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Physico-Chemical and Microbiological Pollution of Wells Water in the Commune of Segou in Mali, 2017

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ABSTRACT

A descriptive and analytical study on the drinking water supply was carried out on a population of 115 wells in the commune of Segou in Mali, respectively selected by simple random sampling in overall households. The objective of this work is to evaluate the level of pollution of wells water consumed by the population of the Commune and its link with health. The physico-chemical and microbiological pollution of the wells has been studied. The wells were heavily polluted by nitrites, nitrates, aluminum, total iron, cadmium, and mercury which are 26.96%, 13.04%, 12.17%, 44.35%, 14.78% and 11.3%, respectively. On the other hand, microbiological pollution (bacteria, parasites, and fungi) that make the water unfit for consumption. The origin of pollution can be attributed to various causes: inadequate sanitation and collection of household waste, transfer of pollutants from the superficial aquifers, conditions of retrieving water, and facilities structure. The use of wells could be a significant health risk for most inhabitants in the study area.

Keywords: Well water, health risk, sanitation, microbiological pollution , Physico-chemical pollution, Segou commune

Introduction

Water is an indispensable commodity for the survival of all living beings and for their well-being. Its use for food, bodily hygiene or recreational purposes requires a high level of physicochemical, chemical and microbiological quality. The substances it carries are indeed likely to be ingested, inhaled, or the entry into contact with the skin.

In developing countries, up to 80% of diseases and over one third of deaths are attributable to water-borne diseases (OMS 2003). Gastroenteritis is the disease most commonly associated with the ingestion of faecally contaminated water and results in very serious health consequences (Bourne & Harmse 2007). Other rarer diseases such as hepatitis or meningitis may also be caused by the ingestion of contaminated water. In Mali, according to statistics from the Ministry of Health and Public Hygiene, water-borne diseases account for more than 50% of all diseases (PRODESS 2014). The predominance of diarrhea is only partly due to the lack of availability of a safe drinking water source, and social factors such as poor hygiene practices are also put at stake (Pande et al. 2008). In the context of the prevention of water-borne diseases, the quality and water hygiene are priority public health requirements. Water intended for human consumption must not contain dangerous chemicals or harmful germs (Kreamer 2009). In the commune of Segou, only a part of the city's neighborhoods is served by the drinking water network. The majority of households use water from wells. More than 70% of the population of Segou commune is currently supplied with water by groundwater wells and boreholes (CPS/MS, DNSI 2006). All households in the commune have a well. The low coverage of drinking water and the risk behaviors of populations are at the origin of serious diseases such as diarrhea, typhoid, and paratyphoid fever, amoebic dysentery (Ait melloul et al. 2002; Hassoune et al. 2010). These factors have fostered the emergence of various episodes of cholera that Mali has experienced in the last ten years (PRODESS 2014). In Mali, geologically protected groundwater is exposed to agricultural, industrial or urban pollution. Population growth is an important indicator of the demand for drinking water. This situation creates many problems, the most important of which are: scarcity of good quality water, degradation of water quality and deterioration of health. The hydrogeological nature of the commune of Segou has a high permeability of the soil, which favors a fairly rapid pollution of the groundwater with a low filtration capacity. This commune knows at times the phenomenon of flooding whose consequence is the infiltration of runoff water that can contaminate the water of the wells.

The aim of this study is to determine the microbiological characteristics and physico-chemical drinking water in the commune of Segou in Mali. A monitoring of physicochemical and microbiological parameters of the 115 wells of the commune is carried out in order to specify the importance of the pollution and to determine its origin.

Materials and Methods

Description of the study area

The urban commune of Segou (Figure 1), chief town of the Segou region, is located in the south-west of Mali, at a distance of approximately 235 km of the capital Bamako. It is bounded on the east by the rural commune of Pelengana, on the west by the commune of Sebougou, on the north by the Niger River and on the south by the rural commune of Sakoïba. The commune covers an area of 23.74 km^2. It is composed of 15 districts: Quartier Administratif, Angouleme, Bagadadji, Bougoufie, Comatex, Dar Salam, Hamdallaye, Medine, Catholic Mission, Missira, Ségou Coura, Sido Soninkoura, Quartier commercial, Sokalakono, Bananissabakoro. It has a total population estimated at 118 814 inhabitants as of population and housing census of 2009. The population density for the commune is estimated at 37.8 inhabitants per km^2, with an annual growth rate of 3.1% (RGPH 2009) and is located between 13° 26' at latitude North and 6 ° 12' at longitude East. Segou has an average rainfall of 513 mm per year with a Sudano-Sahelian climate of two seasons: the dry season which begins in October and ends in May, and the rainy season begins from June to September (AFD 2016), with August and September having the highest rainfall. Temperature variations are between 26°C and 31°C. Farming, animal husbandry, and angling are the predominant activities of the population in the area of Segou.

