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RESEARCH ARTICLE

Analysis of the Implementation of Plasma Fine Bubble in Waste Management Seaweed at PT Hakiki Donarta Company

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ABSTRACT

The potential of Indonesian seaweed is one of the sectors that will support Indonesia's blue economy agenda. The uses of seaweed are very diverse and depend on the production processing of seaweed bases. Seaweed is one of the leading commodities in the mariculture sector. However, the increase can have a negative impact on the environment. This is because seaweed processing produces 65-70% waste, and the handling of Wastewater Treatment Plants (WWTP) still uses treatment chemicals, so this method has not been included in the environmentally friendly and sustainable management criteria. This study uses a descriptive method with in-depth interviews and is supported by literature reviews to strengthen the research validation of implementing Plasma Fine Bubble technology. The PFB implementation analysis aims to determine the cost-effectiveness incurred when managing seaweed waste products using PFB. The results found that Plasma Fine Bubble technology can reduce waste management costs by 50%. Using PFB for seaweed waste management activities is hoped to reduce the company's expenses and support sustainable, environmentally friendly practices.

INTRODUCTION

The potential of seaweed distribution areas in Indonesia is very wide; both those that grow naturally and those that are cultivated in ponds are spread across almost all regions such as Sumatra, Java, Bali, Nusa Tenggara, Kalimantan, Sulawesi, Maluku, and Papua (Hendrawati, T. Y. 2019). The uses of seaweed are very diverse and depend on the production processing of seaweed bases. Seaweed is one of the leading commodities in the *mariculture* sector. Data on seaweed production values in the last 1 decade tends to have increased with an average growth of 14.75%, although in terms of production volume, there has been a decrease in the last 5 years (KKP 2023).

The development of seaweed commodities as the focus of one of the leading products or commodities of the fisheries sector is a strategic step chosen with the consideration that (1) at the level of cultivation development it has high labor absorption, simple cultivation technology, a relatively short planting period of about 45 days *(quick yield)* and the cost per unit of production is relatively very cheap; (2) at the level of seaweed processing through the development of the seaweed processing industry requires the support of other sectors (Anggadireja, 2011). This is evidenced by seaweed production in Indonesia in 2021, reaching 9.12 million tons with a value of IDR 28.48 trillion (still a provisional value). The increase can be seen from the increasing demand for processed seaweed products such as gelatin and carrageenan.

On the other hand, the increase can have a negative impact on the environment. This is because seaweed processing produces waste of 65-70% of the total seaweed inputs used (Kim *et al.,* 2007). Seaweed contains hydrocolloid compounds, and carrageenan is an extraction of sulfated linear polysaccharides processed using alkaline compounds or solutions. In addition, seaweed has a high amino acid content, so the waste produced tends to smell and has a high Nitrite (N) value. The problem that occurs in the seaweed industry is the content of liquid waste from the by-products of the seaweed processing industry; currently, in its management, it requires three repetitions, so it requires quite high production costs.

So far, the handling of the Wastewater Treatment Plant (WWTP) still uses *treatment chemicals, which, of course, are not friendly to the environment, so they* can produce entropy or residue from economic/business activities carried out. This entropy exists, which can be directly absorbed by nature, and some cannot or take a long time to decompose. This second form of entropy/residue is the main problem of human life today. PT Hakiki Donarta in Surabaya is a *leading seaweed processing company* that, in handling its WWTP, is currently still using chemical Polyaluminium chloride and aeration ponds with the help of watermills. This condition, of course, receives special attention in the waste handling process so that businesses can be environmentally friendly and sustainable. This environmentally friendly business process is in line with the concept of *the blue economy,* which is currently being talked about.

The implementation of Plasma Fine Bubble (PFB) technology in the seaweed industry requires a business model to provide sustainability in innovation from an operational and financial perspective. The implementation of this technology is carried out with a model approach using *a business model canvas* and SWOT analysis. The business model itself describes the basis of thinking about how organizations create, provide, and capture value (Maysari, N., & Musbikhin, M., 2023).

