Analysis of Cadmium Contamination in Well Water Around the Terjun Landfill Medan Marelan District

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Abstract

The increase in waste volume significantly affects the waste generation at Landfills. Landfills have been identified as one of the main groundwater pollution sources. The aim of this study was to determine the factors influencing cadmium pollution in well water among the community around the Terjun Landfill Medan Marelan District. This study employed an observational analytic design with a cross-sectional approach. It was conducted in the Medan Marelan District adjacent to the Terjun Landfill from August to November 2023. The study population consisted of all households with wells, totaling 218 households. Sample size calculation yielded 64 samples. Sampling technique was conducted using simple random sampling. Sample collection is based on the direction of water flow. Well water samples were examined in the laboratory using spectrophotometry by the Environmental Health and Disease Control Technical Implementation Class I Medan Unit on October 11, 2023, and the results were received on October 30, 2023. Data analysis using SPSS version 21. Data analysis involved three stages: univariate analysis using descriptive statistics and frequency, bivariate analysis using Pearson and ANOVA tests, and multivariate analysis using multiple linear regression at a significance level of 95% (0.05). Statistics results the relationship between well distance and cadmium levels with a value of (P=0.001;r=-0.676), indicating a significant relationship. The relationship between well depth and cadmium levels yielded a value of (P=0.001;r=0.612), indicating a significant relationship. Cadmium levels with soil types obtained a value of (P=0.001), indicating a significant difference. The factor most influencing cadmium pollution in well water around the Terjun Landfill was well distance (ExpB=0.002;P=0.001). The average cadmium levels in well water are still below the drinking water quality standards, however continuous consumption poses risks. The most influential factor is well distance. It is recommended that residents refrain from using well water as a drinking water source.

Keywords : Cadmium, landfill, Well Water

INTRODUCTION

The target of the sixth goal in the Sustainable Development Goals (SDGs) is to ensure the availability and sustainable management of clean water and sanitation for all. The presence of waste is inseparable from the provision of clean water and sanitation (Agustina et al., 2021). Waste is one of the significant challenges in every country, especially in Indonesia. Almost every river, road, public space, and even within our homes, we encounter waste (Indirawati et al., 2022). The current amount of waste continues to increase day by day (Karamina et al., 2021).

The waste generation in districts/cities in Sumatera Utara, where the highest waste producer is Medan City with 628,749.22 tons per year, followed by Langkat Regency with 190,323.78 tons per year, Simalungun Regency with 186,444.74 tons per year, Asahan

Regency with 172,564.99 tons per year, Pematang Siantar City with 88,121.44 tons per year (Kementerian Lingkungan Hidup dan Kehutanan, 2023).

Medan City in 2019 it waste produced to 1,704.02 tons per day, in 2020 it waste produced to 1,704.68 tons per day, in 2021 it waste produced to 1,767 tons per day, and in 2022, it waste produced to 1,722 tons per day (Dinas Lingkungan Hidup Kota Medan, 2022). The increase in waste volume has a significant impact on the accumulation of waste at the Landfill, causing the Landfills load to become very heavy (Li & Achal, 2020; Rosita, 2023). This increase in waste volume also affects the Landfill waste management system, employing open dumping where waste is discarded directly at the final disposal site and left uncovered (Omeiza et al., 2023).

Improperly managed waste can pose problems for both society and the environment. The negative impact can lead to heavy metal pollution resulting from waste such as used paint, used batteries, used tires, plastic pigments, and batteries (Handriyani, et al., 2020). The decomposition process by microbes on waste left open for more than 24 hours produces toxic soluble organic substances known as leachate (Ibrahim et al., 2023; Gupta & Raju, 2023). Leachate spread through rainwater runoff will seep and contaminate groundwater, including well water in the surrounding area (Imaduddin et al., 2022; Indirawati et al., 2022). Leachate is one of the causes of water pollution (Siddiqi et al., 2022).

