

# Physicochemical and Microbiological Parameters of Water Used in Schools of the Department of Man (Côte d'Ivoire)

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## Abstract

Drinking water remains a major challenge for developing countries. These populations do not always have access to drinking water due to its unavailability and high cost, so they resort to well and river water to meet their needs. The aim of this study is to determine the sources of water used by schools and primary school groups in the Department of Man in Côte d'Ivoire and their physicochemical and microbiological characteristics. Field visits and surveys allowed the observation of various water supply sources. Physicochemical and microbiological analyses of the water were also carried out. The study showed that the majority of water supply sources are school wells (60%). In terms of physicochemical parameters, the pH of the water, with the exception of the Badouel school group, is below 6.5, the reference value. Most well water is acidic. The electrical conductivity of water varies between 16 and 384  $\mu\text{S}/\text{cm}$ . The water in the Fagnampléu, Badouel, Kpangouin, Zélé, EPP 2B Sangouiné, Plateau and Zagoué schools is turbid, with values above the threshold value (5 NTU). Ammonium concentration in all water complies with WHO requirements. The well water from all the schools contained total coliforms (4 - 100 CFU/100mL) and *E. coli* germs (1 - 45 CFU/100mL). However, the total coliform counts of 8, 4 and 5 CFU/100mL in the water from the Kricouma school group, EPP 2 & 3 (Podiagouiné) and the Plateau school group, respectively, were below the WHO requirement. Inexpensive treatment should be considered to make the water potable before consumption.

## Keywords

Water, Well, Quality, Primary School, Man, Côte d'Ivoire

## 1. Introduction

Equitable access to safe drinking water, sanitation and hygiene was recognised in 2010 by the United Nations General Assembly as a human right and reaffirmed the same year by the Human Rights Council [1] [2]. However, in many urban areas around the world, particularly in developing countries, access to these facilities is still inadequate [3]. This situation puts children under the age of 15 at particular risk, with thousands of children dying every day from diarrhoeal diseases and other diseases transmitted by water or caused by a lack of sanitation and hygiene, such as trachoma and skin diseases, which are public health problems [4] [5]. As a result, for decades, the school environment in developing countries has attracted the attention of governments and international organisations in order to guarantee the well-being of school-age children who spend most of their days there.

The number of school days that could be saved if safe water supply and sanitation were achieved, and the incidence of diarrhoeal diseases reduced, is 1.9 billion according to the UNICEF report (2012). Diseases linked to the lack of water, sanitation and hygiene are therefore a huge burden in many developing countries, particularly in the education sector [3] [5]. In Côte d'Ivoire, the government is making huge efforts to improve school enrolment. Many new schools have been built and measures have been taken to improve the school environment. For example, the Water, Sanitation and Hygiene (WASH) concept, which aims to provide schools with drinking water, basic sanitation facilities and hygiene education, has been introduced into the school environment [2] [6]. According to MENET [7], in 2016, only 39% of state primary schools had drinking water points, with a low proportion (27%) in rural areas compared with 61% in urban areas, 41% had latrines and 22% had functional hand-washing facilities. Regional disparities can be seen behind the rate of increase in pupil numbers in state primary schools by administrative region, which was 1.7% in 2019-2020 [6]. The northern regions (Tchologo [4.8%], Bere [4.6%], Poro [4%], etc.) and the western regions (Tonkpi [2.8%], Guémon [2.4%] Cavally [2.2%]) recorded the strongest growth, above the national average. Of all these regions, Tonkpi is one that has suffered the brunt of the country's decade-long socio-political crisis. The aim was therefore to determine the sources of water supply and their physicochemical and microbiological characteristics in public primary and pre-school schools in the department of Man. This mainly involved 1) investigating the sources of water supply and 2) analysing the quality of the water.

## 2. Material and Methods

### 2.1. Study Area

The study was carried out in the west of Côte d'Ivoire, in the Tonkpi region, between latitudes 7°24' North, 7°33' West [8]. Tonkpi covers an area of 12,284 km<sup>2</sup>. It is bordered to the north by the Bafing region, to the east by the Worodougou and Haut-Sassandra regions, to the south by the Cavally and Guémon regions,

and to the west by the Republics of Guinea and Liberia (Figure 1) [9]. The region is home to five (5) departments, 11 sub-prefectures including Bogouiné, Fagnampléu, Gbangbegouiné-Yati, Logoualé, Man, Podiagouiné, Sandougou-Soba, Sangouiné, Yapleu, Zagoué and Ziogouiné. 158 public primary and preschool schools identified in the sub-prefecture capitals of the department of Man, including 124 primary and 34 preschool schools. These establishments are divided into 36 school groups and 10 schools across the entire territory investigated (Source: DREN-MAN, 2023).

