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RESEARCH ARTICLE

IMPACT OF FAECAL SLUDGE FROM THE ATTIDJIN SITE (LOMÉ) ON THE PHYSICOCHEMICAL QUALITY OF WELL WATER AND BOREHOLES

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ABSTRACT

The amount of faecal sludge entering the undeveloped site in Attidjin is changing dramatically, exacerbating pressure on water resources around the site. The aim of the study is to assess the physicochemical quality of water in four concessions near the site. Indeed, water has been collected and treated by physicochemical methods. The organic pollution index OPI for wells is 2.25 and drilling is 3.25.However, the COD/BOD_5 ratio ranges from 1.55 ± 0.34 to 2.35 ± 1.02 and exceeds 1.5 WHO values. The pH of the waters is acidic and their conductivity is very high. Metallic trace elements such as Cu, Zn, Ni and Mn have been determined and are above WHO values. For Cu, its contamination factor CF is greater than 6. The metal geoaccumulation index (Igeo) of the faecal sludge spilled is also evaluated. The results showed that Igeo de Zn is close to 2 and that of Cu is close to 1. The Attidjin site has been identified as a source of chemical groundwater pollution. The next studies will be looking at the treatment model for these faecal sludge-contaminated waters.

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INTRODUCTION

Indeed, chemical pollution of water resources remains the leading water-quality problem in Sub-Saharan Africa. This is due to the weaknesses of the networks for collecting and treating wastewater and faecal sludge in urban areas, but also to the intensive use of agricultural equipment (fertilizers, pesticides, etc.) (Pitrat *et al.*, 2012). Sludge is a real danger to the natural and environmental resources of terrestrial ecosystems (Akpaki *et al.*, 2023). Their seepage through the ground can cause problems for uninformed consumers of these well and borehole waters. Several studies of the impact of liquid effluents on groundwater quality have shown the untreated discharge of faecal sludge. In fact, in the long term, this practice risks destroying surface water, the soil that supports plants and protects groundwater by filtration of surface water (Kholtei *et al.*, 2003, Aboulkacem *et al.*, 2007). Faecal pollution of environmental waters is a major concern for the general public and can lead to serious health impacts, as well as economic and social burdens (Arvanitidoua *et al.*, 2002, Wong *et al.*, 2012). Thus, in order to assess the quality of the water supply sources for the population living near the site where the sludge was dumped in Attidjin, we measured certain physico-chemical parameters of well water and borehole samples in the concessions near the site. Since these waters are consumed and used for certain domestic purposes, a careful study of their quality is necessary.

MATERIALS AND METHODS

Sampling: At the Attidjin faecal sludge disposal site, there are a number of concessions, four of which use groundwater for domestic consumption and needs. Thus, sampling was carried out in the four homes in question. These water points are 80 to 300 m away from the dump. Two (02) different types of water were collected: well water and drilling water. Two samples of well water W1 and W2 and two samples of drilling water D1 and D2 were collected. The sampling was carried out as a function of the conditions of exploitation of the population, by drawing from the well for the well water and pumping for the drilling water (Tapsoba *et al.*, 2006). However, the pH and the electrical conductivity were determined in situ. The conductivity is determined by means of a conductivity meter coupled to a DC-411 ELMETRON thermometer. The pH is determined using a Sartorius-type pH meter.

Mineral filler: The mineral charge is expressed through the measurement of conductivity. It provides information on the total quantity of charged species present in the medium in question. A detail of the species present is given by the assay of cations (NH_4^+)

