed not merely to provide equipment but to increase the empowerment level of both partners. ATRAS was expected to develop independent soap-production and product-management capacity, while AMOR was expected to strengthen plastic-waste processing and data-based operational management. This article describes the implementation process and evaluates changes in partner empowerment in the production and management aspects. Recent literature on circular-economy transitions also emphasizes that sustained community participation and stakeholder engagement are central to maintaining local circular practices [10].

2. Method

The community service program adopted a participatory empowerment and learning-by-doing approach. Partners were actively involved in identifying problems, preparing solutions, participating in training, practicing technology operation, implementing production, and conducting evaluation. Participatory approaches are considered important for strengthening community ownership and increasing the likelihood that the introduced knowledge and technology will continue to be applied after direct assistance ends [11].

The program was implemented at ATRAS Waste Bank and AMOR Waste Management Group in Murangan, Triharjo, Sleman. The implementation consisted of six sequential stages as in figure 1: partner needs assessment, technology preparation, training, technology implementation, mentoring and monitoring, and empowerment evaluation.

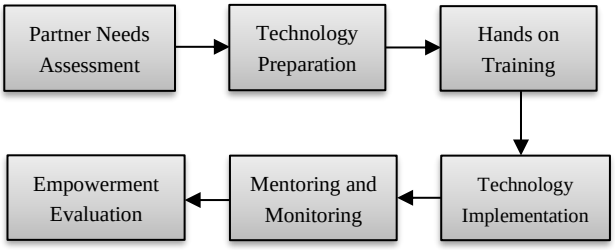


Fig. 1. Overall implementation methodology of the third-year community empowerment program.

2.1 Identifying Partner Needs and Problems

The first stage consisted of observation, discussion, and evaluation of activities from the previous program years. At ATRAS, the identified needs included product diversification based on locally available waste materials, particularly waste cooking oil, as well as improvements in packaging, business management, branding, and promotion. At AMOR, the main needs were the improvement of plastic pyrolysis product processing through distillation and the introduction of a more systematic mechanism for monitoring the pyrolysis process and machine condition. The identified problems were subsequently translated into technology, training, mentoring, and evaluation activities.

2.2 Technology and Evaluation Preparation

For ATRAS, a soap-processing unit with a maximum capacity of 60 liters of oil per production cycle was prepared. Supporting materials included procedures for waste cooking oil preparation, soap formulation, molding, curing, packaging, business management, branding, and promotion.

For AMOR, the intervention included a distillation unit integrated with the existing pyrolysis system and an IoT-based monitoring system. The monitoring system was designed to support observation of important operational parameters, particularly temperature and machine conditions. Evaluation instruments consisted of production observation sheets, input-output records, technology operation records, activity documentation, and empowerment-level assessment rubrics.

2.3 Waste Cooking Oil Processing Training at ATRAS

Waste cooking oil processing training was conducted on June 19, 2026, involving 50 participants consisting of ATRAS members, waste-bank customers, and local community members. The production stages were arranged as figure 2 follows:

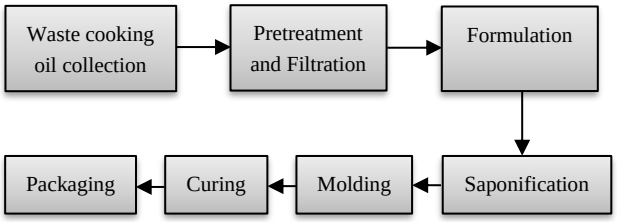


Fig. 2. Waste cooking oil soap-production sequence at ATRAS.

Participants received explanations regarding material preparation and safety before directly practicing the soap-production process.

Packaging assistance was subsequently conducted on June 20, 2026, involving 50 participants. The activity introduced packaging as both product protection and a means of increasing product identity and marketability.

2.4 Business Management, Branding, and Promotion

Production training was followed by business management strengthening. Business management training was conducted on July 3, 2026, involving 20 ATRAS members. Branding and promotion training was then conducted on July 4, 2026, also involving 20 managers. The training covered product identity, packaging communication, pricing, target consumers, promotional content, and the use of digital media for environmental education and product promotion.