LITERATURE REVIEW

Seaweed

Seaweed, or macroalgae, has emerged as a focal point of research and economic interest due to its critical role in marine ecosystems and its applications across diverse industries such as food, agriculture, pharmaceuticals, and biofuels. Categorized into Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae), seaweed is known for its unique pigments and biochemical compositions, which make it a versatile resource (Notario Barandiaran et al., 2024; Machado & Oliveira, 2024). As one of the largest producers, Indonesia contributed 9.12 million tons of seaweed in 2021, supplying raw materials for hydrocolloids like carrageenan and agar, which are essential to global markets (KKP, 2023; Ya'la et al., 2024). The global seaweed market, valued at USD 1.13 billion in 2018, continues to grow, driven by increasing demand for its bioactive compounds, such as proteins, polysaccharides, and essential minerals, which support emerging applications in biofertilizers, renewable energy, and biomedical uses (Pereira et al., 2024; Zocchi et al., 2024). Seaweed cultivation also promotes environmental sustainability by requiring minimal freshwater, land, and fertilizers while aiding carbon sequestration and reducing ocean acidification (Pei et al., 2024; Pereira et al., 2024).

Management waste seaweed

The growing seaweed industry has resulted in a substantial increase in byproducts and waste, driving the need for innovative waste management solutions to mitigate environmental harm and unlock economic potential. Seaweed waste, primarily originating from discarded biomass such as roots, stems, and sporophylls, constitutes nearly 50% of the harvested material (Templonuevo et al., 2024). Improperly managed, this waste contributes to marine pollution, carbon emissions, and reduced farming efficiency in subsequent cycles (Pei et al., 2024). While traditional treatment technologies like flocculation and aeration have been employed, their limitations in addressing the high chemical oxygen demand (COD) and biological oxygen demand (BOD) in seaweed wastewater have prompted the exploration of advanced alternatives (Hakiki Donarta, 2023; Xiao et al., 2022).

Among the most promising innovations is Plasma Fine Bubble (PFB) technology, which has garnered attention for its ability to address the limitations of conventional methods. PFB utilizes advanced oxidation processes (AOPs) to generate hydroxyl radicals (OH•) with higher oxidation potential than standard chemical agents, effectively breaking down organic pollutants in wastewater (Nanobubble Innovations, 2024). Studies show that PFB not only improves wastewater treatment efficiency but also enhances nutrient uptake in aquaponics and agriculture, underscoring its versatility across sectors (Akinmoladun & Adedeji, 2021; Zhang et al., 2021). For the seaweed industry, PFB has proven to significantly reduce COD levels in wastewater, making it a cost-effective and scalable alternative to chemical-intensive processes (Zhang et al., 2022). By enhancing oxygen transfer rates in biological treatment systems, PFB reduces the reliance on external chemical inputs and promotes sustainable production practices.

Simultaneously, efforts to repurpose seaweed waste into high-value products have gained traction. Advanced techniques such as freeze drying enable the preservation of bioactive compounds like fucoxanthin, polyphenols, and phlorotannins for applications in nutraceuticals, cosmetics, and agriculture (Templonuevo et al., 2024). Furthermore, electron beam irradiation and acid hydrolysis are employed to isolate cellulose nanocrystals for energy storage systems, while inedible seaweed is transformed into porous graphitic carbon materials for use in renewable energy technologies (Jeong et al., 2024; Song et al., 2024). Recycled seaweed biomass has also been utilized to create eco-friendly substrates for marine restoration, contributing to biodiversity and carbon sequestration (Yamamoto et al., 2023). Despite these advancements, challenges such as high processing costs, waste composition variability, and limited recycling infrastructure persist (Jeong et al., 2024). Addressing these barriers requires collaborative efforts among policymakers, researchers, and industry stakeholders to scale sustainable waste management solutions.

Plasma fine buble

Plasma Fine Bubble (PFB) technology has emerged as an innovative solution for wastewater treatment, particularly in industries with high organic waste output, such as seaweed processing. This technology combines plasma technology, which generates reactive ozone molecules, with fine bubble technology that produces ultra-fine bubbles with diameters below 1 micrometer. These nanobubbles are stable, long-lasting, and possess unique properties such as high gas solubility and the ability to generate hydroxyl radicals, which have significantly higher oxidation potential than traditional treatment chemicals like chlorine or ozone (Sulistyowati & Prayitno, 2021; Nanobubble Innovations, 2024). These characteristics enable PFB to effectively reduce chemical oxygen demand (COD) and biological oxygen demand (BOD) in wastewater, providing a sustainable and chemical-free alternative that aligns with environmental standards and supports agricultural reuse through treated water irrigation.

