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Spatial Analysis of the Distribution of Heavy Metals Pb and Cb in Well Water Around Terjun Landfill in Medan City

Raihan Uliya[*1], T. Alief Aththorick[2], Bejo Slamet[3], T. Sabrina[4], Rahmawaty[5]

[*1]*Natural Resources and Environmental Management Study Program, Postgraduate School, Universitas Sumatera Utara, Medan, 20155, Indonesia*

[2]*Department of Biology, Faculty of Mathematics and Natural Science, Universitas Sumatera Utara, Medan, 20155, Indonesia*

[3,5]*Department of Forestry, Faculty of Forestry, Universitas Sumatera Utara, Medan, 20155, Indonesia*

[4]*Department of Agrotechnology, Faculty of Agriculture, Universitas Sumatera Utara, Medan, 20155, Indonesia*

[*]Corresponding Author: t.alief@usu.ac.id

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ABSTRACT

The study analyzed the spatial distribution of lead (Pb) and cadmium (Cd) in well water around the Terjun Landfill in Medan City. The research aimed to determine Pb and Cd concentrations in dug and drilled wells, compare their levels, and assess the impact of proximity to the landfill's active zone. A total of 22 wells located 50–500 meters from the landfill were sampled using purposive sampling. Spatial analysis was conducted using GPS, while differences in Pb and Cd levels between well types were analyzed using a t-test ($\alpha = 0.05$, CI 95%). Results showed that Pb concentrations in dug wells ranged from 0.0039 to 0.0379 mg/L, with the highest levels found near SG1 and SG4, indicating landfill influence. In contrast, Pb levels in drilled wells were lower (<0.0001 to 0.0158 mg/L) and primarily influenced by external sources. Cd concentrations ranged from 0.0008 to 0.0032 mg/L in dug wells and 0.0005 to 0.0102 mg/L in drilled wells, with contamination in drilled wells linked to external activities. Proximity to the landfill significantly affected Pb levels in dug wells but had no impact on drilled wells, while Cd levels were unaffected by distance in both well types. The findings suggest that transitioning from dug wells to drilled wells is essential to reduce heavy metal exposure and ensure safer water quality for residents.

Keywords: Terjun Landfill, Heavy Metal Contamination, Lead (Pb), Cadmium (Cd), Well Water, Spatial Analysis

1. Introduction

The Terjun Landfill in Medan City operates using an open dumping system, which generates pollutants in the form of leachate. Landfill leachate contains toxic substances, including dissolved organic compounds, inorganic macro compounds, heavy metals, and xenobiotic compounds, posing a significant threat to the environment (Salam and Nilza, 2021). The disposal of various types of waste results in leachate containing hazardous chemicals, particularly lead (Pb) and cadmium (Cd). These contaminants infiltrate the soil and groundwater, raising concerns about their impact on water quality in the villages surrounding the landfill.

Non-essential heavy metals such as Pb and Cd frequently pollute landfills and originate from waste materials such as cosmetics, industrial byproducts, pipes, plastics, batteries, and combustion residues (Widowati et al., 2008; Martin and Griswold, 2009). Although Terjun Landfill has gradually transitioned toward a controlled landfill system since January 2023, the groundwater contamination caused by previously disposed waste remains a challenge. The lack of research on the spatial distribution of heavy metals in well water near the landfill raises concerns about the potential environmental and public health risks for nearby communities.

Over time, the accumulation and dispersion of these metals are expected to increase, though the precise extent remains unclear. Moreover, the Terjun Landfill is currently the only operational landfill in Medan City, underscoring the urgent need for updated data on Pb and Cd contamination in residents' well water. If left unaddressed, the adverse effects of leachate contamination could lead to significant health and economic losses for local communities. The most recent study on this topic, conducted by Novianti in 2018, reported that well water around the landfill was still within safe limits. However, given the continuous accumulation of heavy metals, it is necessary to reassess their current distribution and concentration. This study aims to provide updated information on Pb and Cd contamination in groundwater near the Terjun Landfill, which is crucial for developing mitigation strategies to safeguard community health.

2. Methods

2.1. Study Area and Research Period

This The research was carried out between March and September 2023. The research was conducted in the vicinity of the Terjun Landfill in Medan City within a radius of 500 meters from the landfill site (Fig. 1). Water samples underwent testing at the Medan Class 1 Environmental Health Engineering Center (BTKL).