This stage aimed to ensure that ATRAS was not only capable of producing soap but also able to manage it as a community-based value-added product.

2.5 Pyrolysis, Distillation, and IoT Implementation at AMOR

Plastic waste selected for pyrolysis was prepared as feedstock and introduced into the pyrolysis reactor. Thermal processing was conducted under limited oxygen conditions, and the resulting vapor was condensed into a liquid product. The liquid product was subsequently processed using the distillation unit. The implementation sequence is as shown in Figure 3 below.

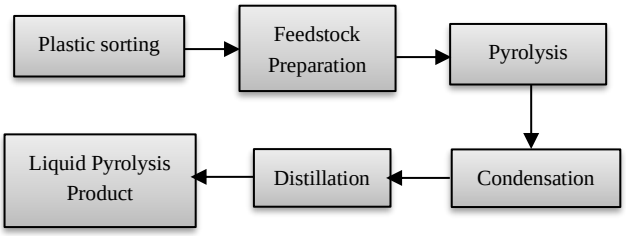


Fig. 3. Pyrolysis-distillation implementation sequence at AMOR.

The electrical power requirement of the system was approximately 300 W. Mixed residual waste was utilized as the heat source during pyrolysis operation.

IoT based process and machine condition monitoring training was conducted on August 8, 2026, involving 20 AMOR members. Participants were trained to observe monitoring information, interpret process conditions, recognize normal and abnormal operating states, and identify conditions requiring inspection or maintenance.

3. Result and Discussion

3.1 Improvement of ATRAS Production Empowerment

Before the third-year intervention, ATRAS did not have an established activity for converting waste cooking oil into solid soap. Following the program as in the figure 4, the partner received a soap-processing unit with a maximum capacity of 60 liters and acquired the skills required to independently perform the production process.

During the evaluation period, ATRAS processed approximately 10 liters of waste cooking oil every two weeks. One liter of waste cooking oil produced an average of 18 pieces of 50 gr soap. Therefore, one production cycle generated 180 pieces soap, at a selling price of Rp. 3.000 per piece, the potential sales value per production cycle was Rp. 540.000. Assuming two production cycles per month, ATRAS can currently produce approximately 360 pieces per month, corresponding to a potential gross sales value of approximately Rp. 1,080,000 per month.



Fig 4. Training in making soap from used oil and Packaging

The result indicates that the introduced technology has been successfully operated, although the available capacity has not yet been fully utilized. Rather than representing technological failure, the 16.67% utilization rate identifies a new development challenge after technology transfer, namely the continuity of waste cooking oil supply, production scheduling, and market absorption.

The result is consistent with previous studies demonstrating that waste cooking oil processing can serve both environmental and economic purposes when communities acquire the ability to transform waste into marketable soap products [4], [5], [12]. Based on the empowerment rubric, ATRAS production capacity increased from Level 0 to Level 3. The partner moved from having no soap-production activity to being able to independently and repeatedly produce a value-added product.



Fig 5. Business-management training

3.2 Improvement of ATRAS Product Management

Production capacity alone is insufficient to ensure product sustainability. Before the third-year intervention, ATRAS already had organizational and administrative experience as a waste bank, but structured management of value-added products, branding, and promotion had not yet become a major activity.

Through business-management, packaging, branding, and promotion training as shown in the figure 5, ATRAS managers began treating soap not merely as a training output but as a product with standardized size, packaging, selling price, identity, and promotional value.

The selling price of Rp. 3.000 per piece indicates that the product has entered an initial commercialization stage. Digital media were also introduced as tools for product promotion and environmental education. This approach allows product communication to simultaneously strengthen organizational identity and increase public awareness of household-waste utilization.

Similar community empowerment activities have shown that branding and social-media training can improve the ability of small community enterprises to communicate product identity and expand promotional channels [13], [14].

Based on the operational assessment, ATRAS product-management empowerment increased from Level 2 to Level 3. The partner moved from basic operational management toward independent initial management of packaging, pricing, branding, and promotion. Advancement to Level 4 will require stronger evidence of routine financial records, inventory control, sales monitoring, and periodic marketing evaluation.