Beyond its environmental benefits, PFB offers operational advantages by enhancing oxygen transfer rates in biological treatment systems, improving microbial efficiency in breaking down organic pollutants in nutrient-rich wastewater (Hakiki Donarta, 2023). This is particularly relevant in seaweed processing, where traditional methods often fall short in addressing wastewater's high nutrient content. Additionally, the technology reduces the reliance on chemical additives, lowering treatment costs by up to 32% compared to conventional methods, making it a cost-effective and scalable solution for sustainable waste management (Lingga & Marsono, 2018; Samekto & Rachmah, 2023). PFB can also address challenges such as the discoloration of treated water and excessive chemical usage by enhancing processes like dissolved air flotation (DAF). By oxidizing dissolved pollutants into suspended particles, PFB simplifies pollutant separation and increases the efficiency of flocculant usage while also boosting dissolved oxygen levels, thereby improving the aerobic decomposition of organic compounds.

The unique capabilities of PFB technology are rooted in its use of Advanced Oxidation Processes (AOP), which rely on hydroxyl radicals (•OH) with an oxidation potential stronger than ozone and chlorine. These radicals effectively oxidize pollutants, including ammonia and organic matter, facilitating a more efficient wastewater treatment process (Luvita et al., 2022). The integration of nanobubbles with plasma reactors has further enhanced treatment effectiveness, demonstrating potential across various environmental applications, including air purification and nanomaterial synthesis (Sato et al., 2019; Hong et al., 2021). Furthermore, nanobubbles are characterized by their durability, negative surface charge, and low buoyancy, enabling them to improve oxygen delivery in aerobic systems, a critical factor for microbial activity in pollutant decomposition (Lyu et al., 2019; Lyu et al., 2023). In the context of seaweed wastewater treatment, PFB technology addresses the challenges associated with traditional anaerobic and aerobic methods that often suffer from low oxygen availability, limiting microbial effectiveness. By improving aeration through nanometer-sized bubbles, PFB enhances the breakdown of COD, BOD, total suspended solids (TSS), and ammonia, reducing environmental impact while supporting the blue economy's objectives. As research and pilot-scale implementations continue to optimize its applications, PFB stands out as a transformative technology for advancing sustainable and efficient wastewater management in the seaweed industry.

METHOD

Data collection

The data collection came from farmers who were around the location of the PT Hakiki Donarta company in the Pasuruan area, Surabaya. The data is primary, and it comes from the results of field observations at the company in October. The collection of respondent data aims to (1) find respondents to measure the impact of seaweed waste produced by PT Hakiki Donarta, (2) Implement *Fine Bubble* Plasma on companies in seaweed waste management, and (3) Measure the cost *and benefit* efficiency of the use of Plasma *Fine Bubble technology.*

Data analysis

This study uses qualitative description. The type of data used is primary data, and the data collection technique used in this study is the in-depth interview method, which involved a total of 50 respondents from farmers. Each respondent was given a questionnaire in the form of 16 statements on a Likert scale (1-5). The Likert Scale is a scale used to measure a person's attitudes, opinions, and perceptions with the Likert Scale, so the variables to be measured are described as variable indicators (Hasbullah, F., & Anraeni, S., 2023). This technique is used to dig up information in depth from the identified sources and then crosscheck the interview results (Siregar, M., & Faddilla, S. P., 2023). The data analysis technique in the study began by conducting interviews with farmers and then making transcripts of the interview results. The presentation of the Likert scale analysis can be divided into two parts, namely, multiple choice and *checklist form*.

$$\text{Index} = \frac{(\text{Total Score})}{Y} \times 100\%$$

Information:

Total Score: Result of the number of respondents * scale number *Likert*

y: Highest score *Likert* * Number of respondents.