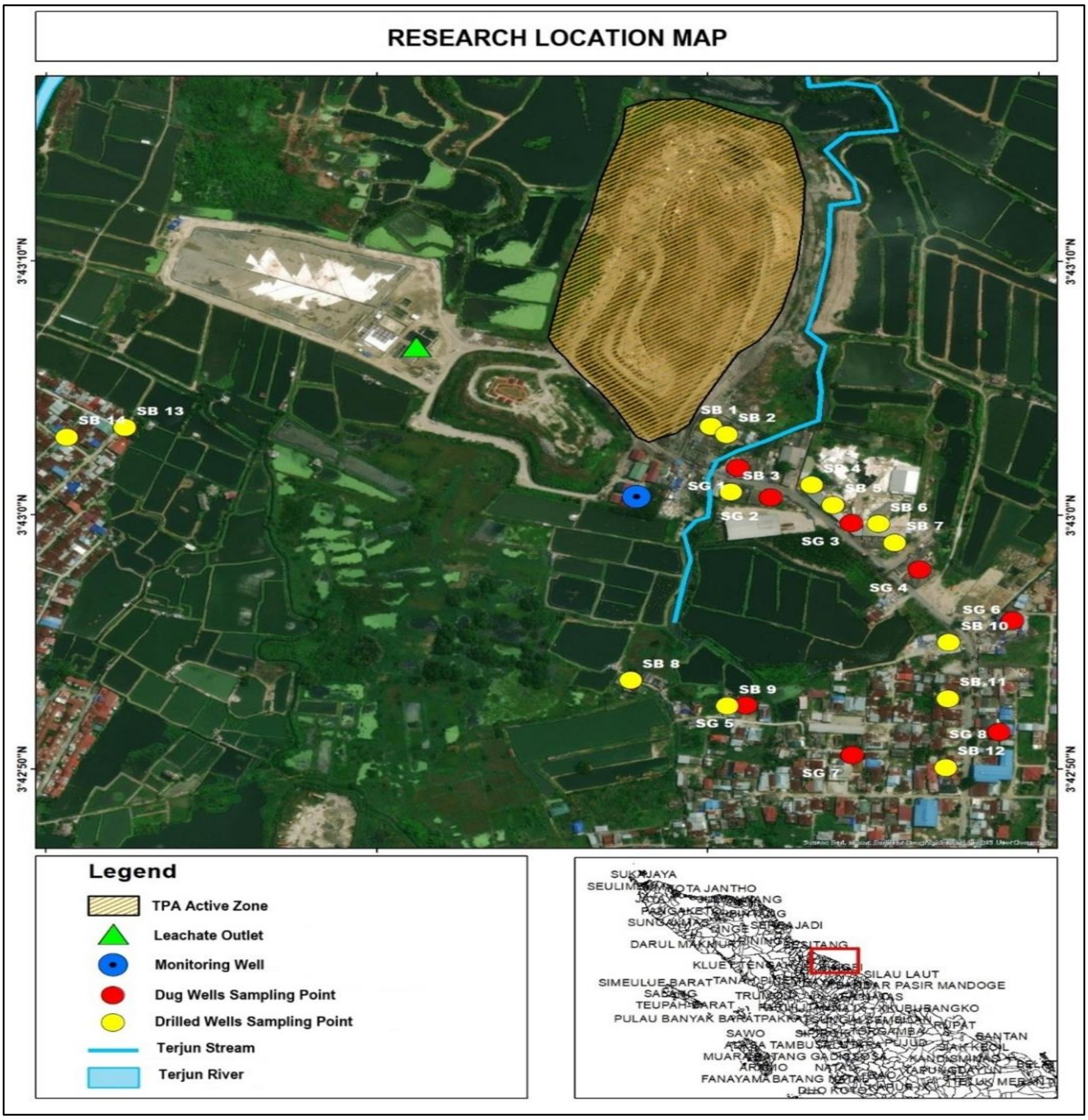

Figure 1. Research Location Map

2.2. Research Instruments and Materials

Water quality assessment often includes measuring dissolved oxygen (DO), as oxygen content indicates contamination levels. In normal, uncontaminated conditions, the minimum dissolved oxygen level should be at least 2 ppm (Swingle, 1968). Higher dissolved oxygen content typically reflects better water quality, with an ideal level of around eight ppm and a saturation rate of 70% (Huet, 1970).

The instruments used in this study included a DO meter (DO9100), a 7-in-1 COM600 Water Tester, a dropper pipette, a stir bar, a glass funnel, latex gloves, sample storage containers, and ArcGIS Desktop software (ArcMap 10.8) for spatial data processing. The study also utilized concentrated nitric acid (HNO_3) for metal dissolution, distilled water for standardization, 1.5-liter plastic sample bottles, markers, and label
paper for sample identification.

2.3. Sampling Method

Following SNI 6989-58-2008, water samples were collected from residential wells using a purposive sampling method. A total of 22 sampling locations were selected within a 50–500 meter range from the active landfill zone. Samples were taken from two types of wells:

- Dug wells : Depth of 2.5–5 meters
- Drilled wells : Depth of 18–120 meters

After field testing, each water sample was stored in a 1.5-liter plastic bottle and preserved with concentrated HNO_3 to maintain a pH below 2. The samples were then stored in a cooler box at 2–4°C before laboratory analysis using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) method, as per SNI 6989.82:2018.

2.4. Spatial Analysis

Spatial data analysis was performed to map the distribution of heavy metals (Pb and Cd) in well water around the landfill. The study employed Inverse Distance Weighting (IDW) interpolation, a technique that assumes each data point has a local influence that diminishes with distance (Yudanegara, 2017). The spatial analysis was conducted at a 1:2,500 scale using ArcGIS software.

2.5. Bivariate Analysis and Statistical Testing

A t-test was used to compare Pb and Cd concentrations between dug and drilled wells, assuming equal variances and using a significance level of $\alpha = 0.05$ (95% confidence interval) (Kurniawati & Ardiansyah, 2020). This test assessed whether there was a significant difference in heavy metal contamination between the two well types.

2.6. A linear regression analysis

It was conducted to evaluate the relationship between well distance from the landfill and heavy metal concentration in the water. The general equation for simple linear regression is:
Y′=a+bXY' = a + bXY′=a+bX
Where:

- Y' = Predicted dependent variable (Pb or Cd concentration)
- a = Intercept (value of Y when X = 0)
- b = Regression coefficient, indicating the rate of change in Y relative to X
- X = Independent variable (distance from landfill)

The formulas for calculating a and b are:

A =(∑Yi)(∑Xi2)−(∑Xi)(∑XiYi)n∑Xi2−(∑Xi)2a = \frac{(∑ Y_i)(∑ X_i^2) - (∑ X_i)(∑ X_i Y_i)}{n∑ X_i^2 - (∑ X_i)^2}a=n∑Xi2−(∑Xi)2(∑Yi)(∑Xi2)−(∑Xi)(∑XiYi) b=n∑XiYi−(∑Xi)(∑Yi)n∑Xi2−(∑Xi)
2b = \frac{n∑ X_i Y_i - (∑ X_i)(∑ Y_i)}{n∑ X_i^2 - (∑ X_i)^2}b=n∑Xi2−(∑Xi)2n∑XiYi−(∑Xi)(∑Yi)

The correlation coefficient (r) was calculated using:

r=n∑XiYi−(∑Xi)(∑Yi)(n∑Xi2−(∑Xi)2)(n∑Yi2−(∑Yi)2)
r = \frac{n∑ X_i Y_i - (∑ X_i)(∑ Y_i)}{\sqrt{(n∑ X_i^2 - (∑ X_i)^2)(n∑ Y_i^2 - (∑ Y_i)^2)}}r=(n∑Xi2−(∑Xi)2)(n∑Yi2−(∑Yi)2)n∑XiYi−(∑Xi)(∑Yi)

The r-value was compared to the critical r-value at a 5% significance level for n = 22 samples. The coefficient of determination (r^2) was also calculated to measure the extent to which the independent variable (distance) influenced the dependent variable (Pb or Cd concentration) (Geyer, 1981).

3. Result and Discussion

3.1. Spatial Analysis of Pb Levels in Residential Well Water Around Terjun Landfill

The test results of eight samples of dug wells indicate that the dug wells have lead (Pb) content ranging from 0.0039 mg/l to 0.0379 mg/l. There are two dug wells that have reached lead (Pb) quality standards, namely at points SG1 and SG4 with a well depth of 2.5 m. Both points are located within a distance range of 100 m (SG1) and 300 m (SG4) from the active zone of the landfill, with respective Pb values of 0.0379 mg/l and 0.0307 mg/l. On the other hand, the remaining six dug wells still meet the quality standards. Fig. 2 also illustrates that as the depth of the tested dug well becomes shallower, the obtained Pb levels increase. Conversely, a dug well with a depth of 5 m tends to have low Pb levels.

The examination of 14 drilled well samples revealed lead (Pb) concentrations ranging from <0.0001 mg/l to 0.0158 mg/l. All test results complied with the quality standards (Government Regulation (PP) No. 82 of 2001 concerning Water Quality Management and Water Pollution Control) for lead in drilled well water. Unlike dug wells, which are relatively shallow and have higher levels of lead, drilled wells with a minimum depth of 18 meters are considered safer. This is because it is estimated that the groundwater at that depth near the Terjun landfill has not been contaminated with wastewater. According to Sweeney et al. (2017), dug wells exhibit elevated levels of lead compared to drilled wells.

