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Determination of Seawater Intrusion Zones Using the Resistivity Method in Kelurahan Soreang, Maros District, South Sulawesi Province

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Abstract

The seawater intrusion into the groundwater layer is one of the factors that can disrupt groundwater quality in Soreang Village, Maros Regency. This is a serious problem for the community in the area, so it is necessary to identify the seawater intrusion zone. Previous study using the resistivity method is in regional scale. In this study, two intersecting lines with a length of 470 meters each were acquired using the Wenner-Schlumberger array with a spacing of 10 meters to get local scale. Based on the resistivity value of the study area, there are three layers interpreted as a layer of fill (1 - 1000 Ωm), alluvium layer (1 - 6 Ωm) and limestone layer (≥ 7 Ωm). The seawater intrusion zone in the study area is in the alluvium layer with varying depths up to 40 meters subsurface. The results of this study can be a reference for the community or government in the search for fresh water.

Keywords: resistivity; seawater intrusion; Soreang; Wenner-Schlumberger.

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Introduction

The problem of fresh water availability in coastal areas is a crucial issue (Jeuken et al., 2017; Rahman et al., 2017; Huq, & Easher, 2021). This is the case faced by the community in Soreang Village, Maros Regency. This area is close to the coast and surrounded by river tributaries that are still influenced by tides. Communities around the area have difficulty obtaining a fresh water source, especially when entering the dry season, well water that was originally fresh becomes very salty. Therefore, a study was conducted with the aim to identify the area and depth of seawater intrusion that is expected to be anticipated by the community in Soreang Village, Maros Regency.

Geophysical methods are considered capable to address the problem. Identification of groundwater in coastal areas using the resistivity method has been carried out by Haroon et al. (2021) on the Maltese Island coast and Masciopinto et al. (2017) on the Bari coast. Both studies successfully identified the presence of freshwater. In South Sulawesi, similar research was conducted by Rahmaniah et al. (2021), but this research is considered too regional so it needs to be done more locally, especially in the Soreang Village area, Maros Regency.

The resistivity method is one of the geophysical methods used for subsurface investigations by utilizing the nature of electricity flow in the earth. This method includes measuring the potential difference and electric current that occurs due to the injection of electric current into the earth through a pair of current electrodes and the potential difference is measured through a pair of potential electrodes (Sufiyanussuari et al., 2021).

Regional Geology

The geology of Maros Regency is unique because in combination with alluvium deposits (Qac), there are also many limestones, making it famous for its karsts. The forming limestones are members of the Tonasa Formation that experienced tectonics, and intrusion by igneous rocks. In the geological view, limestone types and tectonic influences are two factors that play a role in karstification or karst formation (Arsyad et al., 2020). In addition, there are also other factors such as; enough rainfall, temperature, and forest cover (Diah et al., 2021).

Seawater Intrusion

Seawater intrusion or seepage into aquifers on land is basically the process of seawater pressing into fresh groundwater in aquifers in coastal areas (Motalebbian et al., 2019; Prusty, & Farooq, 2020; Costall et al., 2020; Moore, & Joye, 2021). If the hydrostatic balance between fresh underground water and saline underground water in coastal areas is disturbed as shown in Figure 1, movement and seawater intrusion will occur. The continuous exploitation of groundwater causes a lot of empty space in the aquifer layer which results in the seawater intrusion into the soil layer resulting in a difference in groundwater level lower than the sea level (Ardaneswari et al., 2016; Alfarrah, & Walraevens, 2018; Guo et al., 2019).

