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Strengthening the Blue Economy Based on the Utilization of Shell Waste in the Kalibaru Coastal Area

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***Abstract*—** Improving the welfare of coastal communities in Kalibaru, North Jakarta, can be achieved in an integrated manner through circular economy-based management of shellfish waste. This community service activity aims to empower coastal residents by establishing and developing a business that processes shellfish waste into value-added products, specifically paving blocks. The implementation method uses a participatory approach that includes lectures, technical training, and ongoing mentoring in the production process and business management. Participants are encouraged to increase creativity and innovation in product diversification, such as paving blocks, concrete blocks, handicrafts, and squat toilets. The results of the activity show that the community is able to independently process shellfish waste into paving blocks as an effort to manage waste and increase income. Mentoring by a team of lecturers and students plays a crucial role in ensuring the sustainability of the program after the activity. This program has the potential to open new business opportunities and strengthen the economy of the Kalibaru coastal community in a sustainable manner.

***Keywords*—** Shell Waste, Paving Blocks, Community Empowerment, Circular Economy, Coastal Communities

I. INTRODUCTION

Waste management in Indonesia is a problem that is increasing every year. (Puspitasari et al, 2022). Indonesia ranks second as a producer of waste, especially food waste, with an average of 300 kg/year/person. Apart from food waste, some coastal areas also produce waste from the sea, for example shellfish waste. (Endangsih et al, 2025) (Zahroh et al, 2024). In large quantities, poorly managed shellfish can pollute coastal environments, produce unpleasant odors, and become a breeding ground for disease. Chemically, shellfish contain calcium carbonate ($CaCO_3$), which has the potential for reuse. A pressing issue is the accumulation of shell waste. Due to the shape of the green mussel and the slow biodegradation of its shell, an estimated 25% of the total weight of annual marine production is discarded as unused waste (Hou et al., 2016).

The waste problem also occurs in Kalibaru Village, Cilincing District, in Jakarta. Cilincing District has a population of 265 million, with a population growth rate of 1.19 percent (Gidarjati). The Kalibaru sub-district covers an area of 2,467 km2 with a population density of approximately 34,248 people per km2. Most residents in the sub-district are fishermen, relying on marine and aquaculture products for their income. The sub-district produces a high volume of shellfish, a characteristic seen in the activity of the Kalibaru sub-district residents peeling green mussels. (Haryono & Sumiati, 2023). The shellfish peeling activity produces a lot of shellfish waste as a byproduct. The main problem currently being faced is the accumulation of shellfish waste, much of which originates from the shellfish removal process by residents.

Shellfish waste is a type of organic waste from seafood that is inedible. This waste contains several elements, including 98.1% calcium, 0.8% magnesium, and 0.1% iron and sulfur (Aisyah et al, 2024). The element calcium itself is widely used in everyday life as cereal, animal feed (Helda, 2022), fertilizer, as well as hydroxyapatite for bone graft applications (Faber & Sorensen, 2002). Further utilization of shells can also be done as a paving block mixture for infrastructure and roads. The potential use of shell waste will undoubtedly create new jobs and improve the well-being of local communities.

To date, shells, a type of solid shell waste, have been primarily used as craft materials, such as wall hangings and interior design materials. Another emerging use is as

an ingredient in animal feed. However, the uptake of shells in crafts and animal feed is still limited. Shells contain approximately 66.70% calcium carbonate (CaO), which can be used as a raw material for cement production (Martínez-García et al. 2024). Accordingly, shells can be used as a mixed material for making paving blocks and toilets because they have the same chemical compounds as sand (Permana, 2024). Community efforts to address shellfish waste have so far been unsuccessful due to a lack of knowledge, human resources, and capital. Therefore, science and technology are crucial to supporting community efforts to address the shellfish waste problem and to increase community income.

The problem faced by the residents of Kalibaru Village, Cilincing District, is how to reduce green mussel shell waste and create added value. The problems need to be addressed immediately so that Kalibaru residents can demonstrate their independence by empowering their potential. The purpose of this community service activity (PKM) is not only to address mussel shell waste but also to increase the income of the Kalibaru residents through the paving block business using mussel shell waste.

