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MONITORING THE EVOLUTION OF PHYSICAL, CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF THE LEACHATE FROM THE FORMER FINAL LANDFILL OF AGOE

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Abstract: Landfills release leachate, a highly polluting effluent resulting from the percolation of rainwater through waste. The infiltration of this leachate into the subsoil compromises groundwater quality and public health. To assess the level of groundwater contamination two years after the rehabilitation of the former Agoè-Nyivé landfill in Togo, a survey of local residents and physicochemical and bacteriological analyses of the leachate were conducted. Bacteriological and physicochemical analyses were carried out according to the standards of the French Standards Association on samples of collected leachate. The survey found that more than 76% of respondents said they had seen the leachate and believed it had an environmental impact. The leachate had a high pollutant load, with a conductivity of 33660 $\mu\text{S}/\text{cm}$, a high ammonium concentration of 951 mg/l, a BOD₅ of 22 mg/l. The oxidizability (2650 mgO₂/L) is relatively high in the leachate, indicating strong organic degradation activity. However, the ETMs sought in the samples are mostly below the detection threshold. Bacteriological analyses showed that the leachate was contaminated with all the germs tested. Furthermore, mesophilic aerobic germs are present at a very high level of 76,000 CFU/mL. These results demonstrate that the groundwater near this former landfill could be polluted, highlighting the importance of post-closure monitoring for resource preservation.

Keywords : landfill, leachate, groundwater, contamination, health risk assessment.

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INTRODUCTION

Generally, landfilling is the most common method in many countries for disposing of municipal and industrial solid waste, but unfortunately this process generates a huge amount of highly polluting leachate. While this wastewater contains many types of pollutants, such as refractory organic compounds and heavy metals (Lema et al., 1988; Anqi et al., 2020). These landfills, mainly due to the action of rainwater and the fermentation of buried waste, produce leachate when no treatment system is in place (Mejraoua & Zine, 2017). In the literature, works have been published on different methods of leachate remediation. Thus,

(Anqi et al., 2020) mentioned some membrane processes such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO), adding that this technique offers the advantage of a stable effluent and a high rate of rejection of refractory organic matter. Water runoff from these former landfills has significant consequences for human health and the environment. Therefore, municipalities are subject to waste management legislation, requiring recycling and reuse methods before any disposal or treatment (Salem et al., 2008). Previous work has shown that oxidation treatment with ozone (O₃) or hydrogen peroxide (H₂O₂) and simple

adsorption are not effective for treated water intended for environmental discharge. The authors add that membrane techniques and advanced oxidation processes appear effective in wastewater treatment; they point out that highly biodegradable leachates are only suitable for biological processes (Sillet et al., 2001). A study has shown that it is possible to recover treated leachate. Treated leachate from the Aképé Technical Landfill Center (TOGO) was used as inoculum during biogas production from plant biomass and household waste (food waste, green waste, paper and cardboard, wood, etc.) (Hundjoe et al., 2023).

The phenomenon of infiltration of wastewater of all kinds (leachate, sewage sludge, household sludge, toilet water, industrial water, hospital water, etc.) can pollute the water table, compromising the quality of groundwater. For example, a study conducted in Libya showed that groundwater quality is impacted by urbanization, the expansion of tourism and the practice of intensive agriculture (Alfarrah et al., 2017). In Nigeria, environmental pollution from paint industry effluents has been reported. The question of assessing the compliance of wastewater discharged from paint industries with regulatory standards before discharge has therefore arisen (Aniyikaiye et al., 2019). The condition of sanitation facilities is also a key factor in maintaining groundwater quality. Research conducted in the city of Aného (Togo) revealed that septic tanks, toilets, and cesspools are located near wells, increasing the risk of pollution. Bacteriological contamination was observed following analysis of groundwater and the lagoon, as well as the presence of chemical pollutants such as nitrates, sulfates, and chlorides (Poromna et al., 2022). Hospitals generate large quantities of wastewater, which can pollute the environment if it is not treated or transported to a collection area. Indeed, human health becomes problematic when this hospital wastewater, laden with microbes and coliforms, ends up in the environment (A. Chukwu et al., 2018). This damage to the environment cannot remain without consequences for living beings, and in particular humans. Therefore, studies have been carried out to collect information on the health impact of environmental pollution

sources through population surveys (Daniau et al., 2013). In this perspective, a study conducted in Ouagadougou (Burkina) in two districts provided information on knowledge of the risks linked to the use of domestic water and the analysis revealed the processes of appropriation of the biomedical model observed within the population surveyed (Dos Santos, 2011). With this objective, our study focused on the leachate from the former AGOE municipal landfill. More specifically, the objective was to gather the opinions of the local population on the knowledge and dangers associated with contact with the leachate. We then characterized the leachate using physicochemical and bacteriological analyses, which we compared with previous work in order to observe the evolution of the parameters.

