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Risk and recurrence of waterborne diseases linked to groundwater quality in the Hérady district of Selembao (Kinshasa, DRC)

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ABSTRACT

Introduction
In Kinshasa, access to safe drinking water constitutes a critical public health challenge in peri-urban areas, where the population largely depends on well water. This study assesses the physico-chemical and microbiological quality of well water in the Hérady district (Selembao) and examines its relationship with the prevalence of waterborne diseases.

Purpose
To evaluate the physico-chemical and microbiological quality of well water in the Hérady district (Selembao, Kinshasa) and to examine its association with the prevalence of waterborne diseases recorded in local health facilities.

Methods
A total of 42 water samples were collected from seven wells during the dry season (May–August 2023). Physico-chemical parameters were analysed in accordance with World Health Organization (WHO) standards, while microbiological contamination was assessed through the detection of total coliforms, *Escherichia coli*, enterococci, and *Pseudomonas* spp. Health data from 118 medical consultations (November 2022 to January 2024) were used to evaluate the prevalence of waterborne diseases. Statistical analyses included Student's *t*-test, Spearman correlation, and regression analysis. MATLAB was used for data visualisation through histograms.

Results
Waterborne diseases accounted for 74.6% of all medical consultations, predominantly intestinal parasitic infections (47.5%), gastroenteritis, and typhoid fever. Although most physico-chemical parameters complied with guideline values, an acidic pH (4.39) was observed. Microbiological contamination was high, with concentrations of aerobic flora, *E. coli*, and enterococci exceeding recommended standards. A significant correlation was established between these microbiological parameters and disease prevalence.

Conclusion
Despite an overall acceptable physico-chemical quality, well water in the Hérady district presents a high microbiological risk. Public awareness initiatives, water treatment interventions, and continuous monitoring are required to reduce the incidence of waterborne diseases.

INTRODUCTION

Waterborne diseases constitute a persistent global public health challenge, disproportionately affecting populations in low-income urban environments where access to improved water sources and sanitation is inadequate (World Health Organization [WHO], 2017). In Kinshasa, the capital of the Democratic Republic of the Congo (DRC), this problem is particularly acute in peri-urban districts such as Hérady, located within the municipality of Selembao. In these areas, groundwater from shallow wells serves as the primary domestic water source for a significant proportion of the population (Kapembo et al., 2021; Mukeba et al., 2022).

In such settings, inadequate sanitation infrastructure, uncontrolled waste disposal, and the absence of effective water treatment systems expose groundwater aquifers to multiple sources of pollution, including domestic wastewater and surface runoff (Mbala-Kingebeni et al., 2021). Consequently, well water is frequently contaminated with pathogenic microorganisms, significantly increasing the risk of waterborne disease outbreaks such as cholera, dysentery, and typhoid fever (Kyowire et al., 2024).

Studies conducted across several municipalities of Kinshasa, including Selembao, have consistently reported contamination of well water with indicator bacteria such as *Escherichia coli*, total coliforms, and *Pseudomonas* spp., often at concentrations exceeding guideline values established by the World Health Organization (Mbuyi et al., 2021; Mukeba et al., 2022). Epidemiological surveys in peripheral municipalities, including Bumbu and Mont-Ngafula, have further indicated that more than 60% of hospital admissions are associated with waterborne illnesses, underscoring the substantial public health burden linked to unsafe water consumption (Kapembo et al., 2019).

In the Hérady district, this precarious situation is exacerbated by unfavourable socio-economic conditions, limited access to healthcare services, and seasonal climatic variability. Seasonal changes influence groundwater recharge rates and contaminant transport dynamics, potentially leading to fluctuations in water quality and disease risk. Despite these documented risks, integrated data systematically linking groundwater quality parameters with health outcomes in this specific district remain scarce. This data gap hampers evidence-based decision-making for disease prevention and targeted water resource management.

This study therefore aims to: (1) assess the physico-chemical and microbiological quality of well water in the Hérady district (Selembao, Kinshasa), and (2) examine its correlation with the prevalence of waterborne diseases recorded in local healthcare facilities. The ultimate objective is to evaluate associated public health risks and inform the design of targeted intervention strategies.