and anions (NO_2^-, PO_4^{3-}). NH_4^+ measurement: 2 mL of Nessler's reagent was added to 50 mL of the sample and the reaction was allowed to proceed for 10 minutes and the absorbance was measured at 420 nm. NH_4^+ concentration was determined based on the standard ranges (Rodier *et al.*, 2009; Cherrah *et al.*, 2010). For nitrites, the reagents used: pure ammonia (d = 0,925); 0,23 $g.L^{-1}$ standard NO_2^- stock solution; 0,0023 $g.L^{-1}$ standard NO_2^- ion daughter solution; Zambelli's reagent (Rodier *et al.*, 2009). For the measurement of orthophosphates (PO_4^{3-}), 1 mL of ascorbic acid solution was introduced into each flask, stirred and then 4 mL of reagent was added (Rodier *et al.*, 2009), mixing is done carefully, the volume has been completed to 25 mL after mixing. Then, the coloring was stabilized for 30 minutes and the measurements were made with a spectrometer at a wavelength of 700 or 800 nm in a 1 cm tank. The study of the mineral load is supplemented by the measurement of the Alkalimetric Titer (AT) and the Complete Alkalimetric Titer (CAT) which correspond respectively to the content of carbonates (CO_3^{2-}) and hydrogencarbonates (HCO_3^-). The AT and CAT assays were potentiometric. On a 25 mL (Vo) test sample, the pH is adjusted to 8 with sulfuric acid (H_2SO_4) at 0,1 N (V_1); if the pH is below 8, the AT is considered to be zero; the pH is then adjusted to 4 (V_2) to obtain the TAC. The values of AT and CAT are obtained by equations 1 and 2 respectively.

$$AT = \frac{V_1[H_2SO_4]M(CaCO_3)}{V_0} \qquad \text{Equation 1}$$

$$CAT = \frac{V_2[H_2SO_4]M(CaCO_3)}{V_0} \qquad \text{Equation 2}$$

With , M : molar mass of $CaCO_3$ ($g.mol^{-1}$)

Organic filler: The Chemical Oxygen Demand (COD) is determined by the titration method. The samples are oxidized while hot, in an acid medium, in the presence of an excess of oxidizing agent such as potassium dichromate ($K_2Cr_2O_7$). The excess $K_2Cr_2O_7$ is back-determined with a solution of ferrous ion (Fe II) or Mohr salt ($(NH_4)_2Fe(SO_4)_2,6H_2O$), in the presence of ferroin as a colored indicator (Tandia, 2007). Tintometer Oxidirect (Lovibond) was used for BOD_5 measurement.

Organic pollution index: The determination of trace metal elements in this case iron in water is carried out by flame atomic absorption spectrometry (Barty, 2007).

Organic pollution index: For the processing of data relating to the monitoring of organic pollution parameters, the organic pollution index (OPI) is useful (Leclercq *et al.*, 1987). The OPI is dependent on the ammonium, nitrite, orthophosphate and BOD_5 content of the faecal sludge (Edori *et al.*, 2016). The organic parameters of the faecal sludge are classified according to five classes (Table 1).

Table 1. Organic pollution parameter classes

Parameters →	**BOD_5**	**NH_4^+**	**NO_2^-**	**PO_4^{3-}**
Classes ↓	mg $O_2.L^{-1}$	mg $N.L^{-1}$	µg $N.L^{-1}$	µg $P.L^{-1}$
5	< 2	< 0.1	5	15
4	2 – 5	0.1– 0.9	6 – 10	16 – 75
3	5.1 – 10	– 2.4	11 – 50	76 – 250
2	10.1 – 15	2.5 – 6.0	51 – 150	251 – 900
1	> 15	> 6	> 150	> 900

OPI = mean of the class numbers of the 4 parameters (at best):
= 5.0 – 4.6 : zero organic pollution
= 4.5 – 4.0 : low organic pollution
= 3.9 – 3.0 : moderate organic pollution
= 2.9 – 2.0 : organic pollution
= 1.9 – 1.0 : very high organic pollution

The contamination factor CF is an dimensionless number calculated for each sample (j) and for each element (i) (Equation 3).

$$CF_{ij} = \frac{C_{mes}}{C_{ref}} \qquad \text{Equation 3}$$

With C_{mes} ; measured metal concentration and C_{ref} reference concentration.