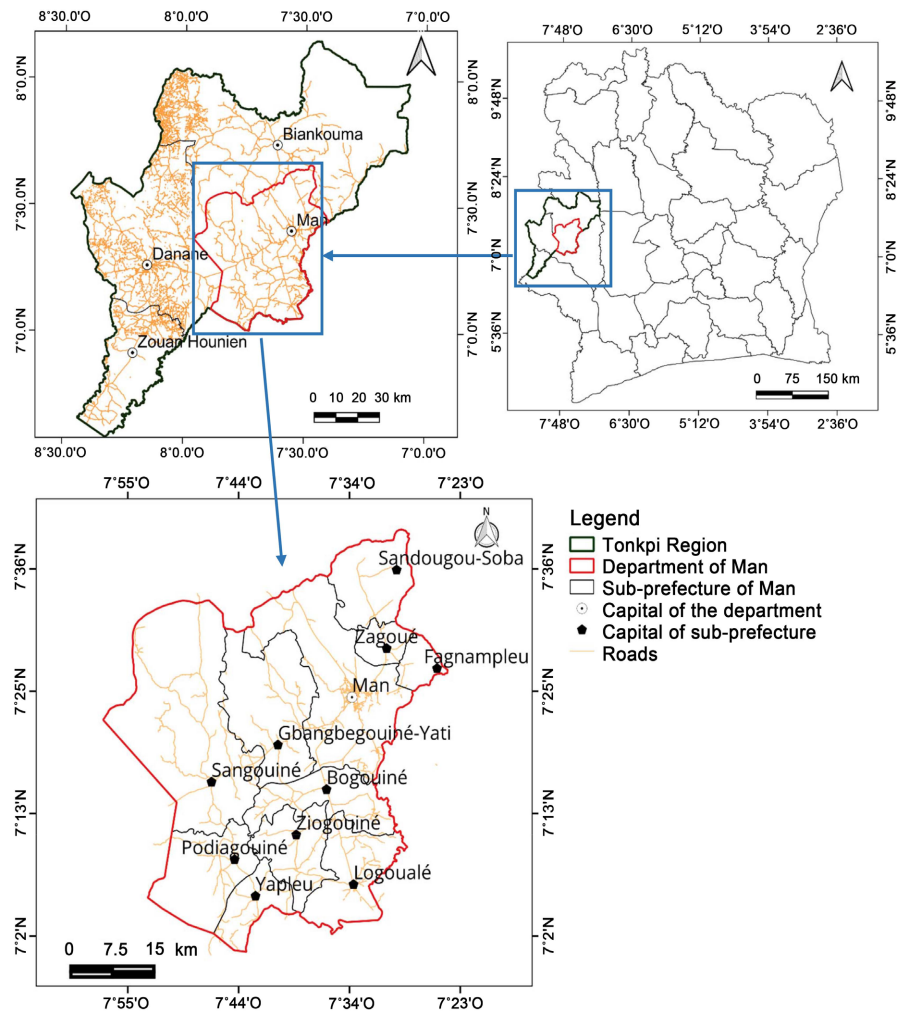


Figure 1. Presentation of the study area.

## 2.2. Data Collected

The inventory of drinking water services and schools covered both primary and pre-school levels, in order to analyse the overall situation of the school environment. Data was collected in 2023. It consisted of meetings with the heads of primary schools and pre-schools (primary school headmasters, pre-school headmasters, presidents of parents’ associations, etc.) in the department’s sub-prefecture capitals. Interviews and questioning took place at these meetings to gather infor-

mation about the availability of water supplies. In addition, guided visits were carried out to make field observations (presence, condition, etc.). During these visits, photographs and geographical coordinates of schools and water points were taken to illustrate the situations observed.

The data collected was coded. The information was then grouped together. The relative frequencies of each variable were calculated in relation to the number of schools according to the following relationship:

$$F = X/Y \times 100$$

F: Frequency (%);

X: Number of individuals in the category under consideration;

Y: Total number of people in the category in question.