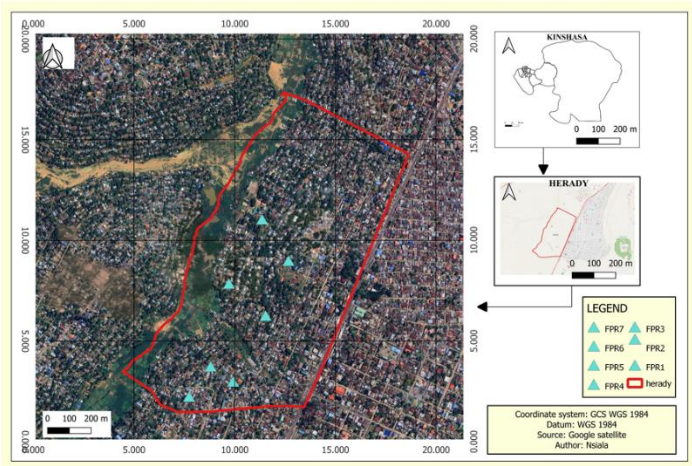
METHODS

Study Area Overview

This study was conducted in the Hérady district, located within the municipality of Selembao, a peri-urban area of Kinshasa (**Figure 1**). Selembao is characterised by unplanned urbanisation, a high population growth rate, and a substantial influx of young Congolese migrants from rural areas due to poverty and limited employment opportunities. These factors exert considerable pressure on local infrastructure, which is already inadequate.

The district is frequently affected by flooding and landslides, which exacerbate hygiene and sanitation challenges. Inadequate waste management systems have led to the proliferation of informal dumpsites, which are often used for open defecation. Although no industrial activities are reported in the area, residents engage in intensive urban agriculture, small-scale livestock farming, and petty commercial activities to sustain their livelihoods. Access to potable water remains a major challenge in Hérady. The district is not connected to the public water supply network managed by REGIDESO, and sanitation services are poorly organised. As a result, residents rely primarily on wells, boreholes, and springs for domestic purposes, including drinking, cooking, and washing. These living conditions highlight the urgent need for sustainable interventions to improve access to safe water and adequate sanitation infrastructure in the community.

Figure 1:
Google Map of the sampling site. (a) Democratic Republic of the Congo, (b) Map showing the location of the city of Kinshasa in the Democratic Republic of the Congo, (c) Commune of Selembao, Herady neighborhood (Sampling sites: Fpr1, Fpr2, Fpr3, Fpr4, Fpr5, Fpr6, Fpr7.)



Research on the Prevalence of Waterborne Diseases

This study analysed the prevalence of waterborne diseases in the Hérady district from November 2022 to January 2024. Data were obtained exclusively from official medical consultation records of local healthcare facilities. A total of 118 consultations related to clinically diagnosed and validated cases of waterborne diseases were analysed.

The primary objective was to assess the contribution of waterborne diseases to overall medical consultations. However, these results may underestimate the true burden, as a significant proportion of the population does not seek care at local health facilities except in severe cases. This behaviour is largely attributed to financial constraints, although other contextual factors may also influence healthcare utilisation.

Water Sampling Procedure

Water sampling was conducted during a single dry season (May–August 2023) in the Hérady district of Selembao municipality. A total of 42 groundwater samples (n = 42) were collected from seven active boreholes (Fpr1–Fpr7), corresponding to six samples per borehole.

The sampling sites were designated as Selembao Fpr1–Fpr7 (**Figure 1**). **Table 1** presents the GPS coordinates, borehole depth, year of construction, and estimated number of users for each sampling site. Representative photographs of selected sampling points are shown in **Figure 2**. In addition, **Figure 3** illustrates a three-dimensional surface plot depicting the relationship between year of construction, borehole depth, and number of users across the sampling sites.

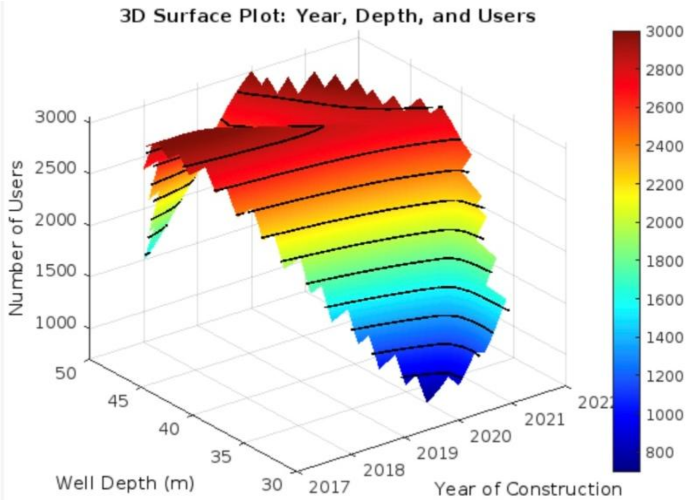
Figure 2:
Sampling points (Fpr1, Fpr2, Fpr3, Fpr4, Fpr5, Fpr6, and Fpr7) in the Herady district, Selembao municipality (photographs by Nsiala, May 2023)

Water samples were collected directly from borehole outlets using sterile 500 mL polypropylene containers, following established protocols (Mukeba et al., 2022). After collection, samples were stored in a cooler and transported to the laboratory for analysis within 24 hours.

