MAGNETIC AND GEOCHEMICAL CHARACTERIZATIONS OF IRONSAND DEPOSITS FROM CIREBON COASTAL AREA, WEST JAVA

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Abstract. Cirebon is a densely populated port city which has ironsand deposits at its coastal area. Due to its vicinity to the port and the estuary, these deposits might contain anthropogenic pollutants including, heavy metals. Magnetic measurements, X-Ray diffraction (XRD) as well as X-Ray fluorescence (XRF) analyses were carried out on iron sand samples from three sites along the Cirebon coastal area to identify the anthropogenic pollutants. The samples were separated based on the grain size before the measurement and analyses. Preliminary results show that the ironsand is less magnetic and has smaller frequency-dependent magnetic susceptibility values than ironsand found on Bayuran Beach in Central Java. Combined XRD result and the regional geological map shows that most of the minerals were originated from eroded volcanic rocks. The XRF results show that the samples have a relatively high content of Si. XRF analyses also show relatively high concentrations of Cr and Zn, the Geoaccumulation Index shows that the sediment is moderately to heavily polluted by Cr and Zn indicating the possibility of anthropogenic origin. The Cr and Zn content exceeds the stipulated value in the Sediment Quality Guidelines (SQGS).

1. Introduction
Cirebon is a densely populated port city located in the Province of West Java. Unlike most of the deposits found on the northern coast, this city has iron sand sedimented along the coast. Lots of activities also transpire in the area, such as industrial activity, fishery, trading, and agriculture [1] due to its strategic location. These activities produce pollutants transported and sedimented by the rivers that flow through the city [2]. At a particular concentration, these pollutants might be detrimental to the environment or aquatic life [3].

To sort out this issue, a geophysical study was conducted. The sample collected from three sites along the Cirebon coastal area was subject to geomagnetic as well as geochemical examination. The geomagnetic method was used to identify the susceptibility of the value and the presence of anthropogenic components [4]. Meanwhile, the geochemical method was used to determine the chemical element as well as the oxide compound. This study is expected not only to analyze the pollutant but also to characterize the ironsand.

2. Material and Method
The sample was collected from the Cirebon city along the North Coast of Java on December 17th, 2019. It was collected at three sites along the coastal area as shown in figure 1. Three liters of iron sand were taken at each site as the sample. The sample was washed with water twice, then the contaminant such as shells was. Afterward, it was washed twice with aquabidest and then dried using an oven at 110°C. Thereafter, we took 1.5 kgs samples from each point, for every 250 grams of it was sieved using mesh 60 and mesh 120 to get fine sand (FS) and very fine sand (VFS). From all of the sediment samples, we...
took nine as the representative samples for geochemical examination. Those chosen samples then were mashed using a mortar and pestle, followed by sieving using the 230 mesh to get the powder sample.

![Figure 1. The Cirebon Quadrangle Geological Map (modified from [5]) with the sampling point along the coastal area.](image)

The susceptibility measurement was conducted using Bartington MS2 susceptibility meter both for high and low frequency. Meanwhile, the geochemical examination was conducted using the Supermini 200 X-ray Fluorescence for XRF and SmartLab X-ray Diffraction for XRD. To determine the correlation between each element and the susceptibility value, we used the Spearman rank correlation method since the data is not normally distributed. The correlation was calculated using python.

3. Result and Discussion

3.1. Sediment Source

Based on the XRD data, all of the samples contain andesine and quartz. Other than that, most of the sites contain hornblende, fuchsite, muscovite, and pyroxene. Some minerals only appeared in certain samples such as pseudo-malachite, cristobalite, and magnesio-hornblende. Most of these minerals are found in volcanic rocks [6]. The regional geological map supports this observation, since there are Older Cereme Volcanic Products (QTVR) and Younger Volcanic Products of Cereme (QVR) formations at most of the Cirebon area, also there is more formation containing volcanic product such as Ciherang, Gintung, and Halang Formation. High SiO$_2$ in the sample indicates that the sediment came from an erosion and weathering process [7].
3.2. Ironsand Characteristics

The ironsand sediment from sampling sites is dominated by fine-grained material. It reflects the low current velocity on the deposition area [8]. As shown in Table 1, the susceptibility values for each site and grain size are lower compared to the iron sand from Bayuran Beach, Central Java [9]. The correlation result shows that titanium has a positive very strong relation to susceptibility. Iron and chromium have a strong relation. Meanwhile, silicon and aluminum have a strong negative relation. This negative value means that the elements are inversely related to the susceptibility value. All of the samples have a very low $\chi_{fd\%}$ as presented on Table 1 that could indicate the presence of anthropogenic components [10].

| Name  | Average $\chi_{lf}$ ($\times 10^{-8}$ m$^3$/kg) | Average $\chi_{hf}$ ($\times 10^{-8}$ m$^3$/kg) | Average $\chi_{fd\%}$ |
|-------|---------------------------------|---------------------------------|-----------------|
| Bulk 1| 825.64                          | 816.51                          | 1.08            |
| FS 1  | 284.60                          | 283.19                          | 0.51            |
| VFS1  | 2961.95                         | 2947.52                         | 0.49            |
| Bulk 2| 354.22                          | 353.07                          | 0.32            |
| FS 2  | 245.14                          | 243.07                          | 0.84            |
| VFS 2 | 457.40                          | 455.59                          | 0.32            |
| Bulk 3| 2937.79                         | 2936.28                         | 0.05            |
| FS 3  | 445.13                          | 444.00                          | 0.25            |
| VFS 3 | 5932.06                         | 5920.55                         | 0.37            |

The most significant chemicals that composed the sediment are silicon and iron. The iron mineral is most likely to be sourced from hornblende and magnetite minerals. Hornblende minerals present in all grain sizes but magnetite mineral only present in FS. Meanwhile, susceptibility data show that VFS has higher values compared to FS, this indicates that hornblende supplied more magnetic elements, for instance, iron mineral. Other than that, the XRF data shows higher content of silicon rather than iron. There are also several heavy metals present in the samples, for instance, titanium, vanadium, chromium, cobalt, zinc, lead, nickel, manganese, and rhodium.