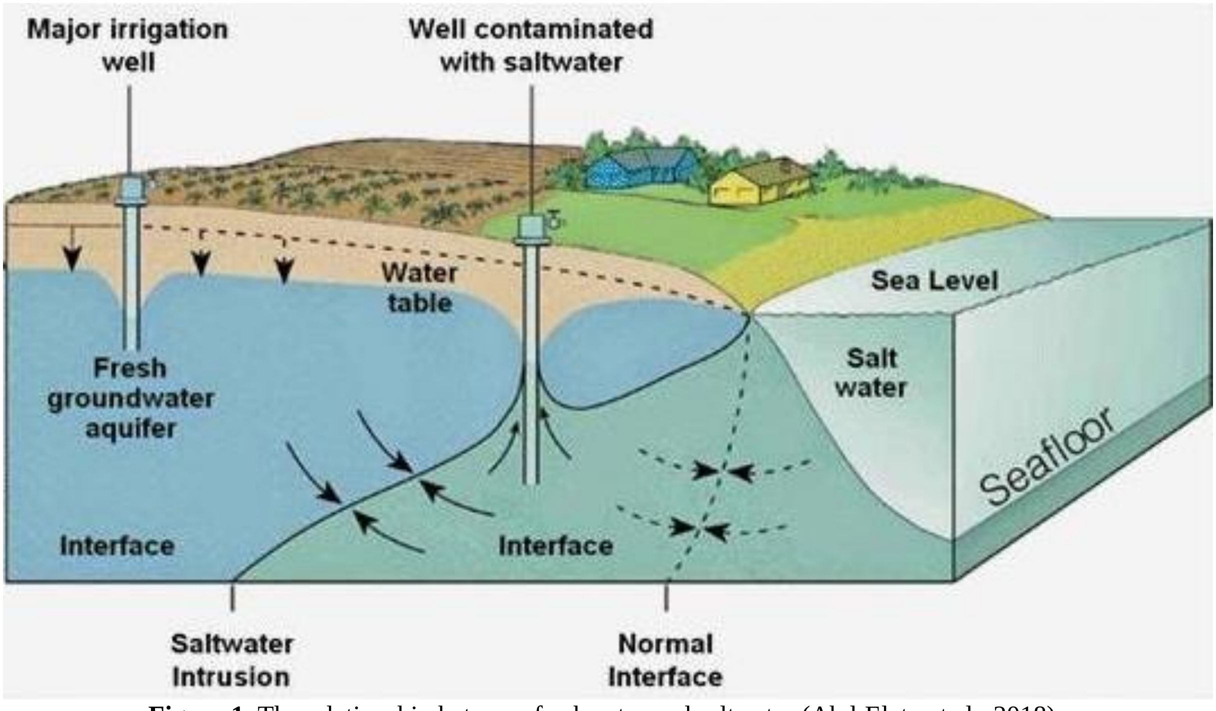

Figure 1. The relationship between freshwater and saltwater (Abd-Elaty et al., 2018).

The main causes of saltwater intrusion include (Abd-Elaty et al., 2018; Prusty, & Farooq, 2020):

1) Overabstraction of the aquifers
2) Seasonal changes in natural groundwater flow
3) Tidal effects
4) Barometric pressure
5) Seismic waves
6) Dispersion
7) Climate change – global warming and associated sea level rise.

Resistivity Method

The resistivity method is one of the geoelectric methods used for subsurface investigations by utilizing the nature of electricity flow within the earth's surface and how to detect it on the earth's surface. This method includes measuring the potential difference and electric current that occurs due to the injection of electric current into the earth through a pair of current electrodes (A and B in Figure 2). The potential difference is measured through a pair of potential electrodes (M and N in Figure 2) (Sufiyanussuari et al., 2021). If ΔV is the potential difference, I is the current and K is the geometry factor, then the resistivity can be written as (Riwayat et al., 2018):

$$\rho = K\frac{\Delta V}{I} \tag{1}$$

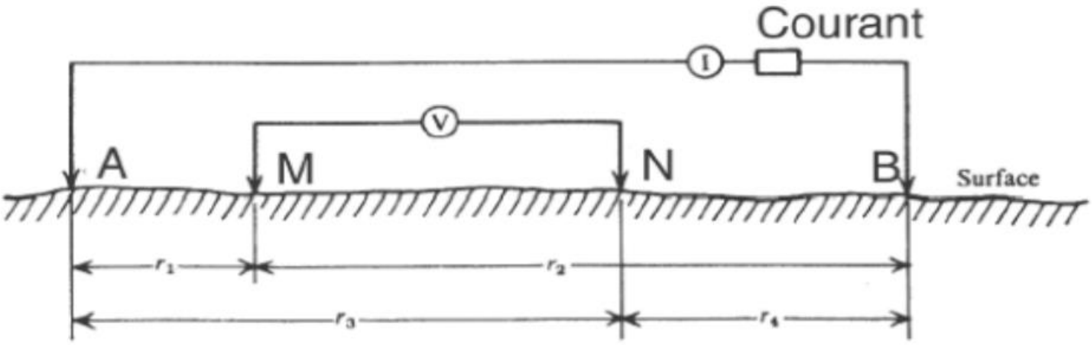

Figure 2. Two current electrodes and two potential electrodes on the surface; Courant is power in French (Baba et al., 2014).