Lead found in landfills can move through the layers of material at the bottom and contaminate the groundwater aquifer below. This movement is caused by a process called linear absorption and first-order decay (Kubare et al., 2010). Lead in drinking water usually comes from a building's plumbing system. Lead service pipes and lead-soldered joints are significant sources of lead contamination in drinking water. Homes with these components often have higher lead levels, especially if the water is corrosive (Jarvis et al, 2018; Chan et al., 2020). There is a growing estimation that an increasing number of these harmful chemicals are seeping out of landfills and waste recycling sites near landfills, resulting in a higher concentration of lead in the leachate.

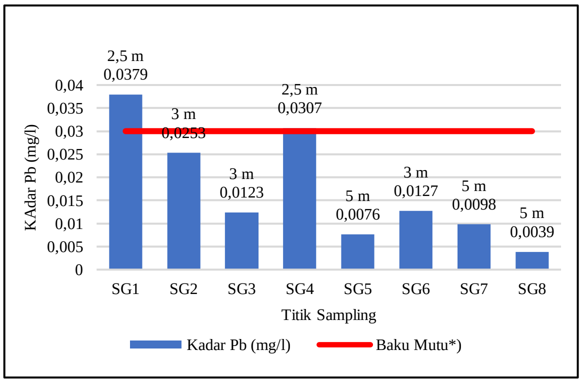

Figure 2. Lead (Pb) Content and Depth of Dug

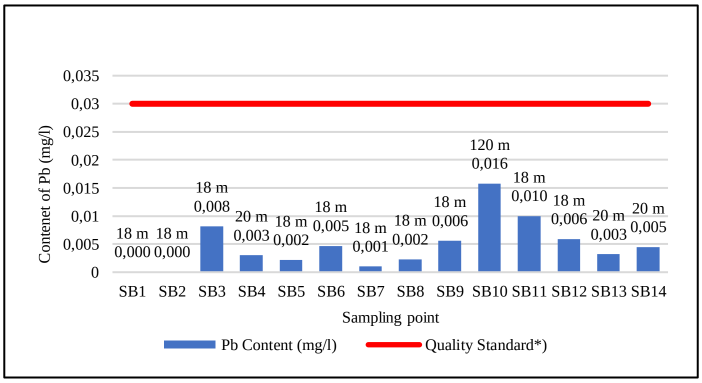

Figure 3. Drilled Wells Around Terjun Landfill

Upon examining the spatial distribution pattern of lead (Pb) levels in Fig. 3, it is evident that two specific dug well points, namely SG1 and SG4, exhibit the highest lead concentrations. Furthermore, it should be noted that these concentrations surpass the established lead quality standard (Government Regulation (PP) No. 82 of 2001 concerning Water Quality Management and Water Pollution Control) value of 0.03 mg/l. Consequently, these two points establish a pattern and contribute to the determination of lead level distribution in the surrounding area. The dispersion of lead in SG4 exhibits a rotational pattern within its vicinity, gradually diminishing as it adjoins SG3, SG2, and SG6, all of which possess lower concentrations of lead. Meanwhile, the spatial distribution pattern of SG1 expands vertically towards the landfill site.

Point SG1 is the closest location to Terjun landfill, with a distance of 100 meters. Due to its shallow well depth of 2.5 meters, this location is highly susceptible to leachate contamination. Furthermore, the wells and houses of the residents in this area are in close proximity to landfill waste, which has extended into the ditches behind their houses (Fig. 4). In addition, this location is situated directly next to the Terjun river channel, which is positioned between the landfill and residential areas (Fig. 5). Hence, the river's current at this specific site will have an indirect impact on the extent of metal pollution in the nearby vicinity. The reciprocal relationship between rivers and well water has a significant impact on water quality (Brunner et al., 2017).
The levels of lead started to decline at point SG2 and continued to decrease until it reached a noticeably verdant state at point SG3, which was located 200 meters away from the landfill. The SG3 point has a lower Pb

concentration, well below the standard quality value, with a well depth of 3 meters. This is due to the absence of specific activities related to waste processing and other activities by residents that could trigger the presence of lead in the environment at that location. It is known that this area is mostly surrounded by vacant land, a coffee shop, and a few residential houses that are not involved in waste processing activities outside the final disposal site (TPA).

In addition, SG4, located 300 meters away from the Terjun landfill, exceeds the quality standard for Pb. In addition to the shallow depth of the well, this site serves as a storage facility for discarded household electronic waste (Fig. 6) and is located right next to the waste recycling area used by the local residents. According to Spalvins et al. (2008), the presence of electronic items in landfills leads to an increase in lead concentrations. Furthermore, the act of recycling plastic waste has been found to result in significant contamination of soil and sediment with heavy metals, which in turn presents a substantial ecological hazard of considerable magnitude (Tang et al., 2015). This suggests that sources beyond the landfill contribute to elevated Pb levels at SG4 and its surroundings.

