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Bacteriological Vulnerability of Surface and Underground Waters in a Faecal Sludge Disposal Area in Dschang, Cameroon

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ABSTRACT

The management of faecal sludge is a real problem for policy makers in developing countries. Liquid waste is being dumped in green spaces at the risk of polluting the groundwater table or surrounding water sources. The objective of this study is the bacteriological characterization of the different water sources affected by faecal sludge around the Central Prison of Dschang (Western Cameroon). Thus, four composite samples of faecal sludge and 18 water samples were taken for physicochemical and microbiological analyses. The Biochemical oxygen demand (BOD) was determined by the incubation method and bacteriological analysis was done by counting the total aerobic mesophilic flora on specific media. The main results showed that the sludge has an average BOD_5 of 2153.75 and a COD of 2505 mg/l with a pH and organic matter of 7.62 and 18.66, respectively. Pathogens in sludge for faecal coliforms (FC), E-coli, total coliforms (TC) and faecal streptococci (FS) counts (CFU/100 ml) stand at 18750, 15000, 526250 and 501050, respectively. The pit waters show significant variations in CF, E-coli, TC and FS of 12000-25000; 3000-17000; 20,000-728,000 and 22,000-36,000 CFU/100ml, respectively. These variations decrease in well water, notably between 6000-8000, 1000-2000, 5000-10000 and 5000-10000 CFU/100ml for CF, E-coli, CT and SF, respectively. On the other hand, river waters show variations of CF, E-coli, CT and SF of 8000-24000; 4000-11000; 2000-85000 and 1000-4000 CFU/100 ml, respectively. The water faecal contamination index (FCI) is high. The principal component analysis shows a very strong correlation between the properties studied. These results reveal that the discharge of sludge into the environment affects the water tables circulating at shallow depths on the site, but also the river and household water wells downstream, constituting a health risk for the population.

1. Introduction

The management of faecal sludge in Africa is a real problem for policy makers. In Cameroon, the problem is most noticeable in rural areas where sanitation coverage is very low. This is the case of the town of Dschang in western Cameroon, which does not have a treatment plant for faecal sludge and is helplessly watching its liquid waste being dumped in green spaces at the risk of polluting the groundwater table or surrounding water sources. This is the case at the main prison in Dschang, which discharges its sludge from the pits directly into the environment. The sludge passes through an agricultural area to the point of discharge, which is a river that serves several neighbourhoods below as its main water source.

Faecal sludge can also be a great environmental hazard in terms of its physico-chemical properties (Defo et al., 2015; Kone et al., 2016; Ndiaye et al., 2018) and is likely to be high in pathogens (Ndangang, 2019; Kra et al., 2020) as well as trace metals (Mercier, 1988; Richard, 2008; Abdessamad, 2022). The World Water Conference in Mar del Plata, Argentina, and the Millennium Development Goals adopted by the United Nations (UN) General Assembly in 2000 emphasise water quality, sanitation and hygiene, and the health risks that can result from them.

Furthermore, conferences on water and sanitation such as Marrakech in 1997, The Hague in 2000, Kyoto in 2003, Mexico City in 2006 and Senegal in 2012, show the magnitude of the problem for developing countries that are struggling to find effective strategies for sludge management. But the composition of faecal sludge can vary from one environment to another (Ndiaye et al., 2018). It is therefore important to study some of the physico-chemical, bacteriological and trace metal parameters contained in faecal sludge and groundwater. The main aim of this work is to study the impact of faecal sludge on water sources. The results obtained will help to establish a better policy in terms of liquid waste sanitation and, in particular, better protection of water tables, which are essential for people's lives.

2. Materials and Methods

2.1. Study Site

Dschang is the Headquarter of the Menoua Division and covers a surface area of 262 km^2. It is located between lattitudes 5 ° 10' and 5 ° 38' N, and between longitudes 9 ° 50' and 10 ° 20' E. The climate is the Cameroon altitude climatic type (Equatorial monsoon), characterized by one shorter dry season of five months (mid-November to mid-March) and one longer stormy season of nine months (mid-March to mid-November). The average annual rainfall is 1750 mm and the mean annual temperature is 22.5°C (IRAD, 2000).

The vegetation is grassland, wooded savannah and mountain forests. The zone is drained by a fifth order stream (Menoua River), through the contribution of many streams that take their rise from the high elevation zone of the southern slopes of Mount Bambouto (Cameroon Western highlands). The average altitude is 1500 m above sea level. The main soils are Oxisols at the midslopes, Gleysols at the swampy lowlands, and lithosols at the hilltops. The main activity of the inhabitants is agriculture as well as commercial activities. Arts and crafts also play an important role in the economy of the area. This includes beautiful traditional regalia, jewelries, ceramics and cotton textiles often featuring elaborate embroidery. The basement rocks in Dschang consist of Neoproterozoic granite-gneiss, Late Proterozoic granitoids intruded within the granite-gneiss and basaltic dykes that outcrop in the two previous units.

