Preliminary design of a low-cost greenhouse for salt production in Indonesia

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Abstract. Salt is an assential material of industry, not only in food industry point of view but also in various industries such as chemical, oil drilling, and animal feed industries, even less than half of salt needs used to household consumption. It is crucial to ensure salt production in Indonesia reaches the national target (3.7 million tons) due to relatively low technology and production level. Thus salt production technology is developed to facilitate farmers consisted of geomembrane and filtering-threaded technology. However, the use of those technologies in producing salt was proved less effective due to unpredictable weather conditions. Therefore, greenhouse technology is proposed to be used for salt production for several good reasons. This paper describes the preliminary design of a low-cost greenhouse designed as a pyramid model that uses bamboo, mono-layer and high density polyethylene plastics. The results confirmed that the yield of salt produced by greenhouse significantly incresed compared with prior technology and the NaCl content increased as well. The cost of greenhouse was IDR 5,688,000 and easy to assembly.

1. Introduction

Salt production technology is one of the important factors to produce salt in the world. There are several technologies have been applied extensively in many areas, particularly in Indonesia. Among the technologies, traditional technology is widely used as a simple salt production technology compared to other technologies due to low-cost, low-energy, and easy to use technology. However, traditional technology has many disadvantages such as low productivity, poor quality, and high efforts to produce salt. Prior studies reported that the productivity of salt produced by traditional technology can yield in the range of 60 tons/ha/year [1], the NaCl purity reaches less than 90 % [2], the colour of salt is brown to grey, and the price is generally inexpensive with the value of IDR 300-500 per kg [3].

Other technologies implemented in salt production are geomembrane liner and filtering-threaded technology. Geomembrane liner is a improved traditional technology by lining the salt pans with appropriate plastic membrane. The geomembrane liner commonly used is high density polyethylene (HDPE) [4]. It has a wide range of properties, for instances high anti-seepage coefficient, chemical stabality, anti-aging, resistant to high and low temperature, and high mechanical strengh. On the other hand, filtering-threaded technology is a modified geomembrane liner by passing water through a series of shallow channels to saturate the water into brine with an additional filtering membrane to

purify the water. Several prior studies have been explored that both the geomembrane liner and filtering-threaded technology can increase productivity, improve quality, dan shorten production time [5], but the filtering-threaded technology is more effective than traditional ones.

On the contrary, one of the most factors challenge salt production in Indonesia is changes in climate resulting in unreliable weather patterns. Those technologies of salt production described above cannot deal with unpredictable wether. Therefore, innovation of new salt production technology is needed to figure out unreliable weather patterns in producing salt. In this study, we focus on designing a new salt production technology by proposing low-cost greenhouse technology. According to Suseela and Rangaswami [6] greenhouse technology can maintains air temperatures and relative humidity. This paper aims to design a low-cost greenhouse that uses bamboo, mono-layer and high density polyethylene plastics. Through this a low-cost greenhouse may be breaktrhough in producing salt and facilitate farmers in several areas throughout Indonesia.

2. Material and Methods
2.1. Main materials required
The following materials are required to construct a low-cost greenhouse for salt production:

- Bamboos, as a main framework to build a low-cost greenhouse. It is selected due to inexpensive, light weight, and non-corrosive material. In addition, it is widely used and readily available in many places, especially in Java, Indonesia. For building geenhouse, it is usually in medium size with diameter of 10-12 cm and the length of bamboos used in the range of 1 m, 7 m and 10 m.

Figure 1. Bamboo framework of a low-cost greenhouse.

- UV plastic, as a glazing material (plastic covering). Typically, the plastic covering the greenhouse is replaced many times before the framework fails due to corrosion and mechanical loading [7]. The specifications of UV plastic used in covering greenhouse are UV plastic of 14% in reducing intensity of sunlight, 200 micron thick, and semi transparent plastic. It is designed suitable for salt production greenhouse.

Figure 2. UV plastic with 14% reducing sunlight intensity.

