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Impact of the Andralanitra Landfill on Groundwater Quality in Surrounding Wells: Physico-Chemical and Microbiological Assessment

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Resume— The objective of this study evaluates the impact of the Andralanitra landfill on surrounding well water quality. Five wells located at different distances were analyzed for physico-chemical and microbiological parameters across two seasons. Pearson correlation coefficients (r) indicate that contamination generally decreases with distance, although some wells still exceed recommended standards, representing a health risk. These findings highlight the direct influence of the landfill and the need for well protection and water treatment measures.

Keywords: Andralanitra landfill, groundwater, water quality, microbiological contamination, Pearson correlation

Abstract– This research investigates the effect of the Andralanitra landfill on groundwater quality in wells serving the surrounding communities. Water samples from five wells located at varying distances from the landfill were analyzed for physico-chemical and microbiological parameters across two contrasting seasons. Statistical analysis using the Pearson correlation coefficient (r) was employed to evaluate the relationship between well distance and contamination levels. The results indicate that pollution indicator bacteria (fecal coliforms, aerobic flora, streptococci) decrease with increasing distance from the landfill, while sensitive physico-chemical parameters such as turbidity and organic matter also show moderate negative correlations. Nevertheless, even the most distant wells exhibited values exceeding recommended standards, indicating a significant health risk. These findings highlight the direct impact of the landfill on groundwater quality and emphasize the need for protective measures and water treatment before consumption.

Keywords: Andralanitra landfill, groundwater, water quality, microbiological contamination, Pearson correlation

I. INTRODUCTION

The Andralanitra landfill, located in the Ikianja Fokontany within the commune of Ambohimangakely, is an uncontrolled waste disposal site that poses a serious threat to the quality of groundwater used by nearby communities. Due to the absence of formal management, the high density of waste, and the close proximity to residential areas, the landfill represents a direct source of contamination for the wells that local residents rely on for their daily water needs. [1][2] The waste deposited at the site includes

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organic matter, household refuse, industrial and agricultural chemicals, as well as heavy metals, which produce leachates containing chemical pollutants and pathogenic microorganisms. These contaminants can infiltrate the aquifers, compromising the potability of the water and creating significant health risks for the population.[3][5]

In this context, the present study adopts a quantitative approach to investigate the impact of the distance between wells and the Andralanitra landfill on groundwater quality. Water samples were collected from wells located at different distances from the landfill in order to assess both physico-chemical and microbiological parameters that could be influenced by proximity to the waste site. By examining these variations, the study aims to provide a clearer understanding of how the landfill affects water quality and to inform local water management and public health interventions.

II. RESEARCH METHOD

This study adopts a quantitative approach aimed at evaluating the influence of the Andralanitra landfill on the quality of surrounding well water. Water samples were collected from multiple wells located at varying distances from the landfill to measure different physico-chemical and microbiological parameters. Statistical analysis plays a central role in this study, as it allows the examination of the relationship between the distance of the wells from the landfill and the observed values for each parameter. To achieve this, the Pearson correlation coefficient (r) was used, as it quantifies both the strength and the direction of the linear association between two continuous variables. Determining this coefficient provides precise insights into the potential impact of proximity to the landfill on the degradation of groundwater quality used by the local population.[1] [2]

The Pearson correlation is a statistical method used to quantify the strength and direction of a linear relationship between two continuous variables. The correlation coefficient r ranges from −1 to +1:

- r > 0: positive relationship, the variable increases as the other increases.
- r < 0: negative relationship, the variable decreases as the other increases.
- r = 0: no linear relationship.

In this study, the Pearson coefficient was used to evaluate the influence of well distance from the Andralanitra landfill on both the physico-chemical and microbiological quality of water. This analysis enables the identification of the parameters most sensitive to pollution and provides a better understanding of the vulnerability of wells located near sources of contamination. [2] [3]

Calculation of the Pearson Correlation for the Wells in Andralanitra:

$$r = \frac{\sum(x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$

Where:

- $x = distance\ (H1 \dots H5 \rightarrow 1 \dots 5$
- $y = measured\ values$

III. RESULTS AND DISCUSSION

A) Results of Water Analysis

The assessment of water quality is based on the analysis of several physico-chemical and microbiological parameters. These indicators are essential not only for evaluating the potability of the water but also for assessing the health risks associated with its consumption. In this study, measurements were carried out over two contrasting seasons (dry and rainy seasons) in order to better understand the influence of climatic and environmental variations on the quality of well water. [1] [2] [3]

