Analysis of iron (Fe) heavy metal content in soil at the Talumelito Landfill in Gorontalo Regency

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Abstract. Soil contamination due to waste accumulation in landfills has the potential to increase the accumulation of heavy metals such as iron (Fe), which can affect environmental quality. The purpose of this study was to analyze Fe levels in soil at the Talumelito landfill in Gorontalo Regency. Samples were taken at four locations, each of which was divided into two sub-locations using purposive sampling. The samples were then analyzed at the Gorontalo Province Regional Health Laboratory (Labkesda) using atomization to obtain accurate Fe concentration values. The analysis results showed that the Fe content at all points was relatively uniform, ranging from 22 mg/L. The highest value was found at point C at 22.82635 mg/L, while the lowest value was at point B at 22.55940 mg/L. This narrow range of values illustrates the stable distribution of Fe in the landfill area. When compared to the quality standard of PP No. 101 of 2014 of 200 mg/L, all research results were well below the threshold.

1 Introduction

Indonesia remains one of the countries facing serious challenges in waste management. Waste refers to residual materials generated from anthropogenic or human activities that no longer have practical value. In many regions of Indonesia, waste management still relies heavily on final disposal sites (Tempat Pembuangan Akhir, TPA) as the primary solution. However, the application of conventional landfill methods often gives rise to new environmental and social problems for surrounding communities. Waste disposed of in landfills originates from various sectors, including medical, industrial, commercial, and household activities, and may contain heavy metals derived from items such as metal cans, hardware, and electronic equipment. Heavy metals, including lead (Pb) and iron (Fe), are considered hazardous because they cannot be metabolized or degraded within the human body (Rachmawati et al., 2024).

The Talumelito Regional Landfill serves as the main waste management facility in Gorontalo Province, providing services for three administrative areas: Gorontalo City, Gorontalo Regency, and Bone Bolango Regency. Gorontalo City covers an area of 79.59 km² with a population of 219,399 inhabitants, while Gorontalo Regency spans 1,750.83 km² with a population of 393,107 people. Bone Bolango Regency has an area of 1,984.31 km² and a population of 162,778. Landfill service coverage reaches approximately 78% in Gorontalo City, 20% in Gorontalo Regency, and only 7% in Bone Bolango Regency. According to data from the Talumelito Regional Landfill, the average volume of waste disposed of between 2019 and 2021 reached 34,714 tons per year. However, most of this waste is not subjected to systematic sorting processes, resulting in a continuous decline in landfill storage capacity over time (Hadjarati, 2023).

Soil naturally contains various metal elements, including heavy metals. Nevertheless, the accumulation of these metals poses a significant environmental risk due to their non-biodegradable or persistent nature. Certain metals—such as manganese (Mn), zinc (Zn), chromium (Cr), molybdenum (Mo), iron (Fe), and nickel (Ni)—are essential micronutrients for soil organisms when present in low concentrations. However, at elevated levels, these metals can become toxic and disrupt ecological balance (Sari et al., 2022).

Iron (Fe) is an essential element required by living organisms in specific amounts, but excessive concentrations can result in toxic effects. Elevated iron levels in the human body have been associated with various health problems, including acute poisoning, gastrointestinal disorders, liver and kidney damage, and chronic diseases such as diabetes, hypertension, and cirrhosis. Prolonged exposure to excessive iron may also accelerate premature aging and reduce overall quality of life (Endrawati, 2015).

Soil pollution occurs when contaminants such as synthetic chemicals, biological substances, or other harmful materials enter the soil and alter its natural characteristics. Sources of soil contamination include industrial wastewater leakage, pesticide application, domestic waste disposal, and landfill activities. Numerous studies indicate that soils

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surrounding landfill areas tend to exhibit elevated concentrations of heavy metals. This condition is further aggravated by landfill construction systems that employ direct waste stacking on bare ground without adequate protective liners, thereby increasing the potential for heavy metal infiltration into the soil profile (Gusti et al., 2022).