EXPERIMENTAL

Presentation of the study site

Our study area is located in the commune of Agoè-Nyivé 1 (including part of Agoè-Nyivé 4). It extends from the former Agoè landfill site to the Agoè-Nyivé–Dikamé road, partially including the neighborhoods of Adouiko (Agoè-Nyivé 1) and Bokor kopé (Agoè-Nyivé 4). Covering an area of over 12 hectares, the site was a former sand and gravel quarry, converted without any development into a main landfill by the Municipality of Lomé in 2000 and receiving almost all of the waste from the city of Lomé and its surrounding areas until 2017. Between 2018 and 2023, thanks to the Lomé Urban Environment Project, rehabilitation and environmental safety work was authorized to limit its impact on local populations.

Material: The survey equipment included a camera, a household survey form, and an observation grid. The sampling equipment consisted of 1.5 L polyethylene bottles, 500 mL Pyrex flasks, a cooler, a marker, and a blowtorch. The material to be analyzed consisted of leachate from the former landfill.

Methodology

This is a descriptive and analytical cross-sectional study that took place from March to July 2025 in the districts of Adouiko and Bokor Kopé, targeting households living near the former Agoè landfill.

Survey: The objective of the survey was to assess the knowledge of leachate towards the local people. A questionnaire was designed by Kobocollect and was primarily aimed at the head of household and, by default, their spouse or an adult representative. The survey involved 133 households according a quota was based on a reasoned approach, and available resources. The selection was done randomly; when one house was considered, two others were ignored before moving on to the next.

Sampling: For physicochemical analyses, samples were collected in 1.5 L polyethylene bottles. We used two bottles for each sample: the first (0.5 L) for metal analysis, to which a few drops of nitric acid were added, and the other

(1.5 L) for the other physicochemical parameters. Samples for bacteriological analysis were placed in sterile 500 mL bottles. A blowtorch was kept on to maintain aseptic conditions. After collection, the samples are placed in cool box kept below approximately 4 °C and then sent directly to the following laboratories.

Physicochemical and bacteriological analysis methods: the analysis methods used for the physicochemical and bacteriological parameters (usual analysis methods of the French Standardization Association AFNOR) are indicated in table 1. These methods have already been used in our previous work (Ouéda et al., 2025).