After obtaining the necessary data, the author provides further analysis to provide a technological overview of the business perspective using BMC *(Business Model Canvas). The Business Model Canvas* (BMC) can not only be used to photograph the company's current business model but can also be used as a tool to provide proposals for new business model designs (Sakti, I. W., Praptono, B., & Sagita, B. H., 2021).

Milestones in the implementation of fine bubble plasma

There are five milestones and *key phases* that are carried out in stages of activities carried out with PT Hakiki Donarta, which are as follows.
Five milestones and key phases

Table 1: *Plasma fine bubble* milestone for PT Hakiki Donarta (Source: Processed Author, 2023).

Moon	Activity Description
July	Prepare a PFB system that will be implemented.
August-September	Process manufacturing and PFB system assembly
October	Application and performance testing of PFB generators at Hakiki Donarta Factory
November	Adopt and scale PFB system using Benefit-Cost Analysis
December	Make business plan

Research stages

The research stages are carried out starting from determining the actors who will be targeted for the implementation of PFB to making *a business plan.* The stages of the research can be seen in figure 1.

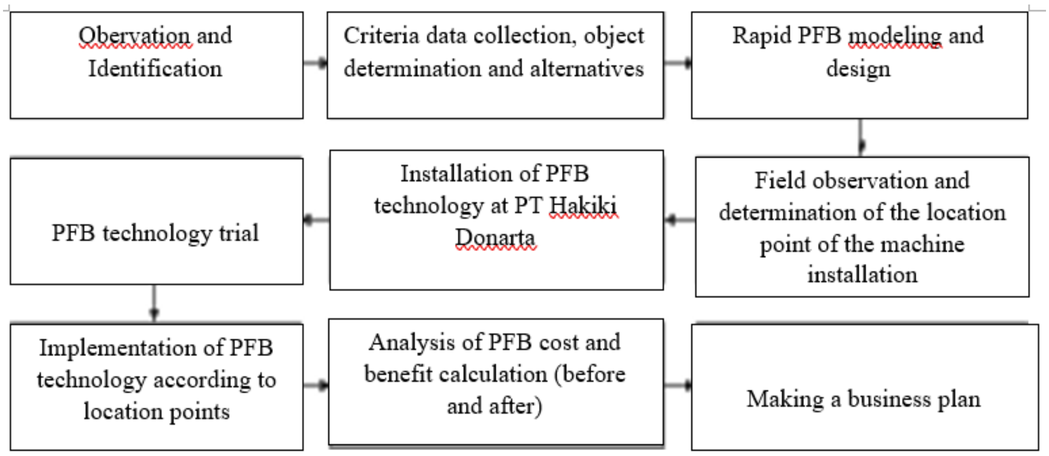

Figure 1: Research stages

RESULTS AND DISCUSSION

Fine bubble plasma on seaweed waste

Plasma Fine Bubble (PFB) technology is a combination of plasma technology and *fine bubble* technology. Plasma is a technology that can produce ozone, while *fine bubble* is a technology that can produce very fine air bubbles in water.with a diameter size of less than 1 micrometer. According to Sulistyowati and Prayitno (2021), nano It has a large specific area, high reactivity, and high kinetics and affinity for various contaminants.

Through this PFB technology, the amount of waste generated by the industry can be reduced by minimizing the use of water and chemicals, as well as improving the efficiency of the production process. In addition, this technology can also help improve the treatment of liquid waste and solid waste by reducing the number of pollutants and increasing the rate of biodegradation.

In the management of seaweed liquid waste, which currently still uses a lot of *treatment chemicals*, PFB technology can be a solution to produce liquid waste that is more environmentally friendly. Seaweed has a high amino acid content, so the seaweed processing industry produces waste that tends to smell and has a fairly high nitrite value. Plasma technology that produces ozone and is injected using *fine bubble nozzles* in seaweed wastewater can quickly decompose ammonia into nitrate and reduce *Chemical Oxygen Demand* (COD) and *Biological Oxygen Demand* (BOD) so as to produce water that meets quality standards to be circulated as wastewater to plantations and community rice fields.

