Influence of Urban Pollution on the Water Quality of the Groundwater of Six Municipalities of Abidjan

Gnahoua Magloire OKOU[1,*], Marie-Jeanne Adélaïde OHOU-Yao[4], Dompé Ghislain AHOULÉ[2],
Agness Essoh Jean Eudes Yves GNAGNE[2], Ossey Bernard YAPO[2,3], Nahossé ZIAO[1]

[1]Laboratoire de thermodynamique et de physico-chimie du milieu, (UFR-SFA), Université Nangui Abrogoua, Abidjan, Côte d'Ivoire
[2]Laboratoire des Sciences de l'Environnement, (UFR-SGE), Université Nangui Abrogoua, Abidjan, Côte d'Ivoire
[3]Laboratoire Central de l'Environnement du Centre Ivoirien Anti-pollution (CIAPOL), Abidjan, Côte d'Ivoire
[4]Unité de formation et de recherche en Environnement, Université Jean Lorougnon Guédé de Daloa Côte d'Ivoire
*Corresponding author: gnahoua.okou@gmail.com

Abstract The groundwater, through the use of domestic wells, is for many populations the source of water they use daily. These wells are located mainly in neighbourhoods where sanitary conditions are very precarious and inadequate sanitation. It is therefore appropriate to highlight the influence of this unhealthy environment on the quality of the waters of the groundwater of Abidjan. Four sampling campaigns spread over the four climatic seasons were carried out. The analyzes of the water samples collected focused on the physicochemical and microbiological parameters commonly used for the quality of drinking water. The precariousness of the protection parameters and the proximity of the probable sources of pollution have been highlighted. Indeed, more than half of the wells are not covered. 55.86% of the septic tanks and 59.29% of the latrines are located upstream of the wells. 77.77% of latrines and 73.83% of septic tanks are below the safe distance of WHO (15 m). 30.17% of the wells and 34.48% have, respectively, nitrate and ammonium concentrations that are above the WHO standards 2011 (50 mg / L for nitrate and 0.01 mg / L for ammonium). This indicates that the well waters are of poor quality for drinking because of the possible impact of urban insalubrity. 41.38% of the wells provide turbid water (turbidity> 5 NTU), of which 21.55% contain organic matter beyond WHO standards 2011 (P.I.> 5 mg / L) and 100% contain excessive suspended matter. 98.27% of the wells are contaminated with total coliforms, 92.24% with faecal coliforms and 90.21% with faecal streptococci. This situation results in a faecal contamination index which varies between 9 and 12, it follows that 96.55% of the wells provide water from high to very high faecal contamination. All this indicates that the poor quality of the waters studied is related to the precarious health conditions of the study area.

Keywords: *underground water, microbiological parameters, physico-chemical parameters, urban pollution, quality of the waters*

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1. Introduction

The city of Abidjan is a privileged agglomeration from the point of view of the available water resources. It has three tiered water layers occupying the basement of the region and constituting major reserves through which this city could have been long in the category of agglomerations away from scarcity [1]. These are: the Continental Terminal aquifer, the Maestrichtian aquifer and the Quaternary aquifer. The water table contained in the Quaternary aquifer is captured by many households from wells for domestic use [2]. This sheet is very close to the surface and is flush with the ground in places. It is therefore very sensitive to urban pollution. Most wells capturing this water table are located in neighborhoods that do not have adequate infrastructure

for sewage disposal. The sanitation system in these neighborhoods has many gaps and the rate of households connected to the sanitation network is low [3]. Besides, the autonomous sanitation system mainly used in these so-called disadvantaged neighborhoods is subject to numerous failures [4]. This reflects the failure of the popular initiative for wastewater management in the municipalities of the city of Abidjan. In addition, the degradation of a large part of the city's structures results in the discharge of wastewater out of the network intended for them. These releases are estimated at 60% of domestic wastewater production [2]. To these domestic effluents must be added industrial effluents that are discharged without prior treatment [5] through these degraded sanitation facilities. Moreover, only 55% of the city's garbage production is evacuated each year [6]. Uncollected waste (45%) remains in the city. The leachate produced by this

waste can dribble towards surface water (lagoon waters in particular) or infiltrate towards the water table located less than 20 m deep [7]. These factors have a very negative influence on the water quality of the water table. And yet, people continue to use well water. Indeed, the proximity of these water sources, the high cost of water distributed by the Water Distribution Company of Côte d'Ivoire (SODECI), the numerous breaks in the distribution of water [8] and the non-existence or deterioration of the drinking water distribution network in some inhabited areas, are some reasons justifying the use of these well water. It is therefore necessary that the influence of urban pollution on the physicochemical and microbiological quality of the waters of the groundwater of Abidjan be highlighted in order to prevent a probable water hazard.