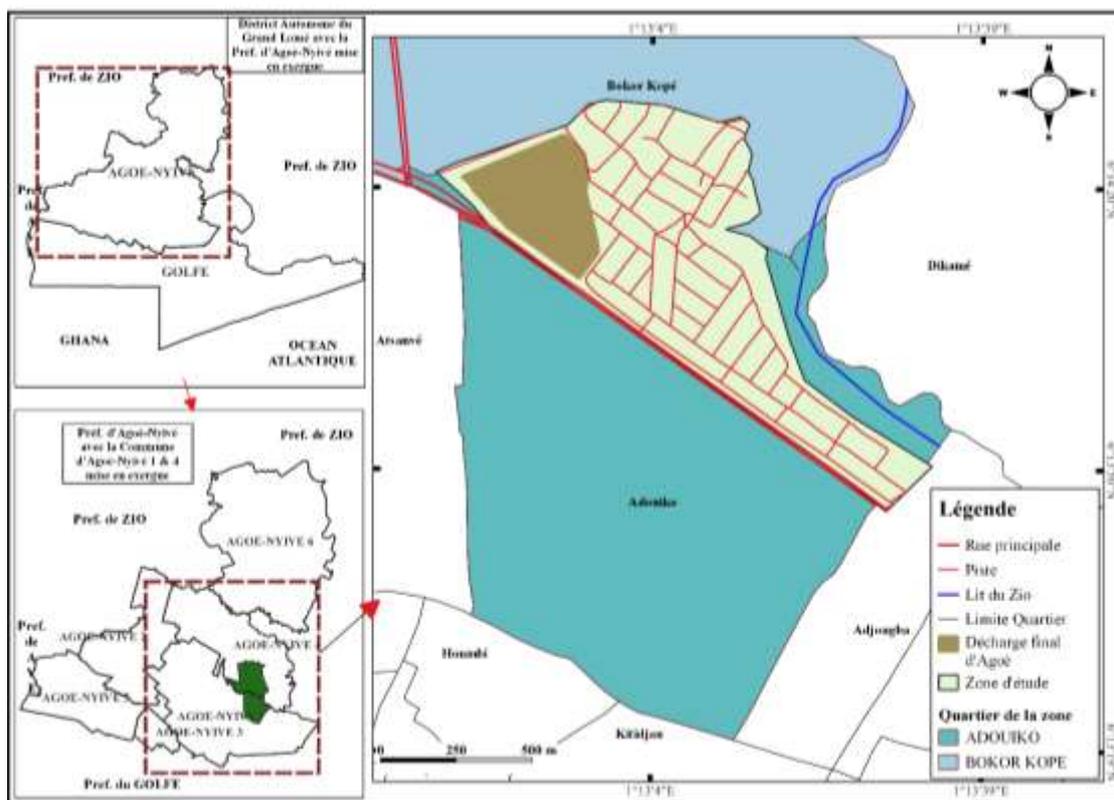


Figure 1. Map of the study area (Source: RGP 5, Google Satellite / Author: KALMOU Essodaninam)

Table 1. Materials and Methods for analyzing Bacteriological Parameters

Identified Germs	Growing medium	Temperature and incubation time	Reference of the Standard used	Coloration
Aerobic mesophilic germs UFC/mL	PCA	72 h/30 °C	NF EN ISO 4833-1	All form
Total Coliforms UFC/mL	VRBL	48 h/30 °C	NF EN ISO 4832	Pink-Red de diameter > 0.5mm
Thermo tolerant Coliforms UFC/mL	VRBL	48 h/44 °C	NF V08060	Pink-Red
Fecal Streptococci UFC/mL	Slanetz Bartley	48 h/37 °C	NF EN ISO 7899-2	Coffee brown

Sulfite -reducing Anaerobes UFC/mL	TSN	24 h/44 °C	NF EN ISO 15213	Black
<i>Escherichia Coli</i>	TBX	24h/44 °C	NF EN ISO 166492	Blue Green Colony

Table 2. Materials and Methods for analyzing Physical and Chemical parameters

Parameters	Methods	Material	Standards OMS*- UE
Temperature - °C	Electrometry	Multimeter « Type WTW Multi 342 »	-
pH	Electrometry		6.50 – 8.50
Elec. cond. 25°C - µS/cm	Conductimetry		400 (guide number)
Dissolved salt - mg/L	Conduct/Salinometer		1000(*) – 1500
Bicarbonates (HCO ₃ ⁻) - mg/L	Acidimetry	Glasses and reagents	> 30 (guide number)
Total Hardness - °f	Complexometry		> 15
Calcium (Ca ²⁺) - mg/L	Complexometry		100 (guide number)
Magnesium (Mg ²⁺) - mg/L	Complexometry		50
Sodium (Na ⁺) - mg/L	AAS/Flame Absorption	flame Spectrophotometer « type JENWAY PFP7 »	200(*) - 150
Potassium (K ⁺) - mg/L	AAS/Flame Absorption		12
Ammonium (NH ₄ ⁺) - mg/L	Spectrophotometry		1.5 (*) – 0.5
Ortho phosphates (PO ₄ ³⁻) - mgP/L	Spectrophotometry		-
Fluorides (F ⁻) - mg/L	Spectrophotometry		1.5(*)
Oxydability KMnO ₄ - mgO ₂ /L	Basic/Hot	Glasses	2 (guide number)
DBO	Respirometry	DBO-meter « Type LH-TB100 »	
Heavy metals			
Cadmium (Cd) - mg/L	AAS/Flame Absorption	Spectrophotometry with flame « Termo Fischer iCE 3000 Serial »	0.003 (*) – 0.005
Lead (Pb) - mg/L			0.01 (*) – 0.01
Nickel (Ni)- mg/L			0.02 (*) – 0.02
Chromium (Cr)- mg/L			0.05 (*) – 0.05
Mercury (Hg) - µg/L	Generation of hydrides-SAA		1 (*) - 1
Arsenic (As) - µg/L		10 (*) - 10	

Statistical Analysis: Household survey forms were processed using Kobotoolbox software. Collected data were exported to Stata software for processing, data entry was performed using Word 2016, and Excel was used to create charts and pivot tables. Map design was carried out using QGIS version 10 software.