Figure 2: Fine bubble plasma technology display

Figure 2: Observation at PT Hakiki Donarta

Analysis business type canvas fine bubble plasma technology

The Business Model Canvas is a means to describe, visualize, assess, and change a business model (Anhar, Z. S., & Marsasi, E. G., 2022). The business model has nine basic building blocks that are able to explain several aspects to help the company in obtaining profits (Osterwalderr & Pigneur, 2017:14).

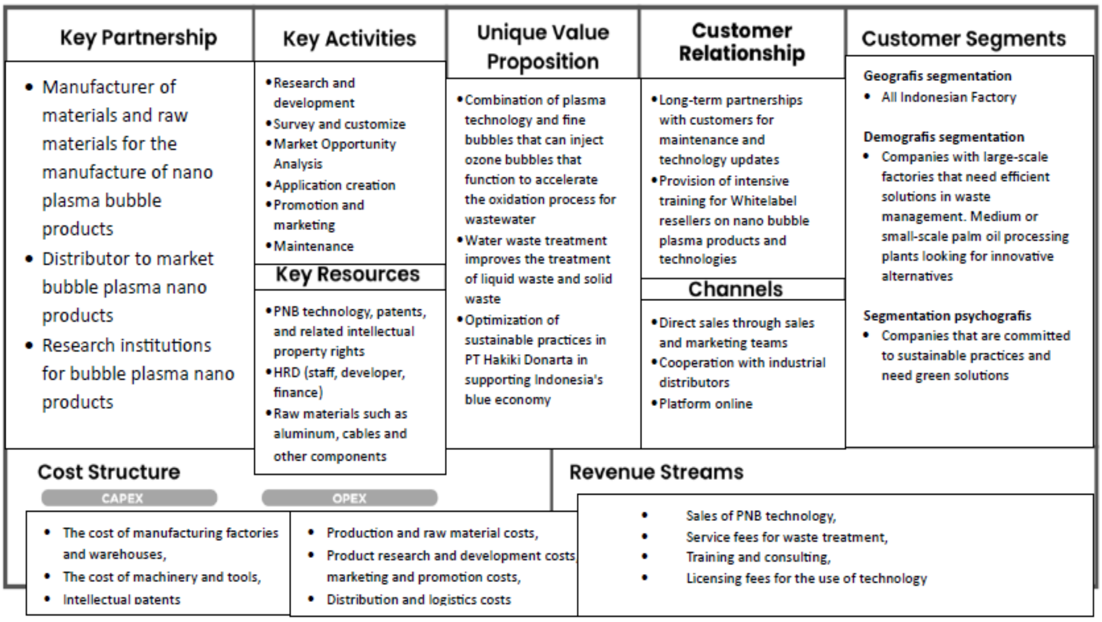

Figure 3: BMC plasma fine bubble

In-depth interview results

In-depth interviews were conducted with farmers who experienced firsthand the waste produced by PT Hakiki Donarta in Pasuruan, Surabaya. The interview was arranged in the form of 16 statements on a scale of 1-5. Scales 1-5 are given information, namely (1) very inadequate, (2) inadequate, (3) neutral, (4) adequate, (5) very adequate.

Table 2: Statement of the PFB Questionnaire at PT Hakiki Donarta.

Code	Question
P1	To what extent are you sure that wastewater from The seaweed plant currently has adequate quality for use in the field?
P2	How do you assess the cost-effectiveness of this current in the use of wastewater?
P3	To what extent do you agree that the water quality waste today has a positive impact on your agricultural products?

P4	Do you believe that the use of water Current waste contributes to the problem milieu?
P5	How often do you have problems with the quality of wastewater today?
P6	How do you judge risk related to the current use of wastewater against your plants?
P7	To what extent are you satisfied with the current quality of wastewater?
P8	How do You judge sustainability? What is the current use of wastewater in the long term?
P9	To what extent do you believe that the use of wastewater today has increased yields in your harvest?
P10	How do you assess the current impact of wastewater on the health of your plants?
P11	To what extent do you feel the current wastewater has the potential to be improved in its use in the field?
P12	How do you assess the current level of wastewater needed to irrigate your corn plants?
P13	To what extent do you believe that the processing method of water waste moment is already maximizing resource efficiency
P14	How do you assess the sustainability of current water waste use in the long term?
P15	What do you think is the effort that seaweed factory waste is making to recycle its waste?
P16	How do you access transparency management with grass sea from the company?