Based on the initial condition analysis, it was found that the community does not yet have the knowledge and skills in managing shell waste and utilizing it as an economically valuable product. Socialization and training activities are needed to increase the community's insight, knowledge, and skills in processing a raw material (worthless) into a superior product with high value. In addition, to facilitate the process of processing shells, Appropriate Technology is needed such as a grinding machine that turns hard shells into powder/flour and a paving block printing machine with certain models, such as squares, hexagons, and other shapes (Alamsyah et al, 2025).

A. Sustainability Aspects

Utilizing shell waste as a building material not only provides a solution to reduce coastal environmental pollution but also has the potential to create added economic value for fishing communities (Seshie et al, 2025). Collaboration with fishing partners in Cilincing demonstrates that this recycling process can be carried out in a participatory manner, while also opening opportunities for the development of circular economy-based businesses in coastal areas. Research on the innovation of recycled shells in the construction of hollow concrete walls can be viewed from three main dimensions of sustainability: environmental, economic, and social.

1. Environment Aspect
   The utilization of shell waste directly contributes to reducing pollution in coastal areas. Currently, most shell waste in Cilincing is simply dumped around the Fish Auction Place (FIP) or directly into the sea, causing unpleasant odors, disrupting coastal aesthetics, and even potentially becoming a source of disease (Kementerian Kelautan dan Perikanan 2021). By processing shells into construction materials, the volume of waste polluting the environment can be reduced, while also supporting the reduce-reuse-recycle (3R) principle in environmental management. Furthermore, the utilization of shells can reduce dependence on natural aggregates (stone and gravel), thereby helping to curb the exploitation of non-renewable natural resources.
2. Economic Aspect
   From an economic perspective, this innovation opens opportunities to create added value from materials that previously had no commercial value. Fishermen and coastal communities can play a role in the production chain, from collecting, cleaning, and processing shell waste. This has the potential to foster environmentally based small businesses and increase local incomes. Hollow concrete wall products made from shells can also compete as an affordable and environmentally friendly alternative building material, especially for building simple houses in densely populated urban areas (Hamama et al, 2023).
3. Social Aspect
   This research involved a group of fishermen in Kali Baru, Cilincing, as partners in providing raw materials. This collaboration emphasizes the importance of community participation in the development of environmentally friendly innovations. From a social perspective, community involvement not only raises awareness of the importance of waste management but also fosters a sense of ownership of the research findings. Furthermore, this can strengthen social solidarity and support the formation of a community-based business ecosystem in coastal areas.

II. METHODOLOGY

The implementation period for this PKM activity is July-December 2025 (Yusoff, 2025). The implementation of the activity begins with an initial observation to see the conditions in the field. After that, further observations are carried out to see the environmental potential, especially shell waste seen from several time periods. Then, socialization is carried out to build participants' understanding and determine their readiness. Participants in this activity consist of prospective paving block and toilet production business managers from Karang Taruna RT 009/RW 001, Kalibaru Village, Cilincing District. The number of training participants is 50 people. The implementation of the activity begins with an initial observation to see the conditions in the field. After that, further observations are carried out to see the environmental potential, especially shell waste seen from several time periods. Then, socialization is carried out to build participants' understanding.

This activity uses the Adult Approach (POD) method, which is conducted in a participatory manner, using lectures, group discussions, and skills practice tailored to field conditions. Skills practice involves conducting independent trials using prepared materials in the form of training modules and equipment for prospective business managers. The training is conducted using lectures and discussions, accompanied by mentoring. Additionally, training is conducted through demonstration and independent practice (Zahroh et al, 2025).

The tools and materials used to utilize shell waste into paving blocks and squat toilets, and in this activity, include shells, sand, cement, lime water, four- and three-diamond paving block molds, a tub/bucket, and a mixing shovel. The shells were previously ground using a stone mortar or grinding machine to a sand-like consistency. The paving block mixture was mixed with lime water to reduce the high salt content in the shells. The following are the materials and equipment prepared for the training, which can be seen in Figure 1.