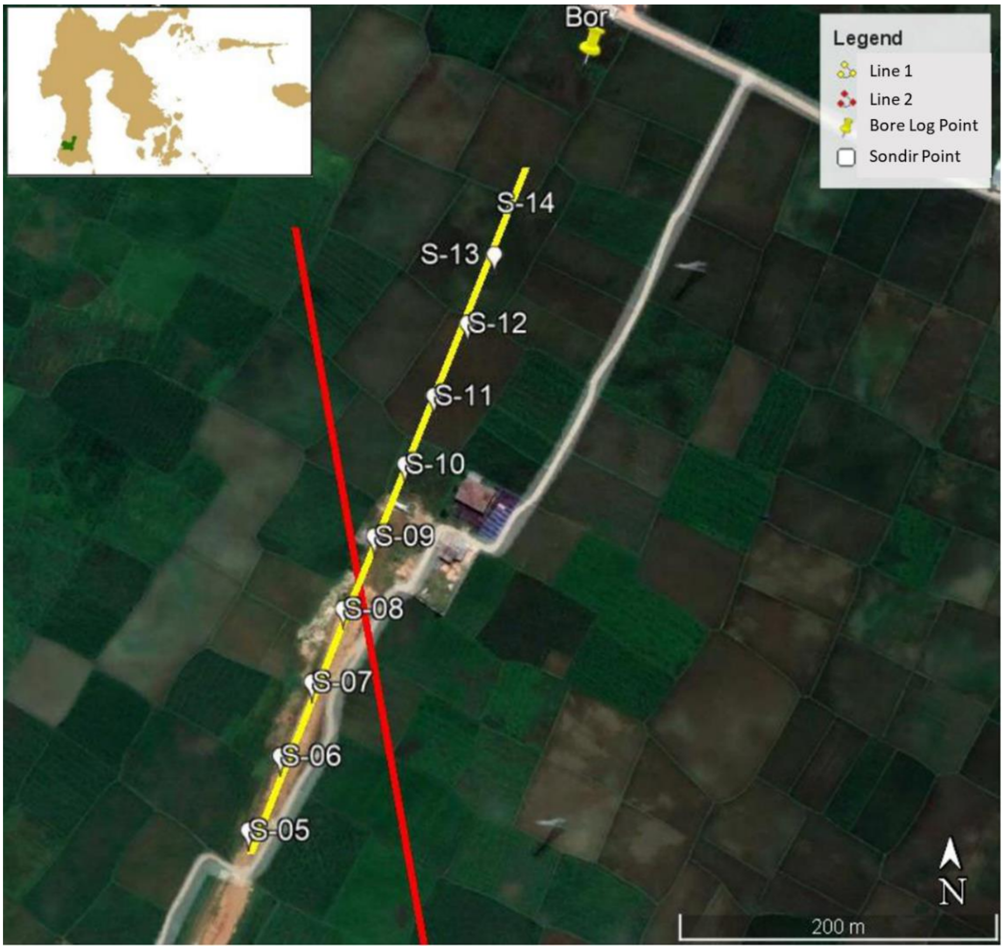

Figure 3. Measurement line map.

Research Methods

This research was conducted in Soreang Village, Maros Regency, South Sulawesi with a total of 2 lines with a length of 470 meters each. The research was conducted using the Wenner-Schlumberger array resistivity method. This array is believed to be better than other configurations such as Dipole-Dipole (Hermawan, & Putra, 2016). The data obtained are current value, potential value, and resistivity value. After data acquisition, data processing and inversion are carried out to produce a subsurface resistivity distribution value at the research location in the form of a 2D cross section.

Figure 3 displays the two measurement lines. Line 1 (yellow color) in the direction of Southwest - Northeast along the Makassar - Parepare railway construction site and Line 2 (red color) in the direction of Southeast - Northwest. In addition, there are also sondir data as support in this study.