2. Material and Methods

2.1. Study Area

Located in West Africa, Côte d'Ivoire's economic capital is Abidjan. This town is located in the south-east of the country, between latitudes 5°00 'and 5°30' North and longitudes 3°50 'and 4°10' West. It covers an area of 577.35 km^2, including 89.81 km^2 of lagoon that is 16% of the area [9]. It shelters an estimated population of 4707404 inhabitants [10]. Abidjan is located on the shoreline between the Atlantic Ocean and Ebrié Lagoon. Located at an altitude of 20 m, Abidjan is subject to a climate characterized by two rainy seasons alternated by two dry seasons. Its coastal sedimentary basin consists of Quaternary aquifers, Maestrichtian aquifers and the continental terminal [11]. It comprises ten municipalities (Figure 1).

2.2. Methodology of the Study

The investigation took place in two stages:
* A survey and observation stage;
* A stage of collection of samples and analyses.

2.2.1. Survey and Field Observation.

The objective of this step was to collect information about wells and their environment. It consisted of informing survey cards by approaching the populations using the water of the selected wells. The questions concerned the people's use of well water, the organoleptic quality of well water and the means available for these populations for its treatment. Well protection parameters against sources of pollution have also been evaluated.
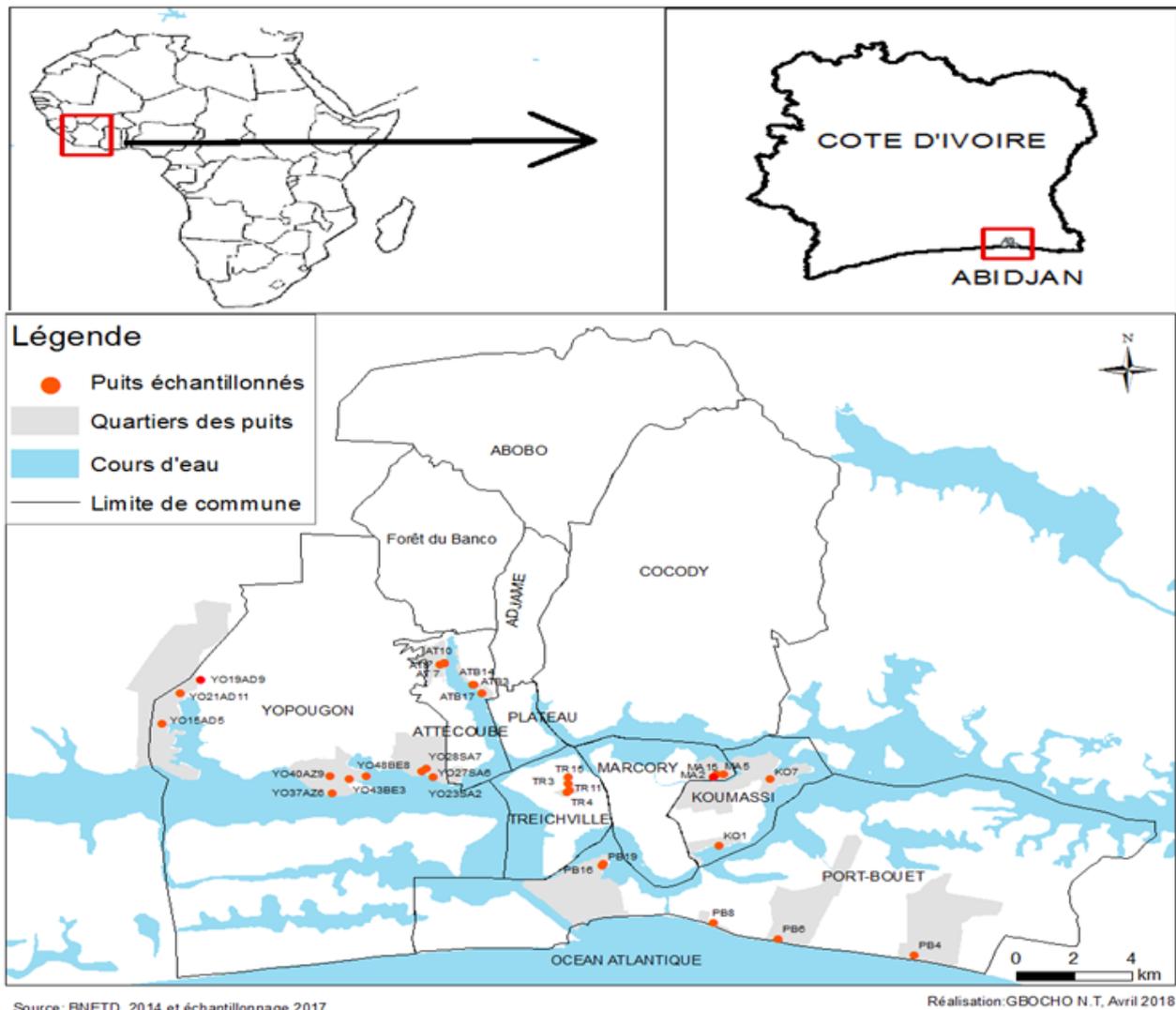