Leachate contains very high levels of heavy metals (Ingle, 2022). Several heavy metals found in leachate include lead (Pb), cadmium (Cd), copper (Cu), and iron (Fe) (Syuzita et al., 2022; Rahmi & Edison, 2019). One particularly hazardous heavy metal for the environment is cadmium. Cadmium is an element that is not required in the body, and its accumulation can have health impacts (Mahajan et al., 2022; Parubak et al., 2023).

Leachate from landfill can infiltrate the soil, causing the groundwater in the vicinity of the landfill to be contaminated by pollutants (Omeiza et al., 2023). Consequently, this contamination can extend to surface water and runoff in the vicinity of the landfill, which is utilized by the local community as a source of water for daily consumption (Pratiwi et al., 2022; Anjelina et al., 2021). In Indonesia, one of the primary water sources is wells. Wells remain a crucial water source widely used by Indonesian communities, especially those residing in rural areas (Nurhadi et al., 2023).

Landfills have been identified as one of the primary sources of groundwater pollution, with groundwater contamination on the rise in recent years (Akhtar et al., 2020; Yang et al., 2022). Areas in close proximity to landfills have a substantial risk of being contaminated by leachate, resulting from the decomposition of organic and inorganic materials within waste piles (Rajoo et al., 2020).

An environment that does not meet the standards in the landfill area, especially residential areas, can lead to health issues for the residing population. This is due to environmental factors such as the quality of well water in the vicinity of the landfill that has been exposed to heavy metal contamination from leachate seepage (Ramadhan et al., 2022). The surface water quality is significantly influenced by the distance from the landfill, well construction, topographical and geological conditions, as well as the activities of the surrounding community (Rahman et al., 2020; Kurbatova et al., 2024).

Based on the preliminary survey results, the condition of Terjun landfill is situated in a highland area, combined with waste piles reaching 5 meters. The accumulation of waste over 28 years has led to prolonged exposure of the population. According to the Indonesian National Standard No. 03-3241-1997 (Standar Nasional Indonesia, 2017), it is mentioned that the closest residential location to the landfill should be 500 meters away. However, in reality, the community residing around the landfill is at a distance of less than 100 meters.

Since a significant portion of the daily water needs of the residents in the Medan Marelan District comes from well water, the researcher is interested in conducting this study with the aim of analyzing the factors influencing cadmium pollution in well water in the community around Terjun landfill in Medan Marelan District, Medan City.

METHODS

This study is an analytical observational research with a cross-sectional design. The research was conducted in Terjun Village, Medan Marelan District, which is adjacent to the Terjun Landfill. The research was carried out from August 2023 to November 2023. The study population comprised all residents with wells in the vicinity of the Terjun Landfill in the Medan Marelan District, totaling 218 wells owned by the community. Based on sample calculations using the Lemeshow formula, the sample size was determined to be 64 samples.

The sampling technique employed in this study was simple random sampling. The data collection procedure involved observation combined with sample collection, using the direction of water flow. Well water samples were examined in the laboratory using the spectrophotometry method by the Unit of Environmental Health and Disease Control Technical Implementation Class I Medan, located at K.H. Wahid Hasyim Street No. 15, Medan 20154. The analysis was conducted on October 11, 2023 and the results were received on October 30, 2023.

The dependent variable for this study is the cadmium level in water measured on a ratio scale (numeric data), while the independent variables include the well distance, well depth measured on a ratio scale (numeric data), and soil type measured on an ordinal scale (categorical data). Data analysis was performed using SPSS version 21. The analysis involved three steps: univariate analysis using descriptive statistics and frequency, bivariate analysis using Pearson and ANOVA tests to assess the relationship between each independent variable and the dependent variable, and multivariate analysis using multiple linear regression to evaluate factors influencing cadmium contamination in well water at a significance level of 95% (p-value ≤ 0.05).

