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RESEARCH PAPER

A new concept for sustaining the marine environment through the recovery of Magnesium Carbonate from the wastewater of the traditional salt production

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Abstract. Environmental sustainability has a significant impact on social and economic sustainability. Without a sustainably productive environment to provide the humans' primary needs, the existence of society would be impossible. The sustainability of the economy depends on the sustainability of the raw material, energy and environmental resources. This work discussed the environmental sustainability in marine which focused on the utilization of the sea water as raw material for salt. We investigated the raw material characteristics and salt quality. The characteristics of raw material showed the high concentration of sodium, chloride, calcium and polluted by trace metal. Based on the SEM-EDX, salt contains lead and copper. The income of the farmers is influenced by the salt quality. The better the quality, the bigger the income they received. Indirectly, the economic condition in the coastal area is influenced by the quality of the sea water. This condition encourages the researches to find a strategy to achieve the sustainability of the marine. The aims of this study are to review and categorize the indicators for marine environmental sustainability into Driver-Pressure-States-Impacts-Response (DPSIR) and suggest some strategies for supporting the environmental sustainability. DPSIR indicators utilized sea water. The wastewater was discharged into sea leading to the increase of the ion concentration, which then disrupted the mangrove growth that functions as the regulator of salt wastewater disposal flowing to the sea. Recovering the magnesium from the salt wastewater is a potential strategy to protect the marine environment and to support the economy-social sustainability.

Keywords: Magnesium, marine environment, recovery, sustainability, traditional salt production.

1. Introduction

Indonesia is a maritime country with 31 salt production buffer areas. One of them is Pliwetan, Tuban, East Java (Ministry of Maritime Affairs and Fisheries, 2014). However,

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Indonesia still needed to do the import in August 2017 due to the salt scarcity (Ministry of Trade, 2017). Traditional salt farmers have not been able to produce a standardized quality with adequate quantity. The quality of salt depends on the quality of seawater as raw material. And the quality of seawater is influenced by the river water discharged into the sea.

Sustainability is to meet the needs of the present but still ensuring the availability of resources for future generations. Environment addresses the ecosystems and supports the mankind life (Dong and Hauschild, 2017). Environmental sustainability concerns on both social and economic sustainability. The sustainability of the productive environment could provide a resource for supporting a sustainable society. Similarly, a sustainable economy depends on the sustainable resources of material, energy and environmental. Without those components, the system of the economy will fail. However, a sustainable environment should not depend on the existence of either society or economy, yet it should stand alone as a sustainable system (Morelli, 2011).

The sustainability of seawater as a part of the marine environment has to be protected. Seawater has a role to support the marine life. As the marine environment, seawater addresses the aquatic ecosystem and supports mankind's life in the coastal area. It is also taken as the raw material for traditional salt production. Salt production and fisheries can support the economy of communities of coastal regions.

Traditional salt production causes salt and wastewater as a concentrated liquid that remains after the crystallization process which is called bittern (Li et al., 2010; Lychnos et al., 2010). Mineral concentration of bittern can be 10 times higher than that of the sea water. Magnesium phosphate is more toxic to marine life when compared to sodium chloride. Wastewater of salt ponds that discharge back into the sea can negatively affect the marine life (Danoun, 2007; Jhala, 2006). Wastewater is toxic on aquatic marine life because the ocean becomes hypersalinity and the ions composition of the seawater is changed. It can bring more magnesium and anoxia, which may also be toxic to invertebrates such as shrimp and coral oysters (EPA, 2008). Mangrove mortality, growth disturbance and deforestation can be caused by sea water pollution because of salt pond wastewater (Gordon et al., 1995; Tewari et al., 2003). To keep the sustainability of the sea, it is necessary to protect the marine environment by firstly reviewing and categorizing some related indicators.

The analysis of some conditions that affect the sustainability of the marine environment is described through Driver-Pressure-States-Impacts-Response (DPSIR). The result of DPSIR analysis will be useful to determine the possible strategies to maintain the marine environment. DPSIR begins with "driver", which shows the need of individual and industry. The driver leads the human activity to invoke "pressure" on the environment. The result of this pressure, the "state" of the environment is changed and resulting "impact" to the environment that is possible to trigger political "response" (Eea, 1999).