Physico-chemical parameters characterize the intrinsic properties of the water (pH, turbidity, temperature, dissolved salts, metals, etc.), while microbiological parameters reveal the potential presence of pathogenic microorganisms, particularly those

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indicative of fecal contamination. The combined analysis of these parameters across both seasons is essential to provide a reliable assessment of water quality and to evaluate the potential impacts on human health. [7] [8]

The two figures presented below illustrate the results of analyses performed on five well water samples (H1 to H5) collected around the Andralanitra landfill. These wells were selected based on their geographical location and their distance from the disposal site to better assess the potential influence of the landfill on groundwater quality. The analyses covered a range of physico-chemical and microbiological parameters, allowing for a comparison of variations in these indicators from one sampling point to another. The figures highlight the differences observed between the wells, differences that can be associated with their degree of exposure to pollutants originating from the landfill.

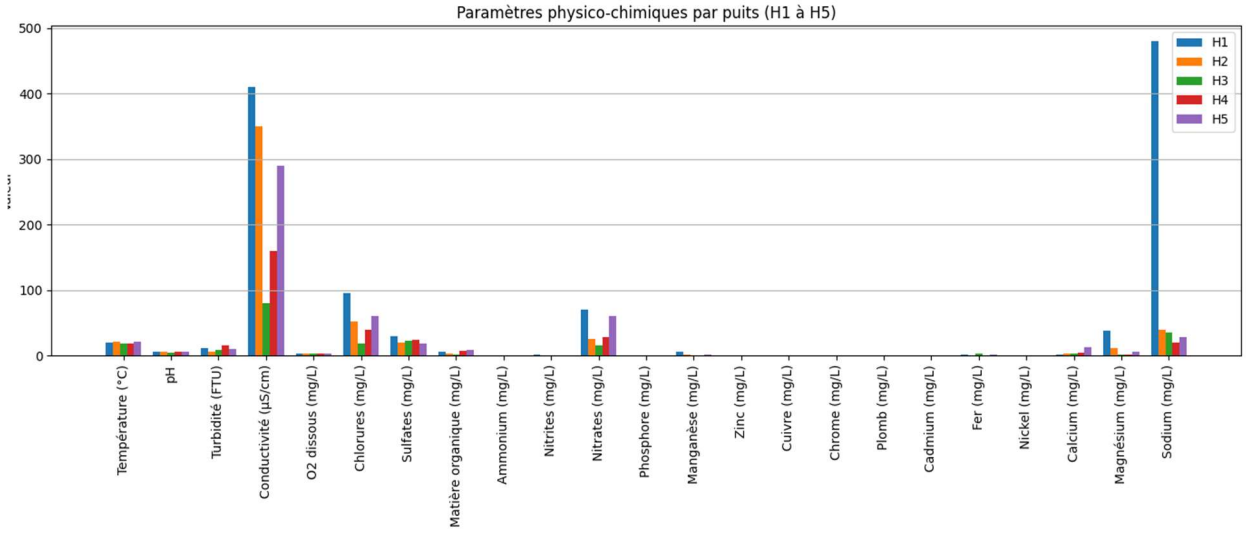

Figure 1: Physico-chemical parameters by well (H1 to H5)