RESULTS AND DISCUSSION

Knowledge of leachate and its potential impacts

Table 3 shows that over 74% of respondents said they had heard of it or seen it, and 76% believe it has impacts on certain elements of the ecosystem, such as water, soil and air. However, 35.35% thought that these effects ceased after

rehabilitation. In addition, 74% of respondents reported having seen or heard of leachate, which confirms the past influence of the landfill and the experience of local residents when leachate runoff reached their homes. In addition, 33% of respondents believed that leachate had infiltrated the groundwater, but 60% had no opinion. These results reflect high uncertainty among the population regarding the link between water quality, leachate intrusion, and health.

Table 3. Distribution of knowledge on leachates and their impacts

Modality	Number (n)	Proportion (%)
Knowledge of Leachate		
Yes	99	74.44

No	34	25.56
Impact of Leachate on Natural Resources		
Yes	102	76.69
No	1	0.75
Do not Know	30	22.56
Impact of Leachate after Remediation		
Yes	47	35.34
No	56	42.11
Do not Know	30	22.56

Health Impacts

Health experiences translate into the occurrence of certain illnesses or health problems. The illnesses encountered during our surveys are illustrated in Table 4. Skin problems (32.5%) and diarrhea (30.1%) are the most common, followed by abdominal pain (18.7%) and vomiting (17.1%).

Table 4. Distribution of households according to health problems

Problem of Health	Number (n)	Proportion (%)
Abdominal pain	23	18.7
Other	2	1.6
Diarrhea	37	30.1
Skin problem	40	32.5
Vomiting	21	17.1
Total	123	100

Finally, the survey revealed some health problems such as abdominal pain, diarrhea, skin problems and vomiting. Several studies conducted in similar contexts show that groundwater contamination by leachate causes health risks and effects (Boateng et al., 2019; Edzoa et al., 2024). This confirms that the manifestations reported by our survey could be related to leachate contamination.

Possible causes of the diseases or health problems identified

During the discussions, we focused on the possible causes of the illnesses, illustrated in Figure 3. In this regard, 14% of respondents attributed the problems to water consumption, while 65% said they did not know whether water was the cause. In addition, 33% of respondents believed that leachate had infiltrated the groundwater, but 60% had no opinion. These results reflect high uncertainty among the population about the link between water quality, leachate intrusion, and health.

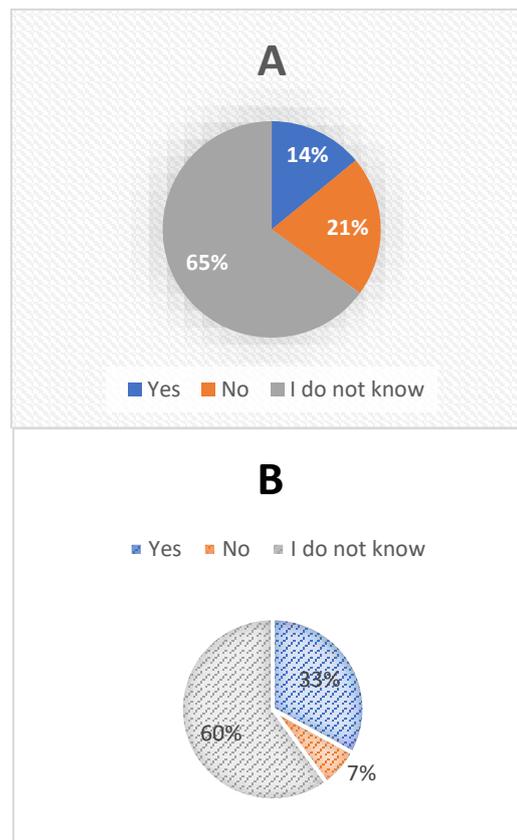


Figure 3. A: Distribution of households by whether water is the cause of health problems; B: Distribution of households according to the estimate of leachate intrusion into water

Physicochemical parameters of the leachate:

The physicochemical parameters such as electrical conductivity, suspended solids, pH, ammonium and phosphorus content, etc. of the leachate summarized in Table 5.