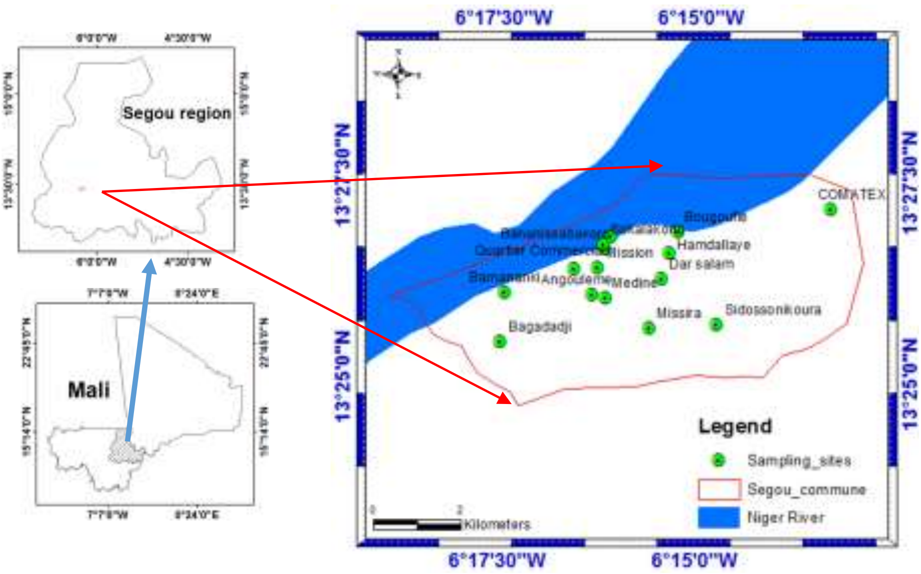

Figure 1 Map of the sampling sites urban commune of Segou

Sampling and evaluation of physico-chemical parameters

In order to better appreciate the physicochemical and microbiological characteristics of the well water, our work was carried out at the level of 115 wells that were respectively selected by simple random sampling in all 23,763 households in the commune of Segou. For the selection of wells, we randomly selected three households among those who consume the well water which totaled 345 households for the overall study. Our study focused on water from wells and households.

For the household survey, three households were randomly selected among those who consume the waters of the wells selected. In one of the three selected households, we interviewed the household head or his representative. When in this household the head of household or its representative has been absent, we moved on to the next household. The investigations were carried out as follows: (1) Administration of household questionnaires (socio-demographic data, drinking water supply, storage method, the existence of pit latrines, management of garbage and animals, health problems related to the consumption of well water); (2) Direct observation of living conditions in households; (3) Well water sampling for laboratory analysis.

The sampling in the wells was carried out in sterile ballasted bottles to which a string was attached to allow them to descend into the well. The water was taken about 50 cm from the free surface. Water samples collected in 500 mL flasks were stored in a refrigerated cooler (4° C) until the time of analysis. The monitoring of physico-chemical parameters was carried out according to the techniques of Rodier et al. (2009). The temperature, hydrogen potential (pH), electrical conductivity (EC) and the total dissolved salts (TDS) were measured in situ by the WTW 340i portable multi parametric analyzer. Nitrates (NO_3^-), nitrites (NO_2^-), ammonium (NH_4^+), total iron (Fe) and aluminum (Al^{3+}) were determined by colorimetric assay using a spectrophotometer (CD/2800). The reagents used were HACH kits. The chemical reactions involved were: the diazotization method with Nitri Ver 3 for nitrites, the cadmium reduction method with Nitra Ver 5 for nitrates, NESSLER method for ammonium, the method for phenanthroline -1.10 for iron, the reaction of which consists in the formation of an orange-red complex, the aluminon method thanks to the Alu Ver 3 reagent for aluminum. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by complexometry with EDTA (Rodier et al. 2009) with permissible limits of 100 and 50 mg / L, respectively. Oxydability of organic matter (OM) was determined by oxidation in an acid medium (Rodier et al. 2009).

