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Chemical and Bacteriological Control of Drinking Water from 15 Villages in Côte d'Ivoire

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Abstract: The High percentage of diarrhea-related child deaths in Africa is related to water, sanitation and hygiene. In Côte d'Ivoire, 20% of the population feeds on water from unimproved water sources and surface water. These waters are not taken into account in the sanitary monitoring of drinking water in the country. Thus, this study aimed to control the quality of the main drinking water sources in several Ivorian localities without a drinking water supply system. The methodological approach was to carry out a campaign to collect water samples from the main sources of drinking water supply in fifteen villages in five regions of Côte d'Ivoire: Agnébi tiassa, Gontougo, Kabadougou, Sud-comoé and Nawa. On these samples, the classical physicochemical parameters were determined by electrochemical and spectrophotometric methods. Microbiological analysis was performed by membrane filtration technique and pesticides by gas chromatography coupled with mass spectrometry. The results showed that the waters are characterized by mineralization ranging from 23.80 to 650 µScm-1, an acidic pH in 63% of cases, an high turbidity values (37% of cases), a color (30% of cases), in iron (20% of cases) and nitrites (17% of cases). All waters are contaminated by indicator germs of faecal pollution. A carbamate pesticide, terbucarb, was identified in 67% of the samples. In conclusion, the waters of the fifteen localities are of unsatisfactory quality and unfit for human consumption. Authorities should take measures to ensure the treatment, protection and continuous improvement of water quality in these areas in order to preserve population's health.

Keywords: Consumer Waters, Physicochemical Parameters, Microbiology, Pesticides

1. Introduction

Water is the fundamental element of life. Its potability and sanitation are essential to health. They are essential to the dignity of all. Yet 884 million people do not have access to improved drinking water sources and 2.5 billion people to improved sanitation facilities. If these figures highlight a worrying situation, the reality is much worse, since millions of people in precarious situations who live in makeshift encampments simply escape national or even global statistics [1]. Of the 2,000 children who die each day from diarrheal diseases worldwide, 90 per cent are related to water, sanitation and hygiene [2]. More than 80 per cent of child deaths due to diarrhoea occur in Africa and South Asia [3]. In the face of life-threatening water-related hazards, in 2016, the United Nations included access for all to drinking water and sanitation at the heart of the Sustainable Development Goals (SDGs). This commitment is very clearly stated in Objective 6 as follows: "Ensure by 2030 access for all to drinking water and sanitation and ensure sustainable management of water resources". To date, the United Nations estimates that over 90% of people worldwide use an improved drinking water source, but not all sources are safely managed [4]. In Côte d'Ivoire, in 2010, statistics showed that 40% of the population was supplied with running water at home, 40% benefited from an improved source of drinking water, 18% from unimproved sources and 2% in surface water [5]. Faced with the lack of drinking water in remote areas, well water and boreholes are an alternative for rural populations especially but also some urban areas. Their quality makes them a resource of very fundamental value. Good quality water is a source of health. Water pollution by pathogenic micro-organisms or by chemical pollutants is a source of water-borne diseases and death of men. Unfortunately the detection of drinking water contamination is often made only after a health crisis that sometimes leads to loss of life. Following an episode of gastrointestinal disease in a school camp in Korea, epidemiological and microbiological surveys have shown the correlation between diarrhea episodes and contamination of drinking water with pathogenic *Escherichia coli* strains. This outbreak pointed to the importance of drinking water quality management in group facilities where underground water is used and emphasizes the need for periodic sanitation and inspection to prevent possible waterborne outbreak [6]. These epidemics become a heavy burden for the State especially for the cost of the treatment of diseases transmissible to humans. No action to fight diseases and save lives would be more effective, particularly in developing countries than providing safe water and adequate hygiene for all [7, 8]. In Côte d'Ivoire, the search for *E. coli* only in drinking water was included in the 5th edition of the multiple indicator variables survey conducted by the national statistical institute. In rural areas, the proportion of water sources containing *E. coli* was estimated at 71.8%. The proportion of households containing *E. coli* in their drinking water was 94.2% [9]. This water, a natural resource around which life is maintained and developed, must be carefully monitored and controlled. In this perspective, the general objective of this study is to control the quality (chemical and microbiological analyzes) of water samples from different wells and boreholes in 15 localities in Côte d'Ivoire.

2. Experimental

2.1. Type and Setting of the Study

This analytical study was conducted in five (5) regions of Côte d'Ivoire (Figure 1). The choice of localities concerned four regions covered by the Support Program for the Improvement of Access to Drinking Water, Sanitation and Hygiene (PADEHA), which are Sud-Comoé (Aboisso), Agnébi Tiassa (Agboville), Gontougo (Bondoukou), Kabadougou (Odienné) and the Nawa region where water quality problems have been regularly reported. In each of these regions, three villages were selected according to the criterion of accessibility. Two main sources of drinking water supply consisting of wells, boreholes or surface water were selected. The physicochemical and bacteriological analyzes were carried out in the five regional capitals. Pesticide analysis was conducted at the National Public Health Laboratory (LNSP) of Abidjan.