Located in the Menoua Division, the Central Prison of Dschang (Fig. 1) in the study area (altitude 1382 m), has septic tanks (open at the base) that receive faeces from outside the prison. These faces are evacuated across an agricultural field to a river running nearby, which falls further down into a basin where there are dwellings with wells about 5 metres deep as a water source. It should be noted that this practice of disposing of prison sludge in the open has been going on for over 10 years. The geomorphology of the study area favours the constant presence of water which outcrops in the vicinity of the ground surface.

2.2. Methodology

2.2.1. Sample Collection

In order to homogenise and have representative composite samples, the faecal sludge is collected sequentially from the bottom of the pit where it exits, then in the flow channel halfway down and at the end close to the contact with the river. The samples were collected in 1 litre plastic bottles, sterilised for microbiological analysis and packed in a cooler. A total of 4 composite faecal sludge samples are taken for bacteriological and trace metal element (TME) analysis at the laboratory.

Groundwater samples are taken after 60 cm depth (as water circulates at shallow depths) on the agricultural area where the faecal sludge flows, notably on the valley, and as one moves away from the valley to the other bank opposite, which is an area not affected by faecal. In addition, river water samples are taken at the point where the sludge falls into the river, halfway down the river and further down the escarpment waterfall. Further downstream, near the houses, water samples are taken from three wells in the area. All the water samples were taken in duplicate in sterilised 500 ml glass bottles and packed in a cooler for those to be used for microbiological analysis on the one hand and for the determination of TMEs on the other and acidified with 2% of a few drops of nitric acid. A total of 18 water samples were taken, including 12 groundwater samples (6 samples from under the agricultural area where the BVs flowed and 6 well water samples) and 6 surface water samples (river).

2.2.2. Laboratory Analysis

The physico-chemical analysis of the sludge, in particular the measurement of pH, was carried out in accordance with the international standard ISO 10390 (ISO, 1994). The pH and Electrical Conductivity (EC) of the water are measured with the multi-parameter HACH HQ40d, this method was in accordance with the AFNOR 90 008 standard. The determination of Suspended Solids (SS) was done by gravimetry after vacuum filtration with a GF/C glass microfibre filter and oven drying at 105 ±2°C, in accordance with the French standard NF 90-105. The measurement of the chemical oxygen demand was done by the "reactor digestion" method. After homogenisation of the sample, 2 ml of sample were introduced into COD tubes with a range of 0 to 15000 ppm containing a mixture of potassium dichromate and concentrated sulphuric acid with silver sulphate as an oxidising catalyst, then incubated in the presence of a control at 150 °C for 2 hours in a Hach COD reactor (multi-tube heating apparatus). The COD value of each basin was then read, after cooling the tubes in the Hach DR/3900 spectrophotometer. The five-day BOD_5 of the sludge was determined by the five-day incubation method in the dark at a temperature of 20 °C using a "LovibondOxiDirect" apparatus. Ammoniacal nitrogen (NH_4^+), nitrate (NO_3^-), and orthophosphate (PO_4^{3+}) were determined by the colorimetric method with a Palintest 7100 spectrophotometer reading at the appropriate wavelengths. The concentrations of sulphates (SO_4^{3-}) were determined volumetrically (AFNOR, 1987).

Orthophosphates (PO_4^{3-}) are determined by calorimetric methods using a spectrophotometer. The BOD_5 in the water was determined using a BOD meter (WTW D 82362 Weilheim). The technique used to determine the total organic carbon content of the sludge was that of Walkley and Black (1934). The cation exchange capacity (CEC) and the exchangeable bases (SEB) are determined using the Metson method.

