

Geomembrane Technology Application in Pulo Nasi: A Pathway to Hygienic Salt Production

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Abstract. Salt is a strategic commodity due to its vital role in various industries and its implications for national security and economic stability. However, Indonesia continues to heavily rely on salt imports despite its extensive coastline. This study examines the implementation of geomembrane technology in salt production by the Sirana Jaya salt group in Pulo Nasi, Aceh, aiming to address challenges in local production and improve the quality. The research included socialization, training, and the adoption of geomembrane layers, which enhanced evaporation efficiency by reducing soil contact and optimizing sunlight absorption. Results demonstrated a significant improvement in salt production, with production time reduced from 40 days to 25 days and quality enhanced over three years (2022–2024). In 2022, salt quality was low, marked by dark and uneven crystals. By 2024, the salt quality had improved significantly, producing larger, whiter, and cleaner crystals that met quality standards. Geomembrane technology also enabled continuous production during adverse weather conditions, mitigating traditional challenges such as dependency on dry seasons. This innovation demonstrates the potential to reduce Indonesia's reliance on salt imports, empower local farmers, and enhance the competitiveness of the national salt industry. Geomembrane technology provides a sustainable and scalable model for local salt production, fostering better economic and industrial resilience.

Keywords: salt production, geomembrane technology, quality improvement, local industry, Indonesia, sustainable innovation

1. Introduction

Salt is considered a critical resource due to its significant role in numerous industries and its impact on national security and economic stability. The growing demand for salt in Indonesia, in particular, underscores the difficulties local producers face in competing with imported salt. This situation highlights the need for government initiatives to boost competitiveness and ensure sustainability within the salt industry (Sunoko et al., 2022). The high level of daily salt consumption in Indonesia, with national demand projected to reach 4.2 million tons in 2019, emphasizes the population's reliance on salt for food and its essential role in industries such as pharmaceuticals and textiles (Setyowisnu et al., 2020).

Despite Indonesia's vast potential for salt production along its extensive coastline, the country remains heavily dependent on imports to satisfy national demand. This reliance is primarily attributed to inadequate domestic production, prompting government policies to permit salt imports (Astuti et al., 2019). Furthermore, technical challenges significantly influence both the quality and quantity of locally produced salt. Although local farmers contribute a substantial amount of salt, more than 60% of the country's demand is still fulfilled through imports. This dependency on imports presents a compelling issue for Indonesia's salt industry, warranting further investigation (Yaqin and Setiani, 2017). Among the solutions explored, geomembrane technology stands out as an

advanced method for increasing salt production rates, offering significant benefits to Indonesian salt producers.

Local salt production is heavily reliant on favourable weather conditions and often comes to a standstill during the rainy season. The Sirana Jaya Salt Production Group, examined in this study, relies on traditional methods, resulting in seasonal production halts during periods of rain. To address these challenges and enhance production quality, the group has implemented geomembrane technology. This technology involves the use of a waterproof plastic layer that accelerates the salt crystallization process by eliminating direct soil contact. Geomembranes also enable better absorption of solar heat compared to conventional salt tables, improving both the quality and hygiene of the final product. Consequently, geomembrane technology has been proven to enhance salt quality, resulting in cleaner products that meet established quality standards. This innovation is anticipated to serve as a benchmark for best practices in advancing the local salt industry, particularly in Aceh, while fostering more sustainable and higher-quality salt production.

2. Method

2.1 Subjects and Location

This research focused on the Sirana Jaya Salt Production Group; a community-based organization formed by salt producers in Pulo Nasi, Aceh, Indonesia. The group comprised 14 members, including both men and women, hailing from various villages such as Deudap, Deumit, Pasi Janeng, Alue Riyeng, and Lamteh. The study was carried out in Gampong Deudap, located in Pulo Aceh District, Aceh Besar Regency. This site was selected because of its high potential for salt production development, supported by the abundant availability of seawater in the region.

2.2 Socialization

The socialization activities were designed to introduce and demonstrate the practical application of geomembrane technology as a means to assist partners in improving salt production. These activities encompassed a variety of empowerment initiatives, including training sessions, workshops, funding opportunities, provision of production tools, and upgrades to infrastructure and facilities. Prior to the program's implementation, several preparatory steps were completed, including (1) Creating a Program Planning Matrix (MPP): This matrix detailed the planned activities, objectives, success indicators, and the timeline for program execution. (2) Developing a Program Blueprint: A comprehensive document offering an overall framework and guidelines to steer the implementation process effectively. Both the MPP and the blueprint served as critical strategic tools, forming the foundation for the program's successful execution.

