ABDIMAS TALENTA
Jurnal Pengabdian Kepada Masyarakat
Journal homepage: https://talenta.usu.ac.id/abdimas

Smart Waste Management for Healthy Communities: Impactful Renewable Energy Innovations in Bekiung Village

Muhammadin Hamid[*1], M Sabri[2], Nursal[3], Nazwa Armi[1], Hanafi Prayogo[1], Windy Indah Septia[1], Surayya Asyfha[1], Zahwan Asyrof Zahirul Ubaid[1]
[1]*Physics Department, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan, 20155, North Sumatra, Indonesia*
[2]*Mechanical Engineering Department, Faculty of Engineering, Universitas Sumatera Utara, Medan, 20155, North Sumatra, Indonesia*
[3]*Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan, 20155, North Sumatra, Indonesia*
[*]Corresponding Author: muhammadin.hamid@usu.ac.id

ARTICLE INFO
Article history:
Received : 18 March 2025
Revised : 08 November 2025
Accepted : 13 December 2025
Available online: 30 December 2025

E-ISSN: 2549-418X
P-ISSN: 2549-4341

How to cite:
Hamid, M., Sabri, M., Nursal, Armi, N., Prayogo, H., Septia, W.I., Asyfha, S., and Ubaid, Z.A.Z. (2025). Smart Waste Management for Healthy Communities: Impactful Renewable Energy Innovations in Bekiung Village. ABDIMAS TALENTA: Jurnal Pengabdian Kepada Masyrakat, 10(2), 245-249.

ABSTRACT
This community service program involves innovative waste management based on appropriate technology, utilizing the smart waste management concept, which processes agricultural and livestock waste into renewable energy sources such as organic fertilizer. The program was conducted in Bekiung Village, Kuala District, Langkat Regency, where cow dung and palm oil waste are the primary waste products. Through composting or cocomposting, these two products can be converted into high-quality organic fertilizer that improves soil fertility. The core of the community service program is to create a community-based, sustainable waste management model that integrates simple technology, training, and mentoring. The goal is to reduce pollution, boost the local economy through waste-based industries, and support renewable energy and socio-ecological sustainability for the wellbeing of the village community.

Keyword: Smart Waste Management, Appropriate Technology, Organic Fertilizer, Sustainable Management, Village Community Empowerment

http://doi.org/10.32734/abdimastalenta.v10i2.22838

1. Introduction

Waste management is currently a serious concern worldwide, particularly in rural areas that generally lack access to modern waste treatment technology and facilities. Household activities, agriculture, and livestock farming generate large amounts of organic waste, which, if not properly managed, can cause soil, water, and air pollution. This waste often contributes to increased emissions of greenhouse gases, such as ammonia and methane, which not only damage the environment but also have negative impacts on public health. Pollution caused by the accumulation of organic waste can even reduce the quality of life in rural communities, exacerbate health crises, and disrupt agricultural productivity [1]. Agricultural production is crucial for sustaining human life. Sustainable agriculture must improve soil fertility without harming the environment for future generations. However, the choice of agricultural inputs is often debated, particularly between the use of chemical fertilizers and environmentally friendly approaches [2].

However, recent research indicates that organic waste, particularly livestock waste, actually holds significant potential as a renewable energy source and an alternative raw material for organic fertilizers [3]. It is wellknown that waste management helps clean the physical environment, and communities can benefit from solid waste management. Waste generated from livestock significantly enhances agriculture and demonstrates sustainable agriculture compared to conventional agriculture. In 2020, cow manure produced from dairy farms is a cheap and easily obtainable biological resource, used as biological fertilizer, biopesticide, fuel, cleaning agent, and mosquito repellent. All types of organic waste can be used for biogas and vermicompost production. Generally, vermicompost is produced using earthworms and cow manure for nutrient recycling and is used in agricultural land for crop production. Biogas technology is considered one of the best technologies for processing organic waste to recover materials and energy from organic waste. The utilization of agricultural waste for biogas and biodiesel production through recycling is a promising approach that will have economic, environmental, and social impacts. Biogas production is highly beneficial compared to other renewable energy sources [4]. Organic fertilizers such as cow manure are considered a sustainable alternative because they can improve the physical, chemical, and biological properties of the soil. Cow manure is rich in organic carbon, nitrogen, phosphorus, and other nutrients beneficial to plants [5].