3.3 Improvement of AMOR Production Empowerment

Unlike ATRAS, AMOR had already developed the capability to operate pyrolysis technology during the previous program period. Therefore, the third-year production assessment did not start from Level 0. The intervention focused on strengthening the existing production process through distillation and more structured operational implementation.

In one production cycle, approximately 50 kg of plastic waste was processed for approximately seven hours, producing approximately 40 liters of liquid pyrolysis product after processing. AMOR conducted production twice per week. Therefore, approximately 100 kg of plastic waste could be processed to produce approximately 80 liters of liquid pyrolysis product per week. At a selling/utilization price of Rp. 6.500 per liter, the potential weekly product value was Rp. 520.000. Assuming four operational weeks, AMOR could process approximately 400 kg of plastic waste and produce approximately 320 liters of liquid product per month, with a potential gross product value of Rp. 2.080.000.

Based on the empowerment rubric, AMOR production empowerment increased from Level 3 to Level 4. Before the third-year intervention, the partner was already capable of independent pyrolysis operation. After strengthening, the process included distillation, routine production, measurable input-output performance, and improved process control.

3.4 IoT-Based Operational Management at AMOR

A major third year improvement as in the table 1 was the transition from predominantly manual observation toward data-supported operational management. Before IoT implementation, pyrolysis process conditions and machine health were monitored primarily through direct operator observation. Such a mechanism strongly depended on individual experience and did not provide systematic digital information on operating conditions.

The implementation of IoT changed this approach by introducing sensor-based process monitoring. Operators could observe process parameters during machine operation and use the information to support operational decisions. Temperature monitoring is particularly important because thermal conditions influence plastic decomposition and product formation [7]. Previous studies have also demonstrated that IoT can be integrated into pyrolysis reactors to provide real time operating information [8]. More generally, sensor-based machine data can support condition monitoring, early fault identification, and preventive maintenance [9].

Following the training and mentoring conducted on August 8, 2026, AMOR members were able to use the monitoring system to observe operational information and recognize conditions requiring attention.

Table 1. Changes in AMOR IoT-Based Operational Management

Indicator	Before IoT Intervention	After IoT Intervention
Process monitoring	Manual observation	Sensor-based monitoring
Temperature observation	Manual	Digital monitoring
Machine-condition assessment	Operator experience	Supported by monitoring data
Abnormal-condition detection	Mainly reactive	Earlier identification supported by data
Operational decision basis	Observation and experience	Observation combined with sensor data
Maintenance orientation	Reactive	Directed toward preventive maintenance

Based on the empowerment rubric, AMOR IoT based operational management capacity increased from Level 0 to Level 3. Level 0 represented the absence of a digital monitoring system, while Level 3 indicated that the partner could independently use the monitoring system and interpret basic process information as in the figure 6.

The partner was not yet categorized as Level 4 because further evidence is required regarding routine use of historical data, predefined warning thresholds, maintenance scheduling, and data-supported preventive action.



Fig 6. IoT-based pyrolysis process and machine-condition monitoring training at AMOR

3.5 Overall Improvement in Partner Empowerment

The two partners demonstrated different empowerment trajectories according to their initial conditions and program interventions.

Table 2. Summary of Partner Empowerment Improvement

Partner	Aspect	Before	After	Main Improvement
ATRAS	Soap production	Level 0	Level 3	Independent and repeated soap production
ATRAS	Product management	Level 2	Level 3	Packaging, pricing, branding, and initial promotion
AMOR	Pyrolysis production	Level 3	Level 4	Routine production, distillation, and measurable output
AMOR	IoT-based management	Level 0	Level 3	Independent process and machine-condition monitoring

Comparison of empowerment levels before and after the third-year community empowerment program.