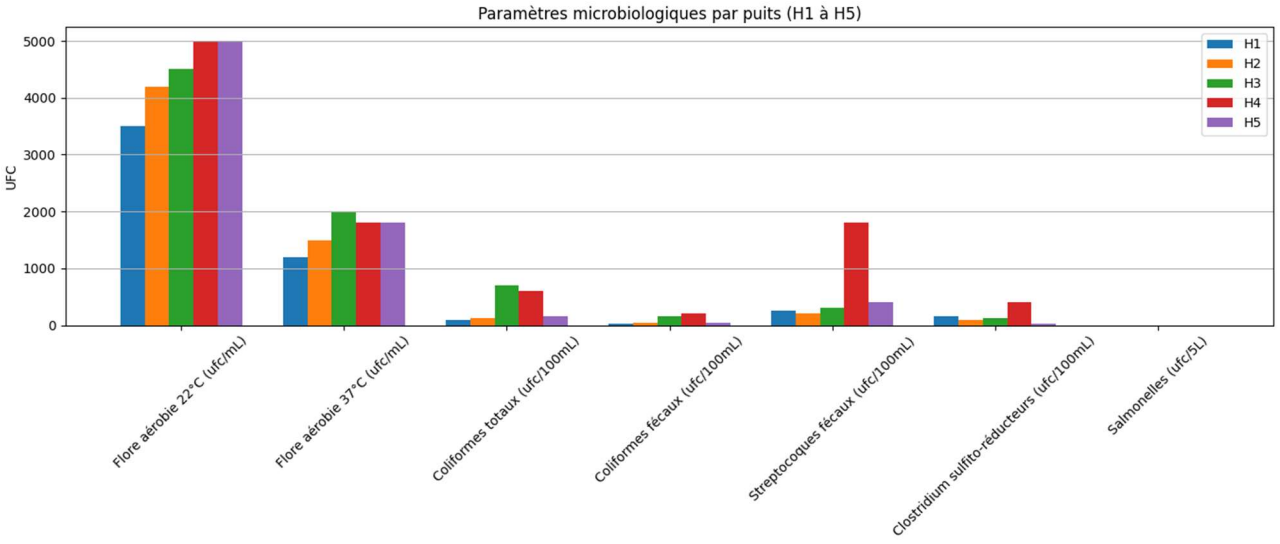

Figure 2: Microbiological parameters by well (H1 to H5*)*

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B) Study of Parameters According to the Distance from the Andralanitra Landfill

The physico-chemical and microbiological parameters of the wells were analyzed in relation to their distance from the Andralanitra landfill. This presentation, shown in the following figure, allows for the observation of how proximity to the pollution source affects water quality and helps identify the wells most at risk. Table 1 shows the distances of the sampled wells from the Andralanitra landfill, which were used to assess the influence of proximity on groundwater quality.

Table 1 : Distances of the sampled wells from the Andralanitra

Well	Distance (m)
H1	500
H2	300
H3	200
H4	50
H5	250

The distances of the wells from the Andralanitra landfill (Table 1) indicate varying levels of potential exposure to contamination. Wells closer to the landfill, such as H4 (50 m) and H3 (200 m), are expected to be more affected by leachates and runoff, while wells farther away, like H1 (500 m) and H2 (300 m), are likely less influenced. H5, at 250 m, represents an intermediate case. This spatial distribution allows for the analysis of how proximity to the landfill correlates with variations in both physico-chemical and microbiological parameters of groundwater.

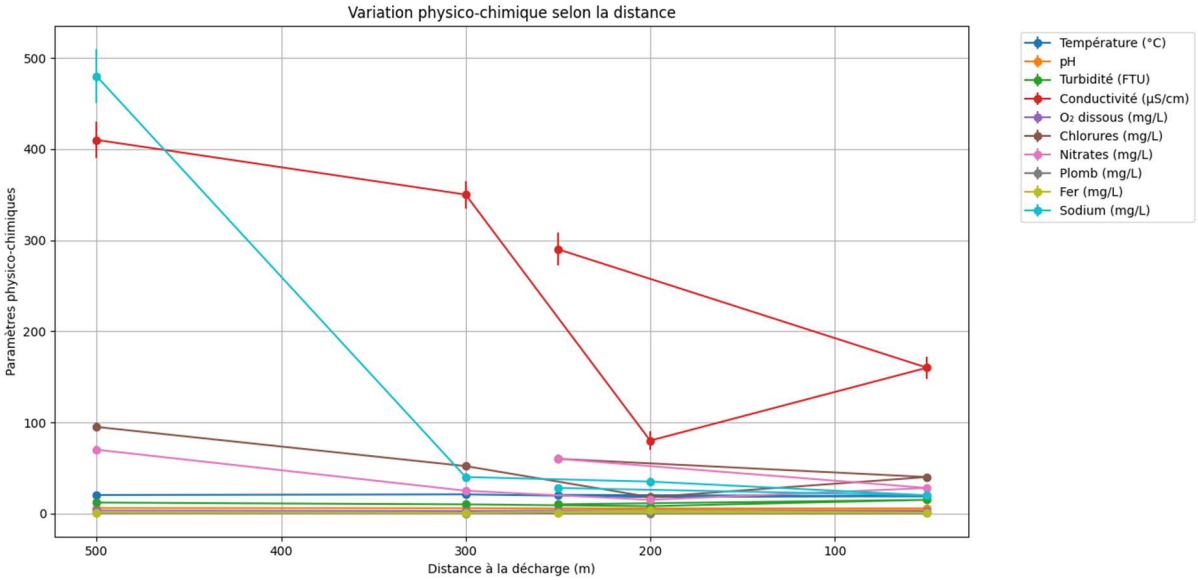

Figure 3: Relationship between distance and physico-chemical parameters

Interpretation

- Wells located close to the landfill (H4, H3) generally show the highest values for contaminants, including turbidity, lead, iron, coliforms, and streptococci.
- The dispersion (standard deviation) indicates that certain parameters, particularly microbiological ones, vary significantly depending on the distance from the landfill.

