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Community-Based Waste Management in the Global South: Capacity Building and Institutional Strengthening with Legal Reflections from Semarang

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Abstract

This community engagement program aims to strengthen community-based waste management in densely populated areas of Semarang City, Indonesia, as a practical model of community-driven environmental governance in the Global South while contributing to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 5 (Gender Equality), and SDG 17 (Partnerships for the Goals). The program adopted a Participatory Rural Appraisal (PRA) approach integrated with Indonesia's national legal framework, particularly the Regulation of the Minister of Environment and Forestry No. 14 of 2021 concerning Waste Banks, beginning with an assessment of the institutional, operational, financial, participatory, and regulatory conditions of existing waste banks to identify priority issues and capacity gaps. Based on these findings, two complementary interventions were implemented: capacity building for waste bank managers and community members, and technical-institutional strengthening. All participants were women, comprising waste bank managers and representatives of the Family Welfare Empowerment (PKK) organization, thereby highlighting the essential role of women in promoting gender-responsive environmental governance and community resilience. Post-training evaluation demonstrated significant improvements in participants' knowledge, awareness, and attitudes toward sustainable household waste management. Institutional strengthening was further supported through the development of a simple Excel-based management system, the preparation of standard operating procedures (SOPs) for operational and financial reporting, the provision of basic administrative facilities, and the establishment of a WhatsApp-based technical assistance service to ensure continuous mentoring. From a legal governance perspective, the program emphasized alignment between community waste management practices and national regulations while encouraging the adoption of complementary local legal instruments, including village decrees, environmental regulations, and partnership memoranda of understanding, to enhance transparency, accountability, and institutional sustainability. Overall, the findings demonstrate that integrating community empowerment, institutional capacity development, and legal compliance can significantly improve the governance and sustainability of community-based waste banks, offering a replicable and context-sensitive model for strengthening urban waste management in the Global South while supporting the realization of multiple

SDG targets through inclusive, participatory, and sustainable environmental governance.

KEYWORDS *Community-Based Waste Management, Community Waste Banks, Environmental Legal Empowerment, Sustainable Development Goals (SDGs), Women's Capacity Building.*

Introduction

Waste has become one of the most pressing environmental challenges in the Global South. Poorly managed household waste can pollute soil, water, and air, increasing exposure to disease vectors and disrupting ecosystems. International reports consistently identify solid waste management as a priority within the sustainable development agenda, particularly in contexts characterized by accelerating urban growth, unsustainable consumption patterns, and weak governance systems [1]. In many countries across Asia, Africa, and Latin America, urban expansion has outpaced infrastructure provision, resulting in service gaps that disproportionately affect informal settlements and marginalized communities[2]. Estimated recent figures suggest that approximately 2–2.7 billion tons of municipal solid waste (MSW) are generated globally each year during the period 2016–2019[3]. Nearly half of this stream consists of food waste, especially in developing countries where high levels of food loss coexist with limited organic waste treatment infrastructure[4]. In practice, waste management systems in many Global South cities remain dominated by open dumping, poorly managed landfills, and informal burning, which

1 Allesch and Huber-Humer, "A Brief Glance on Global Waste Management."
2 Smit, "Urbanization in the Global South."
3 Yatoo et al., "Global Perspective of Municipal Solid Waste and Landfill Leachate: Generation, Composition, Eco-Toxicity, and Sustainable Management Strategies."
4 Agamuthu and Babel, "Waste Management Developments in the Last Five Decades: Asian Perspective."

can produce methane emissions, hazardous leachate, and air pollution[5]. In addition, some cities have begun adopting thermal treatment technologies such as incineration as a method of reducing waste volume and recovering energy, although its implementation remains debated due to high investment costs, emission control requirements, and its compatibility with circular economy principles[6][7]. These patterns signal the urgency of moving beyond a linear collect-and-dispose paradigm toward community-based reduction, source segregation, and circular economy approaches that recognize waste systems as socio-ecological processes rather than purely technical infrastructures.

Southeast Asia represents one of the epicenters of this challenge due to rapid urbanization, expanding middle-class consumption, and lifestyle transformation. Indonesia alone generates around 64 million tons of waste annually, the highest in the subregion, with average generation rates reaching 1.14 kg per capita per day[8]. However, similar to many Global South contexts, waste systems remain disposal-oriented, recycling rates are relatively low, and informal actors play a substantial yet underrecognized role in material recovery[9]. High-density settlements further complicate household-level segregation and increase vulnerability to environmental health risks [10][11]. Recent studies emphasize that environmental interventions in these areas must be socially inclusive to avoid reinforcing inequalities[12]. This perspective aligns with emerging research emphasizing participatory

[5] Abubakar, Fuady, and Achmad, "The Evaluation of Green Open Space of Disaster Prone Coastal Areas."

[6] Amalia et al., "Android-Based Incinerator Efficiency in Handling Covid-19 Infectious Waste."

[7] Tait et al., "Economic, Environmental, and Sociopolitical Aspects of Waste Incineration: A Scoping Review."

[8] Arumdani, Puspita, and Budihardjo, "MSW Handling of Top 5 Leading Waste-Producing Countries in Southeast Asia."

[9] Agamuthu and Babel, "Waste Management Developments in the Last Five Decades: Asian Perspective."

[10] Smit, "Urbanization in the Global South."

[11] Abubakar, Fuady, and Achmad, "The Evaluation of Green Open Space of Disaster Prone Coastal Areas."

[12] Wolff, Haase, and Haase, "Compact or Spread?"

and locally grounded approaches for addressing environmental risks in data-limited regions of the Global South[13]. Therefore, integrating community actors into formal systems and strengthening accessible legal and financial instruments is crucial for advancing sustainable household waste management across the Global South.

Indonesia reflects these global trends and opportunities. Waste production is increasing with economic growth and urbanization, and households are the largest source, contributing approximately 44–75 percent of total municipal waste in large cities. Waste generation increases with economic growth and urbanization, and households are the largest source, contributing roughly 44–75 percent of total municipal waste in major cities[14]. This places household-level interventions at the core of solutions, ranging from behavior change for source segregation and food waste prevention to adaptive transport and collection schemes. One model that has emerged from this narrative is community-based waste management (CBWM) in the form of waste banks. Waste banks adopt simplified banking principles in which residents deposit sorted waste as "savings" and receive economic incentives in return. Beyond education and behavioral change, waste banks can strengthen local recycling value chains and instill circular economy practices at the community scale[15].

However, its implementation is not without challenges, for example, the city of Semarang, Indonesia. This metropolitan city recorded the highest waste production in Central Java Province, with 431,534.65 tons[16]. Since 2018, approximately 320 waste banks have been operating in the city, but this number has reportedly decreased to approximately 87 units by 2023, indicating wide variation in performance and institutional

[13] Fariz et al., "A Participatory GIS Framework for Multi-Hazard Climate Risk Mapping in Indonesia."