### 2.3. Designing the Cards

During the school visits, a GPS was used to record the geographical coordinates of the sites and water points. These coordinates were then entered into QGIS 3.14.16 and maps of the sites and water points were produced.

### 2.4. Physicochemical and Microbiological Parameters of Well Water Found in Schools

All water samples for testing were collected in 2 L vials intended, carefully, pre-rinsed with deionised water and raw water samples, prior to collection. Testing was performed in triplicate for quality control and quality assurance purposes, in accordance with APHA (2017) standard procedure. On each well water sample collected, physicochemical parameters characteristic of drinking water quality, such as, pH, electrical conductivity, TDS and turbidity were analysed *in situ* with HI9829 multi-parameter. The concentration of aluminium was determined spectrophotometrically using a DR1900 spectrometer. Ammonium was analysed by indophenol blue molecular absorption spectrometry in accordance with standard NF T90-015. In addition, *Escherichia coli* and total coliforms were analysed using the ISO 9308-1 (2004) membrane filtration method to assess the microbiological quality of the water. The analyses were carried out at the central laboratory of the University of Man.

## 3. Results

### 3.1. Well Condition

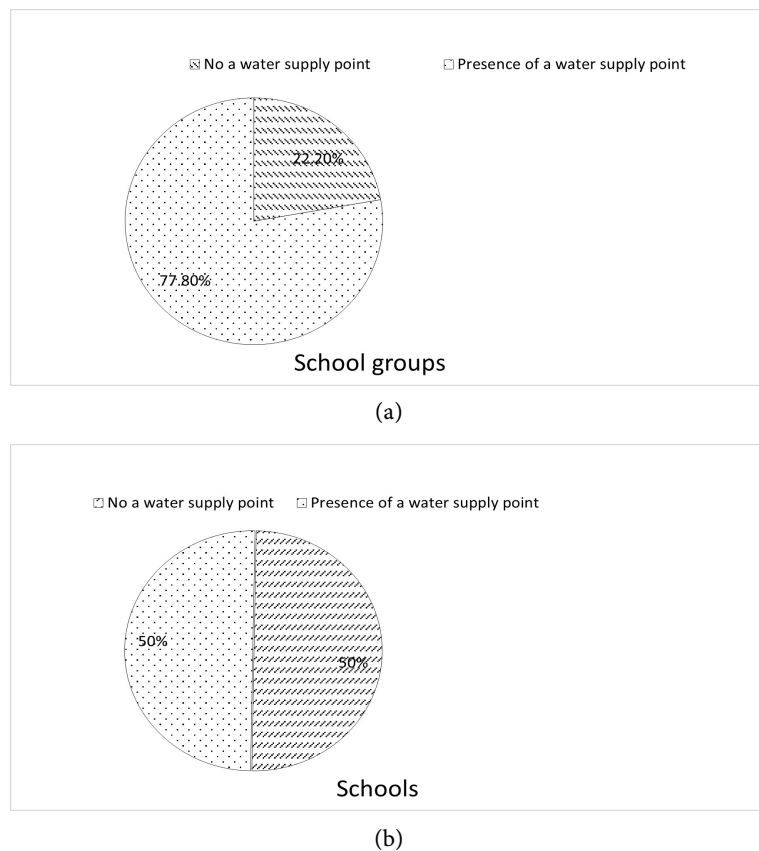
The wells encountered in this study are traditional (**Figure 2**). They are dug by local well-diggers with rudimentary equipment. The diameter is barely equal to one meter with a depth that varies from 0.5 to 20 m. Wells had a covered or partially covered rim with a coping. The toilets were mostly made up of soakaway wells within a radius of 10 to 20 m maximum from the wells. Near some wells there is a tree that provides shade but on which some animals or insects land and can defecate. The water from these wells is used for drinking.