- High density polyethylene (HDPE), as geomembrane liner in salt pan of greenhouse. It is generally fabricated by adding carbon black and antioxidant additives, which are extensively used to retard and inhibit the UV degradation and temperature degradation of geomembranes [8]. The specifications of HDPE can be seen in table 1.
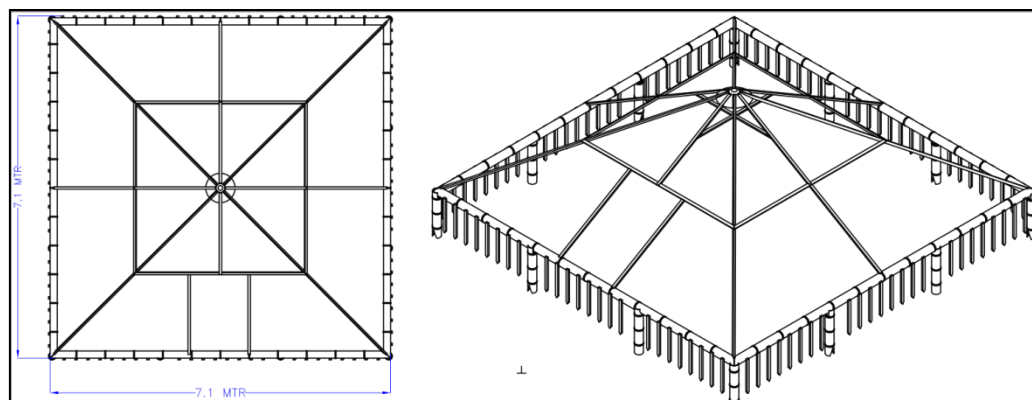
Table 1. HDPE geomembrane properties.

Properties	Test Method	GM 13 STANDARD 1,0 mm	EXTERNAL LABORATORY 1,0 mm
Laboratory			CTT Group *
Thickness	ASTM D5199-12		1.16 mm
Density	ASTM 729-13 Method A	0,94 g/cc	0.941 g/cc
Carbon Black Content	ASTM D1603-14	2 - 3 %	2,53%
Carbon Black Dispersion	ASTM D5596-03 (2009)		1
Tensile Properties	ASTM D6693-04 (2015)e1		
MACHINE DIRECTION			
- Strength at Yield		15 kN/m	17 kN/m
- Elongation at Yield		12%	17%
- Strength at Break		27 kN/m	42.5 kN/m
- Elongation at Break		700%	772%
CROSS DIRECTION			
- Strength at Yield		15 kN/m	17.1 kN/m
- Elongation at Yield		12%	17%
- Strength at Break		27 kN/m	41.6 kN/m
- Elongation at Break		700%	786%
Tensile Strength	SNI ISO 37:2015 (IDT-2011)		
Secant Modulus at 2%	ASTM D5323-92 (2011)		
MACHINE DIRECTION			308.4 kN/m
CROSS DIRECTION			311 kN/m
Tear Resistance	ASTM D1004-13		
MACHINE DIRECTION		125 N	160 N
CROSS DIRECTION		125 N	153 N
Puncture Resistance	ASTM D4833/D4833M-07 (2013)e1	320 N	320 N
Oxidative Induction Time			
Standard OIT	ASTM D3895-14	100 min	151 min
Stress Crack Resistance	ASTM D5397-07(2012) (App)	300 hours	>500 hours

*) CTT Group Geosynthetics - Canada

2.2. Skecth of a low-cost greenhouse

The sketch of a low-cost greenhouse by using AutoCAD mechanical desktop that is a computer-aided design application for 3D mechanical design, simulation, visualization, and documentation. The sketch designed as pyramid model, which is expected as a suitable model of greehouse for salt production located in seashore areas in Indonesia. It has length around 7.1 m with the hight of 3.5 m.

Figure 3. The sketch of a low-cost greenhouse for salt production.