[14] Qonitan, Suryawan, and Rahman, "Overview of Municipal Solid Waste Generation and Energy Utilization Potential in Major Cities of Indonesia."

[15] Budiyarto, Clarke, and Ross, "Overview of Waste Bank Application in Indonesian Regencies."

[16] Kementrian Lingkungan Hidup dan Kehutanan, "Rencana Strategis 2020-2024."

sustainability[17]. This decline indicates structural and operational barriers such as fluctuating material prices, weak incentive structures, inadequate facility maintenance, and limited accountable record-keeping. Social and geographic conditions also matter. Densely populated areas face space constraints for on-site processing, low levels of household waste sorting, and inadequate collection infrastructure[18].

Candisari District exemplifies this complexity. As one of Semarang's most densely populated districts, it generated an average waste volume of approximately 281.19 m^3 per day during 2019–2020 and 285.79 m^3 per day during 2020–2021[19]. The steep hilly topography of the Candisari area further complicates waste collection access, particularly in Tegalsari Sub-district, where access to temporary disposal sites or waste banks is often difficult[20]. Under such conditions, solutions that emphasize source reduction, household segregation, and localized organics treatment, such as communal composters, are highly relevant. Institutionally, the Mugi Berkah Sari Waste Bank, established in 2019, functions as a node for education and waste reduction while strengthening civic engagement in Tegalsari[21]. Yet participation in depositing organic waste remains low[22], which affects the effectiveness of reduction targets and the regularity of

[17] Ubaidillah, Kurniawan, and Siagian, "Estimating Households That Handle Their Domestic Waste in Not Eco-Friendly Ways in Indonesia: An Application of Small Area Estimation Technique."

[18] Kurniawan et al., "Reforming MSWM in Sukunan (Yogjakarta, Indonesia): A Case-Study of Applying a Zero-Waste Approach Based on Circular Economy Paradigm."

[19] Prihatini, "Identifikasi Pengelolaan Pilah Sampah Dengan Pendekatan Komunitas Kecamatan Candisari."

[20] Anindita, "Kajian Aspek Pengelolaan Sampah Untuk Optimalisasi Bank Sampah Di Kelurahan Gedawang Dan Tegalsari Kota Semarang."

[21] Fatmawati et al., "Waste Bank Policy Implementation through Collaborative Approach: Comparative Study—Makassar and Bantaeng, Indonesia."

[22] Anindita, "Kajian Aspek Pengelolaan Sampah Untuk Optimalisasi Bank Sampah Di Kelurahan Gedawang Dan Tegalsari Kota Semarang."

collection schedules[23]. This signals gaps in incentives, technical literacy, and appropriate tooling.

This suggests that waste bank revitalization is a strategic step to consolidate the 3R value chain at the community level and to bridge informal actors into the formal system. Revitalization is understood not simply as reactivating deposits, but as strengthening three core pillars: human capacity, systems and institutions, and clear legal frameworks. Without a coordinated design across these pillars, waste bank programs risk fading due to reliance on a few volunteers or fluctuating market prices for recyclables. This study positions a combined package of capacity building for managers and residents, as well as the provision of supporting infrastructure, and the implementation of appropriate information systems as a series of interventions.

From a policy perspective, this approach aligns with Semarang's medium-term development agenda articulated in the Rencana Pembangunan Jangka Menengah Daerah 2021–2026, a city-level five-year planning document that guides cross-sectoral programs and key performance indicators[24]. One strategic issue identified in the document is the low level of community-based waste management, with the continuity of waste bank operations used as one of the metrics. Revitalizing waste banks therefore provides dual value, operating as a technical intervention and as a policy instrument that consolidates municipal targets.

In terms of sustainable development, the program connects to SDG 11 (Sustainable Cities and Communities) through strengthening environmental services in densely populated settlements, SDG 12 (Responsible Consumption and Production) through material reduction and recovery, and indirectly supports SDG 13 (Climate Action) through reducing open burning and diverting organic waste from landfills. The social dimension is also prominent as most waste bank managers are women. Women's participation has implications for SDG 5 (Gender

[23] Sukoco et al., "Community Empowerment, Waste, and Their Challenge (a Study on Empowerment, Participation, and Economic Value of Waste Management in Manunggal Karso Waste Bank in Paju Village of Ponorogo Regency, Indonesia)."

[24] Pemerintah Kota Semarang, Peraturan Daerah Kota Semarang Nomor 6 Tahun 2021 Tentang Rencana Pembangunan Jangka Menengah Daerah Tahun 2021-2026.

Equality), namely strengthening capacity, access to information, and roles in micro-level decision-making at the household and community levels. Gender-responsive program design, such as flexible scheduling, relevant practical modules, and accessible learning media, is crucial for acceptance and sustainability.

Legally, the program is aligned with the Ministry of Environment and Forestry Regulation (Permen LHK) Number 14 of 2021 on Waste Management at Waste Banks[25]. This regulation provides a standard framework encompassing institutional arrangements, operations, financial mechanisms, service and safety aspects, and community participation. Emphasis on transparent, accountable record-keeping, price lists, and operational SOPs is a prerequisite for waste banks to be recognized as part of the official household waste management system. Compliance is important not only for legal conformity, but also for unlocking partnerships, CSR support, and potential integration of data into broader waste information systems.

Against this background, the community-engagement study titled Community-Based Revitalization of a Waste Bank in Dense Urban Settlements: Capacity Building, Institutional Strengthening, and Legal Engagement in Semarang positions the Mugi Berkah Sari Waste Bank as a case to test a linked intervention package. First, capacity building for managers and residents employs practice-oriented training that emphasizes source segregation, basic organics handling, and conversion of selected inorganics into value-added products. Second, technical and institutional strengthening is realized through the provision of work facilities and an information system tailored to user needs, enabling more transparent recording of deposits, balances, and incentive distribution. Third, all processes are tethered to the legal and policy framework of the locality, ensuring that technical outcomes do not stand alone, but are embedded in governance arrangements that are legitimate and verifiable.

Therefore, the contribution of this article is twofold. At the practical level, it proposes a community service program with a realistic revitalization

[25] Kementrian Lingkungan Hidup dan Kehutanan, "Data Pengelolaan Sampah Dan RTH."

approach for densely populated and topographically challenging settlements like Candisari, where logistical efficiency and waste source reduction are crucial. At the policy level, it demonstrates how community-based instruments such as waste banks can be integrated into the legal framework and urban development targets, while maintaining a focus on participation, gender equality, and accountability. This combination of technical, social, and legal dimensions is intended to address the classic sustainability challenges faced by community-based waste management (CBWM) initiatives.

