Salinity and Sulphate Concentration Mapping and Analysis: Sea Surface at the Madura Island Context

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Abstract: Seawater as the main raw material for making salt has the required chemical elements and impurities. One of the elements that are needed such as chloride (Cl) and the impurity is sulfate (SO₄). In remote sensing the element of chloride can be analyzed through satellite imagery by first estimating the salinity which is salts in sea water where there is chloride. Whereas sulphate can also be analyzed through satellite imagery using the estimation model of the results of previous studies. From the two data, seawater is mapped in the south and north side of Madura Island to recommend better sea water based on chloride content and sulfate. The results of the mapping obtained that the waters of the island of Madura better side than the waters of the North side. Nevertheless waters of the north side is still quite good so it is still possible serve the manufacture of salt.

Keyword: Mapping, Salt Pond, Remote sensing, Sulfate, Salinity, Madura Island, Landsat 8 OLI

1. Introduction

The main ingredient of salt manufacture most widely used by salt farmers is sea water [1]–[3] in addition to the salty lake water, or soil deposits in the form of rock salt mine. The sea water is evaporated using heat energy such as solar power, fuel, how to vacuum, sea water desalination either by thermal energy or with a reverse osmosis membrane, electrodialysis (Ion exchange membrane) [4]–[8]. The main element in seawater as salt forming is NaCl (Natrium Chloride). But there are other compounds in seawater which has been classified as an impurity although relatively minor. Such compounds include iron oxide (Fe₂O₃), calcium carbonate (CaCO₃), calcium sulfate (CaSO₄), magnesium sulfate (MgSO₄), magnesium chloride (MgCl₂) and potassium chloride (KCl). The presence of these impurities will affect salt products, especially for high quality salt [6], [9]. Other compounds have not been obtained in seawater other than NaCl (Natrium Chloride) as the main compound in better salt. Even if there are salty and bitter tastes such as compounds of KCl (potassium chloride) and MgCl₂.
Knowing the elements or compounds as raw materials for salt and impurity compounds in sea water is very important. The information of these elements will be taken into consideration in determining the sea water as a raw material for making salt so as to produce quality salt is good not only for household salt but the salt industry [9]. Technique often used is through measurement in the laboratory by taking samples of sea water. Samples were taken at some point as needed, the conditions of the area and the resources available. So that for the needs of a very wide area sampling will be constrained by time and resource efficiency. In this case there is a remote sensing technology capable of recording the earth's surface with its variety of rides that one satellite [10]–[12]. Remote sensing techniques will record the appearance of the object on the surface of the earth that will save the reflectance values or AOP data (*apparent optical properties*) and absorption of the object or IOP (*Inherent Optical Properties*) data [13]. Data recording results in the form of image which is processed and extracted into values as needed [11].

The use of remote sensing techniques in mapping and estimating elements in seawater is very effective [10], [14]. Besides, in the recording covering the wider region, with remote sensing will be require less resources [12]. However, not all the elements in sea water may be estimated using remote sensing techniques as it requires the signature value as a distinctive or unique value that represents the value of the element [13]. The use of remote sensing techniques to estimate elements in seawater has been implemented such as sea surface temperature [15], [16], sea surface salinity [17]–[20], *chlorophyll-a* and *TSS (Total suspended solid)* [21]–[23] and sulfate at the sea surface [10], [24].

The purpose of this study is to map the waters on the island of Madura which is more suitable for salt raw materials. The indicators used are sea surface salinity data which shows salts with the highest salinity value, and sulfate data at sea surface as impurities. Both can be mapped using remote sensing techniques [17], [19], [25]–[27], [10], [24], [28], [29].

2. **Methodology**

This study includes applied research. The process of estimation and mapping salinity and sulfate in sea surface Madura Island performed by applying the algorithm model of previous research. Then performed a descriptive analysis of the distribution of salinity and sulfate concentration as a raw material recommendations which have better levels to less well.

2.1. **Study area**

This research was conducted in the waters of Madura Island, especially the waters in Pamekasan and Sampang Regencies. Both districts are contributors to salt productivity covered in one landscape of Landsat imagery, on Path : 118, and row : 065.

2.2. **Data**

The primary data used in this study are Landsat 8 OLI / TIRS images as an implementation of algorithms to obtain sulfate and salinity data in the waters of Madura Island. Landsat 8 imagery is downloaded on the page [http://espa.cr.usgs.gov/](http://espa.cr.usgs.gov/) has been ordered through the page [http://earthexplorer.usgs.gov/](http://earthexplorer.usgs.gov/) at path : 118 and row : 065 Landsat 8 OLI/TIRS C1 Level-2 where taken on July 26, 2018. While secondary data is in the form of Madura Island land area boundaries. To get the value of sulfate and salinity through the image takes the value of Rrs (Reflectance remote sensing). In this case the image that has been downloaded subsequently processed by a variety of processes.
The process carried out is to crop the image for the study area only, namely the waters of Madura island in Pamekasan and Sampang regencies. Digital numbers in pixel image cropping results converted into RRS by dividing the DN to 10000 and PHI [30] as an input value estimation algorithm sulfate and salinity. Furthermore algorithm implementation sulfate and salinity to produce sulfate and salinity values at each pixel image. The algorithm for estimating sulfate in sea surface using the research results Muhsi [10] using Rrs value of band 5 of Landsat 8 OLI (Formula 1).

\[
\text{sul} = 3055.5 \cdot \text{RrsNIR}^{0.049}
\]  

(1)

Where sul is sulfate that estimate and Rrs NIR is Rrs value of band 5 (NIR) of Landsat 8 OLI image. As for estimating sea surface salinity using the Muhs algorithm [31] the results of the development of the Son algorithm [20][19] (Formula 2).