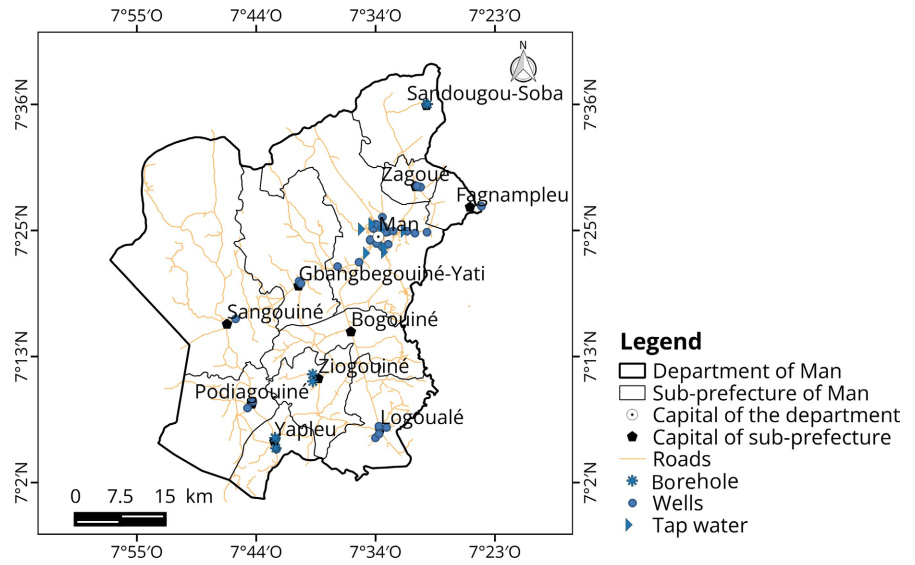
**Figure 2.** Illustration of some wells encountered in schools in the department of Man.

### 3.2. Sources of Water Supply

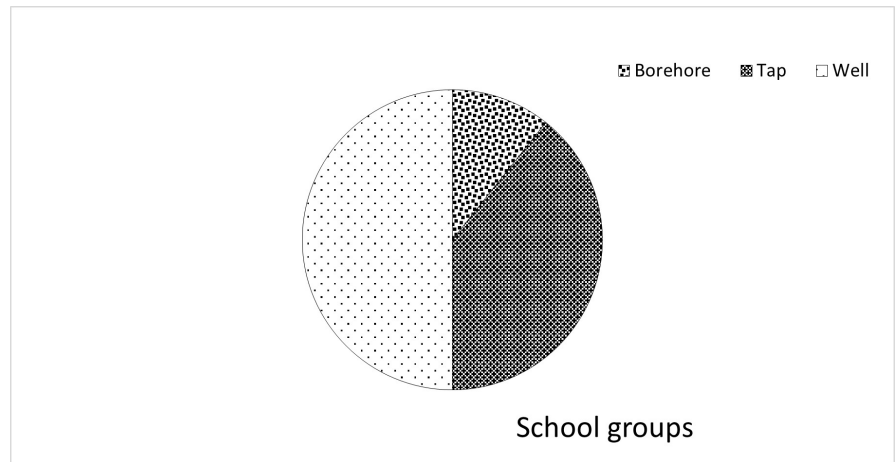
It emerged from the guided visits and observations that there were no water points in 22.2% of the school groups and 50% of the schools visited (**Figure 3**). The water points consist of wells, Côte d’Ivoire Water Supply Company taps (SODECI) and improved village hydraulics (Borehore) (**Figure 4**). However, the majority are wells, both in school groups (50%) and in schools (60%) (**Figure 5**). **Figure 6** illustrates the well water points identified in the department’s schools.



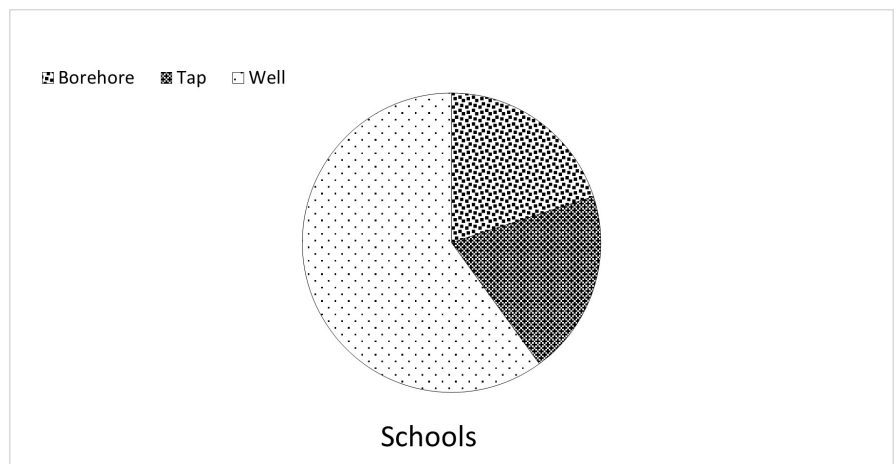
**Figure 3.** Availability of water points in schools in the department of Man.