2. Method

Raw material and salt samples were collected from traditional salt production in Pliwetan, Tuban, East Java. The location of the water sampling is depicted in Figure 1. The raw material was collected from the concentration plot which had the highest Baume

degree at the time. Salt that would be analyzed taken from the warehouse where it was stored since it had just been harvested. The analysis of the raw material sample was conducted based on the American Water Works Association, 2005. The chemical analysis used Complexometry to measure Ca^{2+} and Mg^{2+} . Atomic Absorption Spectrometry method was used to measure Na^+ , K^+ , Br^- , Pb^{2+} and Cu^{2+} . Argentometry method was occupied to analyze Cl^- and Spectrophotometry method was used to measure F^- and SO_4^{2-} . I^- was measured by Iodometry method. The salinity of the sample was analyzed using salinometer. pH was measured by using pH meter (CyberScan pH 510-Eutech) and Baume degree was determined by hydrometer. The salt analysis was conducted using Scanning Electron Microscopy coupled with Energy Dispersive X-ray (SEM-EDX).

Field observations and interviews with salt farmers were conducted to obtain information about the salt production process and its wastewater handling method. A literature study was conducted to determine the effect of the process of salt production on the marine ecosystem around a salt pond. The search for policy and legal products for marine ecosystem protection and enforcement were conducted through literature studies on Indonesia regulation.

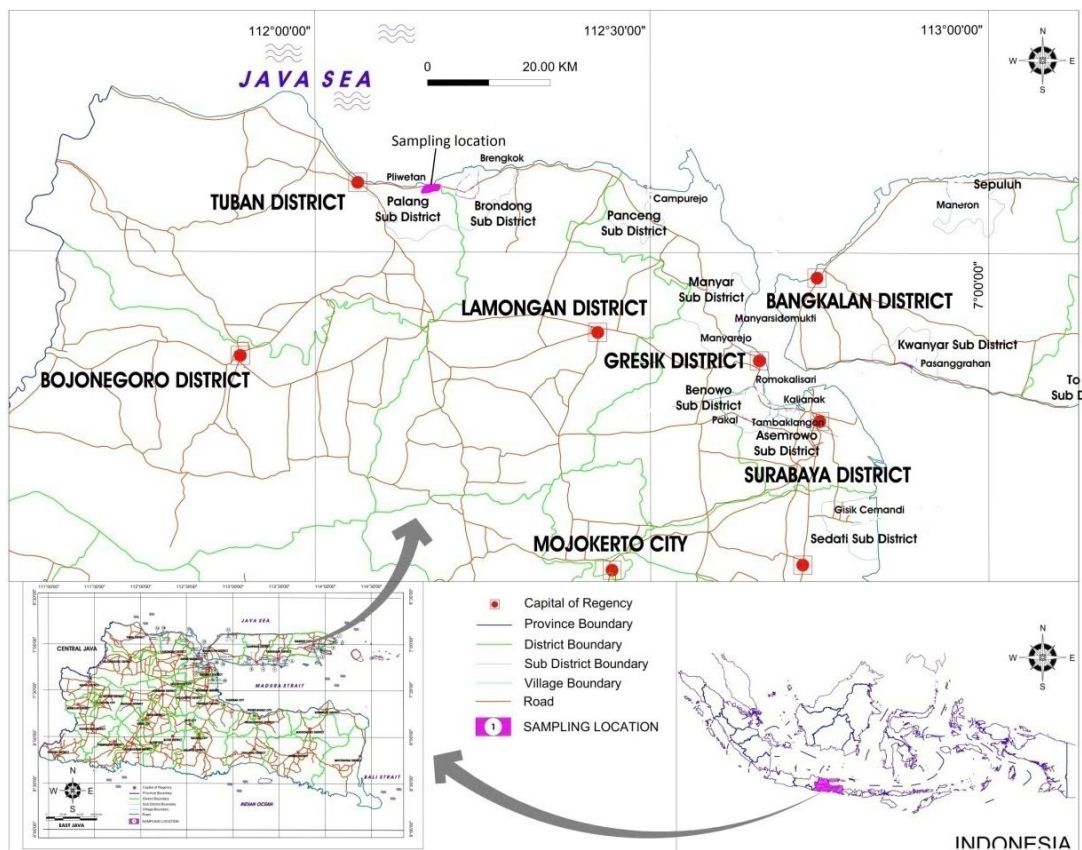


Figure 1. Map of sampling location in the present study

3. Result and Discussion

The characteristics of raw material which were measured in this study are listed in Table 1. The concentration of the ions indicates that the raw water with Baume degree 11 was dominated by Cl^- , Na^+ , Mg^{2+} and Ca^{2+} .