Figure 1. Location of the study area

2.2.2. Sampling of Waters from the Groundwater

29 wells were selected in 6 municipalities of the city of Abidjan, taking into account the existence of wells, the size of the municipality, the density of the population, the failure of the sanitation system and the proximity of source of pollution for the waters of these wells. Figure 1 shows the geographical position of the 29 wells in the study area.

A series of four sampling campaigns spread over the four climatic seasons was conducted for the physicochemical and microbiological characterization of the water from the selected wells. Begun in May 2017, the campaign series ended in March 2018. 116 samples were taken, that is 29 samples per campaign. The samples were taken using the sieves found at the site to take into account the conditions of use of each well. one liter polyethylene bottles were used for the samples for chemical analysis. Each vial was rinsed three times with the water to be taken, then filled with refusal and sealed before being carried in the cooler. Samples for bacteriological analysis were packaged in previously sterilized clear glass bottles. All samples were stored at 4°C in coolers during transport to the laboratory.

2.3. Analysis of Water Samples

2.3.1. Analysis Material

Physical parameters such as pH, temperature, conductivity and dissolved oxygen were measured in situ by a HACH HQ 40d multimeter. Concerning electrical conductivity, it was measured in the laboratory using a HACH LANGE 2001Q conductivity meter. Two spectrophotometers were used for the molecular absorption assays. One brand HACH DR 6000 was used for the determination of nitrates and ammonium. The other brand WFJ-752 was used for the determination of sulphates, orthophosphates and nitrites.

The titrimetric assay equipment allowed us to determine the permanganate index (PI) and chloride concentrations (Cl^-).

The bacteriological parameters were determined using a Memmert brand incubator to incubate culture media and a SANO Clav brand autoclave for the sterilization of glassware and culture media.

2.3.2. Analysis Methods

The parameters and their analysis methods are given in Table 1, Table 2 and Table 3. These parameters were determined according to the French standards (AFNOR, 2001a, AFNOR, 2001b) and the HACH methods.

2.3.3. Calculation of the Faecal Contamination Index

For the calculation of the Faecal Contamination Index (FCI), we used the method developed by Orou *et al.* [12] adapting it to our context. He used it to determine the quality of aquifer waters in the sub-prefectures of Grand-Morié and Azaguié in the department of Agboville. The parameters taken into account for the calculation of the faecal Contamination Index in this method, are bacteria from faecal origin: Faecal Coliforms (FC), Faecal Streptococci (FS) and Total Coliforms (TC) that are found in the digestive tract of humans and animal. FCI is calculated by the following equation:

$$FCI = i_{FC} + i_{FS} + i_{TC}.$$

In this equation, FCI, i_{SF} and i_{CT} represent index values that are attributed to each of the variables that are faecal bacteria in solution according to their concentration. Table 4 specifies this mode of attribution of these indices.

Table 1. Methods and references of physical parameter analyzes.