Faecal sludge is classified on the basis of the CF value according to 4 classes: CF<1 low contamination factor, 1<CF<3 moderate contamination factor, 3<CR<6 considerable contamination factor, CF>6 high contamination factor. The Pollution Load Index (PLI) makes it possible to estimate the degree of overall contamination from the total concentration of all the metals studied. The pollutant load index (PLI) was calculated using equation 4.

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n} \qquad \text{Equation 3}$$

With CFi : facteur de contamination du métal i.

The Metal Pollution Index provides aggregate information on the metal pollution of the site. For PLI = 0, there is no deterioration; for PLI = 1, only the reference levels of the pollutants are present, and the value of PLI > 1 indicates a progressive deterioration of the site. Metal geoaccumulation index of faecal sludge. The metal geoaccumulation Index (Igeo) provides information on the level of metal accumulation in faecal sludge. It is evaluated from equation 5.

$$I_{geo} = log_2\left(\frac{C_m}{1{,}5 \times B_n}\right) \qquad \text{Equation 4}$$

Cm: Concentration of the element measured in the sample; Bn: Concentration of the element in a geochemical background; 1.5:constancy taking into account natural fluctuations in the content of a given substance in an environment as well as anthropogenic fluctuations. The Igeo values are used to define seven contamination level classes in Table 2 (Müller, 1981; Khaled *et al.*, 2017).

Table 2. Different classes according to Müller (1981)

Classes	**Values**	**Level of contamination**
0	Igeo< 0	Uncontaminated
1	0 <Igeo< 1	Uncontaminated to moderately contaminated
2	1 <Igeo <2	Moderately contaminated
3	2 <Igeo< 3	From moderately to severely contaminated
4	3 <Igeo< 4	Severely contaminated
5	4 <Igeo< 5	From severely contaminated to extremely contaminated
6	5 <Igeo	Extremely contaminated

The geochemical background value Bn taken is considered from the global shale mean value ($mg.kg^{-1}$) of the metals determined in the study. The values are Zn=95, Cu=45, Ni=68, Mn=850 (Müller, 1981, Edori *et al.*, 2016; Akpaki *et al.*, 2023).

RESULTATS

Organic pollution parameters: The organic pollution index OPI was calculated from the chemical parameters DBO_5, NH_4^+, NO_2^- et PO_4^{3-} (Table 3).The analysis in Table 3 shows that NO_2^- concentrations in wells W1 and W2 are 296.21 ± 21.14 and 203.05 ± 7.34 µg $N.L^{-1}$, respectively, which are above the WHO standard of 100 µg $N.L^{-1}$. It is also noted that BOD_5 values for these two wells are also above the WHO standard of 20 mg $O_2.L^{-1}$.

pH and electrical conductivity : The pH values are respectively 6.37 ± 0.09 and 6.41 ± 0.04 for wells W1 and W2 and 5.6 ± 0.07 and 6.29 ± 0.05 for boreholes D1 and D2 (Figure 1). It can be observed that the pH of water sources does not comply with WHO standards (6.50 < pH < 9.00) (O.M.S., 2006). Electrical conductivity gives an idea of the mineralization of a water and as such it represents a good marker of the origin of a water. The WHO recommended maximum electrical conductivity of drinking water is 2000 $\mu S.cm^{-1}$. It is noted that the electrical conductivity values recorded on the four (4) water samples studied are respectively 2975.23 ± 103.03 and 2281.06 ± 147.57 µS/cm for wells W1 and W2 and 210.41 ± 113.37 and 858.67 ± 121.61 $\mu S.cm^{-1}$ for both boreholes D1 and D2 (Figure 2).

Metal pollution: The work showed that the faecal sludge at the Attidjin site contains copper (Cu), nickel (Ni), zinc (Zn) and manganese (Mn) (Akpaki *et al.*, 2023).