**Figure 4.** Map of water points found in schools in the department of Man.

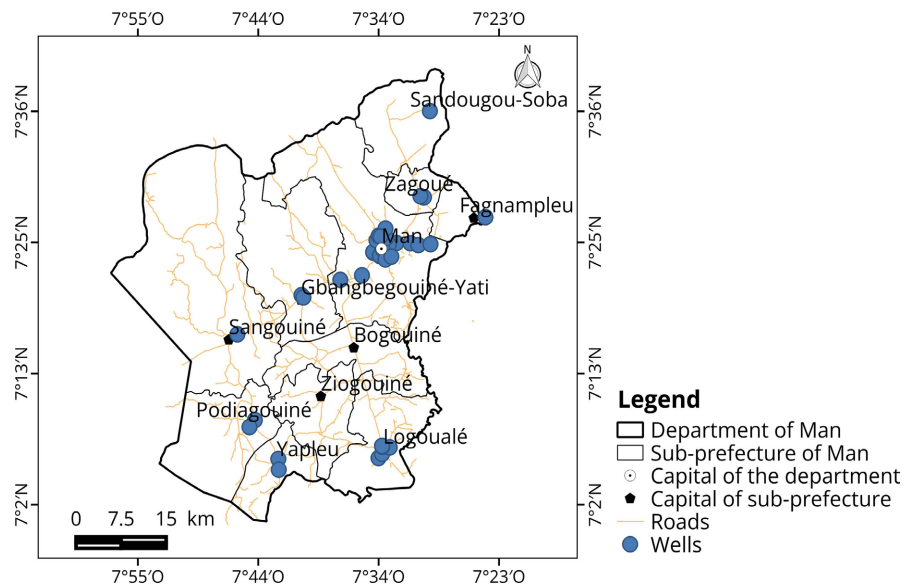


(a)



(b)

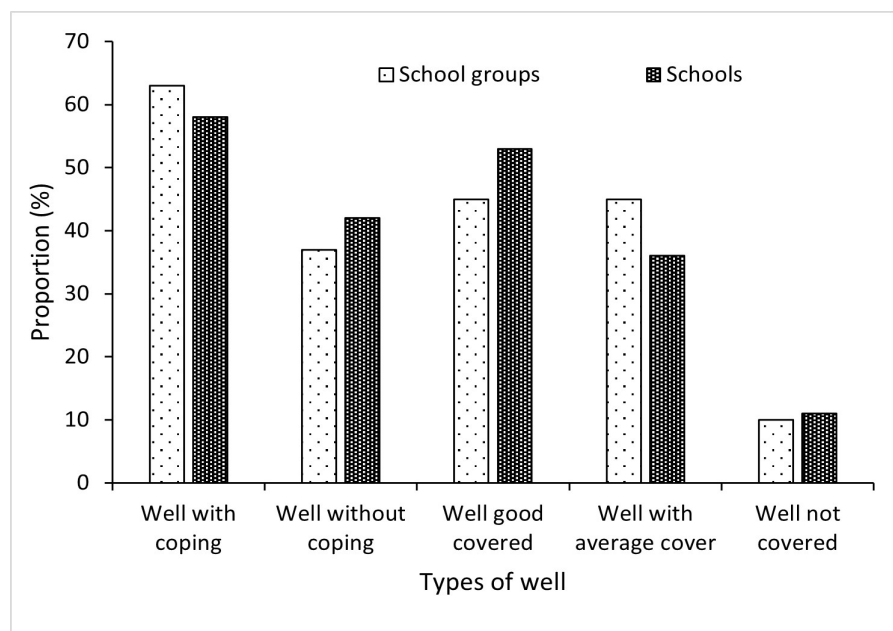
**Figure 5.** Water points found in schools in the department of Man.



**Figure 6.** Map of wells identified in schools in the department of Man.

### 3.3. Types of Wells Encountered

In schools, such as school groups, around 10% of wells are not covered, 36% - 45% are moderately covered and 45% - 53% are well covered (**Figure 7**). However, more than 50% of wells have coping stones.



**Figure 7.** Types of wells encountered.

### 3.4. Physicochemical and Microbiological Characteristics of School Well Water

**Table 1** shows the physicochemical and microbiological characteristics of water taken from school wells in the administrative centres of the department of Man.