Arsenic (As) was determined by atomic absorption spectrometry equipped with an arsenic hollow cathode lamp with hydride generation. The method used is that of ICP-MS according to Rodier's techniques.

Cadmium (Cd) and lead (Pb) in the presence of the flame emitted photons of determined wavelengths whose intensity was measured by spectrophotometry.

Mercury (Hg) was determined by flameless atomic absorption spectrophotometry after bromine mineralization. After oxidation and bromine digestion at 45°C, the mercury was liberated from its solution by reduction and entrained by a stream of inert gas.

Chromium (Cr) was assayed by flame absorption spectrophotometry after complexation with the ammonium salt and pyrrolidinodithiocarboxylic acid.

Determination of microbiological parameters

The microbiological parameters of the well water are determined by bacteriological, parasitological and mycological analyzes.

The bacteriological analysis was carried out in three stages:

- Membrane filtration (Macy et al. 2005). This technique was applied by the following method: a water sample of 100 ml was drawn through a membrane filter (0.45 µm pore size) using a vacuum pump; after filtration, this membrane was deposited in a petri dish containing a culture medium (Analyse and Québec. 2000; Macy et al. 2005); Culture media were used for research germs: ENDO medium for lactose-fermenting coliforms (*Escherichia coli*), Eosin blue methylene medium (EMB) for coliforms (enterobacteria), SLANETZ agar and BARTLEY for *faecal streptococci* (Analyse and Québec. 2004).

- Enumeration of colonies at the binocular loupe after incubation at temperatures 35-37°C of Petri dishes inoculated for 24-48 hours. The enumeration of revivable aerobic bacteria (aerobic mesophilic, heterotrophic bacteria) was aimed at non-specifically counting the largest number of microorganisms, in particular bacteria developing under the usual aerobic conditions of culture. The enumeration of these germs has been used as an indicator of pollution and has also been used as an indicator of treatment efficacy, in particular physical treatments such as filtration which should result in either a very large decrease in bacterial concentration compared to entry, or even an absence of bacteria. This enumeration could give important indications for judging the validity of techniques used to search for other parameters. Counts were taken after incubation at 37°C, 24 hours, or 20°C in 72 hours. Under the term "coliforms" was grouped a number of bacterial species belonging to the family Enterobacteriaceae. The enumeration of these organisms at 35-37°C has been referred to as "total coliform enumeration". The coliforms included the genera: Escherichia, Citrobacter, Enterobacter, Klebsiella, Yersinia, Serratia. "Fecal coliforms" or "thermo-tolerant coliforms" corresponded to coliforms, which exhibited the same properties after incubation at 44°C (Macy et al. 2005).

- The identification of the bacteria either by API 20^E gallery (Bio Mérieux sa 69280 Marcy-L'Etoile / France) consisting of 20 ready-to-use microtubes making it possible to carry out 23 biochemical tests in order to identify Gram $^-$ bacilli belonging to the Enterobacteriaceae family or not, or by the classical gallery composed of five culture media, namely the Kligler medium, Simmons citrate medium, mannitol mobility medium, urea and indole (bio Mérieux sa 69280 Marcy-l'Etoile / France) and the API 20 Strep gallery for faecal streptococci.

The parasitological analysis was performed on the pellet water obtained after centrifugation at 4000 tours/mn for 10 minutes of 5 ml of the sample taken from 5 L of the sample, after 24 hours for the possible search of the parasites.

Finally, the mycological analysis was carried out by the well water culture on the

Chloramphenicol sabouraud agar for the isolation, identification, and enumeration of yeasts and molds.

Statistical Analysis

The results obtained are analyzed by Stata software, version 10.0. On the one hand, calculation of the medians and the percentages and on the other hand, proportions comparison tests (Fisher's exact test and the Pearson's Chi² test) were done. From a level $p < 0.05$, the test was retained as being significant.