Table 1:
GPS coordinates of wells and water sources, depth, and number of users (Fpr1-Fpr7 are the Fitted Wells of the Herady neighborhood)

Sampling site	Longitude	Latitude	Depth of the well (m)	Appearance	Number of users	Year of construction
Fpr1	15°16′46.24″	4°25′15.40″	33	Cloudy	± 700	2020
Fpr2	15°16′54.43″	4°25′8.88″	50	Clear	± 1500	2018
Fpr3	15°16′53.91″	4°24′53.54″	40	Clear	± 2800	2022
Fpr4	15°16′48.96″	4°25′3.09″	30	Cloudy	± 1500	2021
Fpr5	15°16′43.03″	4°25′19.86″	50	Clear	± 3000	2020
Fpr6	15°16′57.84″	4°24′59.69″	48	Clear	± 2500	2019
Fpr7	15°16′49.58″	4°25′17.64″	45	Clear	± 3000	2017

Figure 3:
3D Surface Plot showing Year, Depth and Users in sampling site



Analysis of Physico-Chemical Parameters

Physico-chemical analyses of water samples were performed in the laboratory using standard analytical procedures in accordance with World Health Organization guidelines (WHO, 2017). The parameters analysed, along with the instruments and analytical methods used, are presented in **Table 2**. In situ measurements included temperature, pH, dissolved oxygen (DO), and electrical conductivity (EC). Laboratory analyses focused on total hardness, chlorides, total dissolved solids (TDS), humic acids, and dissolved ions (SO_4^{2-}, NO_3^-, Fe^{3+}, Mn^{2+}), following protocols described by Mavakala et al. (2016) and ASTM International (2018).

All measurements were conducted using calibrated instruments. Analytical accuracy was verified using certified reference material (Ontario-99; Water Research Institute, Canada). Measured values fell within the specified tolerance limits, ensuring the reliability of the analytical results.

Table 2:
Instruments and analytical methods used for physico-chemical analyses

Parameter	Instrument/Method	Manufacturer / Reference
Color	UV–Visible spectrophotometer (Genesys 10 UV)	Thermo Spectronic (DR-12-SCA-01, DGCSCEAEQ, 2023)
pH, Temperature, Dissolved O_2, Electrical Conductivity	Multiparameter probe Multi 350i	WTW, Germany; Mukeba et al. (2022)
SO_4^{2-}, NO_3^-, Fe^{3+}, Mn^{2+}	Ion chromatography (ICS 3000)	Dionex, Canada; Mavakala et al. (2016)
Calibration	Certified reference material (Ontario-99)	Water Research Institute, Canada

Analysis of Faecal Indicator Bacteria in Water Samples

Faecal indicator bacteria (FIB) were identified and quantified using the membrane filtration method, in accordance with guidelines issued by the American Public Health Association (APHA, 2005). The targeted microbiological indicators included total coliforms, *Escherichia coli*, enterococci, and *Pseudomonas* spp. A summary of the detection methods is presented in **Table 3**. For each sample, 100 mL of water was filtered through a 0.45 µm membrane and cultured on selective media under standard incubation conditions. All samples were analysed in triplicate, and bacterial concentrations were expressed as colony-forming units per 100 mL (CFU/100 mL). Negative controls were included throughout field and laboratory procedures to ensure data quality and prevent contamination, in line with recommendations by Nienie et al. (2018) and Mukeba et al. (2022).