The maximum permissible level of cadmium in well water is regulated by the Ministry of Health Regulation No. 32 of 2017 (0,005 mg/l or 5µg/l) and Ministry of Health Regulation No. 2 of 2023 (0,003 mg/l or 3 µg/l). The principal researcher obtained an ethical approval certificate from the Research Ethics Committee of the Sumatera Utara University Health Research (No:1012/KEPK/USU/2023). Additionally, permissions were sought from academic administrators of the university and relevant authorities before data collection.

RESULTS

Descriptive analysis of well distance from Terjun Landfill is presented as follows:

Table 1 Descriptive Analysis of Well Distance from Terjun Landfill Medan Marelan District

	Mean	SD	Min	Max	Confidence Interval (95% CI)
Well Distance from Terjun Landfill (meters)	688.58	284.75	180	1.310	617.45 – 759.71

According to Table 1, it is evident that the average well distance from Terjun Landfill is 688.58 meters with a standard deviation of 284.75. The closest well distance from Terjun Landfill is 180 meters, while the farthest distance is 1,310 meters. The frequency distribution of well distance > 500 meters from Terjun Landfill is presented as follows:

Table 2 Frequency Distribution of Well Distance > 500 Meters from Terjun Landfill Medan Marelan District

Well Distance	n	%
< 500 meters	20	31.2
> 500 meters	44	68.8
Total	64	100.0

According to Table 2, the frequency distribution of well distance > 500 meters from Terjun Landfill is as follows: there are 20 wells (31.2%) are < 500 meters from Terjun Landfill, and 44 wells (68.8%) are > 500 meters from Terjun Landfill.

Descriptive analysis of well depth around the Terjun Landfill Medan Marelan District is presented as follows:

Table 3 Descriptive Analysis of Well Depth Around the Terjun Landfill Medan Marelan District

	Mean	SD	Min	Max	Confidence Interval (95% CI)
Well Depth (meters)	6.66	3.19	2.5	15	5.90 – 7.43

According to Table 3, it is evident that the average well depth is 6.66 meters with a standard deviation of 3.10, the lowest well depth is 2.5 meters and the deepest well is 15 meters. The frequency distribution of well depth around the Terjun Landfill Medan Marelan District is presented as follows:

Table 4 Frequency Distribution of Well Depth Around the Terjun Landfill Medan Marelan District

Well Depth	n	%
< 10 meters	54	84.4
≥ 10 meters	10	15.6
Total	64	100.0

According to Table 4, the frequency distribution of well depth around the Terjun Landfill Medan Marelan District is as follows: there are 54 wells (84.4%) with a depth of < 10 meters and 10 wells (15.6%) with a depth of > 10 meters.

The frequency distribution of soil types around the Terjun Landfill Medan Marelan District is presented as follows:

Table 5 Frequency Distribution of Soil Types Around the Terjun Landfill Medan Marelan District

Soil Types	n	%
Gravel	7	10.9
Sand	5	7.8
Silt	34	53.1
Clay	8	12.5
Colloids	10	15.6
Total	64	100.0

According to Table 5, the distribution of soil types around the Terjun Landfill Medan Marelan District is as follows: gravel for 7 soils (10.9%), sand for 5 soils (7.8%), silt for 34 soils (53.1%), clay for 8 soils (12.5%), and colloid for 10 soils (15.6%).

Descriptive analysis of cadmium levels in well water around the Terjun Landfill Medan Marelan District is presented as follows:

Table 6 Descriptive Analysis of Cadmium Levels in Well Water Around the Terjun Landfill in Medan Marelan District

	Mean	SD	Min	Max	Confidence Interval (95% CI)
Cadmium Levels (μg/l)	1.066	1.923	0.009	9.81	0.616 – 1.613

According to table 6, it is evident that the average cadmium level in well water around the Terjun Landfill is 1.066 μg/l, with a standard deviation of 1.923 μg/l. The lowest recorded cadmium level is 0.009 μg/l, while the highest is 9.18 μg/l. According to the Minister of Health Regulation No. 2 of 2023 and Minister of Health Regulation No 32 of 2017, the frequency distribution of cadmium level in well water around the Terjun Landfill in Medan Marelan District is as follows:

