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Enhancing Community-Based Waste Management through an Integrated Circular Economy Education and Low-Smoke Incinerator Program in RT 31, Karang Joang, North Balikpapan

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ARTICLE INFO	ABSTRACT
Article history: Received: Jun 23, 2026 Revised: Jul 17, 2026 Accepted: Jul 18, 2026 Keywords: low-smoke incinerator; waste management; circular economy; environmental education; community empowerment  Copyright of the article is reserved by the authors. This article is an open-access article under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.	Household waste management remains a significant environmental challenge in densely populated residential areas due to increasing waste generation, limited waste management facilities, and low community participation in waste segregation. This community service program aimed to enhance community knowledge, participation, and capacity in sustainable household waste management through an integrated approach combining circular economy education, waste segregation training, plastic waste upcycling, environmental education for children through the Little Green Hero program, community empowerment, and the construction of a low-smoke incinerator. The program was implemented from February to May 2026 in RT 31, Karang Joang Village, North Balikpapan, using participatory methods. Program evaluation involved 40 participants, consisting of housewives, boarding-house owners, and community leaders, through pre-test, post-test, and questionnaire assessments. The results demonstrated a substantial improvement in participants' knowledge, with the average pre-test score increasing from 80 to 99, while 92.5% of participants achieved perfect post-test scores. Community responses were also highly positive, with questionnaire scores ranging from 4.00 to 4.70 on a five-point Likert scale, indicating strong acceptance of the educational activities, community participation, and the implementation of the low-smoke incinerator. Overall, the integrated approach effectively improved environmental awareness, strengthened community participation, and provided a practical solution for sustainable household residual waste management, contributing to the achievement of SDGs 3, 11, and 12.

INTRODUCTION

Household waste management remains one of the major environmental challenges in Indonesia due to rapid population growth, urbanization, and changing consumption patterns, which continue to increase municipal solid waste generation (Budihardjo et al., 2021). According to the National Waste Management Information System (SIPSN) of the Ministry of Environment, Balikpapan City generated 201,230.52 tons of waste in 2025, of which 141,466.70 tons (70.3%) originated from households, indicating that household waste remains the dominant contributor to

municipal waste generation (SIPSN KLHK, 2025). These conditions highlight the importance of strengthening sustainable household waste management through active community participation and appropriate environmental interventions (Ratnasari et al., 2023).

Previous studies have consistently shown that community participation is a key factor in improving household waste management. Community-based approaches, including waste bank programs, collaborative environmental management, public participation initiatives, and participatory environmental education, have been reported to improve waste segregation, recycling practices, environmental awareness, and community engagement (Asih et al., 2022; Fatmawati et al., 2022; Nafurbenan et al., 2022; Ilhami et al., 2024). Similarly, the implementation of circular economy principles has encouraged waste reduction through reuse, recycling, and resource recovery while improving environmental sustainability (Rimantho et al., 2022; Sapanli et al., 2023; Pravitasari et al., 2025; Putra et al., 2024; Awino & Apitz, 2024; Ismail, 2025). Collectively, these studies indicate that integrating community participation with circular economy principles can strengthen sustainable household waste management at the community level (Awino & Apitz, 2024; Fitriani et al., 2024).

Besides educational interventions, appropriate technology has increasingly been introduced to complement community-based waste management systems, particularly for residual household waste that cannot be recycled or composted (Hidayat & Safitri, 2025; Khoirunisa et al., 2026). Low-smoke incinerator technology has been developed as a practical solution for reducing residual household waste, particularly in communities with limited waste collection services. Community-based implementation of low-smoke incinerators has been reported to reduce waste accumulation while strengthening local participation in waste management (Khoirunisa et al., 2026; Roosinda et al., 2025). These initiatives demonstrate that appropriate technology can complement conventional waste management systems at the community level. However, most previous community service programs have primarily emphasized technological implementation without fully integrating environmental education, circular economy practices, and community participation into a single intervention (Sujito & Anggraini, 2025).