Table 3:
Summary of microbiological indicators and detection methods

Microorganisms	Incubation time	Culture medium	Volume analyzed	Analytical method	Specific observations	References
Total coliforms	37 °C for 24 h	Lactose agar with TTC and Tergitol	100 mL	Membrane filtration technique (0.45 µm)	Red colonies	NF EN ISO 9308-3 (1999)
Escherichia coli	37 °C for 24 h	Selective agar	100 mL	Membrane filtration technique (0.45 µm)	Blue colonies	NF EN ISO 9308-3 (1999)
Enterococci	37 °C for 48 h	Slanetz–Bartley agar	100 mL	Membrane filtration technique (0.45 µm)	Red colonies	NF ISO 7899-2
Pseudomonas aeruginosa	36 ± 2 °C for 44 ± 4 h	CN agar (Cetrimide–nalidixic acid)	100 mL	Membrane filtration technique (0.45 µm)	Green–blue fluorescent colonies under UV light	NF EN ISO 16266 (2006)

Health Data Validation

Data on waterborne diseases were obtained from official medical consultation registers of local healthcare facilities in the Hérady district. Only clinically diagnosed and formally registered cases were included in the analysis. No self-reported data were used, thereby minimising information bias and enhancing epidemiological reliability.

Ethical Considerations

This study utilised secondary data extracted from health facility registers, with prior authorisation obtained from the heads of the respective institutions. No direct contact with patients occurred, and no personally identifiable information was collected. All data were anonymised and processed confidentially. In accordance with national regulations governing retrospective studies based on anonymised administrative data, formal approval from an ethics review committee was not required.

Statistical Analysis

Statistical analyses were performed using SigmaStat version 11.0 and RStudio (version 1.3.1093). Data normality was assessed using the Shapiro–Wilk test (Shapiro & Wilk, 1965). As most variables did not follow a normal distribution, non-parametric statistical tests were applied in accordance with established recommendations (Conover, 1999; Zar, 2010).

Spearman's rank correlation coefficient was used to examine relationships between physico-chemical parameters, bacteriological contamination, and the prevalence of waterborne diseases. Where appropriate, linear regression analyses were conducted to assess the strength of associations. A significance level of 5% ($p < .05$) was applied throughout. Results are expressed as mean ± standard deviation (SD).

RESULTS

Analysis of the collected data yielded two principal findings: first, epidemiological patterns of waterborne diseases identified in the study area; and second, the physico-chemical and microbiological characteristics of the analysed well water.

Epidemiological Survey

Figure 3 presents data obtained from healthcare facilities in the Hérady district on the prevalence of waterborne diseases during the period from November 2022 to January 2024. Although informative, these data do not fully represent the true disease burden in the community, as a substantial proportion of residents do not seek care at health facilities, primarily due to financial constraints or other factors not assessed in this study.

The results indicate a high frequency of waterborne diseases. A total of 56 cases of intestinal parasitic infections were recorded, including yeast infections (3+), amoebiasis (2+), and ascariasis. In addition, 32 cases of gastroenteritis—both febrile and non-febrile—were reported, including cases of salmonellosis and typhoid fever. Overall, all 118 consultations analysed (100%) were related to waterborne diseases, highlighting their alarming prevalence in the study population.

Figure 3:
Epidemiological Data on the Prevalence of Waterborne Diseases

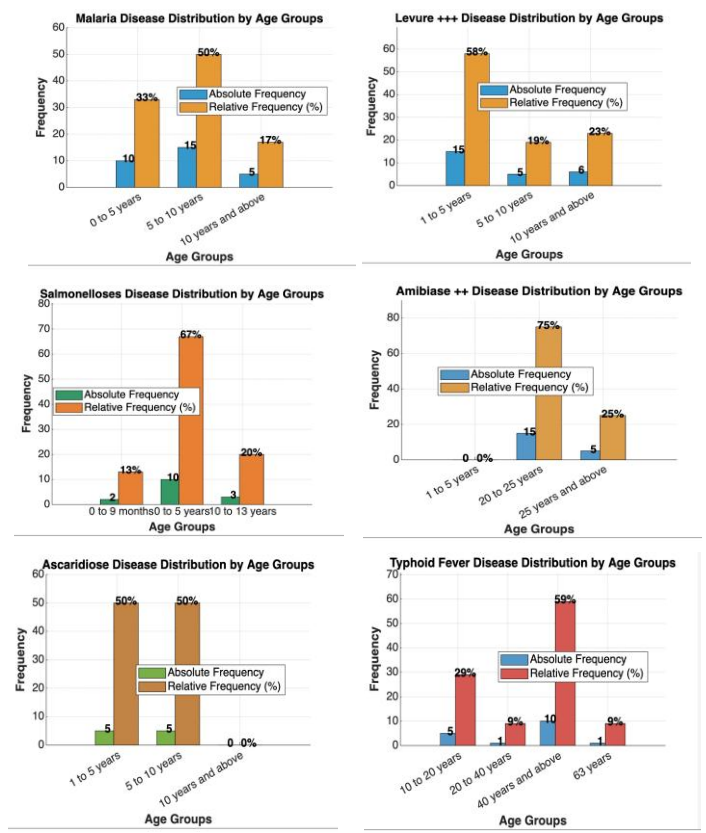


Figure 3 illustrates the distribution of waterborne diseases in the Hérady district. Although malaria remains prevalent, waterborne diseases clearly predominate. Intestinal parasitic infections account for 47.45% of reported cases, followed by gastroenteritis and typhoid fever (27.13%). Malaria represents 25.42% of hospitalised and outpatient cases.