Table 7 Frequency Distribution of Cadmium Levels in Well Water Around the Terjun Landfill in Medan Marelan District

Cadmium Levels in Well Water	n	%
Minister of Health Regulation No. 32 of 2017		
< 5 μg/l	60	93.8
> 5 μg/l	4	6.3
Minister of Health Regulation No. 2 of 2023		
< 3 μg/l	56	87.5
> 3 μg/l	8	12.5

According to Table 7, the frequency distribution of cadmium levels in well water around the Terjun Landfill Medan Marelan District is the acceptable threshold value for cadmium in clean water with the Ministry of Health Regulation No. 32 of 2017. It shows that 60 wells (93.8%) have cadmium levels acceptable cadmium in clean water (< 5 μg/l), and 4 wells (6.3%) have cadmium levels unacceptable cadmium in clean water (> 5 μg/l). Additionally, according to the Ministry of Health Regulation No. 2 of 2023, 56 wells (87.5%) have cadmium levels acceptable cadmium in clean water (< 3 μg/l), and 8 wells (12.5%) have cadmium levels unacceptable cadmium in clean water (> 3 μg/l).

The results of the analysis of the relationship between well distance and cadmium levels in well water around the Terjun Landfill Medan Marelan District can be observed as follows:

Table 8 Relationship between Well Distance and Cadmium Levels in Well Water Around the Terjun Landfill Medan Marelan District

Correlation between Variables	Cadmium Levels in Well Water		
	n	***R***	***P value***
Well Distance	64	- 0,676	0,001

According to Table 8, a correlation coefficient value or r = -0.676 was obtained. Therefore, it can be concluded that the relationship between well distance and cadmium levels in well water around the Terjun Landfill Medan Marelan District indicates a strong and negative correlation. This implies that the closer the well distance, the higher the cadmium levels in well water. The statistic test results yielded a p-value of 0.001, indicating a significant correlation between well distance and cadmium levels in well water around the Terjun Landfill Medan Marelan District.

The analysis of the relationship between well depth and cadmium levels in well water around the Terjun Landfill Medan Marelan District is presented as follows:

Table 9 Relationship between Well Depth and Cadmium Levels in Well Water Around the Terjun Landfill Medan Marelan District

Correlation between Variables	Cadmium Levels in Well Water		
	n	***R***	***P value***
Well Depth	64	0.612	0.001

According to Table 9, a correlation coefficient value or r = 0.612 was obtained. Therefore, it can be concluded that the relationship between well depth and cadmium levels in well water around the Terjun Landfill in Medan Marelan District indicates a strong and positive correlation. This implies that the deeper the well, the higher the cadmium levels in well water. The statistics test results yielded a p-value of 0.001, indicating a significant correlation between well depth and cadmium levels in well water around the Terjun Landfill in Medan Marelan District.

The analysis of the differences in soil types and cadmium levels in well water around the Terjun Landfill in Medan Marelan District is presented as follows:

Table 10 Differences in Soil Types and Cadmium Levels in Well Water Around the Terjun Landfill Medan Marelan District

Soil Types	Cadmium Levels in Well Water			
	n	***Mean***	***SD***	***P value***
Gravel	7	5.55	2.59	
Sand	5	2.85	0.62	
Silt	34	0.63	0.89	0.001
Clay	8	0.14	0.03	
Colloids	10	0.05	0.03	

According to Table 10, the average cadmium levels in well water for the gravel soil type were 5.55 μg/l with a standard deviation of 2.59 μg/l, the sand soil type were 2.85 μg/l with a standard deviation of 0.62 μg/l, the silt soil type were 0.63 μg/l with a standard deviation of 0.89 μg/l, the clay soil type were 0.14 μg/l with a standard deviation of 0.03 μg/l, and the colloid soil type were 0.05 μg/l with a standard deviation of 0.03 μg/l. The statistics test results showed a p-value of 0.001, indicating a significant difference in the average cadmium levels in well water among different soil types.