Although previous community service programs have successfully implemented environmental education, waste recycling activities, or low-smoke incinerator technology, these interventions have mostly been conducted separately and focused on specific community needs rather than integrated environmental management (Hijriah et al., 2023; Gucella et al., 2025; Khoirunisa et al., 2026). Few programs have integrated circular economy education, plastic waste upcycling, environmental education for children, community empowerment, and low-smoke incinerator technology within a single community-based intervention. Therefore, the present community service program offers a more comprehensive approach by combining these components into an integrated waste management model aimed at improving environmental awareness, community participation, and sustainable household waste management.

Based on preliminary field observations, RT 31 of Karang Joang Village, North Balikpapan, experiences challenges related to household waste management. Waste accumulation was observed in communal waste bins, resulting in unpleasant odors that indicate delayed waste collection and excessive waste generation. The increasing number of rental houses and boarding accommodations further contributes to the volume of household waste generated in the area. Waste management remains largely dependent on municipal collection services, while some residents still practice open burning as an alternative to reducing accumulated waste. These conditions highlight the need for an integrated community-based intervention that combines environmental education, community empowerment, and appropriate waste management technology.

Therefore, this community service program aimed to enhance community knowledge, participation, and capacity in sustainable household waste management through an integrated intervention consisting of circular economy education, waste segregation training, plastic waste upcycling activities, environmental education for children through the Little Green Hero program, community empowerment, and the construction of one low-smoke incinerator. The expected outputs included one operational low-smoke incinerator, increased community awareness and participation in waste management, improved environmental knowledge, educational activities

for children, and strengthened community capacity to support sustainable household waste management.

This community service program also contributes to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) through reducing environmental pollution caused by improper waste disposal and open burning, SDG 11 (Sustainable Cities and Communities) through strengthening community-based waste management, and SDG 12 (Responsible Consumption and Production) through the implementation of circular economy principles, waste reduction, and recycling practices (Fandira et al., 2023; Oktavianatun & Nugraheni, 2024).

METHODS

This community service program employed a participatory approach that integrated community education, environmental awareness activities, practical training, and the implementation of appropriate technology. This approach was selected because the waste management issues identified in the target area were associated not only with limited waste management facilities but also with insufficient community awareness and participation. Therefore, educational, participatory, and technology-based interventions were combined to address both behavioral and technical aspects of household waste management.

The community service program was implemented from February to May 2025 in RT 31, Karang Joang Village, KM 15, North Balikpapan, East Kalimantan, Indonesia. The study site was selected based on preliminary field observations indicating a high accumulation of household waste, unpleasant odors around communal waste bins, limited waste segregation practices, dependence on municipal waste collection services, and the continued practice of open waste burning. The area also contains numerous rental houses and boarding accommodations that contribute to increased household waste generation.

The program involved community members of RT 31, particularly housewives, boarding-house owners, and local residents responsible for household waste management. Environmental education activities for children were conducted through the Little Green Hero program. Program evaluation involved 40 adult respondents, while children participated only in educational activities and were not included in the questionnaire-based evaluation.

The materials and media used during the program included educational presentation materials, waste segregation guidelines, plastic waste samples, upcycling materials, environmental education media, pre-test and post-test sheets, evaluation questionnaires, and a low-smoke incinerator unit. Supporting equipment included laptops, projectors, speakers, documentation devices, and construction tools required for the installation of the incinerator.

Program evaluation employed a structured questionnaire consisting of 11 indicators covering participants' knowledge, perceptions, participation, and acceptance of household waste management practices. Responses were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, pre-test and post-test questionnaires were administered to assess changes in participants' knowledge before and after the educational intervention.

Table 1. Indicators of the Program Evaluation Questionnaire

No.	Indicator	Evaluation Aspect
1	Satisfaction with the implementation of the Community Service Program	Program satisfaction
2	Educational materials on household waste management (organic, inorganic, and residual waste) were easy to understand	Educational effectiveness
3	Understanding of the importance of sorting household waste before disposal into the incinerator	Knowledge improvement
4	Understanding of residual waste that can be processed using the low-smoke incinerator	Knowledge improvement
5	Understanding of waste types that should not be processed using the low-smoke incinerator (e.g., glass, metal, PVC)	Knowledge improvement
6	The low-smoke incinerator helps reduce air pollution in RT 31	Environmental impact