Age-specific analysis **(Figure 3)** shows that children under 10 years of age are the most affected group. This observation is consistent with national demographic data indicating that approximately 59% of the Congolese population is under 20 years of age (Multiple Indicator Cluster Survey–DRC [MICS-DRC], 2010), underscoring the heightened vulnerability of children to waterborne diseases in the district.

Physico-Chemical Characteristics

The results of the physico-chemical analyses—including odour, colour, pH, temperature, and electrical conductivity—are presented in **Table 4** and **Figure 4**.

Sensory evaluations of colour and odour indicate that all analysed water samples complied with the organoleptic criteria recommended by the World Health Organization (WHO, 2017) for drinking water quality.

Table 4:
Odour and Colour Measurements of Water Samples from Boreholes

Sampling site	Odour	Colour (mg L⁻¹ Pt–Co)
Fpr1	Acceptable	11.0
Fpr2	Acceptable	10.1
Fpr3	Acceptable	9.2
Fpr4	Acceptable	11.4
Fpr5	Acceptable	9.8
Fpr6	Acceptable	10.0
Fpr7	Acceptable	9.2
WHO standard	Acceptable	≤ 15

Source: *WHO guidelines for drinking-water quality (WHO, 2017).*

Despite acceptable organoleptic properties, pH values were consistently below WHO-recommended limits. The use of methyl red as an indicator revealed a transition from pH 4.4 (red zone) to pH 6.2 (yellow zone), indicating marked acidity in borehole water across the Hérady district.

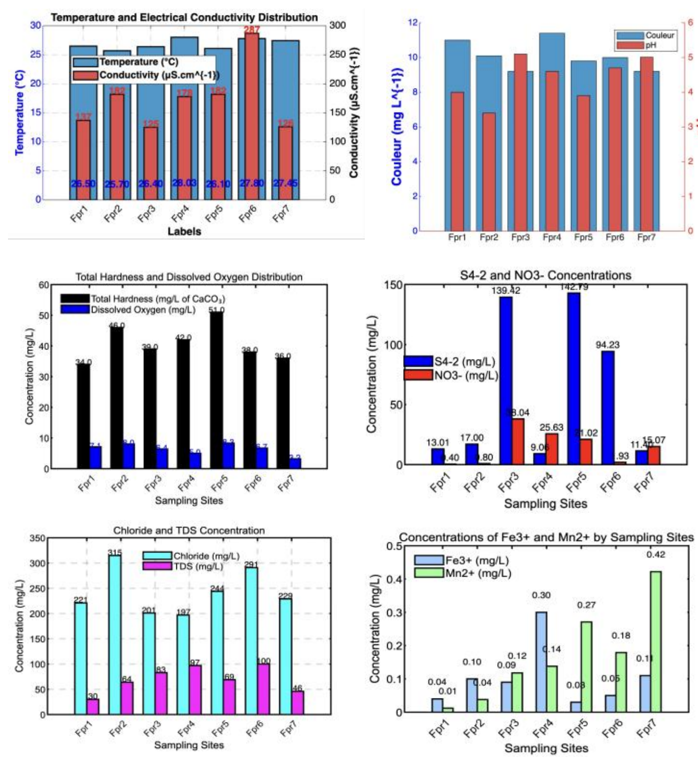
Mean water temperatures slightly exceeded recommended values, likely reflecting elevated ambient temperatures (approximately 28 °C) during the sampling period. However, no substantial variation was observed among sampling sites. Electrical conductivity values averaged 173.86 µS·cm⁻¹, remaining below WHO thresholds at all sites except Fpr6, where values approached the recommended limit.