Overall, this community engagement program demonstrates that strengthening community-based waste management requires an integrated approach that combines community capacity building, institutional strengthening, and environmental legal empowerment within a participatory governance framework. The implementation of the program at the Mugi Berkah Sari Waste Bank confirms that improving managerial capacity, strengthening institutional systems, and aligning community practices with Indonesia's national waste management regulations can enhance the effectiveness, transparency, and sustainability of community waste bank governance. Furthermore, the active participation of women as waste bank managers and representatives of the Family Welfare Empowerment (PKK) organization highlights the strategic role of gender-responsive community leadership in promoting sustainable environmental governance. These findings contribute directly to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) by strengthening community-based urban waste management systems, SDG 12 (Responsible Consumption and Production) through improved household waste segregation, recycling, and resource recovery practices, SDG 5 (Gender Equality) by enhancing women's capacity and leadership in local environmental decision-making, and SDG 17 (Partnerships for the Goals) by fostering collaboration among local communities, government institutions, and academic partners in developing sustainable waste governance. Therefore, this program offers a practical and replicable model for reinforcing community-based waste

management in densely populated urban settlements across the Global South while supporting the localization of the SDGs through participatory, inclusive, and legally grounded environmental governance.

Methods

This community service program was conducted at the Mugi Berkah Sari Waste Bank, Tegalsari Sub-district, Candisari District, Semarang, Indonesia (Figure 1). Tegalsari is the urban village closest to the city center, approximately 3.70 km from the Sub-district Office to the Semarang Mayor's Office. It is the second most populous urban village in Candisari District, with about 13,249 residents. Tegalsari comprises 13 neighborhood associations (Rukun Warga, RW) and 95 neighborhood units (Rukun Tetangga, RT).

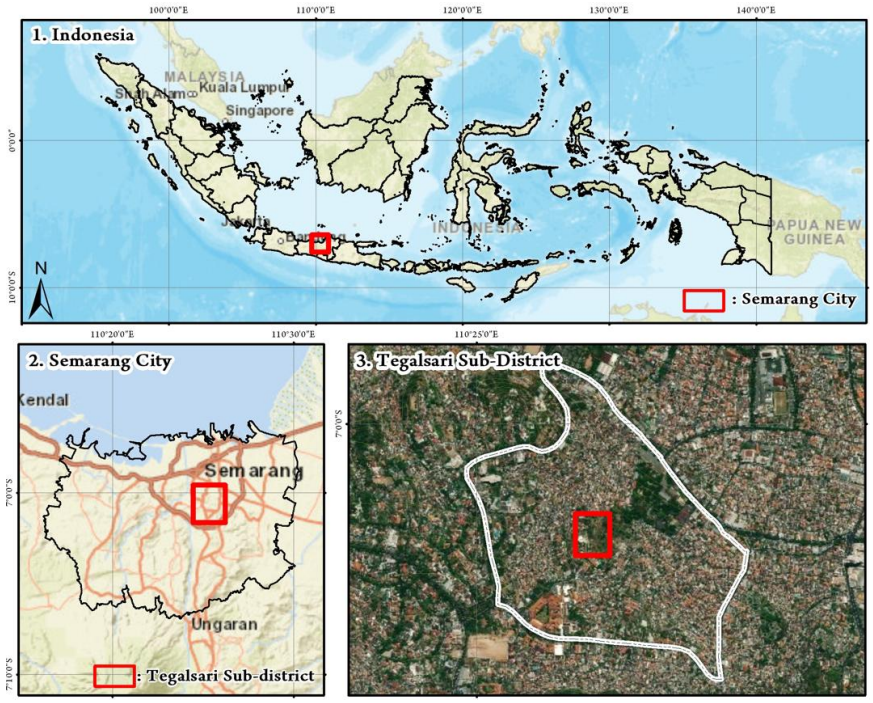

Figure 1. Location of community engagement activities

The intervention adopted a Participatory Rural Appraisal (PRA) approach that emphasizes the active involvement of residents and waste-bank managers from planning through evaluation. PRA is a participatory assessment and planning method that positions community members as principal actors in information gathering, analysis, and decision-making about local development needs and conditions[26].

The method was selected because it aligns with the principle of public participation in environmental governance as mandated by national regulation. In addition, a SWOT analysis was used as an academic instrument to map institutional, operational, financial, community participation, and regulatory conditions, thereby providing a comprehensive picture of the strengths, weaknesses, opportunities, and threats faced by the waste bank[27]. The results of this assessment informed the design of program interventions, which are presented in detail in the results and discussion section.

All activities were explicitly aligned with the legal framework of the Ministry of Environment and Forestry Regulation Number 14 of 2021 on Waste Management at Waste Banks. This regulation requires that waste banks maintain a clear organizational structure, operate in compliance with health and safety standards, ensure transparent financial mechanisms, and sustain meaningful community participation. Using this regulation as the primary reference, the program was directed not only to improve the technical capacities of residents and managers, but also to ensure that the waste bank's institutional governance operates in accordance with applicable legal principles.

The program spanned eight months. During the preparation stage, the team coordinated with partners, collected baseline data on existing conditions, and developed regulatory-based educational instruments. Implementation included legal and technical socialization on waste management, institutional strengthening through accompaniment, and the provision of supporting facilities that comply with Regulation 14/2021.

[26] Garcia-Agustin, "Revisiting Participatory Rural Appraisal (PRA)-Related Studies and Exploring PRA's Success Determinants: A Content Analysis."

[27] Rachmawati and Wilujeng, "SWOT Analysis to Determine Waste Management Strategy in Tenggilis Mejoyo District, Surabaya City."

Evaluation was conducted through surveys, interviews, and focus group discussions to assess the extent to which managers and residents understood and practiced waste management. At this stage, a Likert-scale questionnaire was also administered to measure managers' knowledge using eight statements with four response options, as four choices were deliberately employed to minimize respondents' indecisiveness, considering that the inclusion of a fifth option would likely encourage them to select the neutral midpoint.

Statements:

Q1: I understand the importance of separating organic and inorganic waste to protect the environment.

Q2: I know the various types of inorganic waste that can be processed and recycled.

Q: I understand the basic steps for sorting waste correctly.

Q4: I can apply techniques to process inorganic waste into useful products.

Q5: The community service materials on waste sorting and processing were delivered in an engaging and easy-to-understand manner.

Q6: I feel more motivated to practice waste sorting at home after participating in this activity.

Q7: I can collaborate with other participants in practicing the sorting and processing of inorganic waste.

Q8: This community service activity provided new insights into how to manage inorganic waste.

The sustainability stage focused on forming environmental cadres and strengthening networks with local government and partner institutions to ensure that the waste bank is formally recognized and integrated into local waste-management policy. With this methodological design, the program did not only target technical education outcomes, but also reinforced the legal and institutional dimensions of the waste bank as a participatory instrument that operates within the national regulatory framework.

