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The Effect of Geomembrane Plastic Usage on Microplastic and Heavy Metal Contamination in Salt Field

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Abstract. Seawater is used to produce salt. For 10–15 years, geomembrane plastic has been used in salt fields in Indonesia to prevent contamination and increase quality and productivity. However, it is unfortunate that currently, seawater has been polluted by plastic waste, which has degraded gradually into small pieces about <5 mm in size called microplastics. In addition to microplastics, seawater is also polluted by heavy metals. Previous research indicated that the north coast of Central Java has been polluted by heavy metals whose content exceeded the threshold. The aim of this study was to analyze the amount of microplastic (MPs) and heavy metal contamination in salt. A microscope was used to measure the amount of MPs and AAS was used to measure the concentration of heavy metals. Variables that were conducted included sampling location (4 locations) and crystallization process (with and without using geomembrane). The results showed that the amount of MPs salt with a geomembrane was higher than without a geomembrane, at 337 and 326 particles/kg, respectively. The average is 332 particles/kg. Salts that use geomembranes have more contamination than salts without geomembranes. Heavy metal contamination of Pb, Cd, Hg, As, all of which were still within the threshold. The average Pb and Cd concentration in salts with and without geomembranes were 4.11 mg/kg and 4.14 mg/kg; 0.65 and 1.05, respectively. Meanwhile, the average of Hg and As concentrations for both were below than 0.001 and 0.005 mg/kg, respectively.

Keywords: geomembrane plastic; microplastic; heavy metal; salt field

1. Introduction

Human and industrial anthropological activities produce both plastic and non-plastic waste. Plastic and human are inextricably linked to one another. There are many benefits provided by plastic for instance all household appliances, furniture, and vehicles. The main issue arises when plastic is not treated properly and enter into the environment. Because the nature of plastic waste is not easily biodegradable the processing process causes toxicity and carcinogenic. It takes up to hundreds of years when it decomposes naturally. Plastics wastes can also be found in the marine environment.

The amount of plastic in Indonesia oceans is estimated to be 187.2 million tons per year [1]. Plastic will degrade into smaller forms known as microplastics. Microplastics with diameter sizes smaller than 5 mm could pollute the environment [2,3].

The released of chemical compound, specifically bisphenol from polycarbonate during plastic degradation had the potential to be harmful to the environment [4]. Many studies have been studied microplastic in marine environment such as green mussels, fish and others [5].

Research conducted [2], from several countries, sampled almost all salt contain microplastics in the sea salt produced, such as China, India, Spain, Turkey, France, Portugal, Korea, New Zealand, and Italia. Seawater, in addition to polluted with microplastics, was also polluted with heavy metals. Toxic metals such as Al^{3+}, Fe^{3+}, Cu^{2+}, Mn^{2+}, Ni^{2+}, Zn^{2+}, Ti^{2+}, Cd^{2+}, Cr^{2+}, Pb^{2+}, Co^{2+}, Mo^{2+}, Sn^{2+}, Sb^{2+}, Ag^{2+}, U^{2+}, and Hg^{2+} have been absorbed by microplastics [6,7]. The raw material for making salt was seawater. The seawater was put into evaporation ponds and crystallization pools until salt crystals were formed.

For the past 15 years or so, salt farmers have generally used black plastic to coat their salt fields, the plastic is called geomembrane plastic. This geomembrane plastic serves to coat salt products so that they are not polluted by the soil, dirt or heavy metals in salt fields. In addition, there are also some existing studies, where geomembrane plastics serve to increase the productivity and quality of salt. There have been no earlier studies that have observed microplastics and heavy metal contamination in salt fields that use geomembrane plastics and do not use geomembranes.

Geomembrane was a material in the form of plastic sheets made of HDPE (*High-Density Polyethylene*) components that are waterproof, and resistant to high temperatures. Salt production using geomembranes, or some call them, geoisolators, can be as much as 140 tons per ha, while the traditional process is only 92 tons per ha [8] and can increase production capacity by up to 60%, and increase sodium chloride (NaCl) levels from 94% to 96% [9,10]. The strength of the HDPE material can last up to 10 years.

The sea on the north coast of Central Java has been polluted with heavy metals that exceed the threshold, such as Hg, Cd, Cu, Cr, Pb, Ni, Zn, and As [11], with a content of 0.452 mg/kg of lead metal and 0.252 mg/kg of cadmium metal in cob fish. Research in Pamekasan heavy metal content in salt ranges from 0.066–0.162 ppm [12].