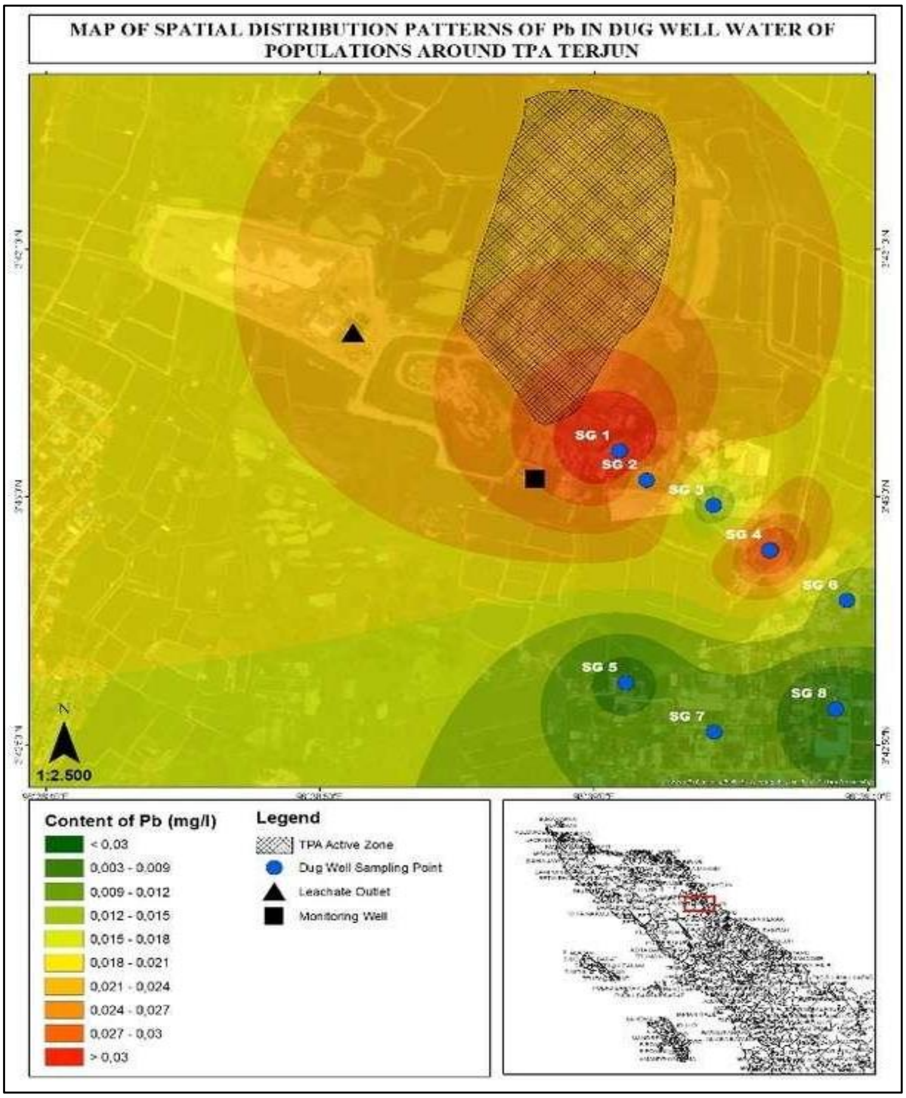

Figure 4. Map of Spatial Distribution Patterns of Pb from Dug Well Around Terjun Landfill, 2023

Figure 5. Residents' house that next to Terjun landfill

Figure 6. Terjun Tributary Channels

Figure 7. Location of Used Waste Collection by Residents Around Terjun Landfill

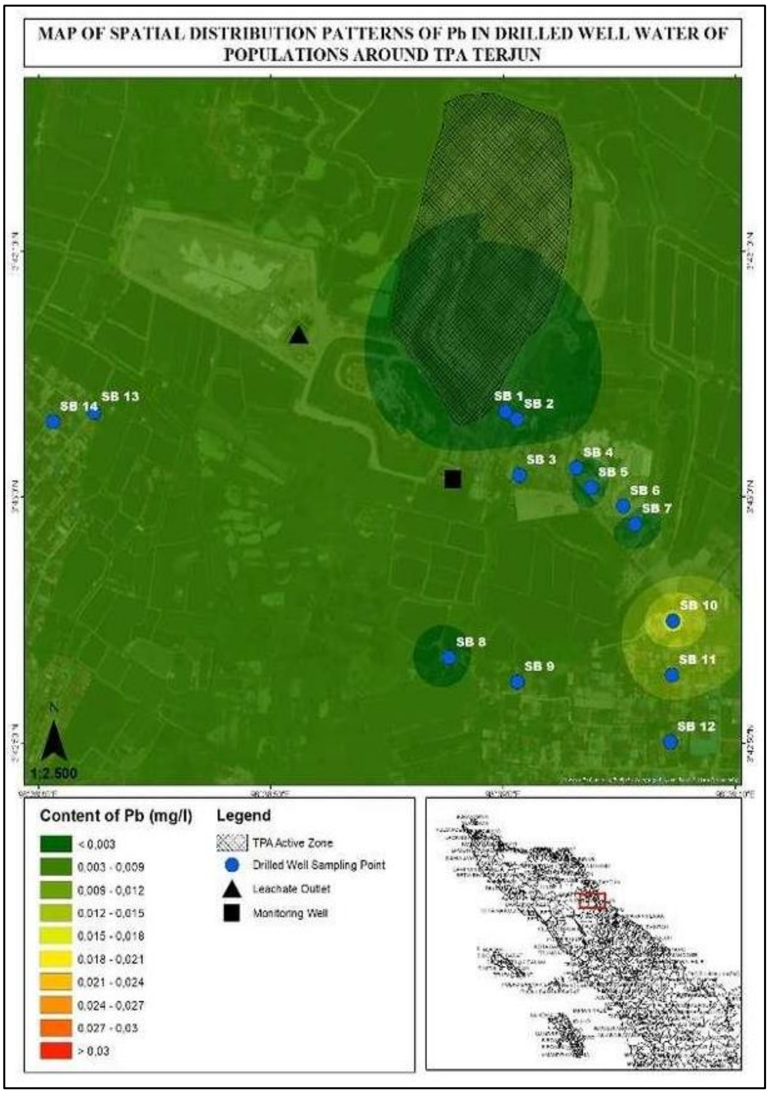

Figure 8. Map of Spatial Distribution Patterns of Pb from Drilled Well Around Terjun Landfill, 2023

Unlike dug wells, drilled wells exhibit comparatively lower levels of Pb, and all Pb levels in drilled wells are found to be below the specified quality standards (drilled well Pb < 0.03 mg/l). Based on the spatial analysis of Figure 5, it is evident that the distribution of Pb in drilled wells is no longer attributed to the Terjun landfill. Instead, it originates from other sources present in that area. For instance, the point with the highest levels of Pb is SB10, which then extends towards the southeast, followed by SB11 and SB12.

The primary site for collecting and recycling plastic waste in this vicinity, particularly SB10, is located outside the landfill. This site is established by local residents and scavengers. It includes various activities such as a business for washing rubbish trucks, stacking recyclable waste, creating a mixture of waste materials, and burning cables and tires. The process is employed to extract any remaining copper from used wire, which can then be sold or repurposed (Fig. 8).

Raudonyte-Svirbutaviciene et al. (2021) reported that the combustion of tires leads to the presence of heavy metals in the soil, specifically an elevated concentration of lead (Pb) reaching 0.9 – 102.9 mg/l in the area affected by the fire. Consequently, the origin of lead (Pb) in the well water in this region is no longer attributed to the Terjun landfill. Instead, it is now attributed to the combustion and gathering areas established by residents near the landfill, operating independently.

The lead levels in all drilled wells seem to be relatively uniform or comparable. The lead concentration in SB10 exceeds that of other drilled wells, with the exception of the factors mentioned earlier. Furthermore, the choice of drilled well pipe can also impact lead levels. SB10 is a government-built drilled well that reaches a depth of 120 meters. Unlike other drilled wells, which typically use PVC pipes and have depths of 18-20 meters, SB10 utilizes iron pipes. Corrosion is more likely to occur in longer iron pipes used in drilled wells. According to Pennino (1990), lead contamination can be caused by leaking drilled well pipes, corroded drilled well casing pipes, or fine sediment from rock formations at the bottom of the ground.