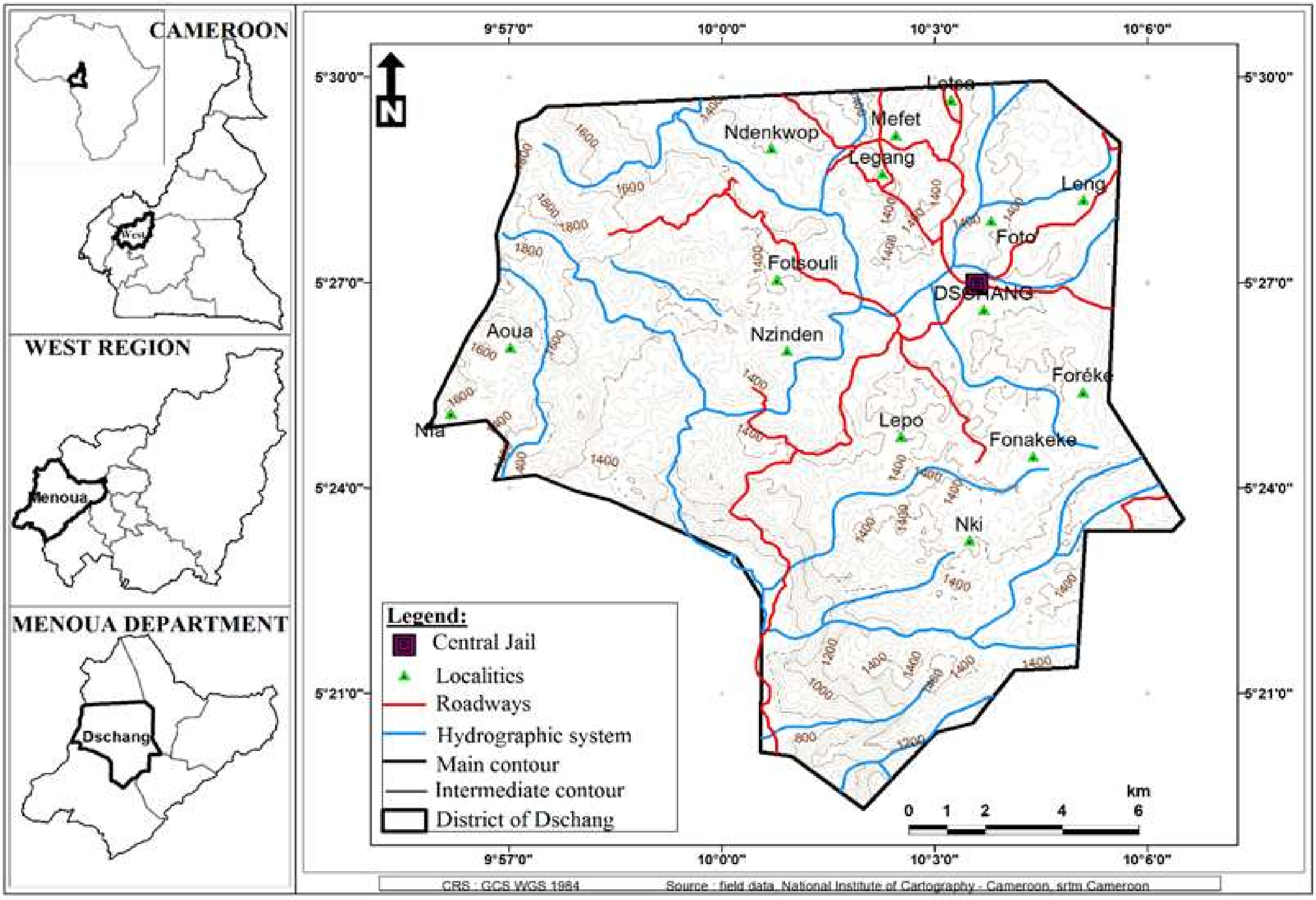

Fig. 1. Location of the central prison in the city of Dschang, Cameroon

The bacteriological analysis in water and sludge concerns the following elements: FS, FC, TC, Escherichia coli. During the analysis, a cellulose ester membrane with a porosity of 0.45 µm was used to sterile filter 100 ml of the sample of water/drainage sludge to be analysed or a dilution of it by means of a filtration device connected to a vacuum tube (Havelaar et al., 1987; Ford, 1994).

Aerobic bacteria were tested by spreading 10 µL and 100 µL of a dilution of the sample. The enumeration of total aerobic mesophilic flora, total and FC, then E. coli, and FS was carried out on Plate Count Agar (PCA), Tergitol TTC medium, Slanetz and Bartley medium, Thiosulphate-Citrate-Bile-Saccharose (TCBS) agar, Salmonella-Shigella (SS) agar, and ketrimide agar, respectively (Guiraudand Galzy, 1980; Havelaar et al., 1987). A FCI (Orou et al., 2016) was determined from the indicator germs of faecal contamination (faecal coliforms (FC), Escherichia coli (EC or E. coli), Faecal Streptococci (FS) according to the equation: FCI = EC + FS + FC. Table 1 shows the concentrations of bacteriological elements by class.

The FCI is the sum of the class numbers of the three (03) variables as mentioned in the previous equation and the grid for the degree of fecal contamination of the waters is as follows (Table 2).

2.3. Statistical Analysis

Statistical analysis was carried out using the XLSTAT statistical software, in particular the Pearson correlation (n) between the physico-chemical properties and the bacteriological parameters.

3. Results and Discussion

3.1 Physico-chemical Characteristics

The faecal sludge from Dschang Central Prison has the physico-chemical properties listed in Table 3. The organic matter content of the sludge of an average of 18.66 indicates the richness of the sludge in biodegradable matter. The pH of the sludge obtained varies between 7.8 and 7.4, which are values compatible with the development of the bacteria that purify the sludge. Indeed, the pH can be a limiting factor for the development of purifying bacteria.

These bacteria generally develop at pH levels between 5 and 9 (Kone et al., 2016). Similar studies in Cameroon show different results, for example Defo et al. (2015) found a pH of 7 in the city of Bafoussam, whereas Maffo et al. (2019) in Douala found an average pH value of 6.6. The EC of the sludge varies between 2841 and 2109 µS/cm as shown in Table 1. This indicates that the sludge is highly mineralised, but still fermentable.

These results probably confirm that there is a high presence of mineral salts in the medium. The degradation of organic nitrogen to ammonium (NH_4^+) is an integral part of the nitrogen cycle in nutrient production. The ammonium levels (861.5 mg/l) found in this study could be explained by the quality of the structure (which is a septic tank with several communicating compartments) but also by the length of time the sludge has been in the tanks. In an anaerobic environment, ammonium production is favoured and the longer the sludge is stored, the greater the mineralization.