Figure 1. Materials and tools

Activity Implementation Stages: a Preparation stage. This community service (PKM) activity begins with identifying partners' problems can be seen in Figure 2, namely a lack of knowledge and competence in utilizing shell waste into marketable products such as paving blocks. This knowledge and insight are conveyed through outreach activities, while the training program provides participants with hands-on experience in the process. The preparation stage of this PKM activity consists of 1 Planning and establishing a schedule for outreach and training activities in Kalibaru with partners; 2 Creating outreach materials and brochures related to the stages of processing shell waste into paving blocks, toilets, and handicrafts; and 3 Preparing the tools and materials needed for the activity.

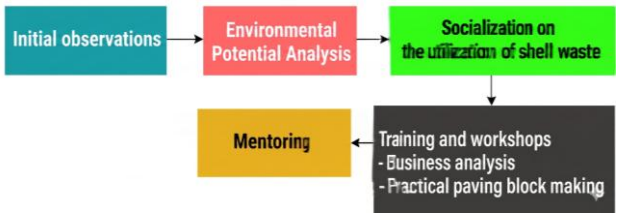

Figure 2. Stages of Community Empowerment Activities (PKM) Processing Shell Waste into Paving Blocks in Kalibaru Village

The implementation phase consisted of two sessions: a socialization session and a training session on processing shellfish waste into paving blocks. The socialization session aimed to provide partners and the community with an understanding of the potential of shellfish waste to become a valuable product for the village economy. These products include being used as a sand substitute in the production of paving blocks, toilets, and handicrafts. The socialization session was conducted through lectures led by two speakers: one external and one representative of the Lecturer Team. The training phase was then conducted through demonstrations led by the speakers, allowing participants to directly observe the process of paving blocks and squat toilets from green mussel shell waste.

The final stage of the Community Service Program (PKM) was the evaluation phase, which aimed to assess the increase in community knowledge after the activity and any obstacles and shortcomings encountered during the PKM activity. This improvement was measured through pre-, and post-tests administered directly before and after the PKM activity. Furthermore, the evaluation was supported by observation data during the activity, including Q&A sessions and discussions, as well as participants' paving block production results during the training sessions.

III Result And Discussion

A. Socialization Activities

The socialization activities were conducted to provide insight and knowledge to partners and the surrounding community about the potential of shellfish waste and its processing techniques. This is based on the large amount of shellfish waste on the Kalibaru coast that has not been widely processed and utilized into high-value products. These products could become superior products and support the local economy, which is currently experiencing rising unemployment and poverty.

The material began with a discussion of pre-test results can be seen in Figure 3, which indicated that some residents understood that shellfish can be used as accessories/souvenirs such as key chains and wall hangings. Through this socialization activity, the community learned that there are many products utilizing shellfish waste with higher sales value, such as animal feed, fertilizer, paving blocks, and toilet bowls. Given that infrastructure is currently a major focus in the Jakarta Special Capital Region (D.K.), paving blocks, as a building material, are highly sought after and have the potential to generate high sales value if traded.

Figure 3. Implementation of Socialization carried out by the Team of Lecturers and External Resource Persons

The second material was delivered by an external resource person who explained the technique of processing green mussel shell waste into a mixture of paving blocks and toilet bowls. Mussel shells have a high calcium content so they can strengthen the compressive strength of paving blocks when added to the mixture. The use of green mussel shell waste as a mixture of paving blocks must be ground or ground first to the size of sand to facilitate homogenization of the mixture/dough. Mussel shell sand (fine and coarse aggregates), cement are stirred then mixed with clean water and sugarcane wastewater. The mixture is then molded and dried.

B. Training Activities

This eight-hour training session, attended by 50 participants, covered two topics. The ecobrick or paving block making training took place on Friday, October 17, 2025, at a shell waste collection point on Cilincing Beach, North Jakarta. Residents of East Kalibaru, RT 01, RT 05, and RT 09/RW 01, Kalibaru Village, attended the training. The training was conducted through demonstrations led by external speakers with assistance from the PKM Lecturer Team. The training activities included:

1. Business Analysis Training
   Business analysis is crucial for community leaders to plan and prepare human resources for their paving block business from the outset. This training guides participants in developing a feasibility study tailored to their business needs to ensure profitability and sustainability.
2. Practical Paving Block Making Training
   This training aims to provide hands-on practice in making paving blocks from shells. In addition to using basic materials, in addition to shells, paving blocks are also made using cement, sifted sand, and water in specific compositions. The composition of the paving materials was tested using several alternative compositions until the optimal composition was achieved, with strength meeting Indonesian National Standards (SNI) so that the resulting paving blocks could be marketed.