Results and Discussion

I. General Conditions and Results of SWOT Analysis

Mugi Berkah Sari Waste Bank is located on Wilis Street, Tegalsari Sub-district, Candisari District, Semarang City, Central Java. Established in 2019, it currently serves 61 customers. Operationally, the waste bank covers six neighborhood units within Community Unit 2 of Tegalsari and maintains partnerships with several stakeholders, including Elisabeth Hospital, Yayasan Bintari, PT POPI, and local government bodies that provide coaching and development support. The legal establishment of the waste bank is codified in the Village Head's Decree (Surat Keputusan) No. 148/68/X/2019 issued by the Tegalsari Sub-district Administration, Semarang City. The appointment of its management board is likewise formalized through Surat Keputusan No. 148/68/X/2019 entitled "Tentang Pembentukan Pengurus Bank Sampah 'Mugi Berkah Sari' RW IV Kelurahan Tegalsari Kecamatan Candisari Kota Semarang," providing official recognition and an administrative legal basis for its operations. A detailed snapshot of five management aspects is as follows.

1) Institutional.

The institutional aspect is evident in the organizational structure. The organizational structure consists of Chair, Vice Chair, Secretary, Treasurer I, Treasurer II, Recording Officers I and II, Weighing Officers I and II, and Sorting Officers I and II. The personnel demonstrated adequate competence, although there was a slight lapse where not all officers attended the weekly sessions, which resulted in double duties during sorting activities.

2) Operations.

Operational aspects are indicated by the storage facilities. They are quite extensive, placing this waste bank in the medium category for infrastructure. However, there are still some shortcomings, including information services for users.

3) Finance.

The financial aspect includes savings and withdrawals. Savings and withdrawals are recorded in individual, social, and neighborhood

women's group accounts, with a minimum withdrawal interval of three months. The savings book is managed as a ledger by the Treasurer and Chairperson, equipped with an Excel database. Prices follow market prices and collector prices. Profits are split 85:15 between customers and operations, with profits used to cover operational costs. Managers receive an honorarium of IDR 50,000 every three months.

4) Community Participation.

Community participation is the active involvement of citizens, both physically and non-physically, in the decision-making process, planning, implementation, utilization of results, and evaluation of the waste bank program. Participation is high due to routine sorting schedules at the household level.

5) Regulatory Practice

An example of regulatory practice is waste sorting. Sorting covers organics, inorganics for reuse and recycling, and residuals, but household hazardous waste is not segregated. Such household hazardous waste is usually disposed of directly to the temporary collection point. Collection systems are organized by material type, yet there is no dedicated collection for household hazardous waste. Inorganic recyclables are sold to collectors, and organic waste composting is carried out communally in each neighborhood unit. Government and NGO coaching includes the sub-district government, Elisabeth Hospital, Yayasan Bintari, and PT Prevented Ocean Plastic Indonesia (POPI).

A compliance check against the Ministry of Environment and Forestry Regulation No. 14 of 2021 indicates partial alignment. The institutional structure is complete and competent, although managerial discipline and attendance require improvement. Table made with the open model (without the vertical lines) as shown below:

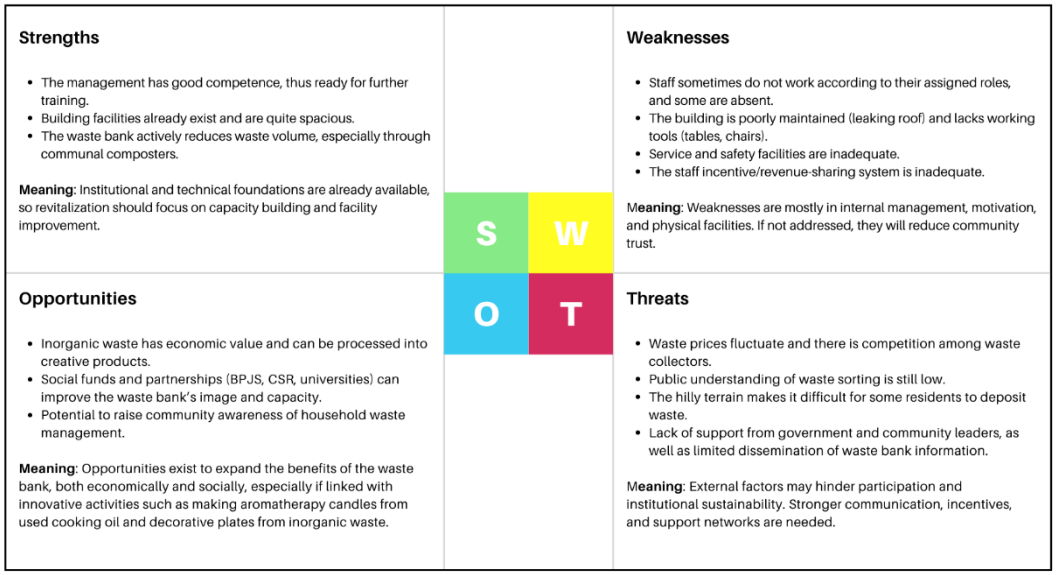

Figure 2. SWOT matrix

Follow-up focus group discussions were conducted to translate the SWOT into strategies. Strengths include competent managers, a relatively large building, and existing communal composting facilities. Weaknesses include low managerial discipline and attendance, deteriorated building conditions and limited work tools, low incentives, and insufficient safety and service facilities. Opportunities include developing innovative upcycling products such as aromatherapy candles from used cooking oil and decorative plates from inorganic waste, leveraging social funds and CSR, and improving public awareness of sorting. Threats include price volatility, low public understanding of sorting, competition with itinerant collectors, and limited support from local authorities and community leaders.

SWOT strategies were then formulated[28]. SO strategies leverage managerial competence and available space to develop innovative waste-based products that reduce volumes and provide additional income. WO strategies focus on upgrading facilities through CSR or university partnerships, including work equipment and the digitalization of waste

[28] Celik, Akyar, and Ceylan, "Navigating Environmental Sustainability in Ship Recycling Industry: Integrated SWOT-TOWS-ANP Approach."

bank management. ST strategies emphasize optimizing existing operations to intensify public education and reduce sensitivity to market price fluctuations. WT strategies prioritize improving managerial discipline and introducing performance-based incentives supported by a transparent management application.

Three priority strategies were established. First, capacity building for managers through technical training in waste processing and hands-on production of innovative products, specifically aromatherapy candles from used cooking oil and decorative plates from textile offcuts. Both products reduce textile and used-oil waste and represent practical circular economy applications[29]. Second, capacity building for residents through socialization and practical sessions in creative upcycling to raise sorting awareness and build long-term participation. Third, technical and institutional strengthening through the provision of work equipment and the implementation of a waste bank management application with training, so that financial recording and incentive distribution are more transparent and accountable.