Tables 3. Organic pollution

Samples	BOD_5 mg O_2.L^{-1}	NH_4^+ mg N.L^{-1}	NO_2^- µg N.L^{-1}	PO_4^{3-} µg P.L^{-1}	OPI
W1	47.10 ± 2.07	0.062 ± 0.02	296.21 ± 21.14	487.02 ± 15.31	2,25
W2	32.26 ± 1.04	0.045± 0.05	203.05 ± 7.34	368.36 ± 10.27	2,25
D1	5.07 ± 0.34	0.012± 0.01	86.60 ± 3.55	259.57 ± 12.10	3,25
D2	8.34 ± 0.17	0.07± 0.01	125.57 ± 1.78	195.08 ± 6.55	3,25

pH and electrical conductivity

Table 4. Contents of Cu, Ni, Zn and Mn in Water

TME (mg.L^{-1})	W1	W2	D1	D2	WHO
Cu	14.24 ± 0.02	21.31 ± 0.60	4.91 ± 0.23	2.87 ± 0.12	2
Ni	1.32 ± 0.01	2.50 ± 0.10	0.42 ± 0.14	0.06 ± 0.01	0.02
Zn	11.03 ± 3.10	8.25 ± 2.02	4.34 ± 1.08	3.74 ± 0.02	3
Mn	5.14 ± 0.41	2.34 ± 1.31	0.74 ± 0.01	0.51 ± 0.01	0.4

Table 5. Geo-accumulation index(I_{geo}) (Akpaki *et al.*, 2023)

MTE	Facteur de contamination (I_{geo})		
	PL	DST	PST
Cu	0.74	1.09	1.07
Ni	-2.81	-2.77	-2.97
Zn	2.62	2.77	2.57
Mn	-2.19	-2.16	-2.11

PL: faecal sludge of pit latrine; DST: faecal sludge of domestic septic tank;
PST: faecal sludge of public septic tank

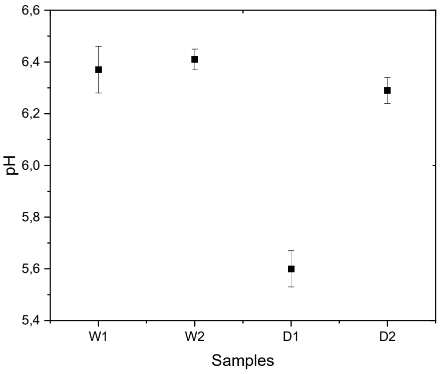

Figure 1. Water pH

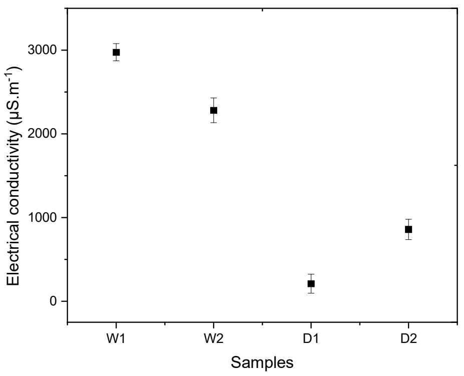

Figure 2. Electrical conductivity of water

The four (4) elements were also found in the four water samples that were the subject of this study (Table 4). The presence of these trace metals (TME) in these waters may be linked to their infiltration as the Attidjin site is a former sand mining quarry. So the infiltration of pollutants into water bodies is obvious. The analysis in Table 4 shows that the four (4) water samples have concentrations of Cu, Ni, Zn and Mn above the WHO standard for trace element levels.

Contamination index: The geo-accumulation index (Igeo) values of trace metal elements in the three types of faecal sludge discharged daily into the Attidjin site are presented in Table 5.