Table 1. The chemical and physical characteristics of raw water in Pliwetan, Tuban, East Java.

Parameter	Concentration (mg/L)
Na^+	77,846
Ca^{2+}	1,286
Mg^{2+}	6,429
K^+	17.89
Cl^-	120,000
I^-	6.56
F^-	3.62
Br^-	0.24
Pb^{2+}	0.32
Cu^{2+}	1.32
SO_4^{2-}	12,100
Salinity	77.2 (ppt)
pH	7.3
Baume degree	11

The morphology of the salt sample was investigated using Scanning Electron Mmicroscopy (SEM) as shown in Figure 2. The result indicates that the salt sample was detected in the form of tubular crystals. Figure 3 shows that the Energy Dispersive X-ray (EDX) analysis can be further observed from the SEM analysis. The EDX result indicates that the quality of the salt sample still does not fulfil the Indonesia Standard (SNI) that NaCl was equal to 94,7%. The composition of salt from Pliwetan-Tuban was affected by the presence of a number of mineral salt impurities and trace metal.

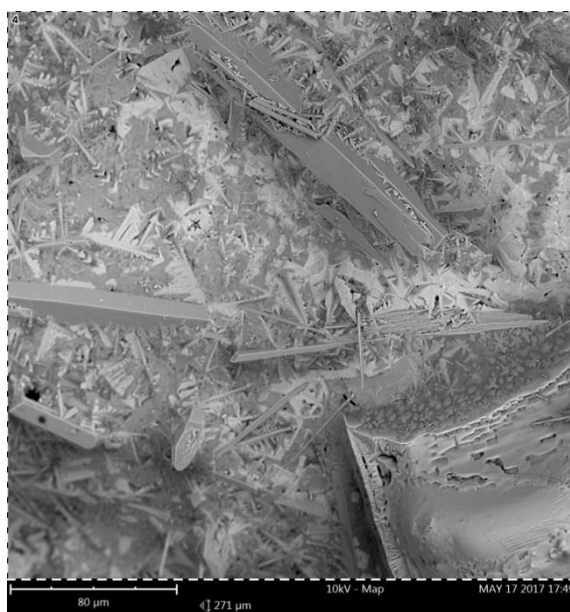


Figure 2. SEM images of the salt sample from the location of study

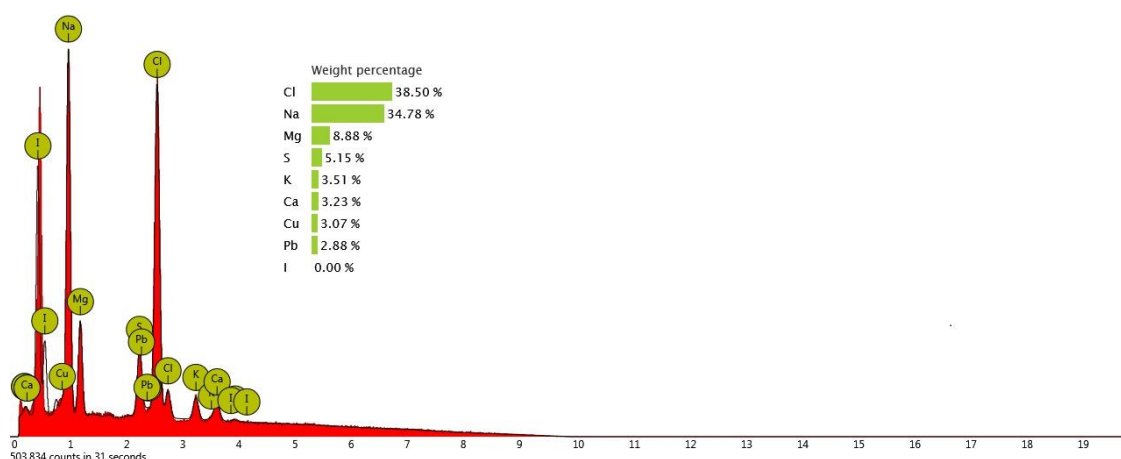


Figure 3. Energy Dispersive X-ray and picture of the percentage of the salt sample

3.1. DPSIR analysis

DPSIR analysis was used to categorize indicators for comparing human activities to environment. In the present study, DPSIR analysis focused on the indicators that compared between human activities and marine environments as described in Figure 4.