Salts from around the world are generally already polluted with microplastics [2]. The microplastic content in salt poses a threat to human health [13,14]. Farmers get benefits from geomembrane plastic that increases productivity.

Based on the things mentioned above, this study aimed to analyze the number of microplastic particles and heavy metal contamination in folk salt, which is made seawater and geomembrane plastic in salt crystallization ponds.

2. Methods

The research was conducted on a farmer's salt field in Kaliori District, Rembang Regency, Central Java Province, Indonesia. The study focused on salt products from crystallization ponds.

2.1. Materials

The material used was geomembrane plastic, seawater 2.5–3.5 ºBé, brine 25 ºBé that was ready to crystallize which came from seawater evaporation ponds (ponds 1, 2, and 3) and pond 4 for the salt crystallization process.

The tool used was a Baume meter, plastic scraper, plastic bottle for sampling, and net plankton. HIROX digital microscope, salt test equipment for heavy metal parameters, including metals (Pb, Cd, Hg, As) with AAS.

2.2. Research Procedure

In this study, salt was processed from seawater. The steps of the process of making salt that must be carried out are as follows: First, prepare the land; Second, install black plastic (geomembrane); Third, gradually pour seawater 2.5–3.5 ºBé into the evaporation ponds for 7–10 days until the viscosity of seawater reaches 25 ºBé (ºBé is the Baumé scale or hydrometer scale used to indicate the various densities). Fourth, seawater containing 25 ºBé put into crystallization pond for 7 days to until salt crystals were formed. Crystallization ponds were treated with and without geomembrane plastics. Fifth, salt harvested at a brine with the viscosity 29 ºBé [15,16].

2.3. Design and data analysis
The variables used in this study were the variables of salt processing location (location 1, 2, 3, and 4) and the use of geomembrane plastic (using plastic and without using geomembrane plastic in salt crystallization ponds). Salt sampling was conducted twice at each predetermined location.

The parameters analyzed were the number of microplastic particles and the number of heavy metal contaminations (Pb, Cd, Hg, and As). The research focused on crystallization ponds. Seawater sampling used plankton nets. Salt crystals taken propositional in crystallization pond. Data from laboratory was quantitatively tested.

3. Result and Discussion
3.1. Microplastics contamination in salt
The results showed that the average number of microplastics present in salt in Kaliori, Rembang, and its surroundings was 332 particles/kg. The number of microplastic particles in salts at location 1 was higher than that at location 2, which was 309 and 293 particles of MP/kg salt, respectively. It can be caused by several factors, including polluted seawater sources with MP content as high as $11.5–13\times10^3$ Particle MP/m^3 seawater (on control treatment) while at location 2, the pond (control) contains as many MP particles as $11–12.5\times10^3$ particles/ m^3. Another reason, from the results of observations made during the study at Location 1, was that there was a lot of plastic waste around the salt production area, with the presence of microplastics that can fly from plastic waste. Likewise, the number of salt microplastics at location 3 and 4 was 359 and 365 particles per kg of salt.

Table 1. Microplastic in salt with and without geomembranes at locations 1, 2, 3 and 4.

Pool Conditions	Unit	Without Geomembranes	With Geomembranes
Location 1	MPs/kg	298	312
	MPs/kg	303	324
	MPs/kg	301	318
Location 2	MPs/kg	218	288
	MPs/kg	324	342
	MPs/kg	271	315
Location 3	MPs/kg	271	315
	MPs/kg	488	360
	MPs/kg	380	338
Location 4	MPs/kg	316	370
	MPs/kg	388	388
	MPs/kg	352	379
Average	MPs/kg	326	337

The results of previous studies [17] show that the higher the concentration of salt water, the higher the number of MP particles, but in evaporation pool 3, there was a decrease because in evaporation pool 3, NaCl crystals had been formed so that MP particles can be trapped in NaCl at the beginning of the formation of salt crystal flowers floating above. The surface of the pool will then be deposited simultaneously. Such plastic polymers as PE and PP float on the surface because their density is lower than that of brine. Polyethylene (PE) 0.91–0.95 and polypropylene (PP) 0.90–0.92. The salt water in the crystallization pool 1.162 will still settle with salt flowers to the bottom of the pond.

When microplastics were in the water, they will float, depending on the density of the polymer. The ability of microplastics to float determines the position of microplastics in water [18,19]. Microplastics can degrade, fragment, and release adhesive materials so that particles will change in density and be distributed between the surface and bottom.

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The amount of MP in the treatment using geomembrane plastic had a higher MP compared to salts without using geomembranes although the value was not much different. This was due to the contamination of raw water from the sea or derived from plastic due to mechanical scraps from salt harvester that were carried out repeatedly.