Phosphorus (P) is one of the most important plant nutrients after nitrogen. Phosphorus plays a crucial role in the formation of ATP, an energy source for plant metabolism, and stimulates the growth and development of fine roots, which are crucial for seedling growth. Various types of phosphorus fertilizers, such as SP-36, RP (rock phosphate), and guano, generally have lower solubility than other inorganic fertilizers. Therefore, microbes and organic materials such as palm oil waste compost can be used to increase solubility [6]. Compost products from palm oil processing have been widely used in the agricultural industry. Most palm oil waste compost is applied as mulch and organic fertilizer. However, several studies have been conducted to assess the suitability of palm oil waste compost as a growing medium, particularly for oil palm nurseries, given the current limited availability of growing media. Topsoil is conventionally used as a growing medium due to its physicochemical properties that support root development [7].

These global and national issues are also reflected in Bekiung Village is located in Kuala District, Langkat Regency, North Sumatra Province, Indonesia. The majority of Bekiung Village residents are engaged in agriculture and livestock farming. The primary livestock raised by farmers are cattle and goats, while the agricultural sector is dominated by plantation crops, particularly oil palm. The target partner for this community service activity is BUMDes Bangun Mandiri. The area of oil palm plantations in Bekiung Village reaches approximately 500 hectares, estimated to produce solid waste of around 30%-40% of the total Fresh Fruit Bunches (FFB), leading to issues of accumulation of oil palm plant waste in Bekiung Village, such as the excessive accumulation of oil palm waste from harvest residues, fallen and dead plants, as well as oil palm plant maintenance waste and factory waste that has not been utilized. Some farmers even burn oil palm harvest residues around their cultivated plants, which can have adverse effects on surrounding cultivated plants. Farmers in this village still practice conventional crop cultivation systems, continuously using synthetic chemical fertilizers. This has adverse effects on soil health and degrades the physical, chemical, and biological properties of the soil. One effort to meet the energy needs of agricultural crops is an innovative approach that requires the implementation of appropriate technology training. The utilization of palm oil and livestock waste into organic fertilizer is a crucial step in meeting the energy needs of agricultural crops [8].

To address these challenges, the Community Service Institute team from the Universitas Sumatera Utara and Bekiung Village residents implemented the smart waste management program as a concrete effort to manage livestock waste. This program is designed as a simple yet effective innovation to process livestock manure into environmentally friendly organic fertilizer. Its implementation not only reduces the impact of waste pollution but also provides a practical solution for farmers in obtaining natural fertilizer at a more affordable cost. Furthermore, the resulting organic fertilizer has the advantage of maintaining soil fertility, improving the quality of agricultural produce, while simultaneously opening up opportunities to produce economically valuable products. Thus, this program presents a multi-layered solution that brings dual benefits, both for environmental sustainability and improving community welfare

2. Methods

2.1. Tools and Materials

The tools used consist of a manual sieve, a grinding machine (cooper), plastic tarpaulin, and a mixing tool, selected to support the screening, refining, mixing, and fermentation processes. The main ingredients include animal manure, palm oil waste (blended), palm oil ash, and bioactivators, with a combination designed to produce high-quality organic fertilizer that is easy to apply and supports environmental sustainability.

2.2. Community Service Location

The community service activity was carried out in Bekiung Village, Kuala District, Langkat Regency, North Sumatera. The location was chosen because it has abundant organic waste potential from the livestock and oil palm plantation sectors. The partner location is 45,7 km from the Universitas Sumatera Utara with a travel time of about 69 minutes by car, as shown in Figure 1 below

(a) (b)

Figure 1. (a) Bekiung Village, (b) Location map of partner network from the Universitas Sumatera Utara

2.3 The Smart Waste Management

a) Smart Waste Management method

The Smart Waste Management Method in Bekiung Village is implemented through a community-based and environmentally friendly approach. Livestock manure is collected, filtered using a manual sieve to remove impurities, and then processed with a Cooper grinder to improve texture and efficiency. The ground manure is fermented under controlled conditions. The mixture is further fermented by maintaining optimal moisture and temperature. Elements of Smart Waste Management are integrated by optimizing local resources, reducing environmental pollution, and ensuring the conversion of waste into products. The community is directly involved through training and hands-on practice, facilitating knowledge transfer and long-term sustainability. Evaluation is conducted by observing the physical quality of the fertilizer, its impact on plant growth, and the reduction of livestock waste in the environment.

b) Procedure for producing organic fertilizer from palm oil waste and animal manure