The training activities followed several stages: preparation of the tools and materials needed for paving block production, preparation of the paving block mixture; and the paving block molding process.

1. Preparation of Tools and Materials
   In this stage, the presenter demonstrates the tools and materials needed to make paving blocks, such as a tub/bucket as a container, sand, cement, a mini trowel/mixer, water, sugarcane wastewater, and paving block molds. The shells used in the mixture must also be ground/refined to the size of sand. The material preparation process begins with the collection of shell waste from a fishing group in Kalibaru, Cilincing, North Jakarta. The waste is then processed through cleaning, drying, and crushing until it reaches a size similar to coarse aggregate. This process demonstrates that shell waste can be processed into a material that meets the initial standards for concrete production. Shell Cleaning and Drying: The collection process is shown in Figure 4. The shells are cleaned of organic matter using running water.

Figure 4. Green Mussel Shell Harvesting Process

The dried shells are crushed using a crusher or hammer to a size close to coarse aggregate (5–20 mm) and fine aggregate. The common standard size of fine aggregate is smaller than 4.75 mm or retained on sieve No. 4, in accordance with standards such as SNI 1970-2008. The resulting broken material is screened using a sieve to obtain a uniform size according to the needs of the concrete mixture. Based on SNI 03-0349-1989, hollow concrete bricks are formed from a mixture of Portland cement, fine sand aggregate, water and or without other additives are one of the wall filler materials (Indonesian National Standards Agency 1989). The tools used for grinding/chopping can be seen in Figure 5:

Figure 5. Shell Flour/Grinding Machine

The shell crushing process uses a flour-making machine equipped with a sieve with the appropriate size for fine and coarse aggregate grains as required by SNI 1970-2008. Furthermore, the raw materials, consisting of sand, cement, and water, must have a ratio of 75:20:5(Indonesian National Standards Agency 2008). The composition of these raw materials is in accordance with the Technical Guidelines issued by the Department of Public Works in 1986. The mixing process uses a mixer to produce a homogeneous concrete mixture (Indonesian National Standards Agency 2002).

The speaker also explained that mixing the paving materials requires lime water when adding the shells to break down the salt content. Furthermore, the speaker explained that paving blocks mixed with shells can easily become brittle if plain water is used as a mixer. Therefore,

a liquid derived from sugarcane mill wastewater is needed to speed up the hardening process.

Figure 6 shows the process of refining shell waste after it has been separated and cleaned using a grinding machine to the size of sand (fine aggregate) and coarse aggregate.

Figure 6. Green Mussel Shell Grinding Process

2. Making the paving block mixture
   The mixture is made by mixing all the solid ingredients, such as sand, cement, and ground shells, in a tub/bucket in a 1:1:1 ratio. Next, 10 ml of sugarcane milling wastewater and clean water are added little by little until the mixture is semi-wet. The presenter explained that a mixture that is too wet will delay the paving block formation process and will create many cavities/pores when dried (due to evaporation).(Kusumaningtyas, Savariski, and Wibawa 2025). On the other hand, if the water content in the mixture is low, the adhesive/binding power will be weak and difficult to mold(Fmea, Pt, and Beton 2023) Figure 7 shows the process of making paving block mixture.

Figure 7. Paving block mixture making process

3. Paving Block Printing Process
   The printing process in this training session uses a manual machine with rectangular, hexagonal, and three-diamond molds. The use of a molding machine at this stage ensures even and consistent pressure is applied to the mixture. The edges of the mold are oiled before the mixture is inserted to reduce the possibility of the mixture sticking to the sides and being difficult to remove. Figure 8. shows the printing process for rectangular, hexagonal, and three-diamond paving blocks. After the mixture is finished being molded, it is then moved and dried outdoors. The presenter recommends that the molds not be heated in direct sunlight, as they are still susceptible to cracking.