II. Capacity Building for Managers and Residents through Applied Waste-Management Training

The training was conducted in September 2025 and was formally opened by the Head of Tegalsari Sub-district and the Community Unit Chair. Participants were all female, consisting of Mugi Berkah Sari managers and representatives of the Pemberdayaan dan Kesejahteraan Keluarga women's group. The training design was gender responsive, with schedules, methods, and practical workloads tailored to domestic and social rhythms. The intervention area is a dense settlement with significant slope, which necessitates an adaptive technical approach for source reduction and for logistical feasibility of collection.

[29] Arifin et al., "Strengthening the Creative Economy of the Community through the Utilization of Used Cooking Oil Waste into Aromatherapy Candles."

Figure 3. Socialization to the community with modules on household waste processing

Pedagogically, the training followed andragogy and experiential learning. Activities began with a concise briefing to align concepts, continued with stepwise demonstration, guided group practice, immediate feedback, and a reflective discussion to consolidate learning. The first module covered household sorting fundamentals, including distinctions among organics, inorganics, residuals, and household hazardous waste, with examples of commonly misclassified items (Figure 3). However, while household hazardous waste was introduced conceptually, its operational management remains limited at the community level. A feasible short-term approach is the establishment of periodic household hazardous waste collection points at the neighborhood level, followed by transfer arrangements with authorized collectors or municipal facilities to ensure safe handling and regulatory compliance. Given the hilly topography, organic management focused on infiltration pits or biopores that provide dual benefits by reducing runoff and serving as simple reactors for household composting. Compost produced in biopores can meet acceptable moisture and pH parameters [30].

[30] Sumartono, Hidayat, and Rahadian, "Utilization of Biopori Infiltration Holes as a Medium for Composting in Purwoyoso Village Semarang City."

Figure 4. Practice making aromatherapy candles from used cooking oil and plates

The second module translated behavior change into tangible products through two safe and easily replicated practices suitable for community scale (Figure 4). The first was the production of aromatherapy candles using filtered used cooking oil blended with stearin or paraffin, enhanced with essential oils, and set with appropriate wick placement. The second was the making of decorative plates using textile offcuts or batik remnants applied to transparent glass plates with thin layers of clear adhesive or epoxy. Occupational health and safety was emphasized in both practices, including glove use, ventilation, non-food labeling, and basic burn tests for candles.

A four-point Likert questionnaire was administered after practice to assess knowledge and attitudes. The overall mean score was 3.78 out of 4, categorized as high (Figure 5). Two key findings emerged. The highest indicator was that the activity provided new insights into managing inorganic waste, with a mean of 4.00, indicating effective knowledge transfer and recognition of upcycling opportunities with acceptable aesthetic quality for local markets. The lowest indicator was the ability to apply techniques for converting inorganic waste into useful products, with a mean of 3.57. Although still high, this indicates the need for additional

hands-on sessions, coaching on the job, and periodic refreshers so that conceptual knowledge reliably becomes routine skill.

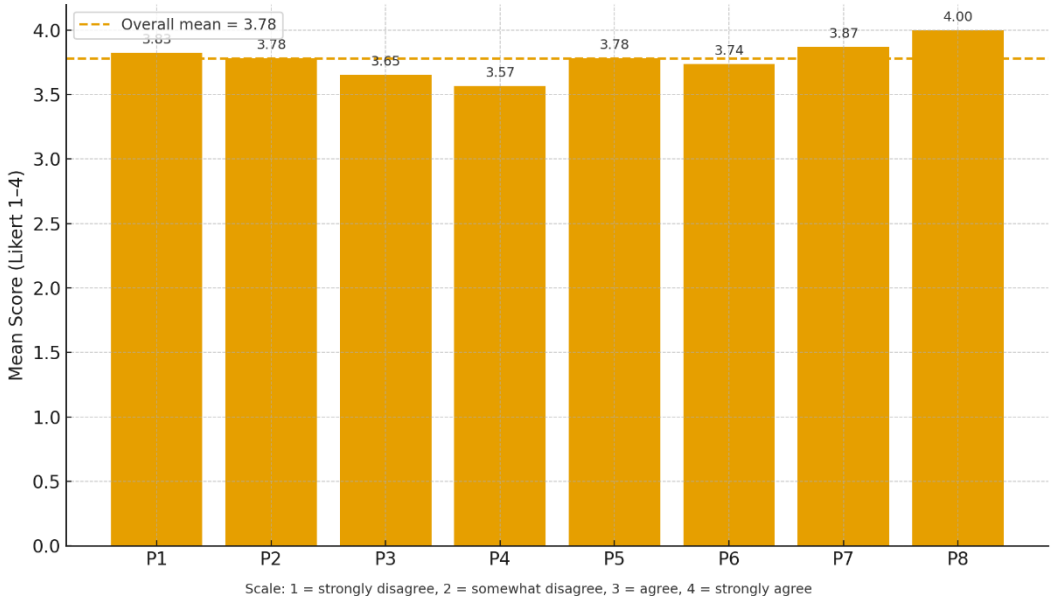

Figure 5. Results of the questionnaire on the level of knowledge of the participants

Survey results aligned with field observations. Participants quickly grasped sorting logic but needed repetition for finer technical details, such as oil to stearin ratios for stable candle flame, wick sizing to prevent tunneling, and finishing techniques for plates to ensure even, non-yellowing clear layers. Heterogeneous digital literacy also surfaced when participants were asked to document work steps for a portfolio. This confirms the need for consistent low-tech support such as templates, recipe cards, and short offline videos.

Group dynamics showed strong collaboration. The item on the ability to work with others during practice scored high, indicating that heterogeneous grouping of experienced managers and newer PKK members was effective for peer learning. Informal role allocation emerged naturally, including mixing, molding, tool sanitation, and documentation. Such patterns are essential because waste-bank operations require orchestrated micro-tasks, not one-off training events.

Training was positioned as a prerequisite for compliance with operational standards mandated by regulation. Regulation No. 14 of 2021 requires safe and reliable service, SOP availability, documentation, and continuous education. Each module ended with a take-home sheet listing safety points, stepwise checklists, and simple quality checkpoints. For candles, checkpoints included post-filtration cleanliness of used oil, two to three hours of stable burn, and non-edible labeling. For decorative plates, checkpoints included pattern neatness, consistent clear-layer thickness, and sufficient curing time. These measures improve product quality and create traceability when supervisors later verify service compliance.

Regarding behavior change, items on understanding the importance of sorting, knowledge of recyclable inorganics, and motivation to sort at home all scored high. This combination of understanding and motivation is a strong foundation for household practice. Since the survey was administered immediately after training, a three-month follow-up evaluation is recommended to confirm knowledge retention and behavior consistency, for example through increases in used-oil deposits, active biopore units, and higher proportions of finely sorted inorganics. Accordingly, the results should be interpreted as indicative of immediate post-training effects rather than evidence of sustained behavioral change or routine practice adoption. The absence of longitudinal follow-up data within the program period limits the ability to assess long-term impacts on waste management behavior and institutional performance.