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- The wells farthest from the landfill (H1, H2) exhibit more stable values, generally closer to the recommended standards.

Proximity to the pollution source (H1):

- Parameters such as turbidity or conductivity may be lower if the water is not stagnant and the pollutant source is still concentrated.
- pH and temperature are generally stable in the absence of specific chemical discharges.

Increasing distance (H2 → H5):

- Turbidity increases, likely due to the accumulation of suspended solids from runoff or infiltration.
- Conductivity increases, reflecting the transfer of dissolved ions associated with pollution (nitrates, phosphates, salts).
- pH may vary slightly depending on soil composition and the nature of pollutants.
- Temperature shows minor variation, except in stagnant conditions that may favor bacterial proliferation.

Discussion

- A progressive increase in turbidity and conductivity with distance indicates a degradation of physico-chemical water quality.
- Parameters may remain within standard limits or deviate depending on the contamination level and environmental influences such as runoff or leachate infiltration from the landfill.

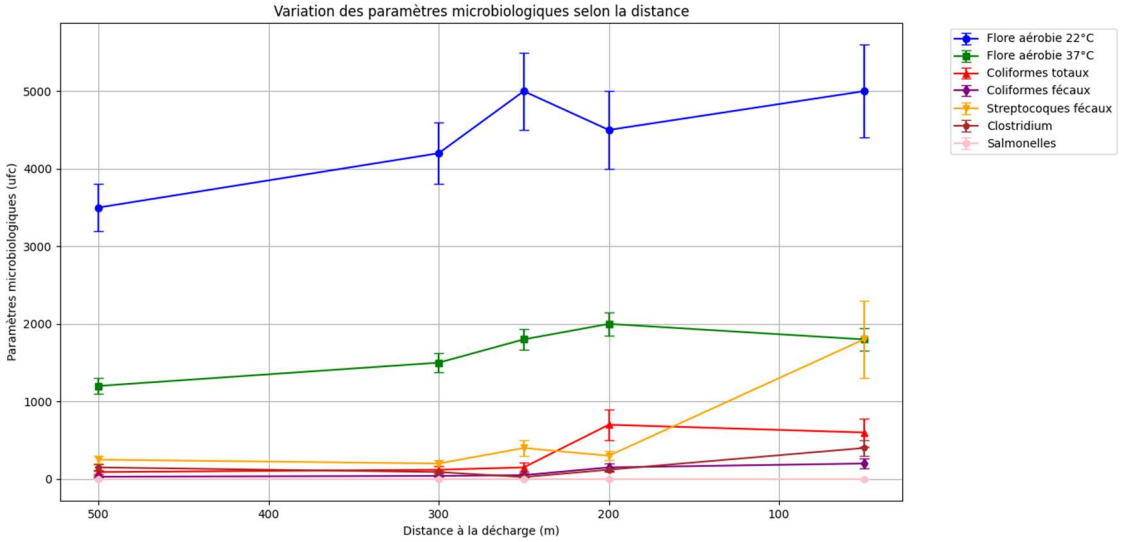

Figure 3: Variation of microbiological parameters according to distance

- **H1 close to the source:** high values, but lower than H3–H5.
- **H2 → H5:** strong increase followed by a slight decrease for certain parameters (e.g., flora at 37°C).
- **Total coliforms:** generally increase with distance if contamination is diffuse.

Interpretation

Microbiological quality tends to degrade with distance in most cases, which is counterintuitive when considering a single point source. This suggests:

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- Secondary pollution from runoff or leachate infiltration from the Andralanitra landfill.
- Conditions favorable to bacterial proliferation, such as stagnation and availability of nutrients.

Even the most distant points (H5) show values far exceeding the standards, indicating a high health risk for the population relying on these wells.

Discussion

Water quality decreases with increasing distance from the initial source, particularly for bacterial indicators and certain physico-chemical parameters. This points to a significant impact of the Andralanitra landfill and/or wastewater runoff on the wells. These findings justify:

- Continuous health monitoring,
- Water treatment before consumption,
- Well protection measures (maintaining distance from pollution sources, fencing, drainage, etc.).