Figure 4 presents the spatial distribution of selected water quality parameters, including total hardness (40.86 mg/L), dissolved oxygen (6.39 mg/L), chloride (242.56 mg/L), and total dissolved solids (TDS) (69.86 mg/L). While most parameters complied with WHO (2017) guidelines, several exceedances were noted:

- **Dissolved oxygen:** Levels below recommended thresholds at sites Fpr4 and Fpr7
- **Chloride:** Concentrations exceeding the 250 mg/L limit at Fpr2 and Fpr6, with a maximum of 315 mg/L at Fpr2
- **Manganese (Mn^{2+}):** Elevated concentrations at sites Fpr4, Fpr5, Fpr6, and Fpr7
- **pH:** Persistently acidic values across multiple sampling sites

Although most dissolved ion concentrations remained within acceptable limits, site-specific exceedances warrant further attention and monitoring.

Figure 4:
Spatial Analysis of Average Values for Various Water Quality Parameters



Microbiological Quality

Microbiological analyses revealed extremely poor water quality at sampling sites Fpr3, Fpr4, Fpr6, and Fpr7 **(Table 5)**. Measured bacterial concentrations, expressed as colony-forming units (CFU), varied significantly between sites ($p < .05$).

- *Escherichia coli:* (2.03–14.99) × 10^2 CFU/100 mL
- *Enterococcus:* Mean concentration of 3.4 × 10^2 CFU/100 mL
- Total coliforms: (1.12–9.08) × 10^2 CFU/100 mL

Site Fpr6 exhibited the highest level of contamination for all bacterial indicators, followed by Fpr3. At sites Fpr4 and Fpr7, *E. coli* was the only detected indicator organism. These results demonstrate that water from the affected sites does not meet WHO (2017) and European Union drinking-water standards, which require zero CFU/100 mL for *E. coli*, *Enterococcus*, total coliforms, and *Pseudomonas* spp. (European Union [EU], 2020; WHO, 2017).

Table 5:
Average Bacterial Counts in Water Samples (CFU/100 mL **× 10^2, Mean ± SD)**

Site	*E. coli*	ENT	TC	Psd
Fpr1	0	0	0	0
Fpr2	0	0	0	0
Fpr3	6.03 ± 1.15	0	1.12 ± 0.25	0
Fpr4	8.31 ± 1.08	0	0	0
Fpr5	0	0	0	0
Fpr6	14.99 ± 4.15	3.4 ± 1.1	9.08 ± 1.31	0
Fpr7	2.03 ± 0.35	0	0	0
EU/WHO standard	0	0	0	0

** EU and World Health Organization standards for drinking water quality 0 CFU 100 mL-1, for E. coli, ENT, TC, and Psd (UE, 2020 ; OMS, 2027). E. coli: Escherichia coli; ENT: Enterococcus; TC: Total coliforms; Psd: Pseudomonas; ± SD: Standard deviation.*

Statistical Correlation Analysis

Correlation analysis suggests that physico-chemical and bacteriological parameters originate from partially distinct sources. However, strong and statistically significant positive correlations were observed among bacteriological indicators (**Table 6**), notably between *E. coli* and *Enterococcus* ($R = 0.8155$, $p < .05$) and between *Enterococcus* and total coliforms ($R = 0.9923$, $p < .05$).

Significant positive correlations were also identified between bacteriological indicators and selected physico-chemical parameters, including:

- *E. coli* and temperature: $R = 0.73$, $p < .05$
- *E. coli* and TDS: $R = 0.80$, $p < .05$
- *Enterococcus* and electrical conductivity: $R = 0.8868$, $p < .05$
- Total coliforms and electrical conductivity: $R = 0.85$, $p < .05$

These findings indicate a strong interdependence between bacterial contamination and the physico-chemical conditions of the groundwater, suggesting that environmental factors play a critical role in shaping microbiological water quality.

Note: Significant correlation coefficients ($p < .05$) are highlighted in bold in **Table 6**.

Table 6:
Spearman Rank Correlation of Selected Parameters in the Analyzed Well Water