Figure 9. Garbage Truck Washing Location

Figure 10. Plastic Waste Collection and Recycling Center

Figure 11. Several wires resulting from burning cables and used tires

The findings of this test diverge significantly from the research conducted by Novianti (2018), which revealed that all residential wells (both dug and drilled) near Terjun landfill had Pb values below 0.005 mg/l. Concurrently, this study discovered that 87.5% of the seven out of eight dug wells and 28.6% of the four out of 14 drilled wells had lead (Pb) values exceeding 0.005 mg/l. There has been a significant increase in the concentration of lead in the wells of residents living near Terjun landfill within a span of only five years. This disparity indicates the possibility of a broader escalation in the dispersion of lead (Pb) levels in communities surrounding the Terjun landfill in the future.

3.2. Spatial Analysis of Pb Levels in Residential Well Water Around Terjun Landfill

The analysis of eight samples of residents' dug wells revealed that the Cd concentrations in these wells varied between 0.0008 mg/l and 0.0032 mg/l. All the wells dug by the residents meet the standards for water quality. Figure 11 a demonstrates that the depth of the dug well has no significant impact on the concentration of Cd (cadmium) in the well. However, the levels of pollutants are uniformly distributed at different depths within the well. The low concentration of Cd in this scenario may be attributed to the fact that the majority of cadmium in the sediment is attached to particles, with less than 5% being present in a dissolved state in the water (Swartz et al., 1986).

Therefore, the presence of cadmium in large quantities is necessary for it to be the primary pollutant in well water, as it does not always dominate well water pollution. Unlike dug wells, which have consistently distributed levels of Cd and minimal fluctuations, drilled wells exhibit Cd levels that tend to vary. The examination of 14 drilled well samples revealed varying levels of cadmium (Cd) content, ranging from 0.0005 mg/l to 0.0102 mg/l. All test results, except for the drilled well at point SB5, complied with the cadmium quality standard. The Cd content in the well at point SB5 exceeded the cadmium quality standard, measuring 0.0102 mg/l (Fig. 11 b).

Cadmium has the ability to readily infiltrate the groundwater from the soil, thereby polluting the food chain. This poses a significant risk to public health (Subasic et al., 2022). Cadmium has the ability to seep into well water from landfills through leachate, but the levels are typically lower than what is considered safe for drinking water (Mansouri et al., 2014).