Results

The wells sampled in our study area are traditional. Most of these traditional wells in the area neither had the perimeter of protection nor curbs and when they exist, they are just a few centimeters (≤ 0.20cm) above the ground. These wells are small in diameter and shallow (2 to 17 m). There were no superstructures, however, trunks of trees, worn tires and masonry stones served as curbs.

Results of the analyzes performed are presented in the tables below.

The chemical analysis (Tables 1 and 2) of these well waters gave the following results:

- 13.04% of the wells investigated had the nitrates concentrations greater than 45 mg / L. In contrast, nitrite was detected in the 115 wells sampled with 31 wells that had a rate above the acceptable limit;

- Of the 115 wells sampled, 14 had an aluminum concentration greater than that recommended by the consumer regulations and 51 had a concentration above the acceptable limit for total iron.

Analysis of the toxic substances (Table 3) in these well waters gave the results listed above:

- 15.65%, 14.78%, and 11.3% of the wells sampled had high levels of lead, cadmium, and mercury, respectively. Arsenic, with an average of 3.02 µg/L and total chromium recorded lower values.

Table 4 showed that coliforms were found in all waters and it was the same for *Escherichia coli*. It is apparent from the same Table shows that 97.39% of the investigated wells are polluted by *Klebsiella pneumoniae* and *Staphylococcus aureus*. Also, 94.78% of the wells are polluted by *Salmonella spp* and Shigella spp. Faecal Streptococci were identified in 102 of the 115 wells sampled in our study area.

Results of the parasitological and mycological analysis were presented in Table 5. From this table, it was found that 29.57% and 26.96% of the wells investigated in our study area were respectively contaminated with *trichomonas hominis* and yeasts.

Table 6 provided information on the percentage of diarrhea according to household parameters in Segou.

Results in this table showed that:

- 81.36% of those who had built their latrines within 15 m of their wells reported diarrhea while this was the case for 18.64% of subjects in the other group with a statistically significant difference (p = 0.005);

- 93.02% of those who did not use latrines in their households reported diarrhea while this was the case for 6.98% of subjects in the other group with a statistically significant difference (p = 0.011);

- 62.86% of those who did not cover their wells had diarrhea, whereas it was the case of 37.14% of subjects in the other group with a statistically significant difference (p = 0.005);

- 93.25%, 80.98%, 74.09%, 63.50% and 30.05% of those who were out of school, at primary level, secondary, professional and Superior respectively, had diarrhea, whereas this was the case of 6.75%, 19.02%, 25.91%, 36.50% and 69.95% respectively of subjects in the other group with a statistically significant difference (P <0.001).

Table 1. Results of physico-chemical analysis related to the natural structure of well water and unwanted chemical substances in Segou commune

Parameters	**Acceptable limit**	**N**	**Median (P25 – P75)**
Temperature (°C)	25	115	28.95 (27.95 – 30.05)
EC (µS/cm)	2000	115	146.86 (96.3 – 239)
total dissolved salts (TDS) mg/L	2000	115	107 (63 – 187)
Ammonium (NH_4^+) mg/L	0.5	115	0.09 (0.05 – 0.12)
Oxydability mgO_2/L	5	115	2.2 (2.09 – 2.7)
Calcium (Ca^{2+}) mg/L	100	115	6.12 (4.07 – 8)
Magnesium (Mg^{2+}) mg/L	50	115	2.81 (2.4 – 5.08)

N: sample size, P25: Percentile 25, P75: Percentile 75

Table 2. Results of physico-chemical analysis related to the natural structure of well water nonconforming and unwanted chemicals in Segou commune

Parameters		**Acceptable limit**	N	**% of different frequencies**
pH	< 6.5	6.5 – 8.5	112	97.39
	≥ 6.5		3	2.61
Aluminum(Al^{3+}) mg/L	≤ 0.2	0.2	101	87.83
	> 0.2		14	12.17
Nitrates (NO_3^-) mg/L	≤ 45	45	100	86.96
	> 45		15	13.04
Nitrites (NO_3^-) mg/L	≤ 0.1	0.1	84	73.04

	> 0.1		31	26.96
Iron (Fe) mg/L	≤ 0.3	0.3	64	55.65
	> 0.3		51	44.35
DBO$_5$ mgO$_2$/L	≤ 3	3	108	93.91
	> 3		7	6.09