3. Results and Discussion

3.1. Design of a low-cost greenhouse

The greenhouse model is generally designed as the hoop and gable. These models are typically constructed of steel or galvanized steel as a framework of greenhouse, but the material costs are expensive and also the maintenance costs are relatively unaffordable. In addition, they are vulnerable to corrosion because steel or metal material tend to get rapid corrosive if it is placed in the seawater [9]. Another constuction of greenhouse is made by wooden frame, but it is heavy and high price, partticulary in East Java. Those materials are not suitable for developing greenhouse technology of salt production, in particular for salt farmers in East Java. Hence, a low-cost greenhouse proposed to facilitate farmers in producing salt with innovative technology, inexpensive, and easy to operate. The design of a low-cost greenhouse technology of salt production is displyed at figure 4.
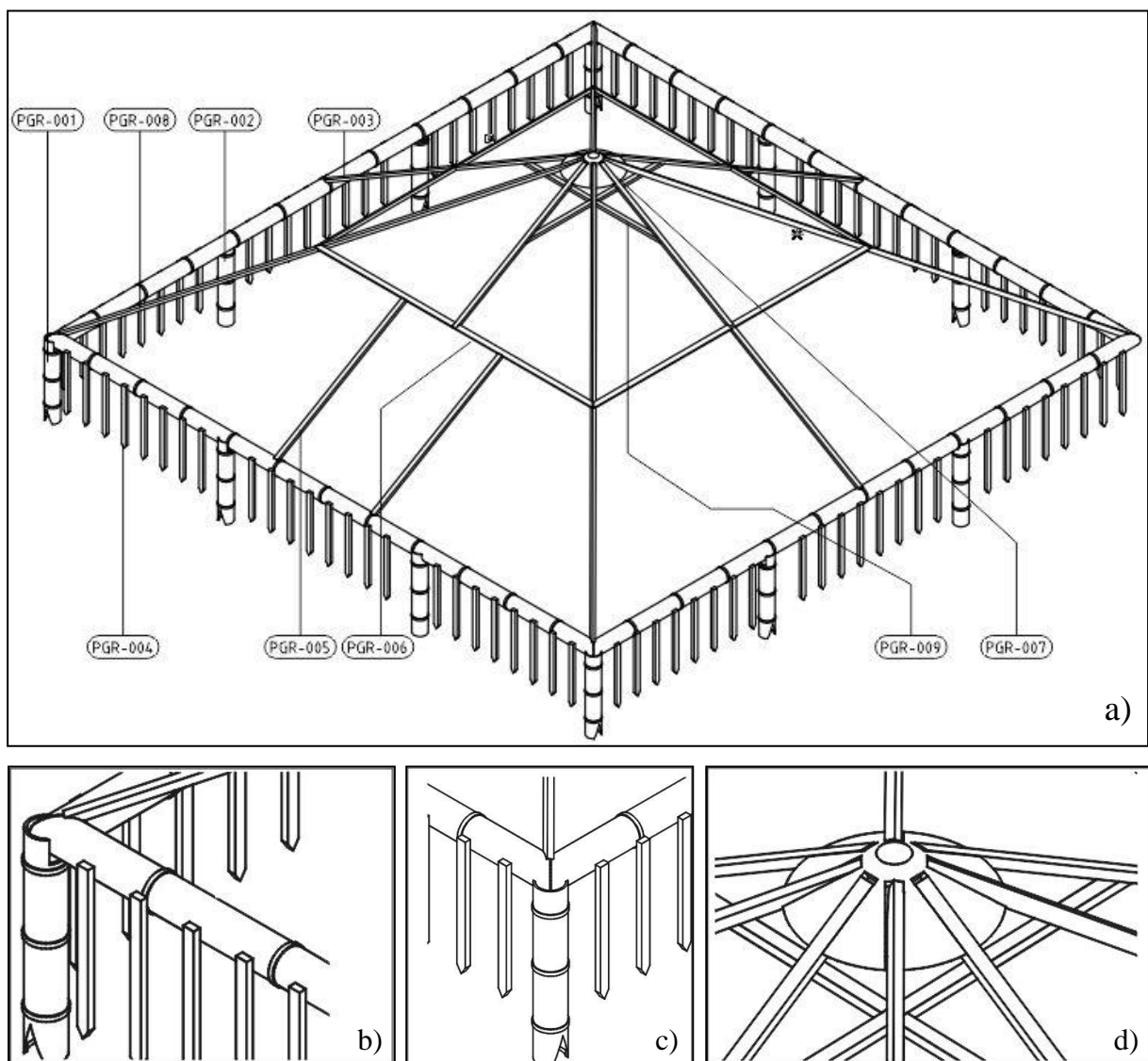

Figure 4. The skech of a low-cost greenhouse with pyramid model. a) the prespective view of pyramid greenhouse; b) the connecting in engle of pyramid greenhouse; c) the angle of pyramid greenhouse; d) the connecting roof of pyramid greenhouse.