The production method for organic fertilizer from palm oil waste and animal manure is carried out in several stages. First, prepare the main ingredients such as animal manure, palm oil waste (mixed), and empty fruit bunch ash, as well as supporting ingredients such as bioactivators. The necessary tools, including a manual sieve, a grinding machine (cooper), a tarp, and mixing equipment, are also prepared. Second, manually sieve the palm oil waste and animal manure to remove impurities and obtain finer particles. Next, grind the sifted materials using a cooper machine until they are fine and ready to be mixed. After that, mix the ground materials with animal manure and empty fruit bunch ash, stir evenly, and cover the mixture with a tarp for the first fermentation stage, which lasts for four days. On the fourth day, uncover the mixture, add the bioactivator, mix thoroughly, and cover again with a tarp for the second fermentation stage. Finally, after eight days of fermentation, the organic fertilizer is ready to be packaged and applied to agricultural land. The final result of the organic fertilizer from palm oil waste and animal manure.

Figure 2. Organic fertilizer from palm oil waste and animal manure

3. Result and Discussion

Technology was essentially created to help humans find solutions to various life problems, including waste management. One example of this is the application of technology to organic waste processing so that it can be reused and provide real benefits to the community. In Bekiung Village, Langkat Regency, the dominant livestock activity produces large amounts of animal waste. If this waste is allowed to accumulate without proper management, it will cause various problems, such as pungent odors, soil and air pollution, and damage to the surrounding environment. To address these issues, the community, along with a support team, implemented the Smart Waste Management program, a smart and environmentally friendly organic waste management system that utilizes animal waste as a raw material for organic fertilizer. The program is designed to be simple, easy to implement, yet effective in supporting sustainable agriculture in the village.

The organic fertilizer processing process begins with the screening of animal waste using a manual sieve. This step is crucial for breaking down impurities and removing foreign matter, such as gravel, plastic, or other materials that could interfere with the fermentation process. Once the animal waste is free of contaminants, the material is further processed using a Cooper machine. This machine functions to grind dirt into a finer and more homogeneous texture, making it easier to mix and speeding up the decomposition process.

The next step is mixing the ground waste. Then, all the ingredients are tightly covered with a tarp and left for approximately four days. During this period, the initial fermentation process begins naturally, marked by an increase in temperature due to the activity of microorganisms. After the fourth day, a bioactivator is added to the fermenting material. The bioactivator plays a crucial role as a stimulant, accelerating the decomposition process of organic matter while enriching the fertilizer's nutritional content. After the bioactivator is added, the material is covered again with a tarp and allowed to continue fermenting until the eighth day.

By the eighth day, the fermentation product, a solid organic fertilizer of good quality, has been formed. This fertilizer is then packaged for easy distribution and use on the agricultural land of Bekiung Village residents. This simple yet systematic process produces organic fertilizer that is not only environmentally safe but also economically valuable and offers significant benefits to the community.

(a)

(b)

Figure 3. (a) Socialization of Smart Waste Management, (b) Demonstration of making organic fertilizer

This method of processing animal waste into organic fertilizer has proven effective as a dual solution: on the one hand, it reduces the environmental impact of livestock waste, and on the other hand, it provides a natural fertilizer alternative that can improve soil fertility. Agricultural products fertilized with organic fertilizer tend to be healthier, more productive, and more sustainable. Furthermore, farmers' dependence on chemical fertilizers which are expensive and often unstable in availability—can be significantly reduced. Through this program, the Bekiung Village community benefits in multiple ways: a cleaner and healthier village environment, increased agricultural productivity, and improved economic well-being through reduced production costs and increased crop yield.

4. Conclusion

The Smart Waste Management program in Bekiung Village, Kuala District, Langkat Regency, successfully demonstrated that livestock and palm oil waste can be processed into high-quality organic fertilizer through a simple yet effective process. This community service activity not only reduces the negative impact of waste on the environment but also provides tangible benefits to the community in the form of increased soil fertility, reduced dependence on chemical fertilizers, and reduced agricultural cost efficiency.

Furthermore, direct community involvement through training and mentoring makes this program sustainable and encourages village independence in waste management. Thus, Smart Waste Management is a relevant solution to support sustainable agriculture while improving the welfare of the Bekiung Village community.

By integrating waste management, renewable energy utilization, and community empowerment, this program has been proven to support the creation of a healthier village environment, more productive agriculture, and improved socio-economic well-being. Therefore, Smart Waste Management is a worthy model for sustainable waste management that can be replicated in other rural areas

5. Acknowledgements

The authors would like to thank Directorate of Research and Community Service from Ministry of Higher Education, Science, and Technology for the Community Service funding through in 2025 with contract number: 234/UN5.4.11.K/Kontrak/PM.01.02/2025. In addition, to all parties who helped this service run well.

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