This study was conducted to analyze the concentration of iron (Fe) as a heavy metal in soils within the Talumelito Final Disposal Site (TPA). The primary objective of this research is to determine the level of iron accumulation in the soil. Such analysis is essential, given that landfills represent potential sources of environmental pollution, particularly affecting soil and groundwater quality. Heavy metals such as iron may originate from various waste streams, including household refuse, small-scale industrial waste, and corroded metal materials. If left unmanaged, the accumulation of heavy metals in soil can adversely affect environmental quality and pose health risks to communities living near disposal sites. Therefore, this study focuses on quantifying and identifying iron concentrations in the soil as an initial step toward assessing pollution potential. The findings are expected to provide a clear overview of soil quality at the Talumelito landfill, particularly in landfill section one.

2 Research Methods

2.1 Research Time and Location

This study was conducted from October to November 2025 using a field observation approach. Soil sampling was carried out at the Talumelito landfill site. Laboratory analysis of iron (Fe) concentration in soil samples was performed at the Regional Health Laboratory (LABKESDA) of Gorontalo Province.

2.2 Research Object

The object of this study was the concentration of iron (Fe) as a heavy metal contaminant in soil collected from the Talumelito landfill area.

2.3 Tools and Materials

2.3.1 Research Instruments

The instruments used in this study included a Global Positioning System (GPS) device to determine sampling coordinates, soil sampling tools (such as a shovel or soil auger), plastic zip-lock bags for sample storage, labeling paper, and sealed containers for transportation.

2.3.2 Research Materials

The primary material analyzed in this study was soil collected from the designated sampling points.

2.4 Data Collection Techniques

2.4.1 Determination of Sampling Locations

Four (4) sampling locations were selected using purposive sampling based on representative environmental conditions within the study area. Each location was further divided into two sampling points, resulting in a total of eight sampling points.

2.4.2 Soil Sampling Procedure for Iron (Fe) Analysis

At each designated sampling point, soil samples were collected at a depth of approximately ±10 cm using appropriate soil sampling tools. The collected soil was placed in clean plastic zip-lock bags and labeled with detailed information, including sampling code, date of collection, and sampling depth. The samples were then stored in sealed containers to prevent contamination and transported promptly to the Regional Health Laboratory (LABKESDA) of Gorontalo Province for further analysis.

2.4.3 Laboratory Analysis of Iron (Content)

The soil samples were analyzed at the Regional Health Laboratory (LABKESDA) of Gorontalo Province to determine iron (Fe) concentration. Laboratory procedures included sample preparation and quantitative analysis using standardized analytical methods to ensure accurate and reliable measurement of Fe levels.