2.3 Training

This training was divided into two stages, the first was land preparation, and the second was geomembrane installation training.

a. Land Preparation

1. The surface of the crystallization table needed to be flattened to ensure uniformity.
2. The ground had to be dry and cleared of any foreign materials, such as stones, wood, shells, marine life, or other debris.
3. The dimensions of the crystallization tables were standardized and measured accurately.

b. Geomembrane Installation Training

Participants were instructed in the proper installation of geomembrane sheets on the crystallization fields. The process involved carefully spreading the geomembrane sheets over the surface, one section at a time, ensuring they were smooth and flush with the ground. The seams between sheets were glued to prevent any leakage. The edges of the geomembrane were secured to the soil boundaries (tabun) using wooden boards and bamboo stakes for stability.

2.4 Salt Production Workflow Using Geomembrane

The process of salt production using geomembrane involved the following steps.

1. Young Water Channels (Caren): These channels served to transport seawater to the salt production fields. The water could be channelled using a pump or naturally carried by tidal movements, sometimes assisted by windmills.
2. Primary Holding Ponds: Seawater was first directed into primary holding ponds and left to settle for 7–10 days. The water level was maintained at about 1 meter, with a slope ratio of 1:1.
3. Pre-Evaporation Pond I: The settled seawater was then transferred to Pre-Evaporation Pond I, where it was further concentrated. The water depth in this pond was approximately 40 cm, and evaporation increased the salinity from 7 °Be to 10 °Be. The land slope remained at 1:1.
4. Pre-Evaporation Pond II: Next, the water was moved to Pre-Evaporation Pond II for 2–4 days. Here, the water depth was reduced to 30 cm, further increasing salinity. The land slope was consistently maintained at 1:1.
5. Pre-Evaporation Pond III: The water was transferred to Pre-Evaporation Pond III, where it was left to settle for another 2–4 days. The water depth in this pond was about 20 cm, and its salinity continued to increase, with the land slope remaining at 1:1.
6. Pre-Evaporation Pond IV: Finally, the water was moved to Pre-Evaporation Pond IV and left to settle for 2–4 days at a depth of approximately 10 cm, achieving a salinity of 18 °Be. At this point, the water was ready to be transferred to crystallization tables with geomembrane lining. However, for traditional soil-based crystallization, the water required a salinity of 21 °Be, necessitating additional settling time in Pre-Evaporation Pond IV.
7. Crystallization Table: The water, with a salinity of 18 °Be, was transferred to crystallization tables lined with geomembrane at a slope of 1:0.5. The water was left to evaporate, forming salt crystals that could be harvested within four days.

In the traditional salt production process, the steps were similar, but the water in Pre-Evaporation Pond IV was left to settle for a longer period until it reached a salinity of 23–25 °Be. The concentrated water was then transferred to conventional soil-based crystallization tables, and the salt could be harvested after one week.

2.5 Mentoring and Evaluation

Mentoring was provided to enhance salt production and assist the target partners in achieving their marketing goals. The evaluation process was structured into three main stages. The first stage, planning evaluation, focused on assessing activities such as dissemination and socialization initiatives carried out at both the village and national levels. The second stage, implementation evaluation, covered all activities during the execution phase, including conducting village meetings, registering workers for

infrastructure projects, developing work plans, organizing administrative requirements, applying for funding, carrying out the projects, distributing incentives for infrastructure activities, and handing over completed projects. Finally, the control stage evaluation emphasized monitoring, supervision, and quality control to track project progress. This stage also included structured and functional reporting as well as financial progress reviews to ensure transparency and efficiency.

2.6 Program Sustainability

To ensure the sustainability of the program, monthly monitoring was conducted to address any issues encountered by the target partners. The program also focused on maintaining production activities with the aim of marketing the salt in packaged form within the local market of Gampong Deudap, Pulo Nasi. Furthermore, steps were taken to register the product for certification by BPOM and to obtain SNI compliance for salt.

3. Results and Discussions

3.1 Modification of Land Area for Salt Production

The salt production process using the geomembrane method involved modifying the land area to ensure a flat surface with suitable elevation. This adjustment eliminated the need for additional tools to channel water from young water ponds to old water ponds and finally to the crystallization stage. The production area, commonly known as the "salt tunnel," was used as a facility for drying or crystallizing salt. This structure was built by constructing a frame and covering it with UV plastic on top, forming a tunnel or a triangular shape resembling a house.

