Seawater intrusion prone areas around Yogyakarta International Airport: a geological approach

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Abstract. Construction of Yogyakarta International Airport on Kulonprogo coastal areas can threaten the groundwater quality because it can cause seawater intrusion. The method in this study is by using a literature review. The purpose of this review is to investigate seawater intrusion prone areas around Yogyakarta International Airport based on a geological approach. The geological approach associated with seawater intrusion in the study site is a lithological characteristic. A lithological characteristic discussed in this study is the origin of the sand on Kulonprogo beach where the Yogyakarta International Airport is located. The elements used in the seawater intrusion test parameters are Na\(^+\), Ca\(^{2+}\), K\(^+\), Mg\(^{2+}\), CO\(_3\)^{2−}, HCO\(_3\)\(^−\), Cl\(^−\) and SO\(_4\)^{2−}. A rise in Cl\(^−\) was reported as suggesting the intrusion of seawater into the groundwater. But if only see the value of one of those elements, it cannot indicate seawater intrusion occurs in that area. The high element's contents can arrive from the solution or weathering the lithological. This study is preliminary research, to assess seawater intrusion in the study site, it is necessary to conduct a groundwater geochemical test in the future.

1. Introduction

Yogyakarta International Airport has been built at Temen District, Kulonprogo Regency, Daerah Istimewa Yogyakarta Province, Indonesia. It is located in an area of 587.2 ha and accommodates up to 20 billion passengers. The government has acquired 67% of the land belongs to the local community, 27% of the land belongs to the Sultan, and the remaining land belongs to the government for the construction of the airport. Yogyakarta International Airport is located on the southern coast of Java Island [1]. Construction of buildings on the coastal areas is usually carried out by intensive pumping. Intensive pumping with the aim of lowering the water table is carried out to support underground structures and building foundations in urban coastal areas. However, this process may threaten the groundwater quality as it can cause seawater intrusion. In addition, that activity can increase land subsidence, unstable buildings, and corrosion of concrete structures due to the increased salinity of groundwater [2]. Moreover, many coastal areas in the world have poor quality groundwater resources due to groundwater overexploitation [3].

Seawater intrusion is not a new case that has been addressed by researchers around the world, at least two-thirds of the world's population that live on the coastal aquifers had to deal with the problem. Seawater intrusion is mostly affected by groundwater overexploitation in coastal aquifers connected to
the sea and sea-level rise due to global warming [4]. Even seawater intrusion can reduce water quality to levels that exceed water standards for irrigation and for drinking water. That problem is getting worse because 70% of the world's population lives in coastal areas. That fact states that the need for fresh water is becoming more acute for 70% of the world's population. Intensive groundwater exploitation in coastal aquifers leads to the decreasing of groundwater level, causing seawater to be transported to inland and mixing with fresh water. The case of seawater intrusion is one of the main problems in the use of groundwater in coastal areas [5]. Groundwater is the main source of water supply in coastal areas. Therefore, coastal aquifer management is essential. Seawater intrusion can worsen human health, damage ecosystems, and reduce the availability of freshwater. The most effective strategy to control seawater intrusion is to combine brine abstraction and desalination, as well as refill artificial groundwater using treated wastewater. In certain circumstances, such cases cannot be avoided even though the costs for mitigating and remediating the saline aquifer are expensive [6].

Geological approaches describe the tectonic movement, basin settings, and lithological characteristics [7]. Current morphological and rock conditions may explain the past conditions of the river such as the rocks that formed it or lithology, the geological structure, and the current processes of erosion and sedimentation [8]. Furthermore, it is essential to understand the provenance geology. Provenance is the main element in assessing and reconstituting a sedimentary basin's paleogeography. Provenance may explain the tectonic setting of source rocks in a clastic sedimentary basin and the amount of weathering encountered by the detrital sediments. This method proved to be useful for understanding the lithology [9]. The whole-rock geochemistry of clastic rocks has been increasingly used in the last decade to establish their provenance and tectonic setting. The use of this approach is based on the assumption that clastic rocks have a specific range of composition representing a geological setting or tectonic terrane. In comparison, the chemistry of these rocks in a tectonically complex area is useful in determining not only the tectonic evolution but also the terrane relationships [10]. The purpose of this review is to investigate seawater intrusion prone areas around Yogyakarta International Airport, Daerah Istimewa Yogyakarta Province, Indonesia based on a geological approach. This review paper should help future research on seawater intrusion assessment.

2. Methods
The study site is in the area around Yogyakarta International Airport, Temon Sub District, Kulonprogo District, Daerah Istimewa Yogyakarta Province, Indonesia (Figure 1).