Fig 7. Comparison of partner empowerment levels before and after the third-year program

Figure 7 illustrates the changes in empowerment levels of ATRAS and AMOR before and after the third-year program. The most substantial improvements were observed in ATRAS production capacity and AMOR IoT-based operational management, both of which increased by three empowerment levels. ATRAS production increased from Level 0 to Level 3 after the partner acquired the capability to independently and repeatedly process waste cooking oil into solid soap. Similarly, AMOR's IoT based operational management increased from Level 0 to Level 3 following the implementation of sensor-based process and machine-condition monitoring. Meanwhile, ATRAS product management increased from Level 2 to Level 3, reflecting improvements in packaging, pricing, branding, and promotion. AMOR production increased from Level 3 to Level 4 because the partner had previously been capable of operating the pyrolysis unit and, during the third-year program, strengthened its production process through distillation, routine operation, and measurable input-output control. These results indicate that the interventions generated different levels of improvement depending on the partners' initial capacities and the specific technologies introduced.

However, several challenges remain. ATRAS currently utilizes only 16.67% of its available soap-processing capacity, indicating the need to strengthen waste cooking oil collection and product market absorption. AMOR requires further fuel-quality testing, emission evaluation, historical IoT data collection, warning-threshold definition, and more comprehensive operational-cost analysis. The environmental performance of pyrolysis should also be periodically reviewed because it depends on energy demand and final product utilization [15].

Program sustainability was designed around partner ownership, routine operation, market continuity, and technology maintenance. At ATRAS, continuity depends on maintaining waste cooking oil collection, scheduling regular production, documenting input-output and sales, and expanding product promotion so that the 60-liter processing capacity can be utilized progressively. Branding and community-based circular economy studies indicate that product identity, stakeholder participation, and continued local engagement are important for sustaining value-recovery initiatives [10], [14]. At AMOR, sustainability is supported by routine pyrolysis-distillation operation, sensor-based monitoring, maintenance records, and gradual use of historical IoT data to establish warning thresholds and preventive-maintenance schedules. Environmental sustainability also requires that pyrolysis be positioned as a treatment option for selected difficult-to-recycle plastic fractions rather than a replacement for reduction and mechanical recycling. Life-cycle evidence shows that the environmental performance of plastic pyrolysis depends strongly on energy demand and the final use of recovered products [15]. Accordingly, the post-program strategy prioritizes partner-operated production, periodic technical evaluation, product-quality testing, maintenance scheduling, and market development to reduce dependence on the university team.

4. Conclusion

The third-year community empowerment program improved the production and management capacities of ATRAS Waste Bank and AMOR Waste Management Group according to the specific characteristics of each partner.

At ATRAS, waste cooking oil utilization increased production empowerment from Level 0 to Level 3. The partner currently processes approximately 10 liters of waste cooking oil every two weeks, producing approximately 180 pieces of 50 gr soap with a potential product value of Rp. 540.000 per production cycle. However, the current utilization rate is only 16.67% of the available 60-liter processing capacity, indicating that raw-material supply and market expansion should become priorities for further development.

At AMOR, strengthening the pyrolysis process through distillation increased production empowerment from Level 3 to Level 4. Each seven-hour production cycle processes approximately 50 kg of plastic waste and produces approximately 40 liters of liquid pyrolysis product,

equivalent to an observed productivity of 0.8 L/kg. With two production cycles per week, the system can produce approximately 80 liters per week.

The implementation of IoT also increased AMOR's operational-management empowerment from Level 0 to Level 3 because operators are now able to monitor process conditions and machine health using sensor-based information. Overall, the integration of waste valorization, appropriate technology, digital monitoring, product management, and community capacity building demonstrates that successful community empowerment is determined not merely by equipment provision but by the ability of partners to independently operate, manage, maintain, and sustain the introduced technologies.

5. Acknowledgements

We would like to express our gratitude to the Directorate of Research and Community Service (DRPM) of the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for the 2026 GDP grant that has enabled the implementation of this community service program. We also extend our gratitude to the Institute for Research and Community Service (LPPM) of Amikom University Yogyakarta for its support and guidance throughout the program.

References

[1] Ministry of Environment of the Republic of Indonesia, "National Waste Management Information System (*Sistem Informasi Pengelolaan Sampah Nasional*), Indicative Waste Management Data 2025," 2026. [Online]. Available: https://sampahnasional.kemenlh.go.id/portal-indikatif/. Accessed: Sep. 8, 2026.