Results and Discussion

The data from the measurement of the resistivity method in the field is processed to obtain the resistivity cross section of the inversion results for all measurement lines, as described below:

Line 1

Sondir with a total of 10 data points and half of the measured line length is a former excavation that has been filled into overburden. The combination of 2D resistivity cross section of inversion results of line 1 with sondir data is depicted in Figure 4.

Based on the resistivity value of the inversion results and geological information in the study area, it can be indicated that there are 3 layers. Layer 1 imaged in gray is interpreted as overburden material which has a resistivity value of 1 - 1000 Ωm. Layer 2 with a resistivity value range of 1 - 6 Ωm (blue color) is interpreted as alluvium deposits consisting of clay, silt, and sand. Layer 3 with a resistivity value ≥ 7 Ωm (green color) is interpreted as limestone. The interpretation results are tied to the sondir data and provide the same layer information. The sondir data provides information that from the top soil up to 22 meters down is an alluvium deposit consisting of silt, clay, and sand, while at a depth of 22 meters it states as a limestone layer which is estimated to be continuous and massive downwards, as shown in Figure 5.

Based on the resistivity values in Figure 5, it can be determined which zones are indicated to be in contact with seawater or to be areas of seawater intrusion. Figure 6 provides an overview of the parts identified as seawater intrusion zones marked with dotted lines and angles.

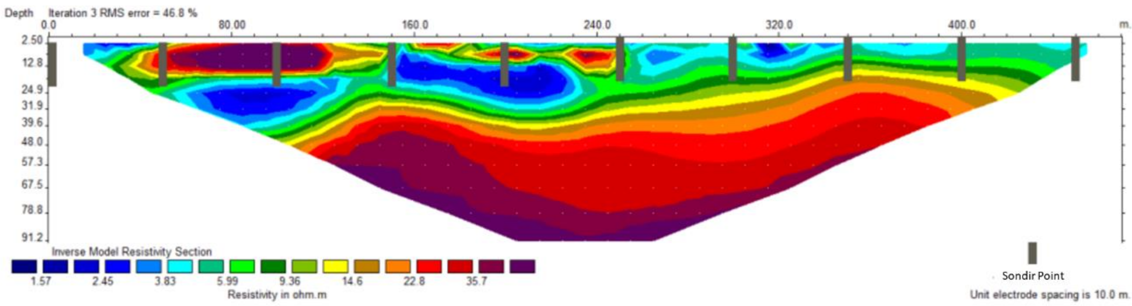

Figure 4. The position of the sondir with respect to line 1.

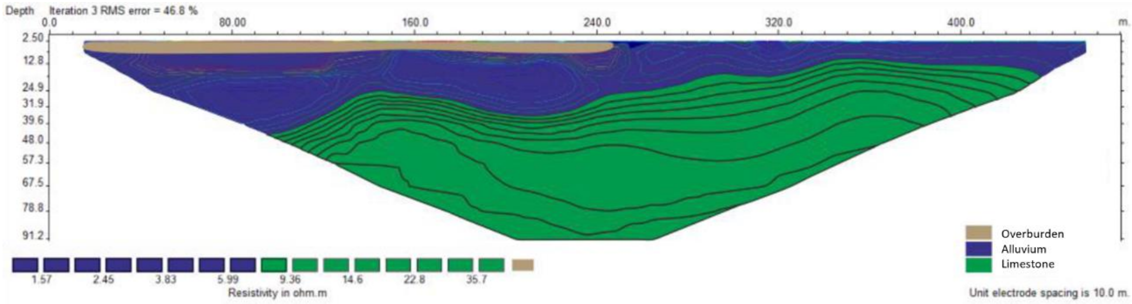

Figure 5. Interpretation of 2D cross-section of the inversion results of line 1 tied to the sondir data.