Furthermore, the nitrate content (between 34.5 and 25.6 mg/l) indicates a good nitrification process during sludge dehydration, but does not comply with the discharge standard, thus justifying a risk of pollution of surface water and groundwater by the pollutant-laden percolate from the sludge (Josse et al., 2016; Nyenje et al., 2010; Baaissa et al., 2022; Rajmohan and Elango, 2005). The COD and BOD_5 show average values of 2505 and 2153.75 mg/l respectively.

Table 1. Classification of concentrations of water variables by class (Orou et al., 2016)

Variables	Classes			
	1	2	3	4
EC	0	> 0 et ≤ 20	> 20 et ≤ 20000	> 20000
SF	0	> 0 et ≤ 20	> 20 et ≤ 10000	> 10000
CF	0	> 0 et ≤ 20	> 20 et ≤ 50000	> 50000

Table 2. FCI degree grid for water (Orou et al., 2016)

Classes	Calculated value	Pollution index
1	0 <FCI ≤ 3	No contamination
2	3 <FCI ≤ 6	Moderate faecal contamination
3	6 <FCI ≤ 9	Heavy faecal contamination
4	9 <FCI ≤ 12	Excessive or heavy faecal contamination

Table 3. Physico-chemical properties of faecal sludge

	Physico-chemical								
	OM	pH	SEB (mg/l)	EC (uS/cm)	NH4 (mg/l)	NO3 (mg/l)	PO4 (mg/l)	OCD (mg/l)	BDO5 (mg/l)
Data size (n)	4	4	4	4	4	4	4	4	4
Mean	18.668	7.625	5.114	2530	861.5	30.52	18.25	2505	2153.75
Maximum	18.7	7.8	5.122	2841	1057	34.5	24	2700	2500
Minimum	18.63	7.4	5.101	2109	534	25.6	14	2320	1760
Coef of variation (%)	0.16	2.24	0.182	12.128	26.782	12.05	22.977	7.002	14.156

Kone et al. (2016) in Zagtouli (Burkina Faso) found COD to be 1950 mg/l and 785 mg/l for BOD_5, a lower value than in this study. The ratio of average COD and BOD_5 is 1.16, which indicates the biodegradable nature of faecal sludge and can guide the future choice of appropriate biological treatment technology. Furthermore, the value of this ratio also indicates that mineralisation is continuing (Degrémont, 2005).

In view of these results, it is logical to assume a negative impact on water. Thus, one of the nutrients often responsible for eutrophication of watercourses, nitrate concentrations, has an average of 86.50 mg/l for groundwater and 116 mg/l for surface water.

Fig. 2 shows a variation of nitrates in the studied waters; thus, nitrates are very abundant in the groundwater sampled through the pits made in the sludge flow area but as one moves away from the sludge flow the contents decrease (WP1, WP2 and WP3). Groundwater WP1, WP2 and river water RW1, RW2, RW3 have values well above the WHO standard. The well water (WW1, WW2 and WW3) used by households has levels below 50 mg/l.

These results indicate significant pollution in the groundwater in the flow area and in the rivers where the sludge falls directly. There would be an infiltration of the nitrate laden leachate into the soil to the shallowly flowing groundwater. These results are very high compared to those of Foka et al. (2018) and Mufur et al. (2021). However, they are close to Poromna et al. (2022). Thus, the presence of nitrate may be a source of concern as consumption of high nitrate water can cause blood disorders (called methaemoglobinaemia) as well as cancer in humans (Palamuleni and Akoth, 2015).

The pH of the different water sources oscillates around 6 (Fig. 3). It is comparable to that of Foka et al. (2018) but lower than that of Kashtanjeva et al. (2022) as well as some works carried out in Cameroon such as Boeglin et al. (2003) in the

Nsimi catchment area (South Cameroon) who finds a lower pH with values ranging from 4.7 to 4.9, while Abendong et al. (2019) records average pH values of 5.71 from groundwater samples in Bamenda. On the other hand, Mufur et al. (2021) obtained weakly acidic to neutral pH values ranging from 5.3 to 7.1 in Melong. It is noted that the pH follows the same trend as the EC which is below the WHO standard (500 uS/Cm) in the different water sources.