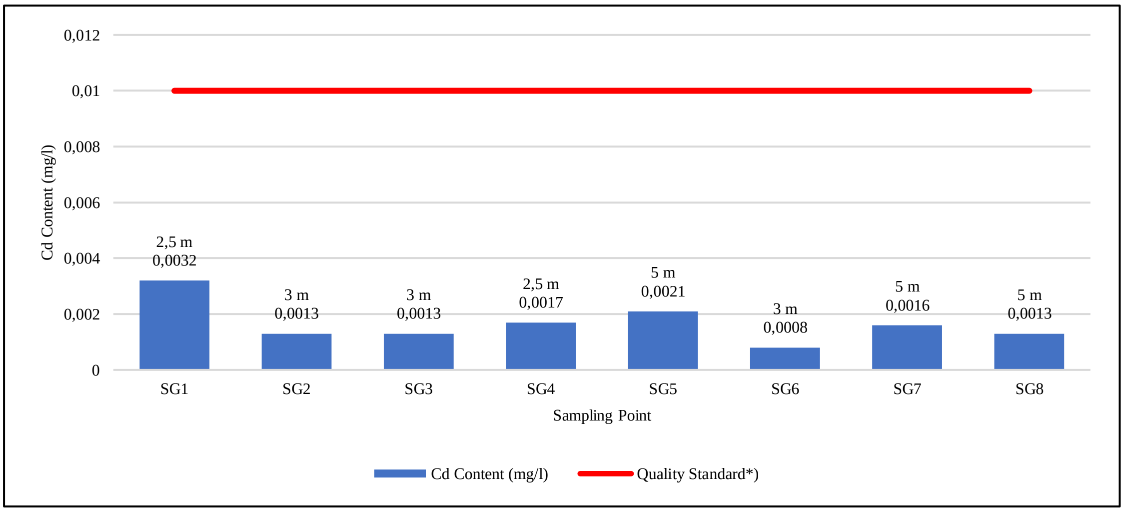

Figure 12. Cadmium (Cd) Content and Depth of Dug

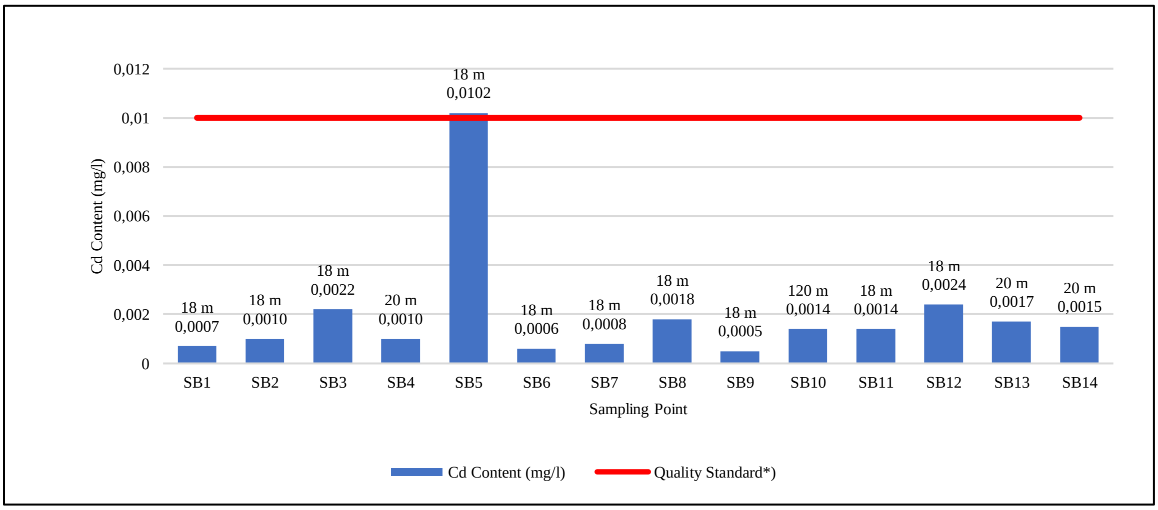

Figure 13. Drilled Wells Around Terjun Landfill

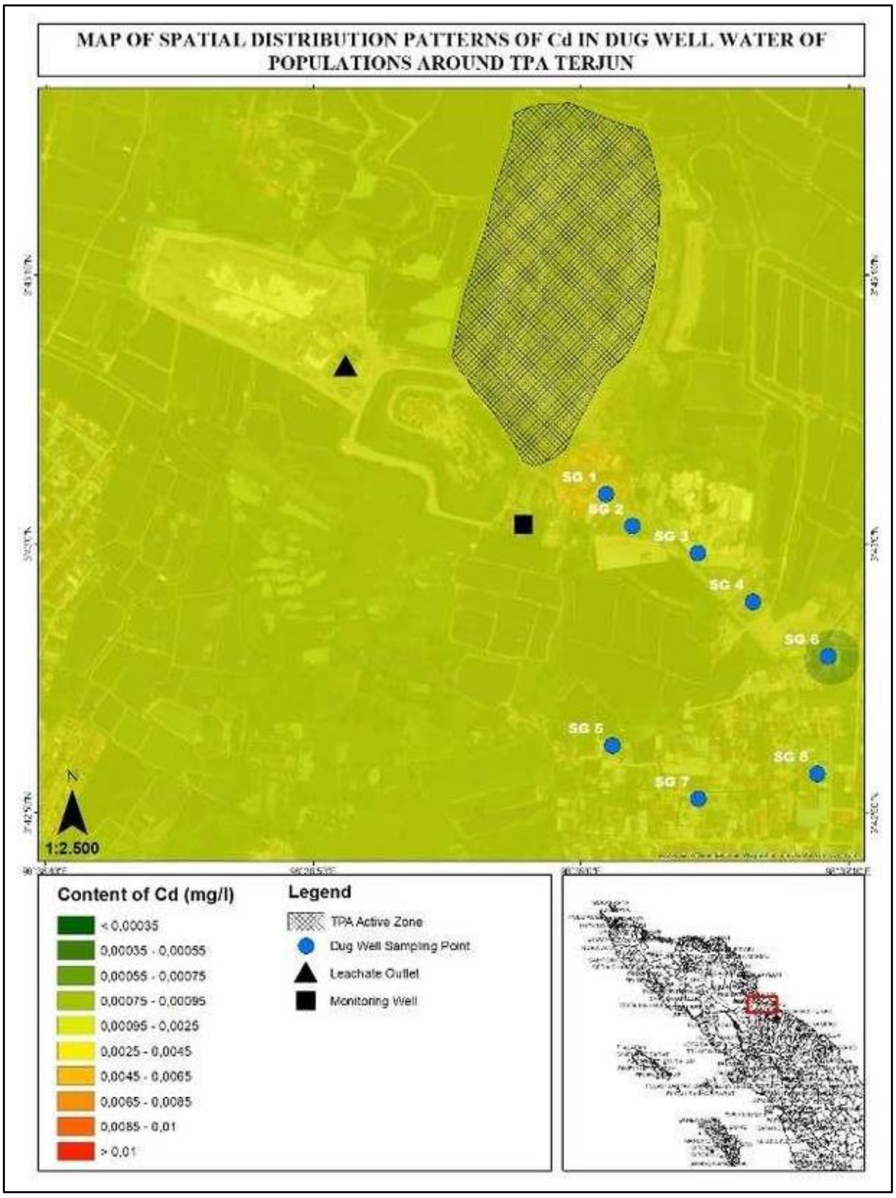

Figure 14. Map of Spatial Distribution Patterns of Cd from Dug Well Around Terjun Landfill, 2023

The spatial map depicted in Fig. 12 illustrates that the concentration of cadmium is most pronounced in the vicinity of SG1 (indicated by the orange color), but decreases in intensity as one moves away from this point. This is typical because SG1 is a susceptible area for pollution due to its close proximity and adjacency to the Terjun landfill. The results show a resemblance to the elevated levels of Pb found in SG1. Although the cadmium level in SG1 is typically higher than other points, it remains below the quality standard limit for dug well cadmium concentration, which is less than 0.01 mg/l.

Subsequently, the spatial distribution of cadmium exhibits a predominately yellow hue, indicating that the levels of cadmium in most dug wells are similar. Nevertheless, the levels of cadmium at point SG6 are the most minimal in comparison to the other points. The absence of cadmium contamination in the area can be attributed to the fact that it is primarily comprised of empty land and serves as a dining spot for local residents, thereby lacking any activities that could potentially lead to the release of cadmium sources. Consequently, the origin of cadmium pollution in the local community's manually excavated wells is no longer attributed to the Terjun landfill, but rather to alternative causes. For instance, cadmium can originate from the ultimate sediment of individuals' household waste disposal, which accumulates in ditches and inundated swamps.

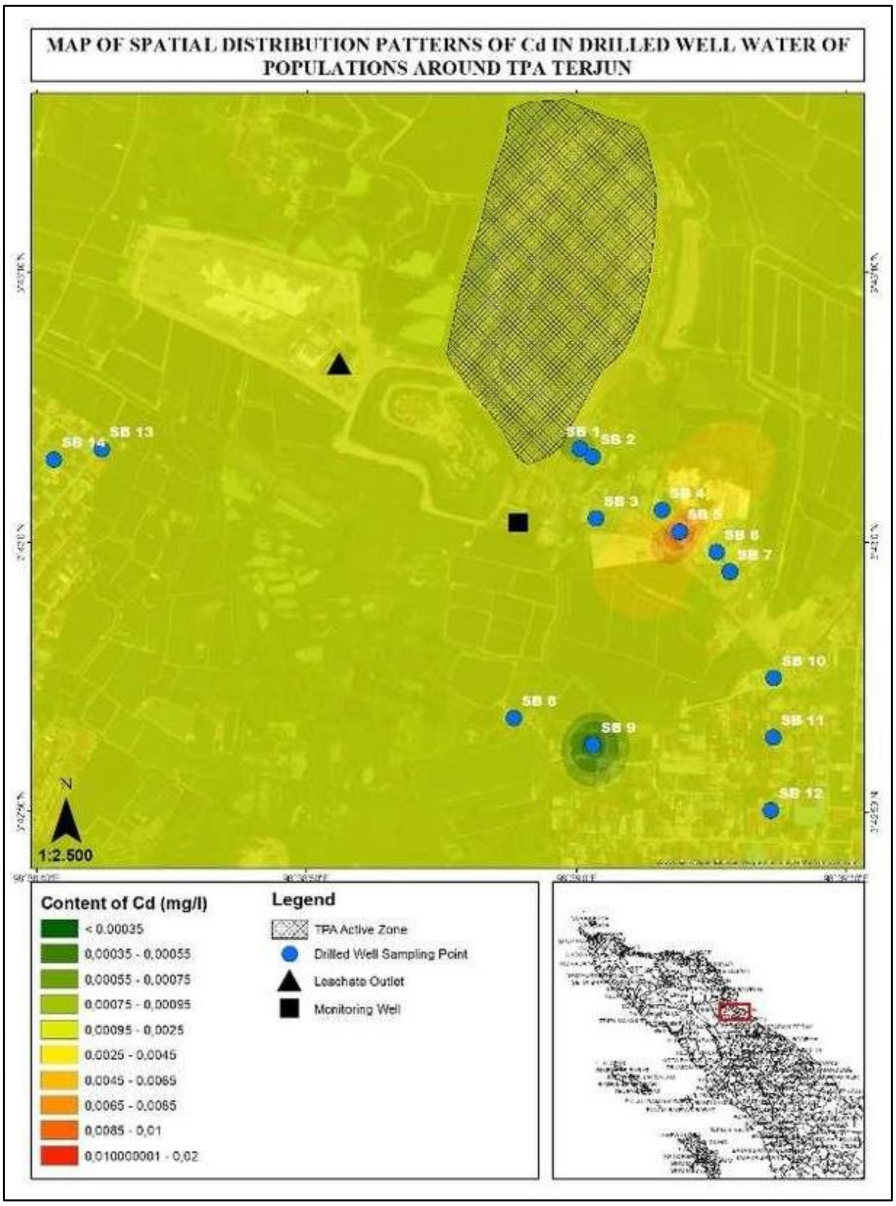

Figure 15. Map of Spatial Distribution Patterns of Cd from Drilled Well Around Terjun Landfill, 2023