3.2. Heavy metal contamination in salt

Other impurities besides microplastics were heavy metal contamination. The data presented in Table 2. The results showed that all salt crystals in Locations 1 and 2. both with and without geomembranes showed the presence of heavy metal contamination. The sea on the north coast of Central Java had been polluted with heavy metals that exceed the threshold, such as Hg, Cd, Cu, Cr, Pb, Ni, Zn, and As [11] with a concentration of 0.452 mg/kg of Pb and 0.252 mg/kg of Cd in cob fish. Research in Pamekasan heavy metal content in salt ranged from 0.066–0.162 mg/kg [12]. While the results of this study showed Pb concentration in salt in Rembang was the highest due to seawater had been polluted by plastic waste both from the sea and the salt field production area. Plastics that have been degraded in the ocean, salt field areas and the possibility of degradation contributions from geomembrane plastics. The average Pb, and Cd concentration in salts with and without geomembranes were 4.11 mg/kg and 4.14 mg/kg; 0.65 mg/kg and 1.05 mg/kg, respectively. Meanwhile, the average of Hg and As concentrations for both were below than 0.001 and 0.005 mg/kg, respectively.

Table 2. Heavy metal contamination in salt with and without geomembrane.

Location	**Treatment**	**Metal Contaminations (mg/kg)**			
		Pb	**Cd**	**Hg**	**As**
Location 1	Without geomembrane	4.17	0.85	<0.001	<0.005
	With geomembrane	4.11	1.03	<0.001	<0.005
Location 2	Without geomembrane	3.97	0.82	<0.001	<0.005
	With geomembrane	4.07	1.05	<0.001	<0.005
Location 3	Without geomembrane	4.19	0.92	<0.001	<0.005
	With geomembrane	4.17	1.05	<0.001	<0.005
Location 4	Without geomembrane	4.11	1.08	<0.001	<0.005
	With geomembrane	4.19	1.08	<0.001	<0.005

According to the Indonesian National Standard [20], the maximum Pb and Cd concentrations are 10 mg/kg and 5 mg/kg, respectively. Meanwhile the maximum Hg and As concentration are 0.1 mg/kg. The concentration of heavy metals in seawater and salt presented in Table 3, Research conducted, that seawater and sea salt contain heavy metals as presented in Table 3 [21] as well as microplastics [2].

Table 3. Heavy metal contamination in seawater and salt.

Metal	**Seawater Metal (mg/mL)**	**Sea Salt (mg/kg)**
Al	15.71±0.18	19.8±0.16
As	25.12±0.21	30.62±0.22
Cd	3.13±0,15	4.43±0.17
Cr	40.06±0.21	47.79±0.19
Cu	3.06±0.11	5.39±0.19
Fe	39.77±0,08	47,5±0,15
Hg	13.21±0.19	15.3±0.18
Ni	18.01±0.19	21.94±0.19
Pb	16.03±0.13	18.43±0,15
Zn	4.08±0,15	6.82±0.11

If humans consumed no more than 5 g salt/day or 1.825 g salt /year, the accumulated l Pb in the body was 71.93 mg/kg. If a human being is 50 years old, the amount of Pb in his body was 3596.5 mg/kg. Microplastics absorb heavy metal contaminants from the environment [22]. Toxic metals such as, Al^{3+}, Fe^{3+}, Cu^{2+}, Mn^{2+}, Ni^{2+}, Zn^{2+}, Ti^{2+}, Cd^{2+}, Cr^{2+}, Pb^{2+}, Co^{2+}, Mo^{2+}, Sn^{2+}, Sb^{2+}, Ag^{2+}, U^{2+}, dan Hg^{2+} found to be absorbed [6,7,23]. The results of heavy metal contamination in salt fields at Kaliori might come from seawater, and also geomembrane plastics.

4. Conclusion

This study showed that the salts in Kaliori, Central Java, were polluted with microplastics and heavy metals. The contribution of microplastics and heavy metal contamination derived from seawater and geomembrane plastics. The number of salt microplastic particles in the crystallization pool is 352 particles/kg of salt. The amount of microplastic in salts with geomembranes was higher than without geomembranes. The salt produced in Kaliori was polluted with heavy metals but remined within the threshold and mets the requirements of SNI 4435: 2017.

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Author contributions

Nilawati conducted all idea concept and analysis data in this research, and drafted manuscript. A. Mukimin participated in the research and compiled data, Silvy Djayanti participated in writing manuscript.

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