Looking at the physicochemical parameters, it can be seen that the pH of the water, with the exception of that from the Badouel school group (Logoualé sub-prefecture), is below 6.5, the guide value. The electrical conductivity of the water varies between 16 and 384  $\mu\text{S}/\text{cm}$ . The well water used in the schools has a conductivity Lower the WHO guide value of 1200  $\mu\text{S}/\text{cm}$ . With regard to the turbidity of well water, values above the threshold value (5 UTN) were recorded in the water from the Fagnampléu, Badouel, Kpangouin, Zélé, EPP 2B Sangouiné, Plateau and Zagoué schools, *i.e.* 41.17% (7 out of 17) of the water analysed. The total dissolved solids (TDS) content of well water varies between 8 mg/L and 183 mg/L. The lowest value (8 mg/L) was recorded in the EPP 2 Podiagouiné school group, and the highest value (183 mg/L) was recorded in a well at Koko. With regard to residual Al in well water from schools and school groups in the department of Man, 94.12% or 16/17 of well water had a concentration of between 0.001 mg/L and 0.039 mg/L and 5.8% or 1/17 had a concentration of 0.256 mg/L. This is the water from EPP 2B in Sangouiné. Ammonium concentrations were below 0.5 mg/L in all waters.

In terms of microbiological characteristics, well water from all the schools contained total Coliforms (4 - 100 CFU/100mL) and *E. coli* germs (1 - 45 CFU/100mL). However, the total coliforms counted (8; 4 and 5 CFU/100mL) in the water from the Kricouma school group (Man), EPP 2 & 3 (Podiagouiné) and the Plateau school group (Sangouiné) were below WHO requirements.

**Table 1.** Physicochemical and microbiological characteristics of water taken from school wells in the administrative centres of the department of Man.

Area		Physico-chemical and microbiological parameters								
Sub-prefectures	Establishments	pH	Conductivity ( $\mu\text{S}/\text{cm}$ )	Turbidity (UTN)	TDS (mg/L)	Al Résiduel (mg/L)	Ammonim (mg/L)	Total Coliforms (UFC/100mL)	<i>E. coli</i> (UFC/100mL)	
Fagnampléu	GS Fagnampléu	4.6 $\pm$ 0.01	174 $\pm$ 0.03	9.9 $\pm$ 0	85 $\pm$ 1	0.02 $\pm$ 0	0.23 $\pm$ 0.01	32 $\pm$ 1.2	20 $\pm$ 0.01	
Gbangbéguiné-Yati	GS Gbangbéguiné	4.4 $\pm$ 0	173 $\pm$ 0.01	3.6 $\pm$ 0	87 $\pm$ 0.5	0.06 $\pm$ 0	0.2 $\pm$ 0.01	11 $\pm$ 0	3 $\pm$ 0	
Logoualé	GS Badouel	6.5 $\pm$ 0	139 $\pm$ 0.01	92.4 $\pm$ 0.2	70 $\pm$ 0.80	0.01 $\pm$ 0	0.2 $\pm$ 0.03	13 $\pm$ 0	10 $\pm$ 0.02	
	GS Mont Glas	4.6 $\pm$ 0	48 $\pm$ 0.01	2.8 $\pm$ 0	24 $\pm$ 1.02	0.023 $\pm$ 0	0.17 $\pm$ 0.01	10 $\pm$ 0.09	2 $\pm$ 0	
	GS Mistrot	5.5 $\pm$ 0	305 $\pm$ 0.04	2.5 $\pm$ 0	152 $\pm$ 2.5	0.003 $\pm$ 0	0.19 $\pm$ 0.01	100 $\pm$ 2	45 $\pm$ 0.01	
	GS Koko	5.3 $\pm$ 0	366 $\pm$ 0.07	0.3 $\pm$ 0	183 $\pm$ 2.43	0.035 $\pm$ 0	0.2 $\pm$ 0.02	20 $\pm$ 0.16	10 $\pm$ 0	
	Man	GS Kpangouin	5.6 $\pm$ 0.01	74 $\pm$ 0.1	9.3 $\pm$ 0.01	37 $\pm$ 2	0.001 $\pm$ 0	0.2 $\pm$ 0.04	11 $\pm$ 0.03	2 $\pm$ 0
	GS Kricouma	5.1 $\pm$ 0.01	127 $\pm$ 0.02	2.7 $\pm$ 0	63 $\pm$ 2	0.001 $\pm$ 0	0.12 $\pm$ 0.02	8 $\pm$ 0.08	2 $\pm$ 0	
	GS HKB	4.5 $\pm$ 0	75 $\pm$ 0.01	0.8 $\pm$ 0	38 $\pm$ 1.3	0.005 $\pm$ 0	0.23 $\pm$ 0.03	12 $\pm$ 0.31	4 $\pm$ 0	
Podiagouiné	GS Zélé	5 $\pm$ 0.01	115 $\pm$ 0.01	43.3 $\pm$ 0.1	58 $\pm$ 1.01	0.03 $\pm$ 0	0.27 $\pm$ 0.01	22 $\pm$ 1	15 $\pm$ 0.01	
	EPP 1 & 4	5.6 $\pm$ 0.02	34 $\pm$ 0.03	3 $\pm$ 0	20 $\pm$ 1	0.001 $\pm$ 0	0.2 $\pm$ 0.01	7 $\pm$ 0.01	4 $\pm$ 0	
	EPP 2 & 3	5 $\pm$ 0.01	16 $\pm$ 0.02	2.3 $\pm$ 0	8 $\pm$ 0.8	0.011 $\pm$ 0	0.22 $\pm$ 0.01	4 $\pm$ 0.02	2 $\pm$ 0	
Sangouiné	GS 1 Sangouiné	4.6 $\pm$ 0	66 $\pm$ 0.3	1.4 $\pm$ 0	32 $\pm$ 0.92	0.036 $\pm$ 0	0.3 $\pm$ 0.02	22 $\pm$ 0.8	18 $\pm$ 0.01	
	EPP 2B	4.3 $\pm$ 0.01	165 $\pm$ 0.19	5.7 $\pm$ 0.01	82 $\pm$ 1.1	0.256 $\pm$ 0	0.25 $\pm$ 0.01	15 $\pm$ 1.1	4 $\pm$ 0	
	GS Plateau	4.9 $\pm$ 0	21 $\pm$ 0.2	18.2 $\pm$ 0	11 $\pm$ 1	0.039 $\pm$ 0	0.2 $\pm$ 0.02	5 $\pm$ 0	1 $\pm$ 0	