Fig. 13 indicates the presence of an SB5 point that has surpassed the quality standard threshold for cadmium levels (Cd > 0.01 mg/l). The well point is situated at the exact location of the plastic recycling factory and has a depth of 18 meters. It is used to extract plastic slurry/ore (Fig. 10). Despite the considerable depth of the well, the groundwater reserves at SB5 may still be at risk of cadmium contamination. During the procedure, the plastic that has been gathered is subsequently fragmented and cleansed. The waste generated during the plastic washing process is promptly disposed of in the ditch. Consequently, the contamination of cadmium in the well water near the Terjun landfill is also affected by waste processing activities occurring outside the TPA, which is located right next to the sampling point

Cadmium can be released from microplastics containing cadmium pigments when exposed to sunlight, due to photo-dissolution processes. This release is size-dependent, with smaller microplastics showing higher rates of cadmium release (Liu et al., 2020). This event is connected to prior assertions made by Muzambiq et al (2023) regarding the contamination of groundwater up to a depth of 17.4 meters by the Terjun landfill leachate. According to Haider et al. (2021), soil factors that affect the absorption and movement of cadmium can impact the contamination of well water with this metal. The physical properties of soil, such as sand and clay content, as well as soil density, can impact cadmium absorption. These factors influence the soil's ability to retain or release cadmium (Correa et al., 2021).

Figure 16. Plastic Ore Drying Activities in the Plastic Waste Recycling Process Around Terjun Landfill

The findings of this study exhibit minor disparities compared to the research conducted by Novianti (2018), which revealed that all wells in the vicinity of Terjun landfill had Cd values below 0.003 mg/l. The disparity in values observed in this study compared to previous research is relatively less pronounced when compared to the disparity in lead (Pb) values. To ensure that the levels of cadmium in all test samples do not present a threat to public health. Nevertheless, there has been a rise in the Cd value over the course of five years, with the possibility of further increases in the future.

The relatively small difference in cadmium values observed between the two research results could be attributed to various factors. One possibility is that the source of cadmium pollution in the Terjun landfill is not the dominant metal causing pollution. Additionally, the weak adsorption of cadmium by soil and groundwater may be due to the majority of pH values being within the normal range. Cadmium, a heavy metal, has a high degree of mobility. Its mobility is affected by various factors including pH, redox state, and ionic strength. The presence of cadmium in groundwater is influenced by pH acidification or elevated nitrate concentrations resulting from agricultural land fertilization, which impacts the movement of the metal (Kubier et al., 2019; Kubier and Pitchler, 2019).

3.3. Bivariate Analisys (t-test and regression)

The results of the t test between lead (Pb) and cadmium (Cd) levels in dug well and drilled well water can be seen in Table 1.

Table 1. T-test result for Pb and Cd levels in water from dug wells and drilled wells for residents around Terjun landfill

No	Variable	Mean	t_{stat}	t_{crit}
1.	Pb of Dug Well – Pb of Drilled Well	0,0175 – 0,0047	3,603	2,086
2.	Cd of Dug Well – Cd of Drilled Well	0,0017 – 0,0019	-0.308	2,086

Table 1 demonstrates that the t-test conducted between the lead (Pb) levels in dug wells and drilled wells for residents living near Terjun landfill resulted in a tstat value of 3.603, which is greater than the critical t-value (tcrit). The results indicate a statistically significant disparity in lead levels between dug wells and drilled wells in the Terjun landfill area.

The substantial disparity in lead (Pb) levels between dug wells and drilled wells suggests that the choice of well utilized by local inhabitants in the region significantly impacts and determines the extent of Pb contamination that will affect the well. Thus, selecting the appropriate well for each household can alleviate the risk of lead contamination that may affect the residents.

Table 1 demonstrates that, unlike Pb, the t-test conducted between the Cd levels in dug wells and drilled wells for residents living near Terjun landfill resulted in a tstat value of -0.308 (tstat < tcrit). These results indicate that there is no statistically significant disparity between the levels of Cd (cadmium) in dug wells and drilled wells in the Terjun landfill area. This value was derived by comparing the mean Cd concentrations of dug wells and drilled wells at each sampling location.

The cadmium (Cd) concentration in both dug wells and drilled wells does not exhibit any significant disparity, indicating that the type of well utilized by the population does not significantly impact cadmium contamination in this area. The presence of a minimal level of contamination and the inherent characteristics of the cadmium and lead relationship can lead to this phenomenon. In their study, Skalny et al (2018) found that the interaction of cadmium and lead with other environmental factors, such as soil and other metals, can influence their uptake and effects. The solubility of cadmium in water is not directly addressed, but its presence in water samples suggests it can be dissolved under certain conditions. Nevertheless, cadmium has the potential to undergo precipitation at elevated pH levels (Effendi, 2003).

The statistical research on dug well yielded a simple linear regression equation: y = 0.0375 + (-7 x 10-5)X. The equation for drilled well Pb is a simple linear regression model: y = 0.0003 + (2 x 10-5)X. Fig. 11 displays a basic linear regression graph illustrating the relationship between the concentration of Pb in dug well and drilled well water and the distance from the active landfill zone. In addition, Table 2 presents the results of a bivariate analysis of the distance between resident's wells and the Terjun landfill on lead values.