3 Results and Discussion

3.1 Result

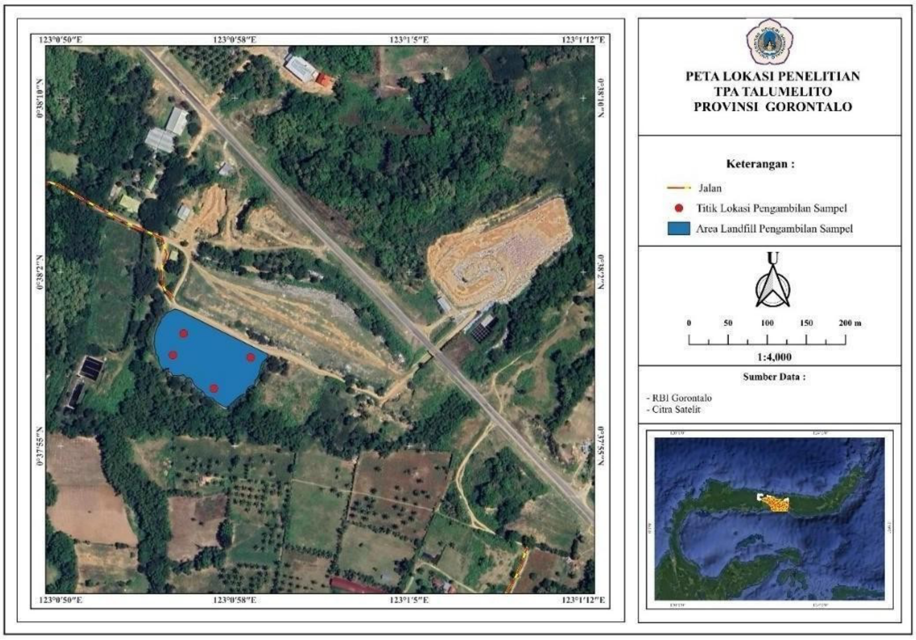

Figure 3.1 Map of Soil Sample Collection Locations

Table 1. Average Fe content in soil samples

No	Sample Code	Result (mg/L)	Quality Standard (mg/kg)	Research Method
1	A	22.81625	200	Atomization
2	B	22.55940		
3	C	22.82635		
4	D	22.76765		

3.2 Discussion

At point A, the average Fe concentration was recorded at 22.81625 mg/kg. Two measurements at this point showed almost identical values, indicating that the Fe content at this location is fairly stable and has not experienced a significant increase. When compared to the quality standard of PP No. 101 of 2014 of 200 mg/kg, the iron content at point A is still well below the threshold. This condition indicates that the soil at point A has not experienced excessive Fe accumulation even though it is located in a landfill area. This is important because if Fe is present in high levels, this metal can cause toxic effects such as digestive disorders, liver and kidney damage, and the risk of chronic diseases (Endrawati, 2015). Therefore, the low Fe condition at point A is still considered safe for the surrounding environment.

At point B, the average Fe content is 22.55940 mg/kg, which is the lowest value compared to other points. Although slightly lower, this value remains within a stable range and indicates that the soil at point B has not been contaminated with Fe from waste disposal activities. The low Fe value also shows that the waste decomposition process at this point has not had a significant effect on the metal content in the soil. Theoretically, Fe is an essential element for soil organisms, but in high concentrations it can disrupt the balance of the ecosystem and cause changes in the chemical properties of the soil (Sari et al., 2022). With values that are still well below the quality standards, point B can be said to be in a safe condition.

At point C, the Fe concentration was 22.82635 mg/kg, which was the highest value of all samples. Although it was the highest, this figure was still less than half of the threshold limit of 200 mg/kg. This slightly higher value may have been influenced by the physical condition of the soil or differences in the composition of degraded waste in the area. The conditions of Landfill 3, which continues to receive waste deposits, may cause slight variations in metal content, but not enough to cause pollution. It should be understood that high levels of Fe in the soil have the potential to enter the food chain through plants and soil organisms, and in humans can cause acute poisoning and internal organ damage if accumulated in the body. Therefore, the low results at point C indicate that the environment is still within safe limits, but it is still necessary to be vigilant in the long term.

At point D, the average Fe content is 22.76765 mg/kg, which is also not much different from other points. This uniformity illustrates that the distribution of Fe in the soil at Landfill 3 is relatively even, and there are no specific areas that have experienced a significant increase. This concentration reinforces the finding that waste disposal activities at the Talumelito landfill have not yet caused a spike in Fe that could trigger pollution. Scientifically, high Fe levels can cause soil to become unhealthy because heavy metals are non-biodegradable and have the potential to damage soil structure and affect soil biota (Gusti et al., 2022). However, the Fe content at point D is still within normal limits, so this threat has not yet emerged in the study area.

Overall, the results of the study show that the Fe content at all points is in the range of 22 mg/kg, showing a uniform distribution pattern. There is no indication that Landfill 3 has significant Fe contamination. However, given the nature of heavy metals that can accumulate over the long term, regular monitoring is still very necessary to ensure that soil quality remains stable and does not develop into a potential environmental or health hazard.

4. Conclusion

This study shows that the iron (Fe) content in the soil at the Talumelito landfill is around 22 mg/kg, with results between points that are almost identical. This value is clearly well below the quality standard of PP No. 101 of 2014, which is 200 mg/kg, so that both research objectives can be answered definitively: the Fe content in the soil is at a safe level and does not exceed the specified limit. These findings indicate that the landfill area studied has not experienced significant Fe contamination. However, routine monitoring remains important, considering that ongoing waste accumulation activities could affect soil conditions in the future.

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