![Figure 1. The study site.](image-url)
The method in this study is by using a literature review. The development of a literature review involves five steps: scanning papers, making notes, structuring the literature reviews, writing the literature reviews, and building bibliography [11]. Scanning papers were carried out by looking for papers related to seawater intrusion prone area based on a geological approach. Making notes was carried out by focusing on sentences in a paper to be cited. Structuring the literature reviews were carried out to compile the notes that have been made to be well organized. Writing the literature reviews were carried out by adding comments that still refer to literature reviews. Finally, building the bibliography was carried out by including each author's name in every sentence that has been cited from a paper.

3. Results and discussion
The geological approach associated with seawater intrusion in the Yogyakarta International Airport area, Daerah Istimewa Yogyakarta Province, Indonesia is a lithological characteristic. A lithological characteristic discussed in this study is the origin of the sand sediment on Kulonprogo beach where the Yogyakarta International Airport is located. Geologic history is one of the determining factors for the lithological characteristics. Geologic history is the secret to knowing past rock stories [8]. Provenance geology or geologic history in this study discusses the weathering process of the original rock, depositional system, and geochemistry of the sand sources of Kulonprogo beach.

Sand sediment in Kulonprogo beach area is divided into two types, namely, type 1 sand sediment and type 2 sand sediment. Type 1 sand sediment is gray sand which is a mixture of mafic minerals, quartz, and fragments of coral reefs, while type 2 sand sediment is black sand which is dominated by iron sand and a little mineral content of quartz. From this statement, it can be interpreted that the minerals contained in the sand deposits are dominated by silica and mafic minerals which are rich in Fe, Mg, and Ca. The provenance of these mafic minerals is the lithology of Kulon Progo Mountains which is dominated by volcanic rocks of the mafic to intermediate types [12]. In addition, the chemical composition of beach sand in the south of Kulonprogo originated from andesite rocks contained in the southern Kulonprogo Mountains, not from the activity of Mount Merapi [13]. On the other hand, there are some sources of sediment from Kulonprogo beach, namely the sandstones of the Sentolo Formation and Andesite. Furthermore, the aquifer in the study area can originate from carbonate rocks in the Sentoto Formation where the carbonate rock provenance is the marine environment [12]. The positions of these formations can be seen in Figure 2.

![Geological map of Yogyakarta area sheet, modified from [14].](image-url)
The cation elements used in the seawater intrusion test parameters are Na\(^+\), Ca\(^{2+}\), K\(^+\), and Mg\(^{2+}\), while the anion elements used in the seawater intrusion test parameters are CO\(_3^{2-}\), HCO\(_3^-\), Cl\(^-\), and SO\(_4^{2-}\). A rise in Cl\(^-\) was reported as suggesting the intrusion of seawater into the groundwater. In addition, an increase in Cl\(^-\) values was found to be followed by an increase in Na\(^+\) and SO\(_4^{2-}\) values to levels above the tolerable threshold, which indicates the adverse effect of water quality [15]. However, elements such as CaCO\(_3\) and Na can originate from weathering rocks or the dissolving processes of minerals that contained coastal areas. For example, the Ca content can originate from a solution of shell fragments or carbonate rock of the Sentolo Formation. The Na element can originate from silica minerals such as plagioclase (andesine - albite) and or Alkali Feldspar from weathering of the Andesite in the north. Thus, if only see the value of one of the cation and anion elements, it cannot indicate seawater intrusion occurs in that area. By testing all cations and anions, TDS, and EC can support the possibility of seawater intrusion in that area [15]. This study is preliminary research, to assess seawater intrusion in the study site, it is necessary to conduct a groundwater geochemical test in the future.

4. Conclusions

The conclusion of this study is if only see the value of one of the cation and anion elements (Na\(^+\), Ca\(^{2+}\), K\(^+\), Mg\(^{2+}\), CO\(_3^{2-}\), HCO\(_3^-\), Cl\(^-\), and SO\(_4^{2-}\)), it cannot indicate seawater intrusion occurs in that area. The high element's contents can originate from the solution or weathering the lithological. By testing all cations and anions, TDS, and EC can support the possibility of seawater intrusion in that area. This study is preliminary research, to assess seawater intrusion in the study site, it is necessary to conduct a groundwater geochemical test in the future.

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Acknowledgements
We thank to Direktorat Riset dan Pengabdian Masyarakat, Deputi Bidang Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi / Badan Riset dan Inovasi Nasional Republik Indonesia and Institut Teknologi Nasional Yogyakarta for the support research funding.