Table 2. Bivariate analysis of the distance of resident's wells to landfills on lead values

Variable	a	*P value*	*A*
Distance between dug wells and landfill – lead in dug wells	-9193	0,02	0,05
Distance between drilled well and landfill - lead in drilled well	17695	0,09	0,05

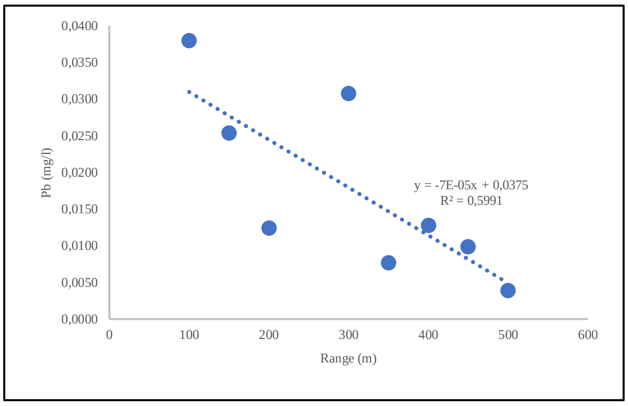

Figure 17. Linear Regression Graph of Distance to Pb of Dug Wells

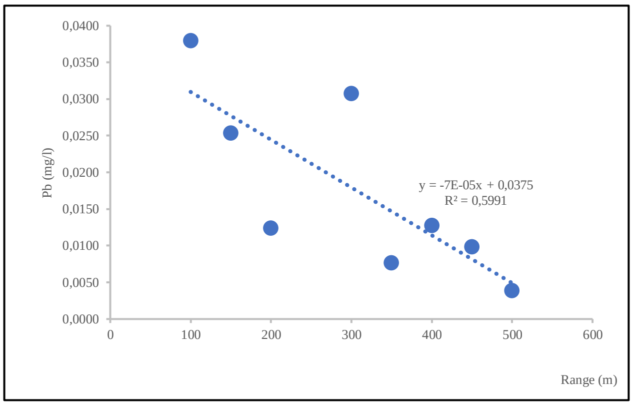

Figure 18. Drilled Wells Population around Terjun landfill

The bivariate analysis conducted in Table 2 and Fig. 15 reveals that the levels of Pb in dug well water are influenced to some extent by the distance of the well from the active landfill zone (p value 0.02 < 0.05). As the distance increases, the concentration of Pb decreases in the dug well. Unlike the Pb levels in drilled wells, the levels do not show a decrease as the distance from the well to the active landfill zone increases. This difference is statistically insignificant, as indicated by the p value of 0.09, which is greater than the significance level of 0.05. The reason for the presence of lead in the residents' drilled wells is not due to the Terjun landfill. Instead, there are other sources of pollutants that affect the lead levels in the wells. These sources, as discussed in the previous spatial analysis sub-chapter, include waste processing activities conducted outside the landfill within the community. The outlier data for Pb levels at certain points exhibits variability and fluctuates in comparison to other points.

The coefficient of determination (r2) for each well indicates that the result is well-supported, with a value of 0.599 for dug wells and 0.353 for drilled wells. The data indicates that 59.9% of the Pb levels in dug wells are affected by distance, while the remaining 40.1% are influenced by other factors. Only 35.3% of the lead (Pb) content in the drilled well was affected by distance, while the remaining 64.7% was influenced by other factors.

The research on drilled wells yielded a straightforward linear regression equation: y = 0.0024 + (-2 x 10-6)X. The equation for simple linear regression, Cd, for drilled wells is derived as follows:

y = 0.0022 + (-6 x 10-7)X. Fig. 16 displays a straightforward linear regression graph illustrating the relationship between the concentration of Cd in dug well and drilled well water and the distance from the active landfill zone. Beside that, Table 3 presents the results of a bivariate analysis of the distance between residents' wells and the Terjun landfill on cadmium values.

Table 3. Bivariate analysis of the distance of resident's wells to landfills on cadmium values

Variable	a	*P value*	*α*
Distance between dug wells and landfill – cadmium in dug wells	-97677	0,22	0,05
Distance between drilled well and landfill - cadmium in drilled well	-4134	0,83	0,05

Upon initial observation, the trend line derived from the regression equation depicted in Fig. 16 indicates that the levels of Cd (cadmium) in both dug well and drilled well water are affected by the proximity of the well to the active area of the landfill. As the distance increases, the concentration of Cd decreases in both dug wells and drilled wells. According to Table 3, it has been determined that the distance of the landfill does not have a significant impact on the levels of cadmium in both types of well water. This conclusion is based on a p value greater than 0.05. The main factor influencing Cd levels in dug well and drilled well water is not distance. The coefficient of determination (r2) for each well indicates the following results: 0.233 for dug wells and 0.001 for drilled wells. This data indicates that 76.7% of Cd levels in dug wells and 99.9% in drilled wells are impacted by additional factors. The impact of distance on Cd levels was observed to be 23.3% in dug wells and 0.1% in drilled wells.

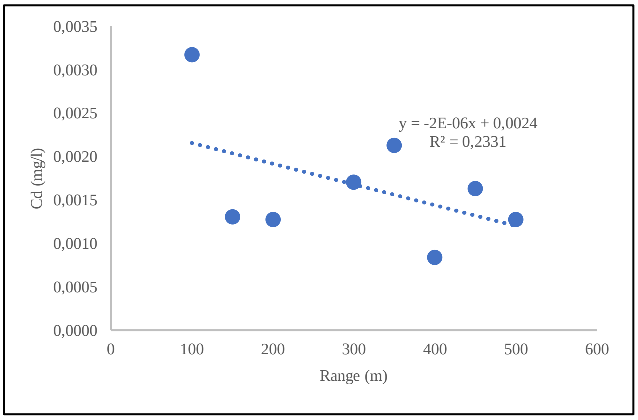

Figure 19. Linear Regression Graph of Distance to Pb of Dug Wells

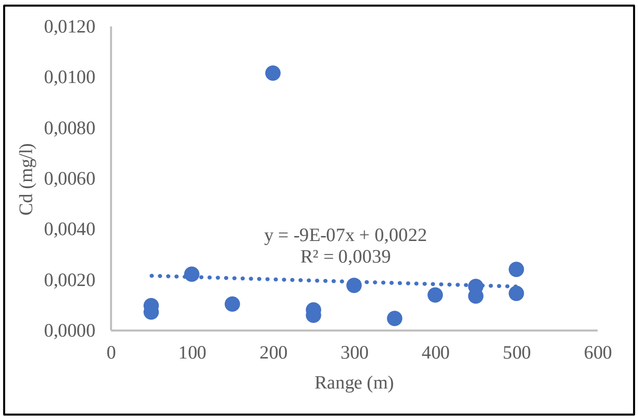

Figure 20. Drilled Wells Population around Terjun landfill

4. Conclusion

SG1 and SG4, located near the landfill and external waste processing facilities outside the Terjun area, serve as the main distribution points of lead (Pb) contamination in dug wells. In contrast, Pb contamination in drilled wells spreads southeast from SB10 and originates from sources outside the landfill. Cadmium (Cd) contamination from the Terjun landfill appears at SG1 in dug wells, while in drilled wells, Cd contamination is linked to SB5 and influenced by external activities. The analysis revealed a significant difference in Pb concentrations between dug and drilled wells, with an average difference ranging from 0.0175 to 0.0047 mg/L ($t\_count > t\_table$). In contrast, Cd concentrations in both well types, ranging from 0.0017 to 0.0019 mg/L, did not show a significant difference ($t\_count < t\_table$). The distance from the active zone of the Terjun landfill significantly affects Pb levels in dug wells but has no impact on Pb levels in drilled wells. Additionally, Cd levels in both dug and drilled wells remain unaffected by the distance from the landfill's active zone.

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