Program design implications include three points. First, because technical skill application scored lowest, the mentoring cycle should include small production clinics using a mentor mentee model at a community hub. Second, to address varied digital literacy, documentation and reporting should be provided through parallel low-tech paper forms and basic digital templates, ensuring no participant is left behind. Third, to strengthen economic motivation while maintaining safety, products that pass quality checkpoints can be piloted in limited local markets through community fairs or consignment with microenterprises. This creates a feedback loop between quality, consumer trust, and income.

Overall, the applied training achieved two outcomes. It strengthened cognitive and affective domains, reflected in the 3.78 out of 4 mean, and it

identified with precision the area that needs further practice, reflected in the 3.57 skill item. By aligning the training with service and safety standards in Regulation 14 of 2021, the activity enhanced individual capacities and institutional readiness for accountable operation, including SOPs, process documentation, and evidence of learning outcomes. This provides a realistic foundation for consolidation, market testing, and integration of operational data into the waste bank's recording system.

III. Technical and Institutional Strengthening of the Waste Bank

This activity operationalizes the previously identified SWOT strategies for technical and institutional strengthening. These activities include providing physical facilities and implementing management applications to ensure transparent and accountable operational, financial, and incentive distribution records. The core intervention was the development of the Mugi Berkah Sari Waste Bank Information System, a lightweight solution tailored to the Candisari context and the user profile of mostly female managers with limited digital literacy[31].

From a systems perspective, the application was developed using PHP Native, compatible with versions 7.2 to 8.3, with MySQL as the database. The stack was selected due to affordability at the sub-district level, ease of knowledge transfer, and the ability to run online or offline on a local computer, which reduces dependence on unstable internet connections. The simplicity of the stack facilitates troubleshooting and daily maintenance by non-IT administrators.

[31] Long, Hoang, and Simkins, "Gender Gap in Digital Literacy across Generations: Evidence from Indonesia."

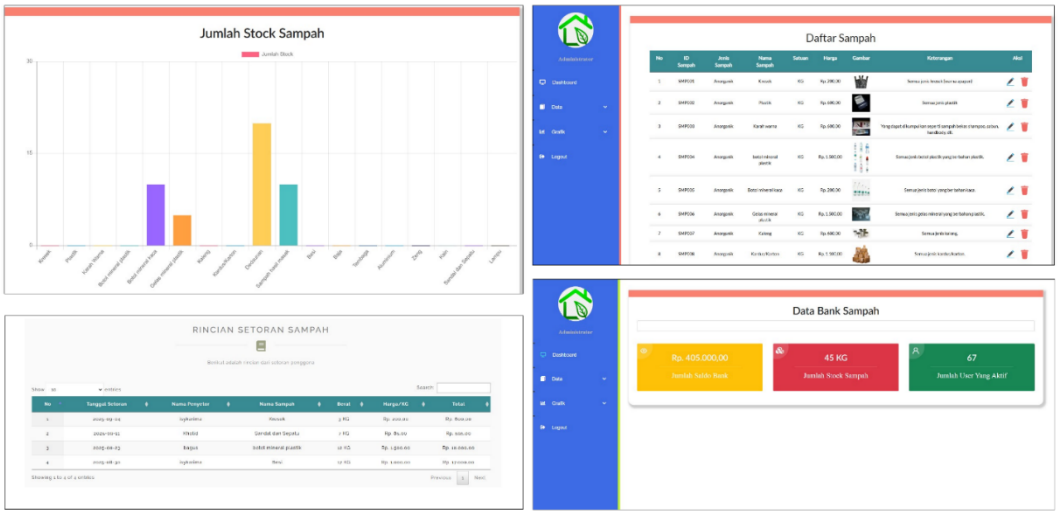

Figure 6. Menu on the information system

Functionally, the system provides two main interfaces, a public home page and an administrator dashboard. The public page publishes educational and operational information, including news or articles on solid waste, collection schedules, and simple summary statistics to enhance social transparency. This channel also supports continuous socialization, which addresses the information gap identified in the SWOT. The administrator dashboard handles data and financial flows. Key modules include master data for waste categories with updatable unit prices, customer records with deposit histories, an automated deposit ledger that converts weight or volume to currency values in line with the 85:15 sharing formula used at Mugi Berkah Sari, a withdrawal module for cashing out balances, and categorical bar charts that display composition and quantities of collected waste, which help managers track trends and negotiate prices with collectors (Figure 6).

To ensure technology acceptance among users with varied digital readiness, the system is accompanied by simple SOPs that cover data entry, daily checks for weight and price validation, monthly archiving, and quarterly reporting. SOPs specify micro tasks and roles for input, review, and authorization to avoid workload concentration. Alongside the web system, an Excel based module is retained as an alternative and backup. The Excel workbook contains attendance sheets, deposit summaries, generation

summaries, and transaction overviews. This dual track approach functions as a failsafe during connectivity or device failures and as a learning bridge for managers who are still adapting to the web interface, ensuring continuity of records.

Hardware support complements software interventions. Filing cabinets, tables, and chairs were provided to improve document security, ergonomics, and safety during weighing and data entry. Space layout was organized into receiving and weighing, data entry, and archiving zones to reduce misfiling or document loss. A WhatsApp help desk was established for ongoing technical support, distribution of short video guides, and incident reporting, which lowers user anxiety and accelerates problem resolution without waiting for on site visits.

From a governance and legal standpoint, the system operationalizes key requirements of Regulation No. 14 of 2021, namely standard service, reliable record keeping, and internal oversight. First, financial accountability is strengthened through a documented deposit ledger. Every deposit and withdrawal is time stamped and tagged with the responsible officer, which clarifies the chain of evidence. Second, incentive transparency is improved because customers can access their balances and transaction histories through simple printed slips or periodic summaries posted on the information board. Third, operational monitoring becomes more objective through generation charts that signal sharp declines, which may indicate collection disruptions, or sharp increases, which may indicate opportunities for price negotiation. Fourth, SOPs guide safe work practices, weight limits, and scale verification, aligned with occupational health and safety principles implied by the regulation.

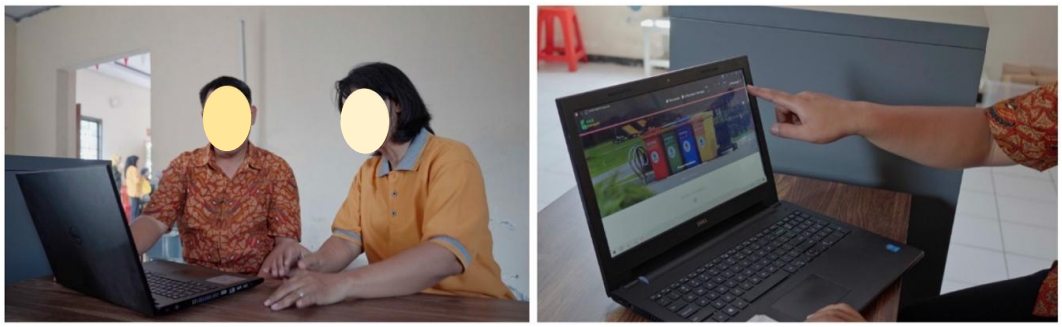

Figure 7. Training for members of the waste bank management to operate the information system

For change management, all managers attended task based hands-on training that covered login and logout, adding customers, recording deposits, correcting transactions, processing withdrawals, and printing reports. Small group practice ensured each person experienced the workflow. A one page cheat sheet was provided for the most frequent tasks (Figure 7), followed by a refresher after two weeks of use. This phased approach was critical given the range of digital readiness.