N: sample size

Table 3. Results of the toxic substances analysis of well water at Segou commune

Parameters		Acceptable limit	N	Mean (St.Dev)	Percentage
Arsenic (As) µg/L		50	115	3.02 (0.92)	
Cadmium (Cd) µg/L	≤ 5	5	98		85.22
	> 5		17		14.78
Lead (Pb) µg/L	≤ 50	50	97		84.35
	> 50		18		15.65
Mercury (Hg) µg/L	≤ 1	1	102		88.7
	> 1		13		11.3
Chromium (Cr) mg/L		0.05	115		100

Table 4. Distribution of wells according to the germs identified in Segou commune

Germs identified	**Number of Investigated Wells**	**Percentage**
Coliforms	115	100
Escherichia Coli	115	100
Fecal streptococci	102	88.7
Clostridium perfringens	111	96.52
Salmonella spp.	109	94.78
Shigella spp.	109	94.78
Klebsiella pneumoniae	112	97.39
Pseudomonas aeruginosa	107	93.04
Staphylococcus aureus	112	97.39
Candida albicans	42	36.52

Table 5. Results of parasitological and mycological analysis of well water in Segou commune

Parameters	Absence/Presence	Frequency	Percentage
Trichomonas hominis	Absence	81	70.43
	Presence	34	29.57
Entamoeba cyst coli	Absence	110	95.65
	Presence	5	4.35
Entamoeba histolytica cyst	Absence	113	98.26
	Presence	2	1.74
Giardia intestinalis cyst	Absence	109	94.78
	Presence	6	5.22

Ankylostoma duodenale	Absence	106	92.17
	Presence	9	7.83
Yeasts	Absence	84	73.04
	Presence	31	26.96

Table 6. Percentage of diarrhea following household parameters in Segou commune

Variables		**N**	**Percentage of diarrhea**		**P-values**
			YES	**NO**	
			81	**34**	
Distance well% to latrines	< 15m	74	81.36	18.64	**0.005**
	≥ 15m	41	58.03	41.97	
Garbage management	1	53	77.52	22.48	**0.262**
	2	62	71.08	28.92	
Use latrines	1	91	63.98	36.02	**0.011**
	2	24	93.02	6.98	
Coverage or not of wells	1	29	89.99	10.01	**0.005**
	2	86	62.86	37.14	
Educational status	Illiterate	42	93.25	6.75	**< 0.001**
	Primary	36	80.98	19.02	
	Secondary	12	74.09	25.91	
	professional	7	63.50	36.50	
	Superior	18	30.05	69.95	

N: sample size, YES: diarrhea, NO: no diarrhea; 1: Yes, 2: No

Discussion

More than 70% of the population of Segou commune is currently supplied with water by groundwater wells and boreholes (CPS/MS, DNSI 2006). The protection of the quality of these waters is, therefore, a priority objective.

The results of the physicochemical analysis presented in this work have shown that conductivity, ammonium, oxidability, calcium, magnesium, total dissolved salts, may be considered allowable and have no impact on the water quality of the wells. These results are in agreement with those obtained by Chippaux et al (2002) in Niger and Saâdia et al (2007) in Morocco. The results of the physicochemical tests also revealed the existence of a high temperature on overall the wells studied with an average of 28.95°C higher than the acceptable limit, which is 25°C recommended by WHO. These high temperatures could be explained by the influence of the ambient heat on the collected water and also by the geothermal gradient of the zone. The results of our study show that 97.39% of the wells sampled have a pH below normal which is 6.5 to 8.5, which could explain a risk of corrosion of cement or metal pipes with entrainment lead. The acidity of pH at the wells in our study is similar to the study done by Nduka et al. (2007) in Warri, Nigeria. Results of the physicochemical analysis show that 12.17% and 44.35% of the wells have an aluminum and total iron content, respectively, higher than the permissible limit of 0.2 mg / L and 0.3 mg/L. The well waters studied also show a high concentration of nitrates and nitrites. Nitrates (NO_3^-) and nitrites (NO_2^-) are naturally present in the environment. They are the result of nitrification of the ammonium ion (NH_4^+), present in water and soil, which is oxidized to nitrites by bacteria of the genus Nitrosomonas, then nitrates by bacteria of the genus Nitrobacter. Nitrates are very soluble in water, so they migrate easily in groundwater when levels exceed the needs of the vegetation. The toxicity of nitrates results from their reduction to nitrites and the formation of methemoglobin on the one hand and their possible contribution to the endogenous synthesis of N-nitroso compounds on the other hand. The presence of nitrates in drinking water is mainly attributable to human activities (Saadia et al. 2007). Water containing nitrites is considered suspect because it is often associated with deterioration of microbiological quality. In our study area, increase in nitrates contents observed is particularly related to human activities and intensive agricultural practices. The deficient septic systems, as well as the decomposition of plant and animal matter, can also be a source of nitrates in water. The risk of contamination is greater if the soil covering the groundwater is vulnerable and if the water table is shallow.