Temperature, pH and suspended solids: The temperature measured in the leachate is lower than the values measured over the past two years; 28.1 and 28.4 °C respectively 2024 and 2023. This reduction may be attributed to the slowdown in reactions within the waste mass due to the cover. The pH is a key parameter affecting leachate quality in landfills, and its value is influenced by the age of the landfill. The analysis shows a value of 7.82 (slightly basic pH), which indicates a leachate typical of an old landfill (pH > 7.5) (Costa et al., 2019). Our results were similar to that of Kulikowska et al., (2008) 7.84 and other studies reported the pH range 8 to 9 and observed no change of the pH value after 100 days in the aerobic conditions (Bilgili et al., 2007). Suspended solids (230 mg/l) are significantly higher than the discharge

standards, but lower than the values found by Pekeyi (2024) and DAGL (2023). This gradual decrease indicates an improvement in leachate quality, probably attributable to the landfill rehabilitation works. However, it is essential to note that, despite this decrease, the Total Suspended Solid level remains significantly higher than the regulatory thresholds, which raises concerns about its potential environmental impact.

Electrical conductivity and major ions: The high conductivity (33660 $\mu\text{S}/\text{cm}$) reflected an extreme salinity confirmed by very high potassium (2000 mg/l) and sodium (6560 mg/l) contents. The very high value of electrical conductivity could be explained by a continuity of biodegradation of the waste under the cover. Consequently, the leachate becomes increasingly rich in inorganic elements. On the other hand, the basic pH is a factor favoring the dissolution of ions. In comparison with other studies, our results are similar to those reported by Chofqi et al., (2007) 16800 - 38200 $\mu\text{S}/\text{cm}$ and (MOUSTAFA, 2021) 13000-34000 $\mu\text{S}/\text{cm}$.

Ammonium ions: The ammonium concentration of 951 mg/l indicates a high nitrogen load. The presence of ammonium, an important indicator of pollution, results from the degradation of nitrogenous organic matter in a reducing environment (Amor, 2018). The high concentration in the present study comparatively to the values of previous years, indicates that the landfill cover contributed to an environment conducive to the degradation of organic nitrogen. As (Gómez et al., 2019) point out, leachates from old landfills retain very high ammonium levels, despite a decrease in the levels of some elements, confirming its persistent nature, widely documented in the literature as a persistent indicator of leachate pollution.

Organics matter (DBO5): The relatively low BOD5 at 22 mgO_2/l reveals a low fraction of biodegradable organic matter in the leachate. This situation could only indicate a stabilized (or in the process of stabilizing) leachate where the biodegradable organic matter is consumed, giving way to refractory (non-degradable or difficult to degrade) organic matter, such as humic and fulvic acids. These compounds

contribute to a high oxidizability despite the depletion of the biodegradable fraction (Han et al., 2009; Kang et al., 2002). These values would reflect a depletion of the biodegradable organic fraction, an accumulation of nitrogenous matter and a predominance of refractory organic matter.

Heavy metals: Trace metals found in the leachate are listed in Table 6. Analysis shows that concentrations are below the detection limit, suggesting stabilization of the leachate following the rehabilitation initiatives. This situation is consistent with observations made on other closed or rehabilitated sites where trace metallic elements tend to diminish over time through adsorption, precipitation and geochemical trapping. A study conducted in South Africa on leachate from a site over ten years old revealed the presence of traces of metallic elements at concentrations below detection thresholds, which corroborates our observations (Edokpayi et al., 2018). But the rapid attenuation observed in our study after two years of rehabilitation contrasts with the literature; especially since 2023, the analysis of metallic elements carried out by the DAGL revealed levels above the standards. Indeed, several studies have highlighted the persistence of heavy metals for a decade or more (Boateng et al., 2019; Kulikowska & Klimiuk, 2008). This attenuation could be explained by sorption mechanisms on the clay matrix of the landfill (presence of a clay layer at the bottom of the quarry that received the DAGL waste) (Bodjona et al., 2018). Column adsorption experiments using clay materials demonstrated that trace metal elements contained in the leachate are significantly attenuated by the adsorption and precipitation of clay in the form of sulfides or carbonates (Bright et al., 2000). Furthermore, in 2018, work by (Bodjona et al., (2018) on the clay layers underlying the Agoè landfill highlighted their role in the retention of trace metal elements via adsorption and speciation. Studies conducted in Brazil have shown that the presence of heavy metals in low concentrations in leachate is due to the fact that metals are less soluble in an alkaline environment (basic pH) (Costa et al., 2019). The low concentrations of heavy metals in the leachates could be due to the fact that the

samples were taken during heavy rainfall and therefore could have diluted the leachate (Edzoa et al., 2024). Selective extractions show that lead and nickel are found in the reducible and residual fractions respectively; Cadmium is distributed in all fractions (reducible, residual, exchangeable and acid-soluble) and zinc is more present in the exchangeable and acid-soluble fraction.