Although the pilot performed well, several sustainability considerations were noted. First, price volatility can be handled through effective date pricing tables to maintain audit accuracy. Second, role based access control should separate input, verification, and authorization for stronger internal control. Third, data protection requires routine backups, such as weekly database exports stored on external media. Fourth, interoperability is enabled through CSV or Excel export for wider reporting, opening a pathway for future integration with SIMBA or SIPSN without re entering data. The system provides a preliminary pathway for future integration with national platforms such as SIMBA and SIPSN, although no formal data exchange or system-level integration has been implemented at this stage. Fifth, the dashboard can display simple key performance indicators such as monthly deposits, organic or inorganic proportions, transaction values, and withdrawal counts to inform decisions and support advocacy with partners or authorities.

Linked to the training outcomes, the information system acts as a clamp that prevents capacity gains from dissipating. However, while the

WBIS improves transparency and record-keeping, it does not fully address underlying motivational and organizational challenges, as managerial discipline and sustained participation remain dependent on incentive structures and perceived benefits. The current honorarium level (IDR 50,000 every three months) may be insufficient to sustain long-term engagement, particularly as operational complexity increases, indicating the need for performance-based incentives linked to measurable outputs such as waste volume, active membership, or transaction value. Knowledge of sorting, processing, and customer service is now supported by tools that enforce disciplined documentation and audit trails. For example, when residents deposit materials intended for value added processing, the deposits are categorized immediately, which eases raw material calculation and micro feasibility assessment. The attendance module organizes work distribution and reduces task overlap, which was a concern revealed by the SWOT.

The combined package of a web application, Excel fallback, and physical facility upgrades delivers realistic and context appropriate institutional strengthening. Administration becomes tidier, incentive distribution more transparent, and managerial capacity higher due to clear and documented workflows. From a legal and governance viewpoint, the waste bank now has a more robust evidentiary corridor for compliance verification by supervisors or local authorities. With this foundation, Mugi Berkah Sari is better positioned to consolidate practice, expand partnerships, and prepare for integration with city or provincial solid waste data networks.

IV. Legal Community Framework for Waste Management, From Global Norms to Local Implementation

A community legal engagement framework at the environmental level needs to connect global norms, national circular economy agendas, and local legal instruments so that community practices can operate within legitimate regulatory frameworks. The Global Waste Management Outlook 2024 report states that the world generates more than 2 billion tons of municipal waste annually, with approximately 27 percent of this being poorly managed, resulting in serious impacts on the environment and

public health (International Solid Waste Association, 2024). Municipal waste generally originates from households, small businesses, markets, and public services, dominated by food scraps, single-use plastics, textiles, and e-waste[32].

As explained in the background section, Indonesia is the largest waste producer in Southeast Asia, producing approximately 64 million tons annually, followed by Thailand, Vietnam, the Philippines, and Malaysia, with an average waste production of 1.14 kilograms per capita per day in the region[33]. The main challenges in waste management in Indonesia include low waste collection rates in some areas, open dumping and incineration practices that increase greenhouse gas emissions, and a high proportion of household organic waste. Therefore, various international organizations, such as UNEP, recommend processing organic waste through composting or biogas, strengthening producer responsibility for single-use plastics, and integrating the informal sector, including scavengers and waste banks, into the formal waste management system due to their significant but often unreported role.

In the Indonesian context, waste banks have developed as a model for community-based waste management, widely implemented in various cities. As explained in the background, waste banks essentially adopt a banking-like mechanism, whereby communities "save" waste with economic value, which is then converted into financial incentives or other economic benefits for community members. In addition to serving as an instrument for waste reduction through the implementation of the 3R principle (reduce, reuse, recycle), waste banks have also been shown to provide social and economic benefits to communities, including increased household income, the formation of community social networks, and increased environmental awareness[34].

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[32] Menon and Dubey, "Opportunities and Challenges in Resource Recovery from Waste."

[33] Arumdani, Puspita, and Budihardjo, "MSW Handling of Top 5 Leading Waste-Producing Countries in Southeast Asia."

[34] Yandri, Budi, and Muhyidin, "Formulasi Dan Validasi Indikator Bank Sampah Berkelanjutan."

The Indonesian government then provided a formal legal basis for this practice through Minister of Environment and Forestry Regulation No. 14 of 2021 concerning Waste Management in Waste Banks, which positions waste banks as waste management facilities based on the 3R principles and as a means of educating the public about changing waste management behavior[35]. This regulation is derived from Law No. 18 of 2008 concerning Waste Management and Government Regulation No. 81 of 2012 concerning the Management of Household Waste and Household-Like Waste, which normatively encourage community involvement in community-based waste management. The absence of household hazardous waste segregation represents a critical compliance gap under Permen LHK No. 14 of 2021, with direct implications for environmental safety and public health. In the study area, HHW is still disposed of into the general waste stream, increasing risks of toxic exposure, contamination, and unsafe handling. This condition is common in dense settlements in the Global South, where limited space, lack of dedicated storage, and absence of collection mechanisms constrain proper household hazardous waste management. As a short-term, context-appropriate solution, a periodic neighborhood-level household hazardous waste collection system is proposed, combined with transfer arrangements to licensed collectors or municipal facilities. This approach allows safe handling without requiring permanent storage infrastructure at the household level.

However, empirical studies indicate that this regulatory framework does not fully address the challenges of waste banks' long-term sustainability. The study shows that while Minister of Environment and Forestry Regulation No. 14 of 2021 provides an operational legal basis for waste banks, the regulation does not comprehensively address aspects of institutional sustainability, particularly in terms of strategic planning, service innovation, utilization of information technology, and strengthening community organizational governance. The study identified 24 indicators of waste bank sustainability divided into five main dimensions: economic, social, environmental, technological, and

[35] Yandri, Budi, and Muhyidin.

institutional governance, which together form a comprehensive framework for sustainable waste bank development.

These findings indicate that the success of a waste bank is determined not only by the existence of formal regulations, but also by the quality of community institutional governance and the organization's ability to integrate social, economic, technological, and environmental aspects into waste management practices. In other words, the sustainability of a waste bank requires a multidimensional governance approach that goes beyond merely administrative arrangements within formal regulations.