The modifications to the land and the implementation of the salt tunnel were designed to accelerate the seawater aging process. By the time the water reached the old water holding ponds, it had already achieved the desired salinity range of 20–30 °Be. The use of geomembrane further enhanced the quality and quantity of the salt. The geomembrane-lined ponds were arranged in a winding pattern with uneven bases to create a natural water flow, which facilitated evaporation supported by sunlight and wind.

The production time was significantly shortened by introducing the filter winding system, which sped up the seawater aging process. This innovation reduced the production cycle from 40 days to 25 days. The water depth within the winding system was maintained between 10 and 20 cm. The ratio of the aging pond area to the crystallization table area was 65:35. The process flow is depicted in Figure 1.

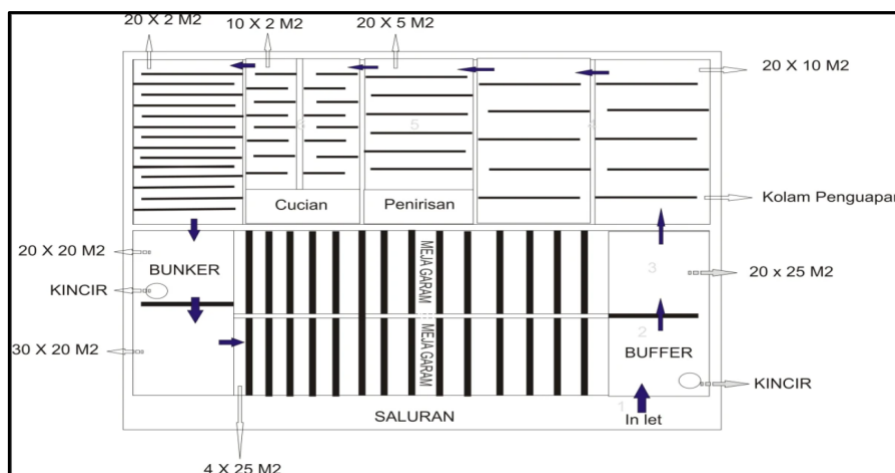


Figure 1. The salt production process flow using the geomembrane method

3.2 Steps in the Salt Production Process

The salt production process using the geomembrane method involves the following stages.

1. **Seawater Storage:** Seawater is directed into an initial holding pond via primary channels. This pond generally has a depth of approximately 50 cm.
2. **Initial Evaporation:** The seawater is moved through a windmill system to accelerate evaporation. The partially evaporated water is then transferred to a secondary storage pond (buffer) with a similar depth of about 50 cm.
3. **Geomembrane Installation:** A geomembrane, typically made of HDPE (High-Density Polyethylene), is installed over the surface of the salt field to act as a waterproof layer between the soil and the water. Its black surface aids in enhancing evaporation by efficiently absorbing heat from the sun.
4. **Evaporation Process:** The pre-treated seawater is filtered and channelled into an evaporation table, where the water level is maintained at 10–15 cm. The use of geomembrane accelerates evaporation by preventing water from being absorbed into the soil, making this process quicker than traditional methods.
5. **Crystal Formation:** As the seawater evaporates completely, the remaining mineral-rich solution forms salt crystals. The geomembrane further expedites this crystallization by reducing soil contact.
6. **Salt Collection:** The resulting salt crystals are harvested and undergo further processing to produce clean, white salt.

This technique produces superior-quality salt by minimizing soil contamination and optimizing solar heat utilization. The production stages implemented by the Sirana Jaya Salt Production Group are depicted in Figure 2.