Parameters	Analysis method	Reference
pH and Temperature	Electrochemical with Glass Electrode	NF T 90-008
Conductivity	Electrochemical with the probe	NF T 90-031
Dissolved Oxygen	Electrochemical with Oxygen Probe	NF EN 25814
Turbidity	Nephelometric method with formazine	NF EN ISO 7027
MES	Method by filtration on fiberglass	NF T 90-105

Table 2. Methods and analysis reference of chemical parameters

Parameters	Method	Reference
Permanganate index	.Hot in an acid environment	NF EN ISO 8467
Nitrite (NO_2^-)	Molecular absorption spectrophotometry at543 nm using diazotization	NF EN 26777
Nitrate (NO_3^-)	By cadmium reduction	Méthode Hach 8039
Ammonium (NH_4^+)	molecular absorption spectrophotometry at 655 nm using salicylate	Méthode Hach
Sulfate (SO_4^{2-}	Nephelometry	NFT 90-040
Chlorure (Cl^-)	Mohr method	NFT 90-014
Orthphosphate (PO_4^{3-})	Molecular absorption spectrometry at 700 nm in the presence of ammonium molybdate	NF EN 1189

Table 3. Methods and analyses references of bacteriological parameters

Parameters	Methods	Volumes	Product used	Temperatures and incubation duration	Observations
Total Coliforms (TC)	Spreading	10 mL	E.coli-coliform. Chromagenic	37°C 24 to 48 h	Yellow colony
Faecal Coliforms (CF)	Spreading	10 mL	E.coli-coliforme. Chromagenic	44°C 24 h	Purple red colony
Faecal Streptococci (FS)	Spreading	10 mL	Bile with esculin and sodium azide (BEA)	37°C 48 h	Black colony with black halo
Clostridium	Incorporation	20 mL	Trypticase Sulfite Neomycin (TSN)	46°C; 18 to 24h	black colony

Table 4. How the indices are assigned according to the concentrations of the groundwater variables by class [12]

Indice i / Variables	1	2	3	4
Total coliforms (TC)	0	> 0 and ≤50	>50 et ≤50000	>50000
Faecal coliforms(FC)	0	> 0 and ≤20	>20 et ≤20000	>20000
Faecal Streptococci (FS)	0	> 0 and ≤20	>20 et ≤10000	>10000

FCI is the sum of the indices of the three variables.

Table 5 gives the grid of degree of faecal contamination. This grid contains four classes that correspond to a type of faecal contamination each.

Table 5. Faecal contamination scale of groundwater.

Classes	Calculated values	Indice of pollution
1	0<FCI≤3	No contamination.
2	3<FCI≤6	Moderate faecal Contamination
3	6<FCI≤9	Strong faecal contamination
4	9<FCI≤12	Excessive or very high faecal contamination

2.4. Statistical Analysis

The STATISTICA software was used for the processing of the collected data. They were processed using statistical approaches such as mean and proportions.

3. Results

3.1. Evaluation of Well Protection Parameters

The curbstone, the lid and the casing constitute for each well protection parameters. The curbstone allows protection of wells against the risk of flooding and pollution by runoff waters. The lid prevents air pollution by precipitation or deposit. The casing provides protection against infiltration, and is a support for the wall of each well.

All of the prospected wells have each a curbstone whose average height is 0.61 m. These heights vary between 0.1 m and 1.09 m. 20.7% of the curbstone have heights less than 0.35 m. Regarding the lids, more than half, that is 55.17% of the wells do not have lids. 53.85% of the lids are made of iron, 7.69% are plastic and 38.46% are made of wood (plywood or plank). This last material tends to degrade quickly in case of rain. As for the casing, each of the wells is provided with. 31.03% of the casings are in concrete nozzle and 13.79% in cement brick. 6.90% of the casings are made of used tires. The tires are not waterproof and can let seepage water. 34.4% of the casings are metallic (iron). Table 6 shows the proportions of wells with and without protection parameters. The number and proportion of materials constituting the protection parameters are summarized in Table 7.

3.2. Assessment of Probable Sources of Pollution

3.2.1. Septic Tanks and Latrines

93.1% of households have latrines, most of which are old and smelly. The distances between wells and latrines vary between 0.4m and 30m. 82.7% of households have septic tanks, 55.86% of which are located upstream of the wells. The distance separating septic tank and well oscillates between 3.2 m and 50 m. 70.83% of the pits are located within 15 m of the wells (Table 8). However, the safety distance is 15 m [13].

Of the 29 wells investigated, six are contiguous to a wild dump. The closest discharge to a well is 1 m away while the furthest is 50 m away. 2 dumps are located within 15 m of the wells. Let's note that one of the wells is downstream of a cemetery and very near by the lagoon. The presence of domestic animals was found in 44.44% of the households surveyed.