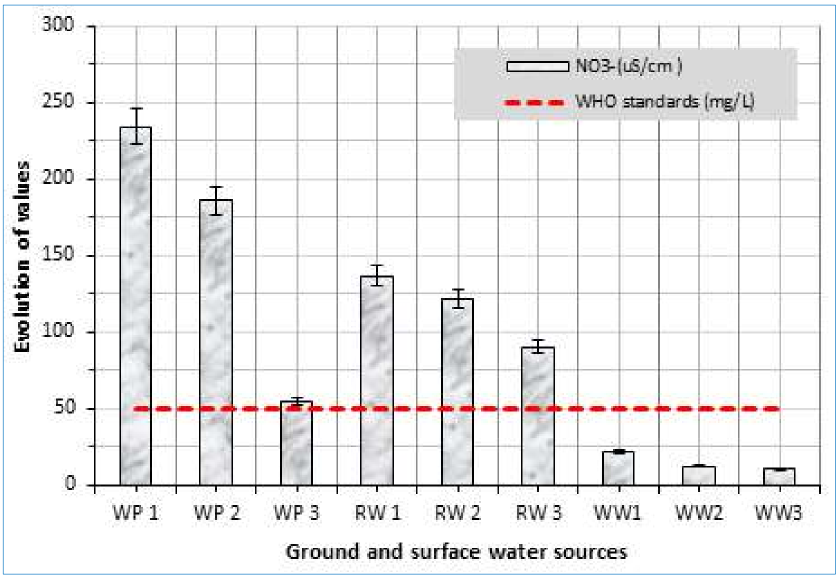

Fig. 2. Variation of nitrate in different water sources

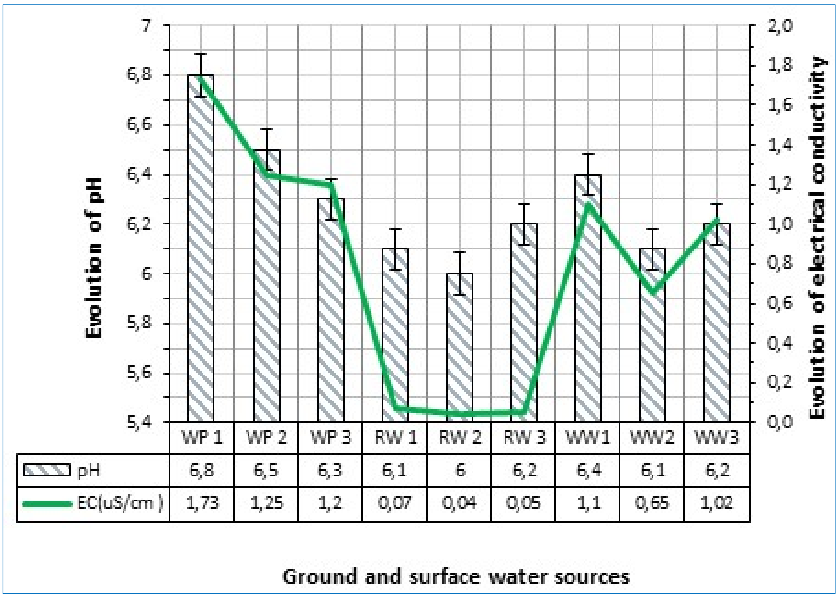

Fig. 3. Variations in pH and EC in different water sources

According to Foka et al. (2018), groundwater can be acidic or alkaline depending on several factors. For example, acidic because raindrops react with atmospheric CO_2, generating acidic rainwater that seeps through decaying organic matter to the groundwater. The characterization of pH is important because biological activities can thrive and survive at certain pH levels (McFarland et al., 2008; Trivedi et al., 2010). One explanation for these observations in this study is that the soil is poor in limestone or dolomite, resulting in pH values around 6 (McFarland et al., 2008). Suspended solids and chloride ions are high in the water profiles (Fig. 4), reflecting the impact of the sludge by the leachate which would have infiltrated the soil to the water table. This also explains why turbidity is very high in this area and low in river and well water.

3.2. Bacteriological Characteristics

The analysis of the faecal sludge shows a significant presence of pathogenic germs (Table 4), in particular FC and FS with respectively averages of 18750 and 501050 CFU/100ml, as well as total coliforms and Escherichia coli with respectively averages of 526250 and 15000 CFU/ml.

The results, although significant, are different from those obtained by Kone et al. (2016) in Zagtouli and show the great variability of the bacteriological characteristics of the sludge from one context to another, which can be justified by several factors, among which the feeding mode, the type of structure receiving the sludge, without forgetting the physico-chemical parameters that contribute to the development of bacteria.

These pathogenic germs were also found in the different water sources studied (Fig. 5). Thus, in the water from the pits at a depth of 60 cm, we found FC varying between 12,000 and 25,000 CFU/100 ml, E-Coli between 3,000 and 17,000 CFU/100 ml, very abundant total coliforms varying between 20,000 and 728,000 CFU/100 ml and FS between 22,000 and 36,000 CFU/100 ml. A slight drop in these levels is observed in the river waters, which have a variation in CF, E-Coli, CT and SF levels between 8,000 and 24,000 CFU/100 ml; 4,000 and 11,000 CFU/100 ml; 2,000 and 85,000 CFU/100 ml; and 1,000 and 4,000 CFU/100 ml respectively. These levels drop further in well water located lower down the escarpment where the river water falls. The levels of CF, E-Coli, CT and SF in the well water vary between 6000 and 8000 CFU/100 ml; 1000 and 2000 CFU/100 ml; 5000 and 10000 CFU/100 ml; also 5000 and 10000 for FS.