At the national policy level, the commitment to strengthening the role of waste banks is also reflected in the Roadmap and National Action Plan for the Circular Economy 2025–2045 prepared by the Ministry of National Development Planning. This document positions waste banks as a crucial instrument for waste segregation at source, reducing the flow of waste to landfills, and diverting economically valuable materials into recycling.

The recycling chain is being developed through economic incentive mechanisms[36]. This policy implementation is strengthened through SIMBA (Waste Bank Management Information System), which serves as a national data integration platform for waste bank management in various regions.

At the local level, the Semarang City Government has adopted various policy instruments to strengthen the role of waste banks in the city's waste management system. The Semarang Mayor's Instruction of 2024 tasked regional officials, schools, markets, and community groups with establishing and developing waste banks, providing waste sorting facilities, and monitoring and evaluating activities. Furthermore, Semarang Mayoral Regulation Number 7 of 2025 expands the role of waste banks within the framework of an energy-based circular economy by encouraging the collection and sorting of plastic waste as raw material for pyrolysis technology to produce alternative fuels[37]. This series of policies forms a relatively coherent chain of norms, from the national regulatory

[36] Kementerian PPN/Bappenas, "National Roadmap and Action Plan Circular Economy Indonesia 2025 - 2045."

[37] Wali Kota Semarang, Peraturan Wali Kota Semarang Nomor 7 Tahun 2025 tentang pemanfaatan sampah plastik menjadi bahan bakar alternatif.

framework, accelerated implementation through city policies, to local innovation in resource management.

Taking into account the limited capacity of community organizations and the dynamics of the recycling market, this revitalization program adopted a realistic bridging approach. Key priorities include strengthening reporting capacity linked to the National Waste Management Information System to enhance transparency, accountability, and access to performance-based financing[38].

In terms of institutional and marketing aspects, a specific legal framework for community-based waste management efforts is still not explicitly regulated in national regulations. Therefore, several practical recommendations are proposed, including the issuance of a Sub-district Head Decree concerning organizational structure, role allocation, standard operating procedures (SOPs), service standards, and quarterly reporting mechanisms; the development of community regulations regarding waste sorting, operational schedules, incentive mechanisms, and gradual social sanctions; the development of a memorandum of understanding with health facilities and recycling industry players for the management of hazardous waste and plastic; and the implementation of a transparency policy through information boards or digital channels that display data on waste savings, profit-sharing systems, and the operational performance of waste banks. These instruments are currently in a partial implementation stage, where several elements have been operationalized through community-level practices and program interventions, although formal legal adoption at the local government level has not been fully realized. This indicates an ongoing process of institutionalization, in which community practices precede and inform the development of formal legal frameworks.

Through this design, various technical outputs such as capacity training, digital recording systems, and facility improvements do not stand alone but are tied into a broader legal and institutional framework. This approach reflects the essence of community legal engagement, namely

[38] Badan Perencanaan Pembangunan Nasional (BAPPENAS), "Laporan Kajian Keberlanjutan Fasilitas Pemilahan Dan Pengolahan Sampah Di Indonesia [Study Report on the Sustainability of Waste Sorting and Processing Facilities in Indonesia]."

connecting global norms, national policies, local legal instruments, and community social practices so that waste banks can operate effectively, accountably, and sustainably. As a broader reflection, the experience of revitalizing community-based waste management in Semarang demonstrates that strengthening community capacity, local institutional governance, and supporting a multi-layered legal framework can be a relevant approach for cities in the Global South facing similar challenges in urban waste management. By connecting global norms, national policies, and community practices, this model demonstrates that community-based waste management systems can be an adaptive and sustainable strategy in the context of rapid urbanization and limited institutional capacity in Global South countries.

Conclusion

This community service activity demonstrates that strengthening community-based waste management in densely populated areas can be effective if supported by three mutually reinforcing pillars: community capacity building, strengthening technical and institutional governance, and linking it to the applicable legal framework. In the case of the Mugi Berkah Sari Waste Bank, initial mapping through a SWOT analysis combined with a gap analysis of the provisions of Minister of Environment and Forestry Regulation No. 14 of 2021 indicated that, in general, the institutional framework, financial management, and community participation were on track to comply with the regulatory framework. However, several gaps were still identified, particularly in the availability of service facilities, daily operational discipline, and the lack of implementation of hazardous household waste segregation at the household level.

The capacity building intervention demonstrated strong cognitive and affective impacts, with an average score of 3.78 on a scale of 4. These results reflect the community's social readiness to implement waste segregation at source. However, the indicator with the lowest score was the

ability to apply technical skills in practice (3.57), indicating the need for further training cycles in the form of hands-on practice and operational mentoring. Furthermore, regular refresher training is necessary to translate conceptual knowledge into standardized routine skills. These results primarily reflect short-term cognitive and attitudinal changes, and their translation into sustained behavioral practices remains to be verified through longitudinal monitoring.

From an institutional governance perspective, we are also developing a PHP Native and MySQL-based Waste Bank Information System that can be operated both online and offline. This system, combined with Excel-based backups, simple SOPs, and the provision of basic facilities such as tables, chairs, and filing cabinets, has proven to strengthen management transparency and accountability. The system includes features for attendance, deposit and withdrawal recording, price lists, and waste accumulation graphs. This intervention package not only improves administrative records and evidence of compliance but also lowers barriers to technology adoption for users with varying levels of digital literacy. A WhatsApp help desk mechanism also plays a role in maintaining the continuity of technical support after training. However, while the system improves transparency, it does not fully address underlying motivational and organizational challenges, as participation remains dependent on incentive structures.

From a legal perspective, aligning management practices with Ministerial Regulation No. 14 of 2021 ensures that technical achievements do not stand alone but are integrated into auditable service, safety, and record-keeping standards. Going forward, several important agendas that need to be strengthened include institutionalizing the sorting of hazardous household waste at the household level, strengthening task discipline and performance-based incentives, and gradually integrating operational data with national systems such as SIMBA and SIPSN to expand access to supervisory mechanisms and performance-based financing support.

Overall, this revitalization experience demonstrates that community-based waste management combined with capacity building, institutional strengthening, and reflection on the applicable legal framework can be a relevant approach for cities in the Global South facing similar challenges in urban waste management. This model demonstrates that the interconnectedness of community practices, local institutional governance, and legal instruments can produce a more transparent, measurable, and sustainable waste management system, while remaining adaptive to the social and spatial realities of dense settlements in developing countries.

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There is no conflict of interest in the publication of this article.

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Generative AI Statement

During the preparation of this manuscript, the authors used ChatGPT Go to refine language and improve readability. Following this process, the authors critically reviewed, edited, and validated the output to ensure accuracy and scientific integrity. The authors maintain full accountability for the final content. AI was used solely as a supportive tool and is not credited with authorship. No original data analysis or interpretations were performed by the AI without human oversight.

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