	pH	**T (°C)**	**CE**	**Dureté totale**	**O_2**	**Chlorure**	**TDS**	**SO_4^{-2}**	**NO^{3-}**	**Fe^{3+}**	**Mn^{2+}**	**Acides Humiques**	***E. coli***	**ENT**	**TC**
pH	1														
T (°C)	0,654	1													
CE	-0,1222	0,3391	1												
Dureté totale	-0,5468	-0,4526	0,1899	1											
O_2	-0,7373	-0,7078	0,3067	0,5634	1										
Chlorure	-0,5672	-0,3057	0,6193	0,3044	0,4714	1									
TDS	0,3194	0,4421	0,6230	0,2931	0,0307	0,0625	1								
SO_4^{-2}	0,1965	-0,2632	0,1977	0,3918	0,4402	-0,0384	0,4037	1							
NO^{3-}	0,5693	0,0858	-0,4269	0,1821	-0,2619	-0,7123	0,3798	0,4848	1						
Fe^{3+}	0,2378	0,5461	-0,1019	0,0129	-0,5096	-0,4053	0,4191	-0,4681	0,3742	1					
Mn^{2+}	0,4812	0,3624	-0,0641	0,0473	-0,5898	-0,1413	-0,0140	0,1329	0,2555	-0,0174	1				
Acides Humiques	0,6257	0,0131	-0,0182	-0,2602	-0,0260	-0,2144	0,4214	0,6236	0,5368	-0,1608	-0,0835	1			
E. coli	0,5573	**0,7301**	0,6979	-0,2678	-0,2176	0,0451	**0,8034**	0,2064	0,0826	0,2487	0,0250	0,4684	1		
ENT	0,2180	0,4631	**0,8868**	-0,2115	0,0779	0,4765	0,5140	0,2350	-0,3877	-0,2524	0,0334	0,2616	**0,8155**	1	
TC	0,2830	0,4414	**0,8507**	-0,2315	0,0794	0,4317	0,5488	0,3074	-0,3042	-0,2634	0,0142	0,3782	0,8413	**0,9923**	1

a The parameters include physicochemical parameters (pH, temperature (°C), electrical conductivity (EC), hardness, dissolved oxygen (O2), TDS, and soluble ions (SO42-, NO3-, Iron, Mn, Humic acids) and fecal indicator bacteria (FIB): Escherichia coli (E. coli), Enterococcus (ENT), and Total coliforms. (CT). The significant coefficients (p<0.05) are in bold.

DISCUSSION

Summary of Key Findings

This study reveals an alarming public health situation in the Hérady district, where drinking water is systematically contaminated and waterborne diseases account for 100% of recorded medical consultations. The population—particularly children under the age of 10—is exposed to a substantial health risk through the consumption of groundwater characterised by two critical deficiencies: active faecal contamination and pronounced acidity. Microbiological analyses demonstrated very high concentrations of *Escherichia coli*, enterococci, and total coliforms at several sampling sites, far exceeding the guideline values established by the World Health Organization (WHO, 2017). Concurrently, the physico-chemical profile of the water is marked by strong acidity (mean pH = 4.39) and nitrate concentrations approaching or exceeding recommended limits.

Consistent with the non-parametric analytical framework adopted in this study, Spearman's rank correlation analysis revealed significant relationships between physico-chemical and microbiological parameters, indicating interdependence between bacterial contamination and environmental conditions. Very strong positive correlations were observed between *E. coli* and enterococci ($R = 0.8155$, $p < .05$) and between enterococci and total coliforms ($R = 0.9923$, $p < .05$), suggesting a common faecal source of contamination. Additional positive correlations between bacteriological indicators and temperature, total dissolved solids (TDS), and electrical conductivity (EC) further support the hypothesis that groundwater quality degradation is driven by unfavourable environmental and sanitary conditions, including stagnant water, shallow aquifers, and inadequate waste management.

The spatial and temporal coexistence of poor-quality drinking water and a 100% prevalence of waterborne diseases establishes a compelling epidemiological link. Although a formal statistical association between water quality parameters and disease incidence could not be computed due to the aggregation of health data at the district level, the concurrence of high faecal pathogen loads in water sources and widespread cases of gastroenteritis and intestinal parasitic infections among users strongly suggests a causal relationship. The pronounced vulnerability of children under 10 years of age—who are biologically more susceptible to waterborne pathogens—further reinforces this interpretation.

Comparison with Previous Studies and Contribution of This Study

The findings of this study are consistent with well-documented regional trends of groundwater quality degradation in Sub-Saharan Africa. The extensive faecal contamination observed aligns with reports from Kikwit and Kinshasa, where human activities, unregulated sanitation, and inadequate waste management were identified as major sources of groundwater pollution (Kayembe et al., 2018; Nienie et al., 2017). Similarly, the disproportionate burden of waterborne diseases among children corroborates observations by Mukeba et al. (2022) in other peri-urban municipalities of Kinshasa.

Beyond corroborating regional evidence, this study makes several novel contributions. First, it highlights the exceptionally low pH of groundwater (mean pH ≈ 4.4), a parameter rarely emphasised in comparable urban studies but one that may increase heavy metal mobility and reduce the effectiveness of conventional water treatment methods. Second, the finding that all recorded medical consultations in the study area were related to waterborne diseases points to an extreme public health emergency. Third, the identification of robust statistical relationships between faecal indicator bacteria and specific physico-chemical parameters—combined with epidemiological evidence based on spatial and temporal coincidence—strengthens the attribution of poor water quality as a primary determinant of morbidity in the Hérady district.