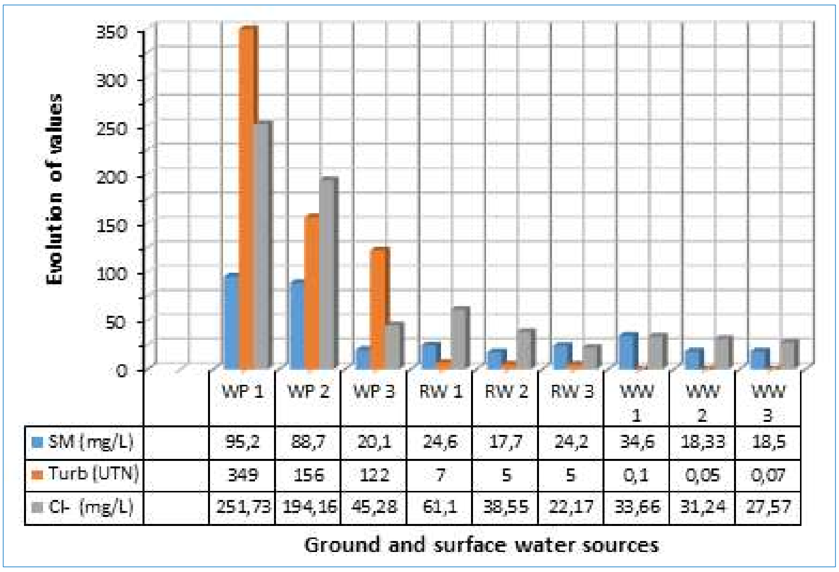

Fig. 4. Evolution of suspended solids, turbidity and chloride ions in water sources

Table 4. Microbiological properties of faecal sludge

	Microbiological			
	CF UFC/100ml	*E-Coli* UFC/100ml	CT UFC/100ml	SF UFC/100ml
Data size (n)	4	4	4	4
Mean	18750.000	15000.000	526250.000	501050.000
Maximum	25000.000	20000.000	602000.000	633000.000
Minimum	14000.000	10000.000	455000.000	420000.000
Coef of variation (%)	25.900	31.740	11.914	18.323

The presence of E. coli bacteria in water is usually a result of the presence of humans and warm-blooded organisms in the area. This bacterium is considered the best FCI and therefore these waters may contain pathogenic microorganisms (Vaurette and Le Duc, 2014).

FS are also mainly intestinal bacteria but less numerous in faeces (Farrow and Collins, 1984). In water, FS do not multiply but disappear rapidly like E. coli and especially faster than other coliforms. Therefore, the characterisation of FS in water samples is a sign of recent FC and is an excellent confirmation of FC as they are not very sensitive controls (Vaurette and Le Duc, 2014). The presence of thermotolerant coliforms in water does not necessarily indicate FC or a health risk, but rather a degradation of the bacterial quality of the water. These bacteria are of faecal and environmental origin as they are naturally found in soil and vegetation.

This degradation can be attributed to surface water infiltration into the well or to the progressive development of a layer of bacteria on the walls called "biofilm" (Orou et al., 2016). Their presence gives information on the possible vulnerability of a well to surface contamination (Vaurette and Le Duc, 2014). These wells are characterised by water with high levels of bacteria of faecal origin. This lack of maintenance results in unbored or unprotected wells. These observations are identical to those of Bengoumi et al. (2015), Orou et al. (2016) and Abuzerr et al. (2019), where the lack of maintenance of the wells has led to high levels of water contamination.

FCI varies between 8 and 9 with an average of 8.66. The analysis of Table 5 and Fig. 6 shows that all the water sources studied belong to one class and therefore have high faecal contamination. The groundwater as a whole and river water are therefore not recommended for human consumption, provided that they receive prior treatment. More specifically, well water must be treated according to drinking water standards before any type of use. These results are comparable to those of Orou et al. (2016) and Poromna et al. (2022) on certain water sampling points.