[2] Republic of Indonesia, "Law of the Republic of Indonesia Number 18 of 2008 concerning Waste Management," 2008.

[3] A. Abdillah, I. Widianingsih, R. A. Buchari, and H. Nurasa, "Trends community-based waste management practice through waste bank in Indonesia: Towards local environmental resilience," Local Environment, vol. 29, no. 8, pp. 1004–1007, 2024.

[4] S. N. K. Azme et al., "Recycling waste cooking oil into soap: Knowledge transfer through community service learning," Cleaner Waste Systems, vol. 4, Art. no. 100084, 2023, doi: 10.1016/j.clwas.2023.100084

[5] N. K. P. Wulandari and M. S. Wibawa, "Empowering Mengwitani Village Community through processing used cooking oil into eco-friendly solid soap," Abdimas: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang, vol. 10, no. 4, pp. 747–758, 2025.

[6] W. Andalia, I. Pratiwi, B. D. Afrah, I. Akbar, and M. I. Ammarullah, "Optimized pyrolysis of household plastic waste in Indonesia for oil production: Hydrocarbon profiling, fuel alternative, and potential biomedical application," Results in Chemistry, vol. 15, Art. no. 102247, 2025.

[7] E. W. B. Siahaan, H. Sitanggang, and R. A. Sidabutar, "Development of an Arduino-Based Microcontroller System to Maintain Temperature Stability in the Plastic Waste Pyrolysis Process," TEKNIK, vol. 46, no. 3, pp. 279–286, 2025.

[8] A. F. R. Kholdani, D. I. Puspitasari, A. Dharmawati, and T. W. Qur'ana, "Rancang Bangun Reaktor Pirolisis Plastik Berbasis Internet of Things (IoT)," Technologia: Jurnal Ilmiah, vol. 16, no. 4, pp. 736–743, 2025.

[9] E. Zero, M. Sallak, and R. Sacile, "Predictive Maintenance in IoT-Monitored Systems for Fault Prevention," Journal of Sensor and Actuator Networks, vol. 13, no. 5, Art. no. 57, 2024.

[10] A. R. Ceddia, S. Oricchio, G. Barberio, and C. Innella, "A systematic literature review exploring the nexus between circular economy and communities," Frontiers in Sustainable Cities, vol. 6, Art. no. 1404279, 2024, doi: 10.3389/frsc.2024.1404279.

[11] B. L. Brush et al., "Success in Long-Standing Community-Based Participatory Research Partnerships: A Scoping Literature Review," Health Education & Behavior, vol. 47, no. 4, pp. 556–568, 2020.

[12] D. P. Anggraini and D. Sulistiana, "Community Empowerment in Reducing Waste Cooking Oil into Eco-Friendly Soap Products," Amaluna: Jurnal Pengabdian Masyarakat, vol. 3, no. 2, pp. 83–97, 2024, doi: 10.21154/amaluna.v3i2.3969.

[13] A. R. Firdaus, S. D. T. Ramadhani, T. Suwarno, W. M. Ardana, and U. R. Rafifah, "Digital Branding Training for MSMEs to Increase Competitiveness of Beringharjo Market Traders," SWAGATI: Journal of Community Service, vol. 4, no. 2, pp. 159–163, 2026.

[14] A. K. Wardhani, N. Ulita, and F. D. Malihah, "The Empowerment of Kembangan Utara Community in Increasing the Value of Soap Products Made from Waste Cooking Oil Through Visual Branding," Jurnal Abdi Masyarakat, vol. 10, no. 2, 2025, doi: 10.22441/jam.v10i2.30258.

[15] T. Xayachak, N. Haque, D. Lau, R. Parthasarathy, and B. K. Pramanik, "Assessing the environmental footprint of plastic pyrolysis and gasification: A life cycle inventory study," Process Safety and Environmental Protection, vol. 173, pp. 592–603, 2023, doi: 10.1016/j.psep.2023.03.061.