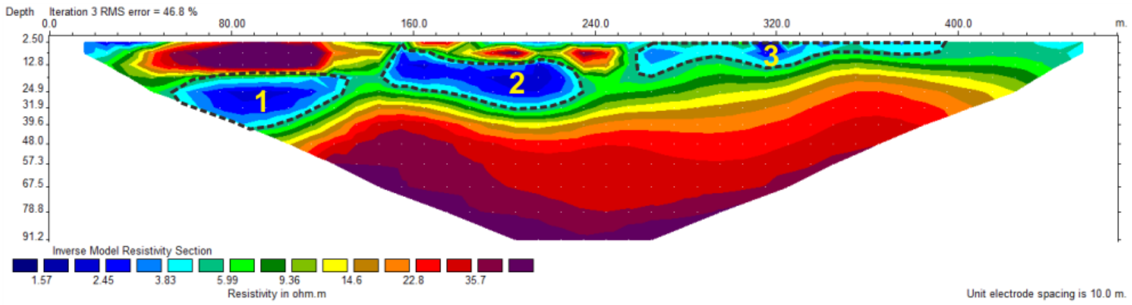

Figure 6. Seawater intrusion zone of line 1.

The seawater intrusion zone is indicated in layer 2 which is an alluvium deposit. This layer has three indicated sections, section 1 is located at electrode 6 (measuring point 50 meters) to electrode 14 (measuring point 130 meters) which is estimated that seawater intrusion starts from a depth of 40 - 20 meters below the surface section 2 is located at electrode 16 (measuring point 150 meters) to electrode 24 (measuring point 230 meters) which is estimated that intrusion starts from a depth of 32 - 2.5 meters below the surface. Section 3 is located at electrode 25 (measuring point 240 meters) to electrode 40 (measuring point 400 meters) and it is estimated that the intrusion starts from a depth of 16 meters and continues to the surface.

Line 2

Based on the variation of resistivity values and regional geological information in the study area, in line 2, 3 layers were identified as obtained similar with line 1. Layer 1, which is considered as overburden material, is only a few meters in the middle of the line. While layer 2, which is interpreted as an alluvium layer, dominates the surface with a depth that varies between 10 - 20 meters from the surface (Figure 7).

Figure 8 shows the seawater intrusion zone on line 2 is also in layer 2 which is marked with dotted lines and numbers. Based on the resistivity analysis in Line 2, there are two sections indicated as seawater intrusion zones in the alluvium layer. Section 1 is located at electrode 1 to electrode 20 (about 200 meters along the line) with a depth of up to 13 meters. Section 2 is at electrode 22 to electrode 48 or 260 meters long and has depths varying up to 26 meters subsurface, including under layer 1.

The relation between the interpretation of Line 2 and Line 1 can be seen after the two cross-sections are combined, as shown in Figure 9.

Figure 9 is a combination of Figure 5 and Figure 7, showing the intersection of the two lines above. Figure 9 (a) and (b) are shown, just to show the connection at the intersection of the two lines seen from different directions. Although the intersection is not exactly right, it still has the same pattern, so it is considered that they are related and mutually reinforcing.

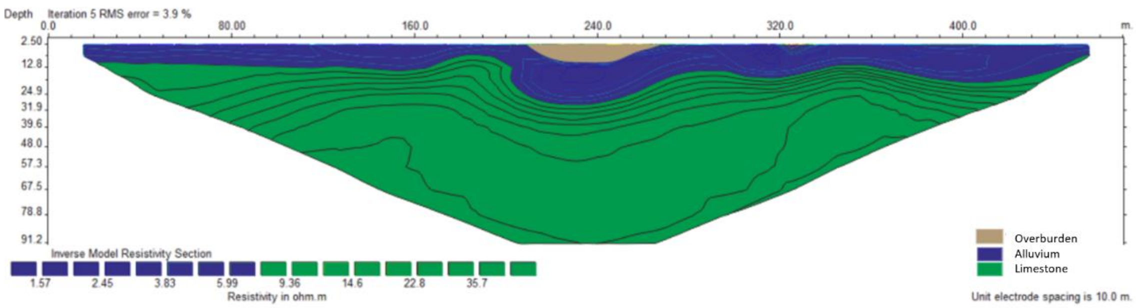

Figure 7. Layer distribution of inversion results on line 2.