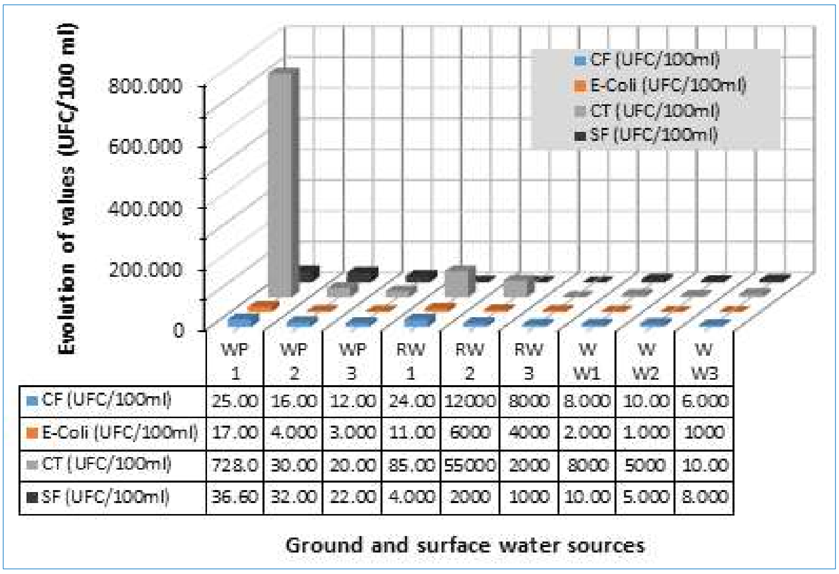

Fig. 5. Evolution of pathogenic germs in water sources

Table 5. Basic statistics and distribution of FCI according to classes

	Min	Max	Mean
Values FCI	8	9	8,66
Classes FCI	**Class type**	**Size**	**% size**
0 < FCI ≤ 3	No fecal contamination	0/9	0%
3 < FCI ≤ 6	Moderate faecal contamination	0/9	0%
6 < FCI ≤ 9	Heavy faecal contamination	9/9	100%
9 < FCI ≤ 12	Excessive or heavy fecal contamination	0/9	0%

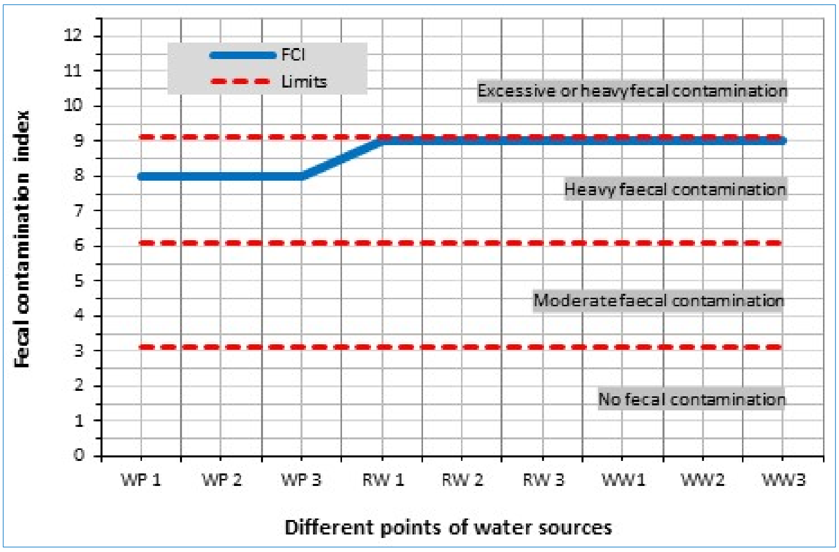

Fig. 6. Evolution of the FCI according to the different water sources

This high faecal contamination of the water sources in this study can be explained by the proximity of the water table to the soil surface, which sufficiently increases the risk of pollution. In addition, the depths of the water wells are also very shallow, averaging 1.5 metres, and they are located close (about 6 metres) to the river where the pollutant-laden faecal sludge falls and stagnates in the water wells. This could lead to another explanation, namely the lithological nature of the rocks making the aquifers vulnerable. The high number of these bacteria indicates that this faecal contamination is permanent and continuous due to a permanent hydraulic communication between the wells and the river water, which is loaded with faecal sludge, as it should be remembered that the river is the main means of transporting the sludge from the prison, where it has been flowing all day long for several years.

These observations can be compared to those of Aka (2013) in Abengourou, where the presence of Escherichia coli in 28% of the wells was shown to be polluted by human or animal waste. The work of Soncy et al. (2015) in Lomé, Togo, indicated that well water is characterised by a higher level of faecal contamination than borehole water. In Niamey, Niger, Chippaux et al. (2002) attributed faecal pollution of groundwater to various causes: lack of sanitation and collection of household waste, transfer of pollutants from surface layers, drawing conditions and structure of installations.

3.3. Correlation Between Physico-Chemical Properties and Bacteriological Characteristics of Water

The results of the correlations and principal component analyses for the physico-chemical and bacteriological elements are presented in Table 6 and Figs. 7-8. These results show that all the elements studied are correlated (Fig. 7), particularly between the physico-chemical properties, which are globally strongly correlated except for EC, and the bacteriological parameters, which are also strongly correlated except for the SF and E-Coli, which are less strongly correlated. Dimensions 1 and 2 of the principal component analyses explain 86.61% of the variation in the results obtained (Fig. 7) indeed 2 eigenvalues respect the Kaiser criterion because > 1. Namely the first percentage of inertia (71.31%) for an eigenvalue of 9.27 and the second percentage of inertia (15.30%) corresponding to an eigenvalue of 1.98 (Fig. 8).