7	The low-smoke incinerator helps reduce open waste burning in the neighborhood	Environmental impact
8	The operation and maintenance procedures of the low-smoke incinerator were easy to understand	Operational understanding
9	Willingness to routinely use the low-smoke incinerator for household residual waste management	Community participation
10	Willingness to participate in the operation and maintenance of the low-smoke incinerator in RT 31	Community participation
11	The Community Service Program provided overall benefits to the residents of RT 31, Karang Joang Village	Overall program effectiveness

The implementation process consisted of several stages. The first stage involved site surveys and problem identification through field observations and discussions with the head of RT 31 and community members. This stage aimed to identify existing waste management practices and determine priority issues requiring intervention. The second stage involved program planning and coordination with the RT administration and local stakeholders to prepare educational materials, activity schedules, participant recruitment, construction plans for the low-smoke incinerator, and logistical requirements. Community approval and implementation schedules were agreed upon during this stage.

The third stage consisted of community education on waste management based on circular economy principles. Educational sessions focused on waste classification, waste segregation practices, and the potential reuse of recyclable materials. To assess participants' understanding before and after the educational activities, pre-test and post-test assessments were administered. The fourth stage involved the implementation of the Little Green Hero program for children. This activity aimed to foster environmental awareness from an early age through interactive learning methods, educational games, question-and-answer sessions, and practical waste segregation activities.

The fifth stage involved the construction and introduction of a low-smoke incinerator as an appropriate technology solution for managing residual household waste. The construction process included material preparation, assembly of the combustion chamber, installation of the chimney system, and operational testing. Community members were also provided with guidance on the proper use and maintenance of the incinerator. The final stage involved monitoring and evaluation to assess the effectiveness and impact of the implemented activities. Data were collected through observations, documentation, pre-test and post-test assessments, and questionnaire surveys. The pre-test and post-test instruments were used to evaluate changes in participants' knowledge regarding waste management, while questionnaires were distributed to assess community perceptions of the program's implementation, usefulness, and overall impact.

Table 2. Stages of Community Service Program Implementation

Stage	Program Activity	Implementation Method
1	Site Survey and Problem Identification	A preliminary field survey and direct observations were conducted in RT 31, Karang Joang Village, to identify household waste management problems, assess environmental conditions, determine community needs, and select an appropriate location for the implementation of the community service program.
2	Program Planning and Coordination	The implementation team coordinated with the RT administration and local community representatives to develop the implementation schedule, prepare educational materials, organize participants, and finalize technical preparations for the community service activities and low-smoke incinerator construction.
3	Community Environmental Education	Educational sessions were conducted for community members through lectures, discussions, and interactive question-and-answer activities covering household waste management, waste segregation, circular economy principles, recycling, and plastic waste upcycling. Participants completed pre-test and post-test assessments before and after the educational sessions.

4	Little Green Hero Environmental Education Program	Environmental education activities were delivered to kindergarten children through the <i>Little Green Hero</i> program using storytelling, educational games, waste-sorting demonstrations, and interactive learning activities to promote environmental awareness from an early age.
5	Construction and Operational Training of the Low-Smoke Incinerator	A low-smoke incinerator was constructed as an appropriate technology for managing residual household waste. Community members received practical training on operating the incinerator, waste loading procedures, routine maintenance, safety precautions, and proper utilization of the facility.
6	Monitoring and Program Evaluation	Program implementation was evaluated using field observations, documentation, pre-test and post-test assessments, and questionnaire surveys administered to 40 participants. The evaluation assessed improvements in participants' knowledge, community participation, environmental awareness, and acceptance of the implemented waste management program.

The collected data were analyzed using descriptive quantitative and qualitative approaches. Quantitative data obtained from the pre-test, post-test, and five-point Likert-scale questionnaire were analyzed descriptively by calculating the average scores and percentages to evaluate changes in participants' knowledge and responses following the implementation of the community service program. Qualitative data obtained from field observations and documentation were analyzed descriptively to support the interpretation of the program implementation and its outcomes.