Infant methemoglobinemia is the only health effect, that has been associated unequivocally to excessive exposure to nitrates by drinking water. Methemoglobinemia resulted from the reduction of nitrates to nitrites by microorganisms of the digestive system, followed by nitrite oxidation of ferrous iron (Fe^{2+}) from hemoglobin to ferric iron (Fe^{3+}), which generates methemoglobin. Methemoglobin, unlike hemoglobin, is unable to fix oxygen, which helps to reduce the transport of oxygen from the lungs to tissues. Nitrite formation could sometimes result from bacterial contamination of water, reducing nitrates to nitrites before they are ingested. These high nitrate and nitrite values are reported by Dégbey et al. (2008) who worked on the quality of well water in the commune of Abomey-Calavi in Benin. Nitric pollution of the groundwater studied is due to the spreading of manure or chemical fertilizers, as well as nearby septic systems. Variation of the nitrate concentration observed between the various wells may be related among others to the heterogeneity of the physical environment. Nitrates are naturally present but in low quantity in soils. Today they constitute the main indicator of degradation of water resources. The increase in levels observed in recent years is the result of human activities, such as intensive agricultural practices. Consumption of this water should be prohibited to pregnant women and infants to prevent methemoglobinemia.

Heavy metals are pollutants generated by human activity that have a strong toxicological impact (Azeez et al. 2009). Toxic metals are numerous, but we can mention mainly arsenic, cadmium, lead, and mercury. They have impacts on consumer products and on humans (Nduka et al. 2008). It is quite difficult to predict the evolution of metals in the environment because they can undergo a large number of transformations (oxidation, reduction, complexation, etc.), and this evolution strongly depends on the environment (Azeez et al. 2009). Indeed, migration of heavy metals to the groundwater is a function of many parameters: the initial chemical form of metal; permeability of the soil and sub-soil; porosity of the soil; pH; biological activity; redox potential of the soil; mineralogical composition of the soil; organic matter content of the soil. The main sources of water contamination are: domestic and industrial wastewater, agricultural production, air pollutants, old landfills, the use of hazardous substances for water, etc. Although heavy metals are most commonly present in trace amounts, they are nonetheless very dangerous, since their toxicity develops through bioaccumulative in organisms. Short-term exposure (few days or weeks) to cadmium in drinking water at high concentrations may cause nausea, vomiting and diarrhea. Long-term exposure (several years or decades) to cadmium in drinking water can cause kidney damage. Lead poisoning caused by excess lead results in clinical disorders, laboratory abnormalities, and various histopathological changes. It is influenced by multiple factors and mainly by action of lead as an enzyme inhibitor. For mercury, its intoxication with mercuric salts results in stomatitis, neurological disorders, nephrotic syndrome. Mercury can also give organomercurials derivatives of significantly higher toxicity. The mechanism of toxic action may be related to an interaction with thiol groups of proteins. In addition, methylmercury inactivates many enzyme systems. Wells of the commune are experiencing high levels of pollution in faecal contamination indicators, in agreement with those found by Boutin and Dias (1987) for the Marrakesh groundwater in Morocco, by Bordalo and Savva (2007) during research for the Safe drinking water in Guinea Bissau and finally by Egwri and Aboaba (2002) in Lagos, Nigeria on the environmental impact of the bacteriological quality of domestic water supply. The majority of pathogenic microorganisms likely to be in water come from human or animal waste. *E. coli* bacteria are part of the total coliform group. It is a very abundant species in the human and animal intestinal flora, and it is also the only species that is strictly of faecal origin. Local sources of contamination can be multiple: arrangement of the well (lack of sealing of the lid), surrounding soil (absence of a mound around the well to remove surface runoff), defective septic system or unsanitary premises (eg, manure spreading or other activities generating faecal pollution). In these cases, it is, therefore, necessary to proceed with the work required to correct the situation. Subsequent analyzes as part of the monitoring of the water quality will make it possible to verify the effectiveness of corrective measures taken. Adequate point-of-fact analysis results alone cannot ensure the quality of drinking water at all times. Therefore, it is necessary to take necessary precautions to ensure the safety and good functioning of an individual drinking water supply system (Gundry et al. 2009). Similar to precautions taken with regard to the well, prevention measures should also be applied to treatment systems to eliminate aesthetic problems (Kreamer et Usher 2009). Failure to follow these precautionary measures could promote the proliferation of bacteria. To ensure effective disinfection, the water that feeds treatment systems for elimination of microorganisms must be clear and limpid (Gundry et al. 2009). High percentages of coliforms and faecal streptococci in the wells of the commune are similar to those found by Nola et al. (1998) at Yaounde groundwater in Cameroon. Similarly, high fecal coliform levels are recorded in the well water of the Yembeul groundwater in Senegal by Tandia et al. (1997). Indeed, high total coliform and faecal streptococci recorded at the wells can be attributed to the poor hygiene conditions recorded in the study area. In addition, surface waters loaded with microorganisms seeping into the sandy soil, reach the aquifer without having benefited from effective filtration, and cause a multitude of point-source pollution. Bacteriological pollution of the well water is more worrying as it could represent a general insalubrity of the area's groundwater. The shallow aquifers, accessible by the wells of the commune of Segou in Mali, appear heavily contaminated by the organic matter of human and animal origin as is the case of a study conducted in Burkina Faso by Poda et al. (2003).