Table 6. Proportion of the presence or absence of protection parameters

Protection parameters	Curbstone	Lid	Casing
Presence (%)	100	44,83	100
Absence (%)	0	55,17	0

Table 7. Number and proportion of materials constituting protection parameters

	curbstone		Lid		Casing	
	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)
Concrete nozzle	3	10,34	-	-	9	31,03
Cement brick	16	55,71	-	-	4	13,79
Wood	-	-	5	17,24		-
Iron	5	17,24	7	24,14	10	34,48
Plastic	4	13,79	1	3,45	0	0
Tire	1	3,45		-	2	6,90
others	0	0		-	4	13,79
Total	29	100	13	44,83	29	100

Table 8. Distances between probable sources of pollution and wells

Distance sources of pollution-well	Minimum		Maximum	% of non-compliance
Latrine-well distance (m)	0,40		30,00	77,77
Septic tank-well distance (m)	3,20		50,00	70,83
Discharge-well distance (m)	1,00		50,00	66,66

Photo 1. Well is located very close to the lagoon

Photo 2. Well located less than 15 meters from the latrine…

3.2.2. Wastewater Evacuation

The household water, produced in more than 58.33% of the surveyed households, is evacuated from the courtyard, directly on the road, in the gutters adjacent to the courtyard, in the manholes or directly in the wild (lagoon, bush etc ....). For grey water disposal, septic tanks are used in 57.14% of households. In 42.86% of households other means are used: they are connections of latrines to the sewerage networks of rainwater, or directly in the nature.

3.3.3. Use of Wells Water Studied

Only 13.79% of well water is regularly used as drinking water. 44.83% of the waters studied are used for cooking. They are mainly used for dishes (75.86%), personal hygiene (82.76%) and laundry (89.66%). 18% are used for ablutions. All users recognize that in the event of a prolonged break in tap water and the depletion of reserves, they use well water as drinking water.

3.4. Results of Physicochemical and Bacteriological Measurements

The results of the various physical and chemical analyzes carried out on the 116 water samples taken from the underground water are given in Table 9 and Table 10.

3.4.1. Physical Parameters

The pH values of the water table of the 5 municipalities vary between 3.47 and 7.98. These waters are predominantly acidic. 42.25% of the samples analyzed have pH levels that do not comply with the WHO standard (2011) [14]. The temperatures of the waters vary between 25.50°C and 30.30°C. Only 3.45% of the analyzed samples have temperatures that do not comply with the WHO guideline (2011). The concentration of dissolved oxygen is between 0.59 mg / L and 8.16 mg / L. 84.48% of the waters studied are poorly oxygenated. The electrical conductivity varies between 100.1 μS / cm and 1570.5 μS / cm. 24.14% of the waters have excessive mineralization. The turbidity values of these waters vary between 0.17 NTU and 129 NTU. 41.38% of the wells provide murky water. Suspended solids in these waters ranged from 1 mg / L to 204 mg / L while the WHO did not allow any suspended solids.

3.4.2. Chemical Parameters

The concentrations of orthophosphate in the analyzed waters are between 0 and 4.53 mg / L. The minimum concentration of sulphates is 3.55 mg / L and the maximum is 238 mg / L. All treated samples have sulphate concentration values that are consistent with the WHO guideline value of 250 mg / L. Not detected in some wells, the maximum nitrite concentration measured is 3.97 mg / L. 14.65% of these nitrite concentrations are above the WHO guideline value of 0.2 mg / L. The measured nitrate concentrations range from 0.2 mg / L to 315.94 mg / L. 30.17% of these wells have waters with a nitrate concentration greater than the guideline value of 50 mg / L. Ammonium concentrations in the samples range from 0.023 mg / L to 16.94 mg / L. 34.48% of the values are greater than 0.5 mg / L which is the guide value for the ammonium concentration. The permanganate index measures the organic matter. Its value in the analyzed samples varies between 0 and 17.36 mg / L. 21.55% of the waters of the aquifer have higher organic matter concentrations than the WHO authorizes (5mg / L). Chloride levels range from 65.67 mg / L to 307.96 mg / L. The chloride ion concentration is in 16.38% of the sampled waters above the WHO guideline value (2011) [14] of 250 mg / L.

Table 9. Results of physical parameter analyzes.