DISCUSSION

The waters of the two wells W1 and W2 are very concentrated in nitrite (Table 3). In addition, their contamination factor is 1< CF <3, which expresses a moderate contamination of nitrite ion. But with long-term exposure, water users are at risk from nitrite poisoning. The poor quality of these waters is confirmed by high nitrite (NO_2^-) concentrations, as the nitrite ion contents of the water sources analyzed are above the WHO standard except drilling 1. This nitrogen pollution from these waters would probably be due to these urban discharges (El-Haj *et al.*, 2012).

Thus, it can be said that the presence of nitrite and ammonia ions in these drinking waters near the site is a direct consequence of the discharges of faecal sludge, since they contain significant amounts of these ions. However, nitrites are a public hazard because if ingested, they attach to hemoglobin instead of oxygen and cause difficulty breathing (asphyxia)—methemoglobinemia (cyanosis) (Barhéa *et al.*, 2013) which affects mainly infants (born or pregnant) and poses a short-term risk. The calculation of the organic pollution index OPI gives for the two wells W1 and W2 a value of 2.25, which corresponds to an organic pollution (2.0<OPI<2.9). As regards the two boreholes D1 and D2, OPI is equal to 3.25 corresponding to a moderate organic pollution. Thus, it can be said that the organic pollution of these waters is due to an exogenous input, hence to the infiltration of the leachates from the faecal sludge deposited at the Attidjin site. Next, the COD/BOD_5 ratio for the four (4) sources of water near the site is between 1.55 ± 0.34 and 2.35 ± 1.02, thus exceeding 1.5 the WHO value(O.M.S., 2006). This result thus shows the presence of a large proportion of biodegradable materials in these waters and a biological treatment can be envisaged (El-Haj *et al.*, 2012). However, the composition of the waters may have an effect on the composition of the by-products formed during its disinfection (Touron *et al.*, 2007). However, water pH measurement gave values below 7 (Figure 1). So, the waters are acidic and would be very aggressive for the stomach when consumed. And the results show that the conductivities recorded are quite high in the waters. However, these values are much higher than the WHO value. This is justified by a strong mineralization of these waters. These results confirm the mineral, aggressive and harsh nature of these waters. This can lead to the production of calcium bicarbonate ($Ca(HCO_3)_2$) precipitate or scale by temperature rise, (Barhéa *et al.*, 2013). The Cu contamination factor for the 2 wells is greater than 6, which shows a high contamination. However, the contamination is moderate for the other 3 elements Ni, Zn and Mn with their contamination factor which is $1 < CF < 3$ in the 4 water samples studied. The process of accumulating these elements in the waters poses enormous risks to consumers. The Igeo index remains close to 2 for Zn and 1 for Cu. These values are characteristic of anthropogenic pollution, which indicates a source of pollution of high intensity. However, the pollution load index PLI gives 0.51; 0.37, 0.54 and 0.29 for Cu, Ni Zn and Mn respectively (Akpaki *et al.*, 2023). These PLI values show that these metal elements can cause progressive deterioration of the site. And if faecal sludge continues to spill in this area, it could further impact surface and groundwater quality. As the site remains operational, the process of accumulating trace metal elements continues. It can be concluded that the Attidjin site is a source of continuous chemical pollution of water sources.

CONCLUSION

The study found that the water from wells and boreholes around the Attidjin site is of poor quality and can cause water-borne diseases. The results showed that the waters are acidic with a $pH < 7$. As regards organic pollution, it is noted that $2 < IPO < 2.9$ for wells and $3 < IPO < 3.9$ with a COD/BOD_5 ratio > 1.5. Results corresponding to anthropogenic pollution with a contamination factor $CF > 6$. Secondly, the geoaccumulation index metallic Igeo showed that the faecal sludge dumped on the site is a source of considerable contamination. The pollution load index PLI in the faecal sludge of trace metal elements Cu, Ni Zn and Mn is $0 < PLI < 1$. This shows that faecal sludge at the site is the only reference level for pollutants.

In this way, water pollution is more anthropogenic than natural. However, future work will focus on a tailored treatment model.

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Conflict of Interest: The authors declare that there are no conflicts of interest.

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