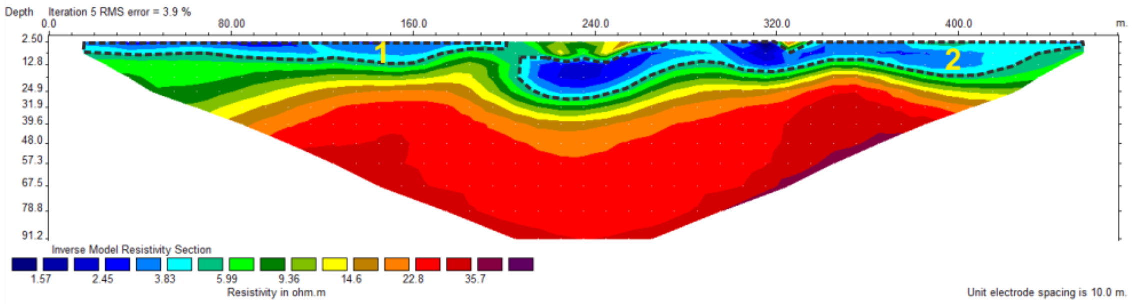

Figure 8. Seawater intrusion zone of line 2.

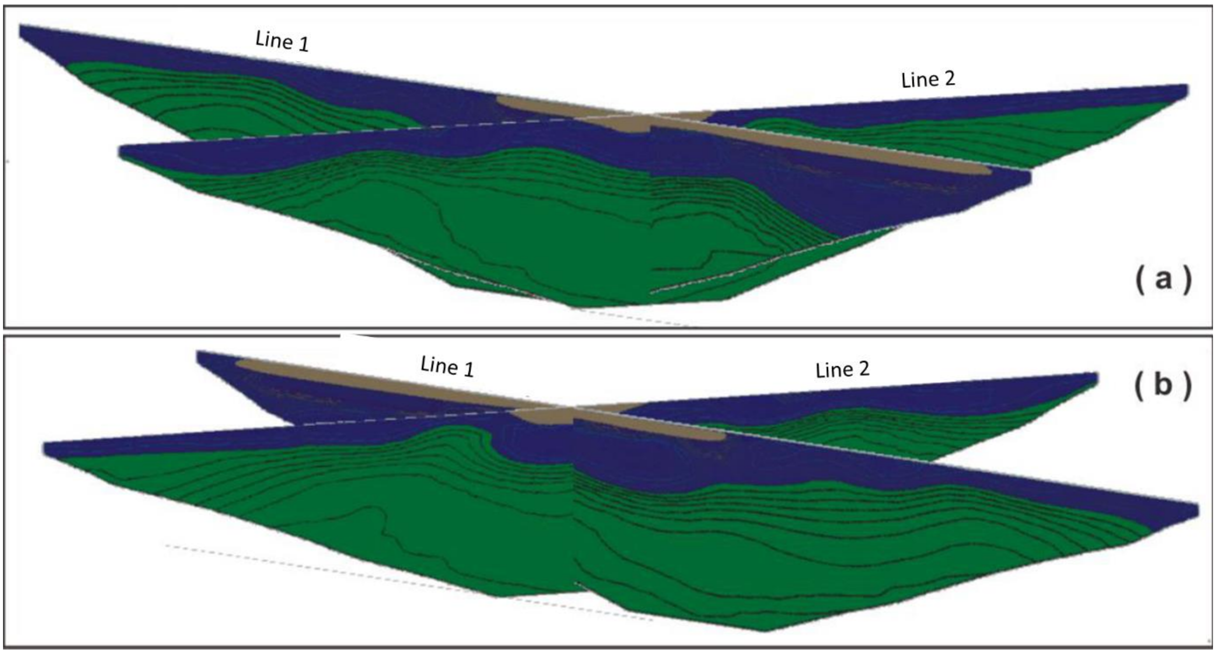

Figure 9. (a) from the west, and (b) from the east.

Conclusion

The subsurface structure in the study area consists of two layers, the first is alluvium deposits (silt, clay, and sand) with a resistivity range of 1 - 6 Ωm and the second is limestone with a resistivity value between ≥ 7 Ωm.

Seawater intrusion is in the alluvium layer with a resistivity value of 1 - ≤ 5 Ωm with varying depths. Line 1 has 3 zones with varying depths ranging from 20 - 40 meters below the surface, 2.5 - 32 meters of subsurface and 16 meters from the surface. The intrusion zone on line 2 has a depth that varies from the surface to 26 meters of subsurface.

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Author Contribution

Syamsuddin, MF, AHW, NS, R, MFIM, Selfiana, BH conceived the study; Syamsuddin and MFIM contributed to the writing of the manuscript. All authors contributed to the preparation of the manuscript. All authors have read and approved the final manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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