	Min	Max	WHO Standards (2011)[14]	Percentage of Compliance	Percentage of non-compliance
pH	3,47	7,98	6,5-8,5	57,75%	42,25%
T°C	25,5	30,30	≤ 30	96,55%	3,45%
O$_2$ (mg/L)	0,59	8,16	-	15,55%	84,48%
Cond (μS/cm)	100,10	1570,00	≤1000	75,86%	24,14%
Turbidity(NTU)	0,17	129,00	>5	58,62%	41,38%
MES (mg/L)	1,00	204,00	0	0%	100%

Table 10. Results of chemical parameter analysis

	Min	Max	WHO Standards (2011) [14]	Percentage of Compliance	Percentage of Non-compliance
PO_4^{3-}(mg/L)	0,00	4,53	-	100%	0%
SO_4^{2-}(mg/L)	3,55	238	≤ 250	100%	0%
NO_2^- (mg/L)	0,00	3,97	≤ 0,2	85,35%	14,65%
NO_3^-(mg/L)	0,20	315,94	≤ 50	69,83%	30,17%
NH_4^+(mg/L)	0,01	35,38	≤ 0,5	65,52%	34,48%
PI(mg/L	0,00	17,36	≤ 5	78,45%	21,55%
Cl^- (mg/L)	28,40	571,55	≤ 250	83,62%	16,38%

3.4.3. Bacteriological Parameters

The results of the various bacteriological analyzes on well water are noted in Table 11.

The analyzes show a strong presence of the desired germs: total coliforms, faecal coliforms, faecal streptococci and clostridiums. Total coliform values range from 0 FCU / 100 mL to 15.10^6 FCU / 100 mL. 98.27% of the wells are contaminated with faecal coliforms. The number of colony forming units of faecal coliforms present in 100 ml is between 0 and 86.10^3. 92.24% of the wells have their water contaminated by faecal coliforms. The number of faecal streptococci oscillates between 0 and $10.2.10^3$ FCU / 100 ml. 90.21% of the waters of the analyzed wells are contaminated with faecal streptococci. Clostridia,

ranging from 0 to 200 FCU / 100 mL, infected 60.3% of the wells.

These results show that all sampled wells are contaminated with faecal matter.

3.5. Faecal Contamination Index

The contamination index varies between 6 and 12 with an average of 9 (Table 12).

Table 13 shows that the waters of the studied wells are divided into three classes of contamination index out of four possible. None of these wells is microbiologically safe. Only one well, that is (3.45%) has moderate faecal contamination. 75.86% of the wells have a high contamination and 20.69% have a very strong faecal contamination.

Table 11. Results of analyzes of bacteriological parameters.

	Min	Max	WHO Standards (2011) [14]	Percentage of Compliance	Percentage of Non-compliance
Total coliforms (UFC/100 mL)	0	15000000	0	1,73%	98,27%
Faecal Coliforms (UFC/100 mL)	0	86000	0	7,76%	92,24%
Faecal Streptococci (UFC/100 mL)	0	102000	0	9,79%	90,21%
Clostridium (UFC/100 mL)	0	200	0	39,70%	60,30%

Table 12. Faecal contamination indices statistics

Statistics	Minimum	Maximum	Average
FCI	6	12	9

Table 13. Distribution of faecal contamination classes-

FCI Class	Calculated value	Pollution index	Number of wells	Proportion of wells (%°)
1	0<FCI≤3	No contamination	0	0
2	3<FCI≤6	Moderate faecal contamination	1	3,45
3	6<FCI≤9	Strong faecal contamination	22	75,86
4	9<FCI≤12	Excessive or very high faecal contamination	6	20,69

Table 14. Recurrence of faecal contamination by neighborhood

	Total coliforms (UFC/100mL)	Faecal coliforms (UFC/100mL)	Faecal streptococci (UFC/100mL)	Clostridium (UFC/40mL)
AT	100	90	90	100
TR	100	82	75	100
YO	100	97,5	97,5	80
PB	100	100	100	65
KO	100	100	100	100
MA	100	100	100	58

3.6. Recurrence of Faecal Contamination by Neighborhood

Table 14 shows the recurrence of faecal contamination by area. The most common contamination is that of total coliforms. It affects all the wells in all neighborhoods. 100% of the wells of Port-Bouët, Koumassi and Marcory are affected by faecal coliforms and faecal streptococci. Clostridia are recurrent in all the Attécoubé and Koumassi wells.