C) Pearson Correlation (r)

The Pearson correlation is a statistical method used to quantify the strength and direction of a linear relationship between two continuous variables. The correlation coefficient r ranges from −1 to +1:

- $r > 0$: positive relationship; one variable increases as the other increases.
- $r < 0$: negative relationship; one variable decreases as the other increases.
- $r = 0$: no linear relationship.

In this study, the Pearson coefficient was used to evaluate the influence of well distance from the Andralanitra landfill on both physico-chemical and microbiological water quality. This analysis helps identify the parameters most sensitive to pollution and provides a better understanding of the vulnerability of wells near contamination sources.

The following figure visually presents the Pearson correlation coefficients (r) between well distance and various physico-chemical and microbiological parameters, allowing for the rapid identification of variables most influenced by proximity to the landfill.

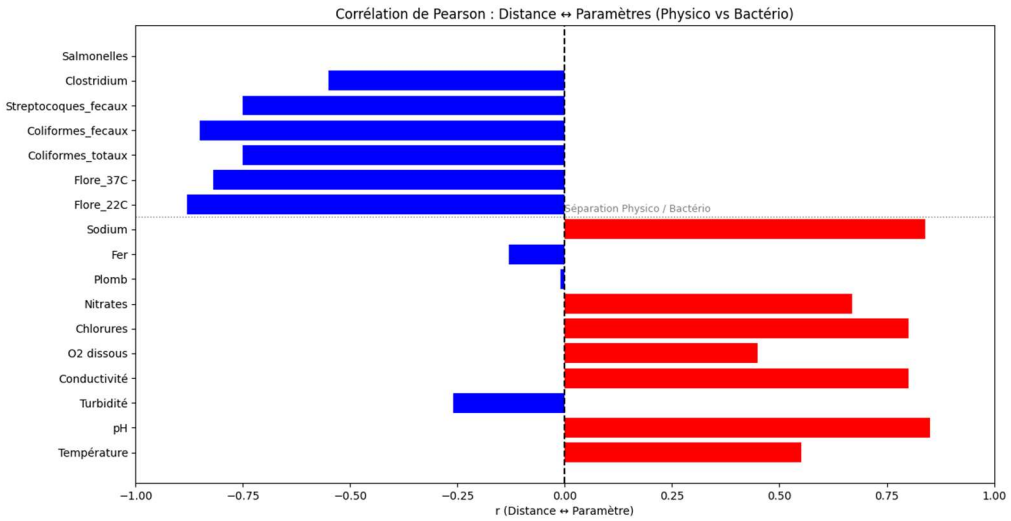

Figure 4 : Pearson correlation coefficients (r) between well distance and the Andralanitra landfi

Interpretation

- Pollution indicator bacteria (aerobic flora, coliforms, streptococci) clearly decrease with increasing distance from the landfill.
- Bacteria such as **Clostridium** show a moderate trend.
- **Salmonella** could not be statistically analyzed here, as all values were identical.

IV. CONCLUSION

The analysis of Pearson correlation coefficients (r) shows that the quality of well water around the Andralanitra landfill improves with distance. Pollution indicator bacteria, such as fecal coliforms and aerobic flora, exhibit high negative r values (e.g., $r = –0.85$ and $r = –0.78$), indicating a strong inverse relationship between contamination and distance from the landfill. The most sensitive physico-chemical parameters, such as turbidity and organic matter, also show moderate negative correlations ($r \approx –0.60$), confirming their decrease with distance. These results confirm the direct impact of the landfill on groundwater quality and highlight the importance of well distance as a relative protective factor.

1. Recomendation

Regular monitoring of wells around the Andralanitra landfill should be conducted to assess temporal variations in physico-chemical and microbiological parameters, coupled with the application of appropriate water treatment methods such as filtration, chlorination, or boiling prior to consumption. Wells should be protected by maintaining adequate distance from the landfill, installing physical barriers or fencing, and improving drainage systems to prevent leachate infiltration. Proper management of the landfill, including waste segregation and leachate control, is critical to mitigate environmental contamination. Furthermore, enhancing community awareness regarding the risks associated with using contaminated well water and promoting safe water handling and hygiene practices is essential. Finally, long-term studies on seasonal variations and additional contaminants are warranted to refine risk assessments and optimize mitigation strategies.

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