RESULTS AND DISCUSSION

The Community Service Program (PMMD) implemented in RT 31, Karang Joang Village, KM. 15, North Balikpapan, consisted of several integrated activities, including circular economy-based waste management education, early childhood environmental education, the construction of a low-smoke incinerator, operational training, and program evaluation. These activities were designed to improve community literacy regarding waste management while supporting the establishment of a more independent and sustainable community-based waste management system.

The first activity focused on improving community knowledge regarding household waste management based on circular economy principles. The educational workshop involved RT 31 residents, particularly housewives, boarding-house owners, community leaders, and neighborhood administrators. Participants were introduced to household waste segregation into three categories, namely organic waste, recyclable inorganic waste, and residual waste, through interactive presentations and discussions.

To reinforce the educational materials, participants took part in a practical upcycling session using discarded plastic containers. During this activity, two reusable flower pots were successfully produced as demonstration products. Although produced on a demonstration scale, the activity illustrated a simple household-scale approach to plastic waste reuse while providing participants with direct experience in applying circular economy principles. The educational activities and completed upcycling products are presented in Figure 1.

The effectiveness of the educational activity was evaluated using pre-test, post-test, and questionnaire assessments. The average participant score increased from 80 in the pre-test to 99 in the post-test, while 37 of the 40 participants (92.5%) achieved perfect scores during the post-test assessment. Questionnaire responses also indicated positive perceptions toward the educational materials and waste segregation guidance, with average scores ranging from 4.00 to 4.10 on a five-point Likert scale.

These findings suggest that integrating classroom-based education with practical demonstrations can improve participants' understanding of household waste management and encourage the application of circular economy principles in daily life. Similar observations were reported by [Ilhami et al. \(2024\)](#) and [Prasetya et al. \(2025\)](#), who found that participatory

environmental education enhances community engagement and promote environmentally responsible behavior through active community involvement.



Figure 1. Community Education on Waste Segregation and Plastic Waste Utilization

Following the community waste management education activities, environmental awareness was further strengthened through the Little Green Hero program conducted at TK Harapan Bunda. The activity involved 70 kindergarten students aged 4–6 years and was implemented with the approval and cooperation of the school. The program aimed to introduce basic environmental values and household waste management concepts through age-appropriate learning methods, including interactive presentations, educational games, question-and-answer sessions, and simple waste segregation simulations. These activities encouraged active participation while introducing environmentally responsible behaviors in an enjoyable learning environment.

Program implementation was evaluated using structured classroom observations conducted jointly by the implementation team and classroom teachers. The observations focused on children's participation during the learning activities, their ability to follow waste segregation simulations, and their engagement throughout the educational sessions. Observation results indicated that most children actively participated in the activities and were able to correctly distinguish basic waste categories during the guided simulation exercises. Teachers also reported that students showed high enthusiasm and actively interacted with facilitators during the educational activities.

The involvement of classroom teachers throughout the program is expected to support the continuation of environmental education beyond this single intervention by reinforcing similar environmental practices during routine classroom activities. Early environmental education provides an important foundation for developing environmentally responsible attitudes and sustainable habits from an early age. These findings are consistent with previous studies reporting that participatory environmental education can effectively strengthen environmental awareness and encourage positive environmental behaviors among young children. These findings are consistent with previous studies reporting that participatory educational activities and community service programs can strengthen environmental awareness and learning engagement among children (Hijriah et al., 2024). The implementation of the Little Green Hero program is presented in Figure 2.



Figure 2. Little Green Hero Environmental Education Activities

In addition to educational interventions, the program introduced an engineering-based solution through the construction of a low-smoke incinerator designed to manage residual household waste in RT 31, Karang Joang Village. The facility was developed collaboratively with community members and neighborhood administrators to ensure that the selected location and

operational design met local needs and site conditions. The incinerator incorporated an aerated concrete combustion chamber and a double-combustion system intended to achieve combustion temperatures above 600°C, thereby improving combustion efficiency and reducing visible smoke compared with conventional open burning practices.