Figure 8. Paving Block Printing Process

C. Monitoring and Evaluation Activities

The monitoring phase aims to determine the improvement in participants' abilities following the socialization and training activities, which encompass two aspects: increased understanding/knowledge and increased skills. The knowledge aspect was obtained from pre- and post-test responses, supported by observation data during the activities, while skills assessment was conducted separately through online mentoring via WhatsApp. The pre- and post-test results indicated a 95% increase in participants' understanding of the utilization of shell waste. This understanding extends beyond theory to encompass processing techniques, particularly the use of shells as a paving block mixture.

The skill aspect of the partners is demonstrated by comparing the paving block molding results made before and after the implementation of the PKM activity. The first experiment, during the training activity, the paving block mixture contained too much water, making the mold difficult to dry and easily cracked. In addition, cavities appeared in the paving blocks due to empty spaces during heating (Putri et al., 2019). The presenter provided suggestions to reduce the amount of water when making the mixture. After the PKM activity, the partners' skills began to show improvement, marked by the paving block molding results looking solid and not hollow.

The evaluation method used in this PKM activity is a qualitative method using the Context, Input, Process, and Product (CIPP) program evaluation method. Data collection techniques include observation, interviews, and documentation shown in Table 1.

Table 1. Evaluation Criteria for PKM Activities Processing Shell Waste into Paving Blocks in Kalibaru

Evaluation Components	Aspects/ Subcomponents	Evaluation Criteria
Context	1) Policy	Environmental conservation and waste management efforts
	2) Goal	To address shell waste and increase community income
	3) Object	The people of Kalibaru Village, Cilincing
	4) Demand	Transfer teknologi pengolahan limbah cangkang kerang menjadi paving block
Input	1) Readiness Resources	Materials, tools, and practical materials for processing shell waste into paving blocks are available.
	2)Community Readiness	The community is willing to participate in the PKM Shell Waste Processing Shells into Paving Blocks
Process	1) Implementation of all planned programs	All programs have been achieved periodically
	2) Active community participation in program implementation	Community elements actively participated, as shown in the photos of the activities (pictures 3 and 7).
Product	1) Increasing public interest	Public interest in processing shell waste into paving blocks is quite high and has received support from Indonesian fishermen's associations.
	2) Increasing awareness of maintaining a clean home environment	Increased awareness of maintaining a clean home environment, demonstrated by not littering shellfish waste.

D. Sustainability Efforts

Sustainability aims to ensure that the solutions offered resolve partners' problems and that the program will continue even after the Community Service Program (PKM) activity has concluded. Furthermore, this product is expected to become one of the village's flagship products, boosting the economy of the Kalibaru village community. Based on monitoring via WhatsApp several days after the activity, partners remained highly enthusiastic about this innovation. Partners consistently discussed and consulted regarding paving block mix materials and the resulting molds. Sustainability programs that can be implemented to support partners include determining the best composition of paving block mix materials; market analysis and marketing methods; measuring paving block performance according to SNI standards; and capital assistance/ Corporate Social Responsibility (CSR). Thus, this PKM activity not only contributes to the development of alternative construction material technology but also has a tangible impact on environmental sustainability, improving the welfare of coastal communities, and strengthening the local economy.

IV. Conclusion

The Community Service (PKM) activity involved socialization and training on the use of shell waste as a material for paving blocks and toilets to improve the economy of the Kalibaru community. Fifty participants, both from the partner team and the surrounding community, attended the activity. The socialization was conducted through a lecture method to provide knowledge on the potential of shell waste, while participants' skills in processing the waste were provided through training and direct experience. The activity went well and smoothly, as evidenced by the increase in participants' knowledge and skills in processing shell waste into paving blocks. Partners expressed high enthusiasm in developing these paving blocks into superior village products, so monitoring and evaluation were carried out by the community service team to support this desire. In addition, ongoing assistance and support from the community service team and the local government will provide the potential for achieving independence and improving the economy of the community in Kalibaru. Assistance and support can be provided through the Community Service program, focusing on increasing the diversification of shell waste products through the addition of molds using appropriate technology.

Following the training, participants demonstrated increased awareness of the need to establish a paving block business in Kalibaru Village, Cilincing District. This is due to its promising prospects for managing shellfish waste and increasing local incomes. Establishing a paving block business using shellfish waste not only helps existing businesses in Kalibaru Village but also helps address the ongoing problem of shellfish waste. Suggestions are made for the local government to support sustainable waste utilization.

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