Figure 4: Field survey with Farmers around the location of PT Hakiki Donarta

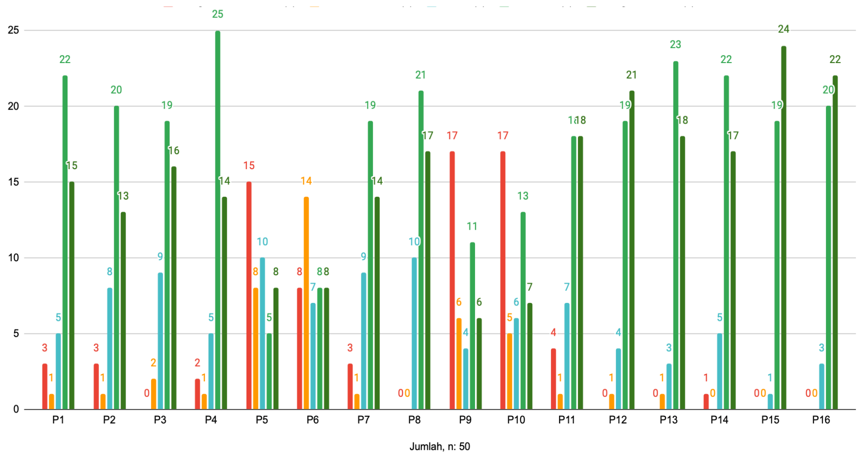

Figure 5: Results of the fine bubble plasma implementation field survey report

Based on the graph above, it can be seen that the score obtained by each statement represents the number of respondents as many as 50. From very inadequate is also seen from some statements such as P5; P9; and P10. For each statement, the dominant respondent answered very adequately (5). On the other hand, the number of answers companies will be social and environmental. Therefore, the researcher analyzed the implementation of Plasma *Fine Bubble* (PFB) technology for PT Hakiki Donarta to see how cost-effective and effective the machine is for seaweed waste management.

Table 3: Questionnaire index results

Code	Very inadequate	Inadequate	Neutral	Adequate	Very Adequate	Indeks
P1	3	1	5	23	18	22%
P2	3	1	8	20	13	25%
P3	0	2	9	19	16	26%
P4	2	1	5	25	14	20%
P5	15	8	10	5	8	33%
P6	8	14	7	8	8	36%
P7	3	1	9	19	14	26%
P8	0	0	10	21	17	24%
P9	17	6	4	11	6	29%
P10	17	5	6	13	7	29%
P11	4	1	7	18	18	28%
P12	0	1	4	19	21	24%
P13	0	1	3	23	18	22%
P14	1	0	5	22	17	23%
P15	0	0	1	19	24	26%
P16	0	0	3	20	22	25%

Managerial implication

This research contributes to understanding the impact of unsustainable practices on seaweed management in a company, especially PT Hakiki Donarta which is one of the *lead companies* that produce seaweed products. Understanding sustainable seaweed waste management accommodates the path that can be taken to achieve the *blue economy agenda*. It needs to be understood that encouraging the development of environmentally friendly sustainable practices will be one of the important steps to provide responsibility The implementation of Plasma Fine Bubble (PFB) technology in seaweed waste management at PT Hakiki Donarta can reduce waste management costs by 32%. The results showed that PFB was effective in overcoming the negative environmental impact of seaweed processing which produced waste of 65-70%. This technology not only helps to reduce the amount of waste, but also minimizes the use of water and chemicals, and improves efficiency in the production process. The use of PFB is expected to support environmentally friendly and sustainable practices in accordance with *the evolving* concept of the blue economy.

CONCLUSION

Based on the research results, the author recommends that the government, seaweed processing companies, and the community collaborate to apply Plasma Fine Bubble (PFB) technology in seaweed waste management. This collaboration is necessary to ensure that PFB technology can be implemented effectively and sustainably.

The government can provide support through subsidies, incentives, or regulations that encourage using PFB technology. Seaweed processing companies can commit to implementing PFB technology by investing in its procurement and training employees in its use. The community can support the application of PFB technology by socializing about its benefits and participating in maintaining wastewater quality.

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