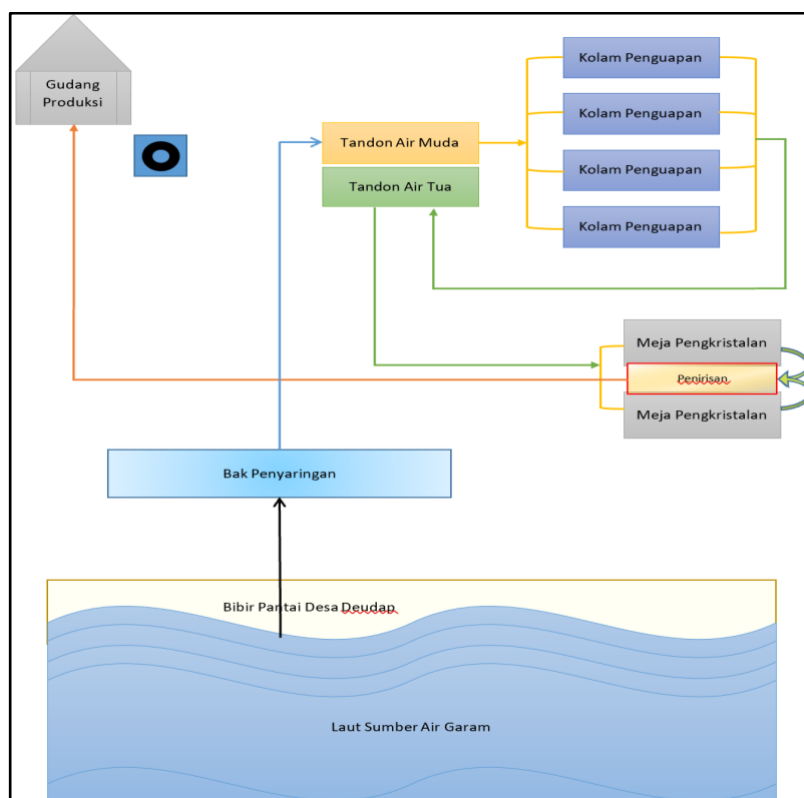


Figure 2. Production stages implemented by the Sirana Jaya Salt Production Group

3.3 Salt Production Quality with the Geomembrane Method

Table 1 highlights the enhancement in salt quality over the three-year period from 2022 to 2024. In 2022, the salt produced was of poor quality, exhibiting a dark colour and uneven texture, primarily due to the reliance on conventional production methods without the use of geomembrane technology. By 2023, the quality of the salt showed noticeable improvement, displaying a whiter appearance, although it was not entirely free of impurities, as the geomembrane technology had only been partially adopted. By 2024, the salt quality reached its peak, characterized by large, uniform crystals with a clean white colour. This significant improvement was a result of the full implementation of geomembrane technology, which increased production efficiency, reduced contamination, and accelerated the crystallization process.

Table 1. Salt quality over from 2022 to 2024

Tahun 2022	Tahun 2023	Tahun 2024
		

4. Conclusions

This research highlights that the use of geomembrane technology in salt production significantly enhances both the quality and quantity of the output. The technology accelerates the crystallization process by maximizing solar heat utilization and minimizing direct contact between seawater and soil, resulting in cleaner and whiter high-quality salt. The adoption of geomembrane by the Sirana Jaya salt production group in Pulo Nasi successfully shortened the production cycle from 40 days to 25 days and brought about substantial improvements in both the volume and quality of production over a three-year period (2022–2024). Initially, in 2022, the salt produced was contaminated, but by 2024 it had transformed into large, uniformly clean white crystals, showcasing the success of this innovation. Moreover, the geomembrane method effectively overcomes weather-related challenges that often disrupt traditional salt production, ensuring continuity even in less favourable conditions. With its potential to significantly reduce Indonesia’s dependence on salt imports, geomembrane technology presents a strategic approach to empowering local salt farmers, strengthening the competitiveness of the national salt industry, and supporting sustainable salt production.

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6. References

- Astuti, R., Qurniawati, D., & Kismartini. (2019). Import of salt: Needs or interest. *ICOMA Proceedings*. <https://doi.org/10.2991/ICOMA-18.2019.11>
- Setyowisnu, G. E., Febriawan, M. R., Asiyah, A. A. S., & Khasanah, N. U. (2020, April). Production Rate Modelling towards Salt Consumption as a Solution to Avoid Hypothyroid Disease for Indonesian People. In *Proceeding International Conference on Science and Engineering* (Vol. 3, pp. 339-340).
- Sunoko, R., Saefuddin, A., Syarief, R., & Zulfainarni, N. (2023). Do the Government Support Salt Small and Medium Enterprises' Competitiveness? *Binus Business Review*, 14(1), 61-72.
- Yaqin, A., & Setiani, S. (2017). Karakteristik petani dan kelayakan finansial usahatani garam secara tradisional dan teknologi geomembran (Studi Kasus di Desa Pangarengan Kecamatan Pangarengan Kabupaten Sampang). *Jurnal Pamator: Jurnal Ilmiah Universitas Trunojoyo*, 10(1), 54–60.