Microbiological quality is an essential health concern. The water consumed must be free from pathogenic organisms. The short-term risk may be intestinal disorders which the onset and significance depend on the general health and sensitivity of the consumer. Bacteriologically, there is a massive presence of streptococci and faecal coliforms in these waters regardless of the sources in Segou and other countries by Levesque et al. (2008). The health impacts of this phenomenon are the high prevalence of diarrhea and intestinal parasitosis in children under 5, pregnant women and elderly in the ecosystem studied. In our study, endemics diarrheas are associated with faecal contamination of wells water that poses major risks to the consumer. This is also the observation made by Gundry et al. (2009) in their area.

Parasitological qualitative and mycological analysis revealed the presence in water Entamoeba histolytica cysts, Giardia intestinalis coli, Ancylostoma duodenal eggs and larvae, and yeasts that may cause diarrhea, gastroenteritis, amoebic dysentery, and fungal infections.

In this commune, not only the population does not a garbage disposal system, but also a system for collecting, treating and disposing of wastewater. For latrines, 81.36% are located at a distance that does not meet the WHO recommended minimum limit of 15 m between latrines and wells. Mismanagement of household waste and wastewater, contamination of the soil by human excreta, non-observance of the distance between latrines and wells result in the high content of water in some chemical substances (nitrites, nitrates, biological oxygen demand in 5 days), which are indicators of pollution. This chemical pollution observed after the analysis of certain well waters sampled in our study series is consistent with the conclusions of Dégbey et al. (2008) in the commune of Abomey-Calavi in Benin. Results of the bacteriological analysis of water revealed that all the wells sampled were contaminated.

Conclusion

Results of the physicochemical analysis of wells water in the commune of Segou in Mali have shown that conductivity, ammonium, oxidability, calcium, magnesium and total dissolved salts, may be considered eligible and present no danger for consumption. On the other hand, low pH values may often present a problem of solubilization of various toxic metals (lead, cadmium, mercury, etc.). The well waters studied show nitrate and nitrite concentrations, respectively higher than the WHO standards. These results confirm the impact of intensification of agriculture, discharges of domestic and industrial wastewater. It should be noted that the wells of the commune have high concentrations of aluminum and total iron. The high presence of indicator germs of faecal contamination, as well as the presence of other germs responsible for water-borne infections, is likely to pose a threat to inhabitants who sourced water from these wells. Studies must continue to monitor the evolution of groundwater pollution, particularly at depth.

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