**Continued**

Zagoué	GS Zagoué	5 ± 0	81 ± 0.015	6.4 ± 0	50 ± 1.7	0.02 ± 0	0.22 ± 0.01	25 ± 1.54	6 ± 0
	EPP 2	5 ± 0.1	101 ± 0.06	3.3 ± 0.02	11 ± 1	0.011 ± 0	0.3 ± 0.01	28 ± 0.9	7 ± 0
Drinking standards OMS		<b>6.5 - 8.5</b>	<b>1200</b>	<b>5</b>	<b>1000</b>	<b>02</b>	<b>0.5</b>	<b>10</b>	<b>0</b>

## 4. Discussion

This study focused on the current conditions of 158 public primary and nursery schools in the departments of Man, divided into 36 school groups and 10 schools, in terms of the supply and quality of drinking water. This study shows that the schools and school groups use different types of drinking water sources such as well water, tap water supplied by Côte d'Ivoire Ivory Coast Water Distribution Company (SODECI) and improved village hydraulics (boreholes). The water sources are similar to those identified by Isukuru *et al.* [10] in Nigeria. In Dacope Upazila in the Khulna district of Bangladesh, well water is also used in schools, but at a lower rate than ours (16%) according to the work of Hossain *et al.* [11].

In schools such as school groups, there are uncovered, moderately covered and well-covered wells. Of these types of well, more than 50% have coping stones. These different aspects of wells could affect water quality. This is illustrated by the work of Kouadio *et al.* [12], on wells in Agboville (Côte d'Ivoire).