\[
\text{sal} = 10^{-0.0092 \cdot \log_{10} \text{Kd} + 1.4903}
\]  

(2)

Where sal is sea surface salinity that estimate and Kd is attenuation coefficient. Kd value obtained through the input value of the MNDCI algorithm (Formula 3)

\[
\text{MNDCI} = \frac{nLw_{555} - \max(nLw_{412}, nLw_{443}, nLw_{490})} {nLw_{555} + \max(nLw_{412}, nLw_{443}, nLw_{490})}
\]  

(3)

Where MNDCI is maximum normalized difference carbon index, and nLw is spectral normalized water-leaving radiance. Whereas to determine the value of Kd is using the following model (Formula 4):

\[
\text{Kd} = 100.70 \cdot \text{MNDCI}^3 + 0.96 \cdot \text{MNDCI}^2 + 1.14 \cdot \text{MNDCI} - 0.25
\]  

(4)

Where Kd is attenuation coefficient and MNDCI is maximum normalized difference carbon index.

The image of the results of the algorithm implementation is converted to vector data such as SHP files. SHP of salinity, sulfate and boundaries area of Madura island are overlayed to get information about the suitability of sea water as a raw material salt of the content aspects of salinity and sulfate as raw material impurities salt. So that will be mapped in accordance with the provisions in Table 1.

| Rules | Recommendations |
|-------|-----------------|
| Salinity | Sulfate |
| High    | Low    | highly recommended |
| High    | High   | quite recommended  |
| Low     | Low    | less recommended   |
| Low     | High   | very less recommended |

Table 1. Rules and Recommendations

Where will be mapped with high salinity color gradation and low sulfate is highly recommended as the raw material of salt. High salinity and high sulfate color gradations are quite recommended, low salinity and low sulfate color gradations are less recommended and low salinity and high sulfate color gradations are very less recommended.
3. Salt Land Suitability Analysis

Research on salt, especially the suitability of the salt field has been carried out. As research conducted Muhsoni (2012) [2] in Sampang District using data on sea water content and pond land as criteria. The content of the sea water is ammonia (mg/l), acid sulfate (mg/L) and pH. While the data of pond land in the form of embankment, water level, distance from the beach and reservoir. Whereas Muhsoni et.al (2013) [3] also conducted research in the Pamekasan Regency area with the addition of criteria in the socio-economic aspects of salt farmers. For criteria elements contained in sea water is still the same as previous research but on the criterion of pond there are additional criteria such as channel capacity, availability of water pumps, sludge precipitate capability, capacity and condition of sewer disposal. While the criteria of social and economic aspects such as age, education level, capital adequacy, capital and information access capabilities involvement in salt farmer groups. In another study conducted by Efendy et.al (2013) [1] more emphasis on natural conditions. The study was conducted to describe the natural conditions of an area that allows the creating of salt ponds. Whereas in this study more emphasis was placed on aspects of the content of supporting elements and impurities in sea water as raw materials for making salt.

4. Result and Discussion

The image data used are band 2, band 3 and band 5 of Landsat 8 OLI imagery. The image cropping conducted for the study areas, namely the water of Pamekasan and Sampang regency both the south and north side. From the results of these cropping then the pixel value be converted into waters Rrs value. The results are shown in Figure 1.

![Fig. 1 Rrs distribution map of the study area](image)

Based on Rrs data (Figure 1) further implementation of the algorithm for estimating sea surface salinity (Formula 2) and sulphate estimation algorithm (Formula 1), the result as shown in Figure 2.
The distribution of salinity tend to be high in the outskirts of the waters near the coast. For in areas farther from the coast of lower salinity values. Whereas the highest sulfate value is in the waters north of Madura Island. Although on the outskirts of the southern side of the high waters but does not exceed the value that is on the north side. Both of these maps (a) and (b) they are presented in the form of raster. To perform overlay image as the process of mapping the waters that have potential as a raw material salt, then created a vector map to then be overlaid as shown in Figure 2.

In Figure 2 it is shown that there are four overlay between high salinity with low sulfate, high salinity with high sulphate, low salinity with high and low salinity sulfate with low sulfate. Furthermore, it is mapped as a waters area are recommended and not recommended as a raw material for making salt based on the main elements (salinity) and impurity elements (sulfate) as shown in Figure 3.

Fig. 3. Map of sea water recommendation distribution for salting
In Figure 3 above shows that there are four recommendations sea water can be used as the raw material of salt from the aspects of the content of salinity and sulfate. In this case the content of high salinity and low sulphate (recommended 1) highly recommended to be used as the raw material of salt, high salinity and high sulfate (recommended 2) quite recommended, low salinity and low sulfate (recommended 3) less recommended then low salinity and high sulfate (recommended 4) very less recommended. The map also shows that the waters on the southern side of the island of Madura have a dominant value of recommended 1 compared to the waters of the north side, especially in the waters of Pamekasan Regency. While the waters on the north side are dominated by waters of value recommended 2 even though on the south side there are also but not too broad. For waters the value of recommended 3 is only found in the waters of the north side due to the high sulfate content and low salinity in the rather deep waters. As for the waters of the value of recommended 4 equally found in the waters of the north and south, but the most widespread is in the waters south side.

5. Conclusions
Based on the recommendation map obtained that the waters of the south side of the waters of the island of Madura have the best sea water as a raw material salt. Of both districts Pamekasan and Sampang, Pamekasan regency waters have a wider range of recommendations. While the waters on the north side of the island of Madura based on salinity and sulfate aspect are quite good.

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