The multivariate analysis aims to analyze the factors influencing cadmium pollution in well water around the Terjun Landfill in Terjun Village, Medan Marelan District, Medan City. The factors considered are well distance, well depth, and soil type, which will be included in the final multivariate model, presented in the following table:

Table 11 Multiple Linear Regression Analysis on Factors Influencing Cadmium Pollution in Well Water around the Terjun Landfill in Terjun Village Medan Marelan District

Model	Variables	Exp B	Pvalue
1	Cosantant	3.982	0.001
	Well distance	-0.002	0.001
	Well depth	0.214	0.001
	Soil type	-0.461	0.015

According to Table 11, it is observed that there are three variables that can predict the cadmium levels in well water namely well distance, well depth, and soil type. The conclusions drawn from the multiple linear regression statistic test are as follows: The obtained constant value of 3.982 indicates that if all independent variables are valued at 1, the cadmium levels in well water will increase by 3.982; The regression coefficient for the well distance variable is -0.002, which means that if the well distance variable increases by 1 unit, assuming the other variables remain constant, it will result in a 3.982 decrease in cadmium levels in well water; The regression coefficient for the well depth variable is 0.214, indicating that if the well depth variable increases by 1 unit, assuming the other variables remain constant, it will result in a 3.982 increase in cadmium levels in well water; The regression coefficient for the soil type variable is -0.461, meaning that if the soil type variable increases by 1 unit, assuming the other variables remain constant, it will result in a 3.982 decrease in cadmium levels in well water; The variable that most significantly influences the increase in cadmium levels in well water is the well distance.

DISCUSSION

Contamination of well water in the vicinity of the landfill is caused by the leaching of waste piles, carrying dissolved substances or by-products of the waste decomposition process, resulting in leachate (Ergene et al., 2022). The leachate enters the water following the groundwater flow direction, eventually converging into wells (Beinabaj et al., 2023). Leachate contains various heavy metals, including cadmium (Astuti et al., 2020). Well water containing cadmium levels can affect the well water quality. If the concentration of cadmium exceeds the standard quality level in a water body, the water is considered contaminated (Meyrita et al., 2023).

Well water located near the landfill has a higher potential for being contaminated by leachate. Therefore, landfills with proper waste management systems have monitoring wells designed to monitor water quality (Wdowczyk & Pulikowska, 2021). Well water serves as the primary source for drinking, cooking, bathing, washing, and other needs for the residents around the landfill (Puspitarini et al., 2023). Changes in leachate water quality will affect the well water quality. Leachate water will impact well water users, especially concerning health

(Amano et al., 2021). If well water is contaminated with leachate, it is no longer considered clean water and is not suitable for use due to potential physiological impacts on the human body (Thomas & Santoso, 2019).

The presence of the heavy metal cadmium in water is hazardous both directly to human life and indirectly to human health. Cadmium, exceeding the standard limits, has negative impacts on human health (Edzoa et al., 2024). For instance, elevated levels of cadmium in the body can trigger kidney damage, especially in protein excretion. This damage can be detected through the level of protein content in urine (Mood et al., 2021). Chronic effects of cadmium exposure can also lead to anemia due to the relationship between high cadmium levels in the blood and low hemoglobin levels (Peters et al., 2021). After 20 years of cadmium exposure, pulmonary emphysema, characterized by lung swelling, may occur (Pratiwi et al., 2022). Cadmium poisoning can result in digestive issues and kidney diseases. Furthermore, the clinical symptoms of cadmium poisoning closely resemble common glomerulonephritis (Ngibad, 2023; Edzoa et al., 2024).

Health requirements to be fulfilled by dug well facilities include the distance between the dug well and the source of contamination, such as waste disposal sites. Dug wells must be located far from potential sources of contamination. If the contamination source is in close proximity to the well, and it is estimated that groundwater flow reaches the well, it is suspected to result in a decrease in the well water quality (Rohmania, et al., 2022).