4. Discussion

The household survey revealed that only 13.79% of well water is regularly used as drinking water. This assumes a certain mistrust of the underground water by the users. The major causes of this mistrust would be the general appearance of these waters as reflected by their turbidity. Turbidity values range from 0.17 to 129 NTU. Overall, 41.38% of the water has turbidity values that are not in line with the WHO guideline value (2011) of 5 NTU. The non-compliance of the turbidity is due to the intrusion of organic or inorganic or microbiological matter into the well water. In fact, 55.7% of the selected wells are not covered. They are therefore not immune to atmospheric pollution by precipitation or deposit. All the wells investigated are each equipped with a coping and a casing. Rims that are not elevated enough or in poor condition and the materials used for the construction of the casing (used tires) may facilitate the contamination of well water by rainwater runoff or by infiltration due to the sedimentary nature of the area of study. However, the deterioration of the protection parameters or their state cannot alone justify the poor quality of the waters studied. 77.77% of the latrines and 70.83% of the septic tanks are located within 15 m of the wells. This distance represents the minimum distance recommended by the WHO between a drinking water point and a wastewater and / or excreta management structure [13]. 55.86% of the septic tanks are located upstream of the wells. These individual sanitation structures are unsealed and often dug into the water table. According to Ahoussi *et al.* [15], this type of structure allows direct infiltration of wastewater into the soil. In general, the depth of the wells is low. It is between 0.57 m and 9.92 m. Besides, 20% of the investigated wells are contiguous to a wild dump.

Indeed, the non-compliance of pit-septic pit distances, shallow well depths, the localization of wells downstream of the probable sources of pollution and the very nature of the type of pits could contribute to favoring the infiltration of wastewater into the underground water. Several works confirm the possible pollution of water from a water table by septic tanks or latrines lost in water. Youmbi *et al.* [16] have shown that domestic well water pollution comes from faeces stored in dry latrines and septic tanks. According to Koné [17] latrines with unmapped bottom and walls, present risks of contamination of the shallow aquifer by pathogens and a physico-chemical pollution, especially since the depth of the structure can reach 10 m. All these reasons could justify the high concentrations of nitrogen, orthophosphate and chloride in many water samples analyzed. The proportions of exceedance of samples of waters rich in ammonium, nitrite and nitrate

are respectively 34.48%, 14.65%, 30.17%. For Yapo *et al.* [18], the use of an unsealed pit for the evacuation of faeces is a source of contamination and enrichment of underground water by nitrate, ammonium and chloride ions. These results confirm an anthropogenic pollution of the waters analyzed. Indeed many researchers [19,20] consider nitrate as an indicator of anthropogenic underground water pollution. The waters of this aquifer are mainly acidic. 71.55% have pH below 7, and 42.25% have non-WHO-compliant pH 6.5-8.5, which is pH below 6.5. This acidic tendency of the waters is perceptible in many works [2,7,9].

The acidity of these waters could be explained by the passage of water on permutolites releasing H^+ ions [21], the dissociation of bicarbonic acid from CO_2 in the atmosphere [22], and in a lesser extent by anthropogenic acidification due to the phenomenon of nitrification which is accompanied by the release of H^+ [9]. The acidic character of these waters gives them a greater corrosive property of the cement or the metallic material used for making the casings [23]. The phenomenon of corrosion of iron occurs according to the reaction (1):

$$\mathbf{Fe} + 2\mathbf{H_3O^+} \rightarrow \mathbf{Fe^{2+}} + 2\mathbf{H_2O} + \mathbf{H_2}. \qquad (1)$$
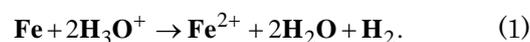
In the short term, the iron ions II can be oxidized to iron ion III and give a reddish color and a metallic taste to the water. It should be noted that 34.45% of the casings of the sampled wells are made of iron. This reaction is, long-term, causing deterioration of the casing and exposing well water to contamination due to infiltration or landslides due to the destruction of support walls. On the other hand, the presence of iron in water promotes the growth of ferrobacteria, the proliferation of which also depends on the temperature of the environment [24].