Bacteriological parameters of the leachate:

Analysis of the leachate reveals the presence of all the germs sought, with levels exceeding the recommended standards for leachate according

the table 7. The results show that the leachate is contaminated by aerobic mesophilic germs the germs at 76,000 UFC/mL. However, in comparison with the previous work of Pekeyi (2024) (760 UFC/100 mL, 130 UFC/100 mL) and the DAGL (2018; 2023) analyses, a decrease in the bacterial load (especially fecal indicators) is observed; this can be explained by the rehabilitation that stopped the new waste inputs and a probable maturation of the leachate. On the other hand, the persistence of streptococci could be due to their resistance reported in the literature.

Table 5. Physicochemical Characterization of the Leachate in comparison with the Concentrations found in previous years

Parameters	Our study	PEKEYI 2024	DAGL 2023	DAGL 2018	Rejection Standard
Temperature °C	26.5	28.1	28.4	--	≤ 35 °C
pH	7.82	7.68	8.5	8.3	5.5 – 9
Conductivity (µS/cm)	33660	15510	12030	12000	≤ 2500 µS /cm
Suspended solids (mg/L)	230	331	580	280	≤ 50 mg/l
NH ₄ ⁺	951	153.29	148.7	150.5	< 1.5
Total phosphorus	64	--	83.7	24.1	
Ca ²⁺	200	31	59	--	
Mg ²⁺	120	13.8	22	--	50
Na ⁺	6560	200	124	--	
K ⁺	2000	20	13	--	
Oxidazibility (mgO ₂ /L)	2650	829.5	410	520	< 5
DBO ₅ (mg/l)	22	572	485	405	≤ 100

Table 6. Metal composition of the leachate compared to concentrations recorded in previous years

Heavy metals	Our study	Pekeyi 2024	DAGL 2023	DAGL 2018	Standards OMS (*) - UE
Cu ²⁺	NR	Abs	212	---	2 (*) - 2
Zn ²⁺	NR	Abs	230	0.11	3 (*)
Cd ⁺	<0.0028	Abs	10.1	<0.002	0.003(*) - 0.005
Cr ⁺	<0,0054	Abs	946	---	0.05(*) – 0.05
Co ⁺	NR	Abs	30	---	
Fe ²⁺	NR	20,093	1520	1.4	0.3 (*) - 0.2
Mn ²⁺	NR	Abs	661	0.16	0.5 (*) – 0.05
As ²⁺	<0.05	0.31	6.5	<0.005	10(*) - 10
Hg ²⁺	<0.15	Abs	8.3	Sup 0.001	1(*) - 1
Pb ²⁺	<0.01	NULL	57.8	Sup 0.05	0.01(*) – 0.01
Ni ²⁺	<0.008	1.8	10	---	0.02(*) – 0.02
Ag	NR	NR			-

Table 7. Bacteriological content of the leachate

Identified germs	Aerobic mesophilic germs UFC/mL	Total Coliforms UFC/mL	Thermo tolerant Coliforms UFC/mL	sulfite - reducing Anaerobes UFC/mL	Fecal Streptococci UFC/mL	<i>E. coli</i>
Leachate	76000	20	15	12	300	2
Criteria UE	100/ml	<1/250ml	<1/250ml	<1/50ml	<1/250ml	<1/250ml

CONCLUSION

Our study conducted in the municipality of AGOE showed that a significant portion of the local population (74.4%) is familiar with leachate and that at least 76.69% are aware of the dangers of this water coming from the landfill. This study focused on monitoring leachate from a former landfill two years after its rehabilitation, specifically by determining its physicochemical and bacteriological parameters. The rehabilitation appears to indicate a maturation process of the landfill, as evidenced by certain physicochemical parameters. High conductivity reflects the mineralization of organic waste, as the high concentration of ammonia ions. Bacteriological analysis revealed the presence of harmful microorganisms capable of contaminating groundwater. Therefore, policies aimed at quality control of water sources near the landfill site and raising household awareness of health risks should be encouraged.

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