The pH of the water varied between 4.4 and 5.6 for the most part, whereas the WHO recommends a range of 6.5 - 8.5 [13]. The pH of the water analysed was in almost all cases lower than the lower limit of 6.5. This shows that the water is acidic. This acidity is thought to result from the decomposition of the abundant plant organic matter in the study area [14]. It is also linked to the dissolution of free CO<sup>2</sup> in the soil which in-turn affect the rate of neutralizing alkaline materials, metals mobility and rock-water interactive [15] [16]. The conductivity of the water varied between 16 µS/cm and 366 µS/cm. Water from the Mistrot and Koko wells had an electrical conductivity greater than 300 µS/cm, *i.e.* 11.76% of the well water analysed. Some water points (47.06%) were very weakly mineralised, with an E.C of less than 110 µS/cm. These results show similar characteristics to the Boguédia water in the Daloa square degree studied by Koffi *et al.* [17], Kanohin-Otchoumou *et al.* [18]. According to Huang *et al.* [19], low water mineralisation could pose a health problem, as soft water could be associated with cardiovascular disease. The water from the Mistrot and Koko wells can be considered as medium mineralisation water with a conductivity of between 333 and 833 µS/cm [20]. The high turbidity (greater than 5 N.T.U) of well water in seven schools suggests the presence of suspended solids, thus promoting microbial activity in the water according to Rabearisoa *et al.* [21]. The total dissolved solids (TDS) content determined in the water from all wells was below the maximum allowable limit (1000 mg/L) recommended by the WHO [13]. Consequently, the TDS values recorded in this study could be considered tolerable. TDS (35 to 90 mg/L) in well water in Kono District is located in Eastern Province of Sierra Leone area have in concen-

tration below standard (1000 ppm) values [22]. The concentration of residual Al in well water is between 0.001 mg/L and 0.039 mg/L for the most part. Well water from EPP 2B in Sangouiné had a concentration of 0.256 mg/L, above the WHO recommendation of 0.2 mg/L given the potential health effects. The level of Al needs to be reviewed to avoid risks to human health and lead to brain changes characteristic of Alzheimer's disease [23] and neurotoxicity [24]. Aluminium concentrations above the detection limit in 56% of the tap water samples analysed, and 6% of samples were above the maximum contamination level for Florida (concentrations ranged from 0.009 mg/L to 0.429 mg/L) were determined by Weisner *et al.* [25]. It justifies the presence of Al at lower socio-economic status. In all the wells studied, the ammonium concentration complied with national and international standards, so ammoniums were not involved in the pollution observed in the well water. The relatively low levels of ammonium could be explained by the change in form, from ammonium to nitrite, by oxidation conditions or by adsorption by particles.

All well water is contaminated with total coliforms. The presence of total coliforms shows that these waters are either polluted by faecal matter or by the environment of the water recovery systems. However, the presence of *Escherichia coli* in the water analysed confirms faecal contamination of this water, according to Dey *et al.* [26]. Environmental factors such as dust, environmental sanitation (failure to monitor wells), insect and animal corpses. A possible mode of contamination would be when someone touches the well outlet after defecation without maintaining proper hygiene, and bacteria attach themselves to the surface of the outlet and grow rapidly [27]. In addition, the wells were installed in an open area without a roof, so contamination with total coliforms and even *E. coli* can come from human disturbance and most often from bird droppings [28] [29]. Field observations suggest that the presence of these bacteria in well water is linked to contamination of wells dug close to latrines. The distance between latrines and wells does not comply with international standards, which according to WHO should be at least 15 m, depending on the hydrological and hydrogeological context of the area. Teikeu *et al.* [30] observed that well water sources that were located proximity of latrines are more likely to get contaminated by microorganisms. Mangoua-Allali *et al.* [31] obtained much higher concentrations of *E. coli* in well water from the city of Bocanda in Ivory Coast. Total coliforms (5.30 + 7.87) and faecal coliforms lower than this study were counted during the assessment of water quality in the city of Kerman, in south-eastern Iran for the same reasons [32].

## 5. Conclusion

The assessment of drinking water in public primary and pre-school schools in the department of Man made it possible to take stock of the existence of water points and their quality. There are 158 state schools in the sub-prefecture capitals of Man department, including 124 primary schools and 34 pre-schools, divided into 36

school groups and 10 schools. There were no water points in 22.2% of the school groups and 50% of the schools surveyed. The ammonium concentration of all the water complied with WHO guide values. The water in EPP 2B at Sangouiné has an Aluminium concentration of 0.256 mg/L. However, most of the existing water points are wells, and the water is acidic and contains total coliforms and *Escherichia coli*, in excess of WHO guidelines. This study is a first for schools in the department of Man. However, the quality of the well water used by the children could have an impact on their health. Consequently, the use of less costly water treatment technology is necessary to protect the health of pupils. Biosand filters are recommended or filtration, adsorption on geomaterials such as laterite and shale.

### Conflicts of Interests

All authors declare that they have no conflict of interests.

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