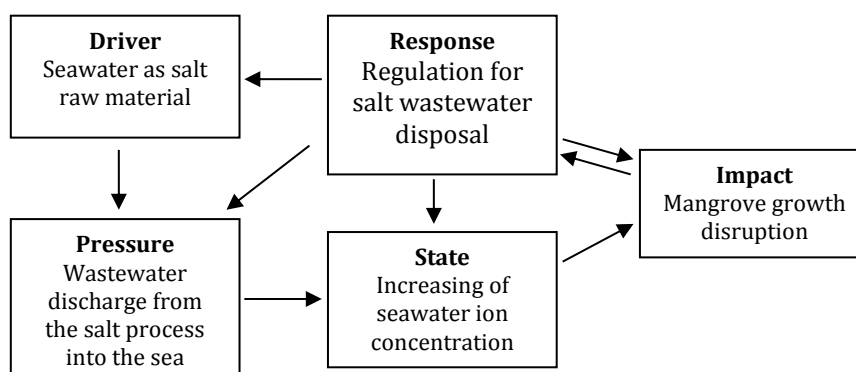


Figure 4. DPSIR framework form traditional salt production

DPSIR analysis for traditional salt production was started by sea water as the driver. Traditional salt production used seawater as the raw material. The quality of the salt depended on the quality of the sea water. However, polluted river water which flows to the sea would also pollute the sea water. From the SEM-XRD analysis, we could predict that the salt sample containing trace metal (Pb^{2+} and Cu^{2+}) was caused by river water pollution. The quality and quantity of salt were influenced by characteristics of raw material (Kasedde et al., 2014).

Traditional salt farmer produced salt and wastewater from a process that discharges into the sea at present as pressure. The mineral concentration of wastewater could achieve tne times larger than seawater concentration thus it could become a pressure to the marine environment. The pressure could increase the mineral concentration of the sea water as “state”. This condition influenced the marine ecosystem such as the growth of the mangrove. Wastewater from salt production which reached 29 Baume degree and

more could inhibit the growth of mangrove leading to deforestation and mangrove death (Tewari et al., 2003).

The indicator analysis for protecting marine sustainability needs to be included in a policy to prevent the discharge of salt wastewater into the sea. At present, the regulation of wastewater discharge into the sea has been established for industry such as power plants. For traditional production, regulations are also required in order to manage the wastewater discharge system to avoid damage on the sea environment.

3.2. Recovery magnesium as a strategy to protect the marine environment

The characteristic of traditional salt production wastewater is the emission of high concentration of mineral such as magnesium. This waste is potential to be recovered as one of the alternative treatment. Magnesium recovery is possible to be a promising strategy to preserve the environment (Liu et al., 2013). The recovery of salt wastewater can reduce the high operation cost for the salt farmer. The main problem faced by the farmer is the operational cost which is expensive but the price of the salt remains cheap (Sintusaard, 2009).

Besides for human health, magnesium is also needed in some industrial chores. The recovery of magnesium carbonate from salt wastewater can support the raw material supply for industry. Magnesium carbonate is required in the paper, ceramics, cosmetics, paints and pharmaceuticals industry (Lou et al., 2004). Other studies promoted various technologies for recovering magnesium from salt wastewater i.e. through precipitation (Alamdari et al., 2008; Tran et al., 2016), reactive crystallization (Taylor et al., 2014) and a heating process.

4. Conclusion

Marine environment sustainability can support both economy and social sustainability. Besides producing salt, the farmers can recover magnesium from wastewater to support their economy as well as to protect the environment. The magnesium recovery has also a possibility to support the operational cost.

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