These findings are consistent with broader continental dynamics characterised by the intrinsic vulnerability of shallow aquifers, as documented in Ghana by Adimalla et al. (2021). Such vulnerability is further amplified by anthropogenic pressures, facilitating recurrent public health crises, including those reported in Nigeria (Afolayan et al., 2022).

Public Health Implications

The consumption of contaminated groundwater in Hérady represents a direct and significant public health threat. The predominance of intestinal parasitic infections and gastroenteritis is a predictable outcome of chronic exposure to faecal pathogens, whose presence and persistence are confirmed by microbiological analyses. This situation is exacerbated by inadequate sanitation infrastructure and limited access to safe drinking water—conditions commonly reported in other African settings, such as South Kordofan, where inadequate risk perception further compounds disease burden (Asmally et al., 2025).

Study Limitations and Research Perspectives

This study has several limitations. The water sampling campaign was conducted during a single season and therefore does not capture the full extent of seasonal variability in contamination patterns. Future studies should incorporate year-round monitoring to identify periods of heightened risk. Although the sample size provided meaningful insights, it limits the generalisability of findings across the entire district; larger-scale environmental and epidemiological studies are warranted. The absence of longitudinal data also precludes analysis of temporal trends, underscoring the need for permanent groundwater and health surveillance systems. Additionally, transient local factors influencing contamination could not be fully controlled.

These limitations highlight opportunities for future research, including:

1. Conducting quantitative microbial risk assessments (QMRA) to estimate pathogen-specific health risks;
2. Investigating the hydrogeochemical origins of groundwater acidity and its synergistic effects on contaminant mobilisation; and
3. Evaluating the effectiveness, uptake, and health impact of WASH interventions using implementation science methodologies.

Policy and Community Recommendations

In light of the observed contamination and its public health implications, urgent, integrated, and sustainable interventions based on the WASH (Water, Sanitation, and Hygiene) framework are essential to mitigate risks faced by the Hérady population. The following actions are recommended for local authorities, community leaders, and non-governmental organisations:

1. **Point-of-Use Water Treatment:** Promote affordable household water treatment methods (e.g., pH-adjusted chlorination, filtration, and simple disinfection), alongside safe water storage practices, to immediately reduce exposure to pathogens.
2. **Strengthening Sanitation and Waste Management:** Implement Community-Led Total Sanitation (CLTS) programmes to reduce open defecation, improve faecal sludge and solid waste management, and limit diffuse groundwater contamination.
3. **Regulatory Framework and Water Point Protection:** Enforce minimum separation distances between wells, latrines, and waste disposal sites to interrupt faecal pollution pathways in densely populated areas.
4. **Awareness and Hygiene Education:** Enhance targeted community education initiatives focusing on health risk perception, well maintenance, excreta management, and essential hygiene practices, particularly handwashing with soap.
5. **Community-Based Water Quality Monitoring:** Support participatory monitoring systems that enable communities to periodically assess microbiological water quality and promptly report public health risks.

Collectively, these measures are critical to reducing population vulnerability, improving access to safe water, and bridging the gap between policy commitments—particularly Sustainable Development Goal 6—and the realities of peri-urban communities.

CONCLUSION

This study evaluated the quality of groundwater used by households in the Hérady district of Selembao and examined its association with the persistence of waterborne diseases. As in many peri-urban settings, residents rely predominantly on shallow wells, often located near latrines, septic tanks, and open waste disposal sites—conditions that significantly increase the risk of contamination and disease transmission.

While several physico-chemical parameters complied with WHO guideline values, the markedly low pH (approximately 4.39) indicates acidic water, and microbiological analyses revealed substantial contamination at multiple sites. Elevated concentrations of *E. coli*, *Enterococcus* spp., and total coliforms confirm widespread faecal contamination, consistent with epidemiological data from local healthcare facilities documenting persistent waterborne illnesses.

These findings underscore the urgent need to strengthen groundwater protection and public health safeguards. Priority actions should include establishing protected zones around wells, upgrading sanitation infrastructure to reduce faecal infiltration, and enhancing community awareness of safe water handling practices. To minimise the formation of disinfection by-products such as trihalomethanes during chlorination, visibly coloured or turbid water should be filtered or allowed to settle prior to treatment.

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