3.3. Sediment Quality

Based on Bradl [11], some heavy metals including chromium, manganese, and zinc are related to anthropogenic. These heavy metals are present in the XRF data for every sample but not in XRD mineral analyses. It gives the possibility that those elements came from anthropogenic pollutants with the fact that the sampling locations are surrounded by port and fishery industrial. To determine the sediment quality, the heavy metal concentrations are compared to sediment quality guidelines.

Based on Table 2, chromium concentrations exceeded the stipulated value both in the Sediment quality guideline [12] and the Canadian Council of Ministers of the Environment [13]. It's considered to be toxic to the aquatic environment and adverse effects are probable to be observed [14]. Meanwhile, zinc concentrations in all of the samples are above the midrange effects value. Only VFS 3 concentration exceeds the TET value. But based on CCME, zinc concentrations are above the PEL values. In this case, manganese is not stipulated because it’s not considered as pollutant since it’s a ubiquitous element that composed 0.1% of the earth [15] and also a chemical element that composed iron sand deposits.
### Table 2. Chromium, zinc, and manganese concentration in the sample with the Sediment quality guidelines [12-13]

| Sample Code | Cr (ppm) | Zn (ppm) | Mn (ppm) |
|-------------|----------|----------|----------|
| Bulk 1      | 839      | 444.4    | 6100     |
| FS 1        | 386      | 426      | 5960     |
| VFS 1       | 1630     | 484      | 7560     |
| Bulk 2      | 873      | 402      | 5130     |
| FS 2        | N/A      | 426      | 5180     |
| VFS 2       | 750      | 431      | 5040     |
| Bulk 3      | 993      | 417      | 4970     |
| FS 3        | N/A      | 326      | 5820     |
| VFS 3       | 1310     | 587      | 5930     |
| SQG         |          |          |          |
| **Midrange Effect** |          |          |          |
| Effect Range Median (ERM) | 145 | 270 | - |
| Probable Effect Level (PEL) | 90 | 315 | - |
| **Extreme Effect** |          |          |          |
| Toxic Effect Threshold (TET) | 100 | 540 | - |
| Severe Effect Level (SEL) | 110 | 820 | - |
| **CCME, 2001** |          |          |          |
| Probable Effect Level (PEL) | 160 | 271 | - |

The Geoaccumulation Index ($I_{geo}$) values show the comparison between the heavy metal concentration in the samples and the concentration in pre-industrial time [16]. This will give more proof to say if chromium and zinc came from anthropogenic activities. Based on Table 3 $I_{geo}$ level, the samples are moderately to heavily contaminated by zinc and chromium and it has the possibility for those heavy metal to be anthropogenic.

### Table 3. $I_{geo}$ values for chromium and zinc with the classification [16]

| Sample Code | Zn $I_{geo}$ | Classification | Cr $I_{geo}$ | Classification |
|-------------|--------------|----------------|--------------|----------------|
| Bulk 1      | 2.08         | Moderately to heavily contaminated | 2.46         | Moderately to heavily contaminated |
| FS 1        | 2.02         | Moderately to heavily contaminated | 1.34         | Moderately Contaminated |
| VFS 1       | 2.20         | Moderately to heavily contaminated | 3.41         | Heavily contaminated |
| Bulk 2      | 1.94         | Moderately Contaminated | 2.51         | Moderately to heavily contaminated |
| FS 2        | 2.02         | Moderately to heavily contaminated | N/A          | - |
| VFS 2       | 2.04         | Moderately to heavily contaminated | 2.29         | Moderately to heavily contaminated |
| Bulk 3      | 1.99         | Moderately Contaminated | 2.70         | Moderately to heavily contaminated |
| FS 3        | 1.63         | Moderately Contaminated | 1.89         | Moderately Contaminated |
| VFS 3       | 2.48         | Moderately to heavily contaminated | 3.10         | Heavily contaminated |
4. Conclusion
The iron sand deposit on Cirebon coastal is dominated in fine-grained and very fine-grained sand that reflects the low deposition energy in the estuarine area. Geochemically, the deposit contains more silicon (Si) than iron (Fe), causing lower susceptibility values compared to the iron sand deposit in Bayuran Beach, Central Java. The most significant minerals in the sample are andesine and quartz. The mineralogy of the deposit informs that the source of the iron sand is eroded volcanic rocks. The most major heavy metals that are possible to be anthropogenic in the sample are chromium (Cr) and Zinc (Zn). The Cr and Zn concentration in all of the samples exceed the Sediment Quality Guidelines (SQGs) as well as CCME (2001) stipulated values. Hence it is considered to be toxic to the environment and aquatic life. Based on the Geoaccumulation Index, the iron sand deposit on Cirebon coastal is moderately to heavily polluted by chromium and zinc.

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