Table 6. Pearson correlation between physico-chemical properties and bacteriological

	pH	SM	Turb	EC	NO^-_3	Cl^-	BOD_5	FC	E-Coli	TC	FS
pH	1										
SM	0.886	1									
Turb	0.883	0.853	1								
EC	0.851	0.664	0.737	1							
NO^-_3	0.568	0.795	0.748	0.201	1						
Cl^-	0.849	0.971	0.918	0.644	0.857	1					
BOD_5	0.777	0.695	0.871	0.569	0.656	0.780	1				
FC	0.442	0.588	0.648	0.177	0.824	0.713	0.640	1			
E-Coli	0.508	0.569	0.695	0.166	0.831	0.691	0.823	0.905	1		
TC	0.743	0.687	0.862	0.521	0.699	0.785	0.995	0.702	0.872	1	
FS	0.894	0.877	0.921	0.862	0.623	0.890	0.652	0.506	0.442	0.635	1

SM (mg/L); Turb (UTN); EC(uS/cm); NO_3-(uS/cm); Cl^- (mg/L); BOD_5(mg/L); FC (UFC/100ml); E-Coli (UFC/100ml); TC (UFC/100ml); FS (UFC/100ml)

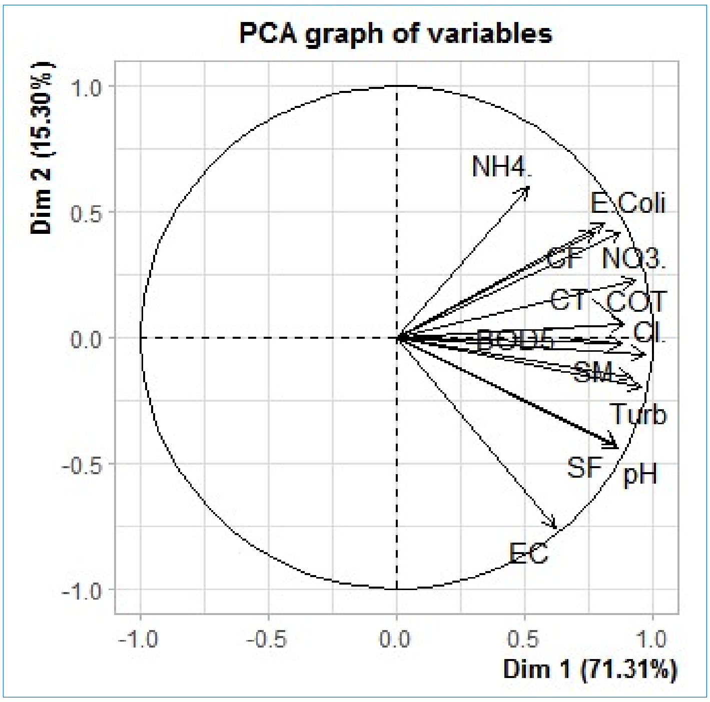

Fig. 7. Principal component analyses between physicochemical properties and bacteriological parameters

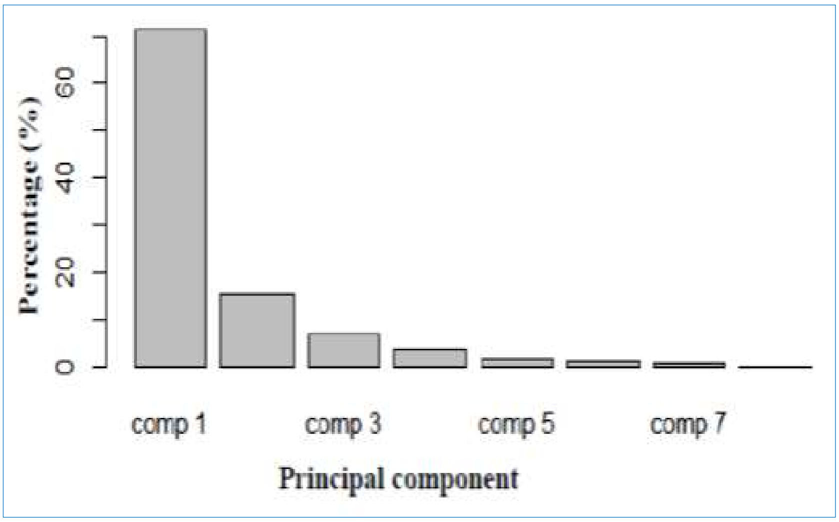

Fig. 8. Percentage of inertia associated with each dimension of the principal component analyses

Thus, the results are mainly explained by the first dimension (71.31%) which shows a strong correlation between the physico-chemical and bacteriological parameters (Table 6 and Fig. 7). The EC is weakly correlated with NO_3^-. FC and E-coli. Also, NH_4^+ shows a weak correlation with other parameters such as BOD_5 and chloride ion which tend to form a right angle because they are very distant, but it shows a good correlation with NO_3^- or some bacteriological parameters such as FC, E. Coli. Indeed, the EC and NH_4^+ are closer to the axis of the second dimension which explains the results at 15.30% of the second percentage of inertia.

4. Conclusion

The aim of the study was to assess the impact of the discharge of faecal sludge on groundwater and surface water. The main results of bacteriological analyses show that water sources close to the faecal sludge flow are highly polluted, compared with sources further away. The same is true of the physico-chemical parameters studied, which also reveal a high level of pollution in the water sources. This pollution was confirmed by the FCI, which evaluates it as highly polluted. It should therefore be noted that there is a great risk of its use by the population which is exposed to water-borne diseases. It is recommended that the population treat the water from the wells before any use and above all that the penitentiary adopt a better policy for managing its liquid waste.

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Competing Interests

Authors have declared that no competing interests exist.

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