The construction process resulted in one operational low-smoke incinerator unit, complete with supporting operational equipment and a Standard Operating Procedure (SOP) prepared for community use. Functional testing demonstrated that the combustion chamber operated as designed and was capable of processing residual household waste while maintaining stable combustion under supervised operating conditions. Community participation throughout the construction process also strengthened local ownership of the facility and increased readiness for its long-term operation and maintenance.

The installation of the low-smoke incinerator provides an alternative to uncontrolled open burning, which has commonly been practiced for residual waste that cannot be recycled or composted. Although the present program did not include laboratory measurements of air emissions, field observations during commissioning indicated visibly lower smoke generation than conventional open burning methods. Therefore, the environmental benefits reported in this study should be interpreted as observational rather than quantitative. Similar community-scale low-smoke incinerator systems have also been reported as practical alternatives for improving residual waste management while reducing environmental impacts associated with open waste burning (Khoirunisa et al., 2026; Gucella et al., 2025; Hidayat & Safitri, 2025). The construction process and completed facility are presented in Figure 3.



Figure 3. Construction Process and Final Installation of the Low-Smoke Incinerator

Following the completion of the incinerator installation, operational training and commissioning activities were conducted to ensure that community members could operate and maintain the facility independently. The training was based on a Standard Operating Procedure (SOP) developed specifically for the incinerator and covered furnace preheating procedures, waste feeding intervals, combustion monitoring, and bottom ash removal. Participants also received guidance regarding routine maintenance and operational safety.

The training results indicated that community members were able to understand and follow the operational procedures provided. This outcome is important for supporting the sustainability of the facility and ensuring its continued utilization after the completion of the program. The operational training and testing activities are shown in Figure 4.



Figure 4. Operational Training and Incinerator Testing Activities

The effectiveness of the community service program was evaluated using pre-test and post-test assessments together with a questionnaire survey administered to 40 respondents, consisting of housewives, boarding-house owners, and community leaders aged 20–56 years. The questionnaire comprised 11 indicators designed to assess participants' perceptions of the educational activities, the implementation of the low-smoke incinerator, community participation, and the overall effectiveness of the program. In addition, program implementation was evaluated in relation to the achievement of Sustainable Development Goals (SDGs) 3 (Good Health and Well-being), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production).

The average pre-test score was 80, indicating that participants already possessed basic knowledge regarding environmental cleanliness and household waste management. Nevertheless, field observations identified several misconceptions concerning residual waste suitable for incineration, particularly the inclusion of materials such as PVC, glass, and metal that should not be processed using the incinerator.

Following the educational workshops, practical waste segregation activities, and operational training, the average post-test score increased to 99. Furthermore, 37 of the 40 respondents (92.5%) achieved perfect scores in the post-test assessment. These results indicate a considerable improvement in participants' understanding of household waste management principles, waste segregation, and appropriate residual waste handling following program implementation. The comparison between pre-test and post-test scores is presented in Figure 5.

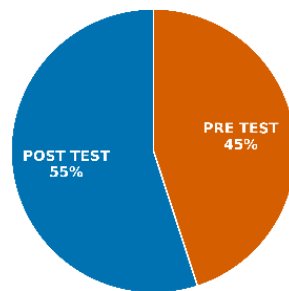


Figure 5. Pre-Test and Post-Test Results

The questionnaire results indicated predominantly positive responses across all evaluation indicators, with average scores ranging from 4.00 to 4.70 on a five-point Likert scale. The findings were categorized into three major aspects: educational effectiveness and literacy improvement, environmental solutions and behavioral change, and program sustainability and community independence. Participants provided positive evaluations regarding the educational sessions and waste segregation materials, with average scores of 4.10 and 4.00, respectively. In addition, respondents demonstrated improved understanding regarding waste types that can and cannot be processed using the incinerator.