Areas near landfill have high metal content in community well water (Mariadi & Kurniawan, 2020). Wells in close proximity to landfills may potentially have heavy metal pollutants due to leachate seeping into the groundwater, subsequently entering community wells (Puspitarini et al., 2023).

The presence of a landfill acts as a source of heavy metal contamination, with the closer the well distance to the landfill, the higher the pollution index value. Conversely, as the well distance from the landfill increases, the pollution index value decreases. The existence of landfill locations can lead to well water pollution due to leachate seepage originating from the landfill (Thiesya, et al., 2019).

This study aligns with the research conducted by Anamevia et al. (2023), demonstrating the influence of the distance from the Borobudur Temporary Disposal Site on the level of heavy metal cadmium contamination in community well water. This implies that the closer the well distance to the Temporary Disposal Site, the higher the risk of well water pollution. This is corroborated by the findings of the study conducted by Khoiroh et al. (2020), which indicates a relationship between distance and metal concentration. The study suggests that the closer the well distance to the waste processing site, the higher the concentration of heavy metals in the well water. During the passage through the soil layers, with varying distances, pollutant particles are absorbed by the soil type at the research site, resulting in a reduction in pollutant concentration at a certain distance.

Community wells around the Landfill Terjun, Medan Marelan District, have a well depth of 84.4%, with a well depth of < 10 meters, whereas the recommended well depth should be a minimum of 10 meters from the surface. Well depth influences the concentration of cadmium levels in well water, where the deeper the well, the smaller the concentration of cadmium levels in the well water, and vice versa, the shallower the well, the greater the concentration of cadmium levels in the water.

The findings of this study align with the research by Qadriyah et al. (2019), stating that improper construction of dug wells may facilitate the entry of contaminants from pollution sources into well water. Therefore, proper construction is crucial to prevent contamination from entering the well water used for daily activities.

The soil in the Medan Marelan District is predominantly sand, constituting 53.1% of the total soil type. This sand soil has a sand texture and a fast permeability coefficient ranging from 1 to 102. Consequently, sand or peat soils may facilitate the direct entry of metal content into well water.

The sand or peat soil conditions facilitate the easy spread of pollutants from leachate to the soil, necessitating the use of impermeable layers to mitigate this. Clayey soil, as a clay barrier, serves as an impermeable layer to contain contaminant pollution and prevent it from contaminating groundwater and soil based on hydraulic conductivity properties. The use of clayey soil can reduce the porosity of the landfill soil to restrain the leachate seepage rate (Imaduddin, et al., 2022).

The Medan Marelan District has sand or peat soil, where the sand or peat soil layer consists of large pores. A soil layer with large pore sizes prevents the absorption of cadmium, leading to higher concentrations of the heavy metal cadmium in well water in the Medan Marelan District.

CONCLUSIONS

The most influential factors in cadmium pollution in well water around the Terjun landfill in the Medan Marelan District are well distance, followed by well depth, and then soil type. The average cadmium levels in community-dug well water around the Terjun landfill are still below the quality standards for clean water requirements. However, when compared to the quality standards for drinking water requirements, the well water around the Terjun landfill should not be consumed by the community due to its cadmium content, even though the concentration of cadmium is very low.

For the residents of Terjun Village, Medan Marelan District, it is recommended to use a specialized water filter to remove cadmium. Additionally, residents are advised to plant vegetation around their wells, such as rapa plants, and mangrove trees. It is hoped that the community refrains from using well water for drinking purposes. For the Medan Marelan District Government is encouraged to facilitate alternative water sources for the community, especially for drinking purposes. For the Environmental Agency is urged to implement measures for the management and mitigation of the Terjun Landfill, Medan Marelan District. For future researchers, it is suggested to conduct further studies on community-dug well water to examine other types of heavy metals.

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