As regards the temperature of the sampled waters, it varies between 25.5 and 30.30°C. 96.55% of the well water samples studied are consistent with the WHO guideline (<30°C) in terms of temperature. However, being above 15°C, they can promote the growth of microorganisms and increase problems related to taste, odors and corrosion (WHO, 2011) [14]. The electrical conductivity of the underground water studied varies between 100.1 μS / cm and 1570 μS / cm and is greater than 1000 μS / cm in 24.14% of the well water samples studied. An excessive mineralization is therefore observed in these water samples. This mineralization can be explained by the dissolution of some minerals due to the acidity of the environment, but also by the contribution of minerals due to pollution. These include: nitrites, nitrates, sulphates, phosphates and chlorides. All water samples analyzed have orthophosphate and sulfate ion concentrations in accordance with the WHO Potability Standard. For orthophosphate ions, the WHO does not indicate a guide value. But Rodier [25] reports that ortphosphate concentrations above 0.5 mg / L should be a pollution index for water. However, 27.58% of the water samples studied have orthophosphate concentrations higher than this indicator value. Regarding sulphate ions, their concentrations in all water samples are less than 250 mg / L and therefore comply with the WHO standards 2011 [14]. Chloride ion concentrations range from 28.48 mg / L to 571.55 mg / L. 16.38% of the water samples analyzed have concentrations below the guideline value of 250 mg / L. The presence of

chlorides in drinking water can be attributed to natural sources, sewage and saline intrusions (WHO, 2011) [14]. This presence can also be explained by the addition of chlorinated products directly introduced into the wells for water disinfection. This practice can be dangerous because the chlorinated products can react with the organic matter and form trihalomethanes which are cancinogenic. The permanganate index that measures the presence of organic matter in drinking water is greater than 5 mg / L (WHO, 2011) in 21.55% of the well water samples studied. Nil in some samples, its maximum value is 17.36 mg / L. These high levels of organic matter lead us to suspect microbial contamination of these well waters [24]. Concerning the concentration of dissolved oxygen, it oscillates between 0.59 and 8.16 mg / L. This concentration is less than 5 mg / L in 84.48% of the well water samples analyzed. These waters are therefore mostly less oxygenated. This result is consistent with that of Ahoussi *et al.* [3]. These researchers found that the concentration of dissolved oxygen varies between 1.72 and 4.11mg / L in waters catching the water table in the village of Abia Koumassi in the municipality of Marcory (Abidjan). On the contrary Goné *et al.* [26] found values ranging from 6.4 to 6.7 mg / L in Agboville well waters. The low oxygenation of the waters observed at the level of the water table of Abidjan is explained by a strong urban pollution justifying a strong presence of microorganisms in the waters of the wells studied. Indeed, microorganisms use oxygen for the biodegradation of organic matter. Regarding the microbiological characteristics of well water from the water table, they reflect a high contamination of water by fecal germs. The faecal contamination index varies between 9 and 12. 96.55% of the wells provide water from high to very high faecal contamination. The values found by Orou *et al.* [12] indicate that only 65% of the wells in the Agboville region are victims of high faecal contamination. This confirms that the well water pollution is of urban origin. 98,27% of the water samples studied are contaminated by total coliforms, 92,24% by faecal coliforms, 90,21% by faecal streptococci and 60.30% by the sulphite clostridiums reducers. The high presence of faecal coliforms and faecal streptococci is a sign of old and recent faecal contamination. This could reflect continued infiltration of effluent from upstream septic tanks and wastewater latrines into domestic wells [27].

5. Conclusion

This study has highlighted the influence of urban pollution on the physicochemical and bacteriological quality of the waters in six communes of Abidjan. The various analyzes carried out have made it possible to highlight the acidity of the underground water, very high values of turbidity and those of nitrogen compounds which are nitrites and nitrates. The analysis of faecal pollution indicators (total coliforms, faecal coliforms and faecal streptococci) gave values that generally attest the very high pollution of these waters. The faecal origin of this pollution confirms its anthropic origin. Indeed, unhygienic activities around the wells, the proximity of leaky septic tanks, wild garbage dumps, and animal excrements are likely sources of

pollution. Urban pollution has led to the denaturation of the water quality of the Abidjan water table. These waters, in considerable proportions, do not meet the standards of physical, chemical or microbiological potability. However, the ease of access, the proximity of the wells, the availability of their water even in case of cut-off of the water of the public network, and their less expensive characters make them indispensable to these populations. Solutions must therefore be considered in order to significantly reduce the risks associated with the use of the waters from the Abidjan water table.

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