Table 3. Community Responses to the Program Evaluation Questionnaire

No.	Questionnaire Indicator (Shortened)	Mean Score
1	Satisfaction with program implementation	4.10
2	Educational materials were easy to understand	4.00
3	Understanding of waste segregation	4.13
4	Understanding of acceptable residual waste for incineration	4.08
5	Understanding of prohibited waste types	4.03
6	Incinerator reduces air pollution	4.13
7	Incinerator reduces open burning	4.10
8	Operation and maintenance procedures were easy to understand	4.13
9	Willingness to routinely use the incinerator	4.03
10	Willingness to participate in operation and maintenance	4.08
11	Overall program benefit	4.70

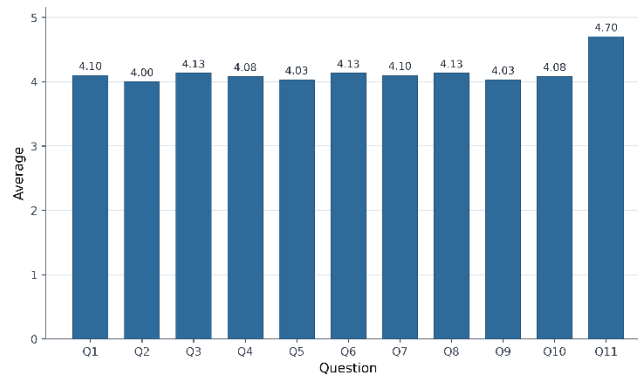


Figure 6. Questionnaire Results on Program Acceptance and Impact

Regarding environmental solutions and behavioral change, respondents perceived that the low-smoke incinerator contributed to reducing environmental pollution (mean score = 4.13) and had the potential to reduce open waste burning practices (mean score = 4.10). In terms of sustainability and community independence, respondents expressed positive perceptions regarding the usability of the Standard Operating Procedure (SOP) and their commitment to operating and maintaining the facility. The overall program usefulness received the highest average score of 4.70, indicating strong community acceptance and perceived benefits of the implemented activities. Detailed questionnaire results are presented in Table 3, while the overall evaluation profile is illustrated in Figure 6.

Overall, the community service program successfully integrated environmental education, appropriate technology, and community participation to address household waste management issues in RT 31, Karang Joang Village. The program enhanced community knowledge regarding waste segregation, strengthened environmental awareness among both adults and children, and established a functional low-smoke incinerator to support residual household waste management. These outcomes indicate that combining educational interventions with practical technology can promote greater community participation in sustainable waste management practices.

Several limitations should be acknowledged. Although the program was implemented from February to May 2025, the evaluation was conducted immediately after the intervention and therefore primarily reflects short-term outcomes. Furthermore, the activities were implemented in a single neighborhood (RT 31), limiting the generalizability of the findings to other communities. Long-term operational performance of the incinerator, changes in waste management behavior, and environmental impacts were beyond the scope of the present study.

To improve program sustainability, continued monitoring by the RT administration and community representatives is recommended to evaluate the routine operation, maintenance, and utilization of the low-smoke incinerator following the completion of the community service program. Future community service activities are also encouraged to expand implementation to multiple neighborhoods and include longer follow-up periods to assess behavioral retention, operational sustainability, and broader environmental impacts. Such efforts would provide stronger evidence regarding the long-term effectiveness and scalability of community-based waste management programs.

CONCLUSION

The Community Service Program (PMMD) successfully enhanced community-based household waste management in RT 31, Karang Joang Village, North Balikpapan through the integration of circular economy education, the Little Green Hero environmental education program, and the implementation of a low-smoke incinerator. The intervention increased the average participant knowledge score from 80 in the pre-test to 99 in the post-test, with 37 of 40 participants (92.5%) achieving perfect post-test scores, while the overall program acceptance reached 4.70/5.00, indicating strong community support for the implemented activities. These findings demonstrate that combining environmental education with appropriate technology can

effectively strengthen community participation and promote more sustainable household waste management practices. Although the program was implemented in a single neighborhood and evaluated over a relatively short period, limiting assessment of long-term behavioral and operational sustainability, the proposed model may serve as a practical reference for community-based waste management initiatives in similar settings. The approach may also be considered by the Balikpapan Municipal Government for replication in other neighborhoods, while future studies are recommended to evaluate long-term emission performance, public health impacts, and the economic feasibility of community-scale low-smoke incinerators. Furthermore, universities are encouraged to integrate similar community-based environmental programs into community service and experiential learning activities to strengthen collaboration between higher education institutions and local communities.

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