The a low-cost greenhouse technology designed as a pyramid model, which was composed by several materials, such as bamboos, UV plastics and geomembrane liners. The pyramid model of a low-cost greenhouse was choosen due to suitable for sesshore areas, generally the salts pan located in the seashore, especially in East Java, Indonesia. The prespective view of the a low-cost grenhouse as shown in figure 3a that has connecting part in every angles and roof of the preliminary design by using bamboos as seen in figure 3b, 3c, 3d, respectively. Bamboos, as a primary construction of a low-cost greenhouse bacause they were low-price, light weight, non-corosive, and easy to obtain materials. The diameter size of bamboos in the range of 16 cm and the length of bamboos used in the range of 1 m, 7 m and 10 m, repectively. Furthermore, for glazing material of a low-cost greenhouse applied UV plastic with the specifications of UV plastic was 14% aiming to reduce intensity of sunlight, 200 micron thick, and semi transparent plastic. According to Ghany *et al.* [10] UV plastic used in glazing material for greenhouse is suitable to increase temperature and reduce sunlight intensity. For the liner in the a low-cost greenhouse performed by HDPE, which is generally manufactured by carbon black and antioxidant additives are widely used to inhibit the UV degradation and temperature degradation of geomembranes [4].

3.2. Field testing results

After designing the greenhouse, we conducted the performance and feasibility testing of greenhouse technology in producing salt. The field testing performed in salt pan located in Lamongan, East Java, by investigating the salt productivity and quality. The data were described in table 2.

Table 2. Field testing results in producing salt.

Parameters	Value
Average temperature	45 °C
Productivity	150 kg/ha
Sodium chloride/NaCl	95 %
Colour	white

The results of this study revealed that the productivity of salt was in the range of 150 kg/ha, which significantly increase compared with the traditional technology. According to Mustofa and Turjoyo [1] the salt productivity by using traditional technology around 60 tons/ha. In addition, the quality of salt produced by greenhouse improved with the content of sodium chloride about 90% and the colour of salt was white (purified). Arwiyah *et al.* [2] stated that the quality of salt produced by traditional technology displayed the NaCl content less than 90% and its colour is brown to gray.

3.3. Investment analysis

Investment analysis is carried out to evaluate a total cost required to construct a low-cost greenhouse. As a low-cost greenhouse of salt production, we decided to use not only affordable materials, but also easy to assembly and operate for farmers. The invesment analysis is shown at table 3.

Table 3. Investment analysis of a lo-cost greenhouse technology.

Materials	Lifetime	Total	Price per items (IDR)	Total (IDR)
Screws	5	800 pcs	350	280,000
Bamboos	5	20 pcs	50,000	1,000,000
labourage	-	3 people	200,000	600,000
Geomembranes	5	15 kg	119,000	1,785,000
UV plastics	5	17 kg	119,000	2,023,000
			Total	5,688,000

The investment analysis of a low-cost greenhouse of salt production might account for IDR 5,688,000 per units. It is more affordable that that of greenhouse constructed by metal materials. The predicted lifetime of geenhouse around 5 years, which is appropiate technology for salt production. The benefits of the low-cost greenhouse of salt production, as follows:

- Greenhouse costs: Less than IDR 5,688,000 for an affordable greenhouse with a minimum planting area of 64 square meter.
- Ease of assembly: Three individuals with minimal training should be able to assemble the greenhouse from the ground-up in a day.
- Lifetime: Minimal lifetime of five years for the greenhouse structure and five years for the glazing; only limited maintenance should be required by the salt farmer.
- High productivity: It can improve productivity compared with traditional technology.
- Purity of salt: Sodium chloride can reach more than 95%.

4. Conclusion
This study deduced that the preliminary design of a low-cost greenhouse for salt production designed as a pyramid model constructed by bamboos, UV plastic, and HDPE. It can increase the salt productivity and quality. In addition, it is an affordable, easy to assembly, and suitable for salt farmers.

5. References
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