Figure 1. *Study areas (colored in yellow) on the cartography of Côte d'Ivoire regions.*

2.2. Sampling

By water point, three water samples were taken in 500 mL borosilicate glass vials for bacteriological analyzes, 1000 mL for physicochemical analyzes and 1000 mL for pesticide research. The water samples are stored in a cooler in order to bring them to the laboratory while respecting the cold chain by ice accumulators.

The samples taken are transported in the dark at a temperature ranging from 4 C to 8 C [10] within 4 hours after sampling for the various analyzes. Samples for pesticide analysis are stored at 4 C to 8 C and sent to Abidjan for analysis. They are placed on the laboratory bench before the analysis so that their temperature returns to the ambient temperature.

2.3. Equipment

The apparatus consists of an Agilent 6890N gas chromatograph, coupled to the WATERS mass spectrometer (GC/MS), a probe pH-meter (HACH HQ 11d-France), a turbidimeter (TURB 430 IR) France), a conductivity meter with probe (HACH HQ 14 d-France), a water bath (MEMMERT-France), a photometer (HANNA-Belgium), a filtration ramp (SARTORIUS Goething-Germany), field incubators (LABNET), UV sterilizers, benchtop autoclaves (P SELECTA), GPS (GARMIN-USA), digital camera (SONY-Japan) and classics laboratory glassware.

2.4. Reagents

The reagents used are of analytical quality. They consist of methanol, methylene chloride, acetonitrile, sulfuric acid (d = 1.84), sodium oxalate, pH 4 standards, pH 7 and pH 9, potassium permanganate and pellets or powder of the brand PALINTEST® (Great Britain): DPD (N,N-diethyl-p-phenylenediamine) 1 and DPD3 for the determination of free chlorine and total chlorine, Nitratest pellet, Nitratest powder and Nitricol pellet for the determination of nitrates, the pellet Nitricol, Ammonia No. 1 and Ammonia No. 2, Iron HR Aluminum No. 1 and Aluminum No. 2, Manganese No. 1 and No. 2, Hardicol No. 1 and No. 2, Fluoride No. 1 and No. 2, Alkaphot, Acidifying CD, Chloridol, SulphateTurb, Potassium K, HR phosphate and SR phosphate, Calcicol No. 1 and Calcicol No. 2, Magnecol. The microbiology reagents consist of culture media: Rapid'E coli 2 Agar (Biorad France), Bile esculin agar (Biorad France), Plate count agar (Biorad France).

2.5. Water Analysis

2.5.1. Analysis of Organoleptic Parameters

The determination of the color was based on the principle of color comparator. The determination of turbidity is made by a nephelometric method.

2.5.2. Physicochemical Analyzes

The pH is determined using a pH meter after calibration. Conductivity is determined using a conductivity meter. Organic matter is determined according to the AFNOR method. The classical chemical parameters are ammonium, nitrites, nitrates, chlorides, sodium, iron, manganese, fluorides, aluminum, calcium, potassium, magnesium, sulphates, phosphates, the total alkalimetric title (TAC), the total hydrotimetric degree (hardness) are determined by colorimetric methods after reactions with specific reagents.

2.5.3. Pesticide Analysis

The samples were analyzed by gas chromatography coupled with mass spectrometry. For the extraction procedure, the supelclean Envi-18 SPE cartridge was preconditionned and activated with 10 ml methanol: water (80:20) followed by 10 ml methanol (30% v/v) [11]. Each drinking water sample (200 mL) was percolated using a regulated vacum through the SPE cartridge at approximatively a flow rate of 2 mL/min [12]. Cartridge was dried for 30 min in the manifold system under vacuum. The analytes were eluted with 1 mL of methylene chloride followed by 1 mL of methanol [13]. Solvents were removed using a rotavapor (40°C; 100 mb). Dry residue was recovered with 1.3 mL of acetonitrile in an injection vial. GC temperature program of the analysis is the following: initial temperature started at 70°C, held for 1min. Then the temperature increases from 10°C / min to 160°C, held for 5 min at this temperature and increases again from 3°C / min to 240°C. We stay at this temperature for 18.5 min. The source, the injector and the GC interface temperatures are respectively 230°C, 250°C and 280°C. The carrier gas used was helium. The injections were made in splitless mode.

2.5.4. Microbiological Analysis

The filter membrane method is the method that has been used to search for microbiological indicators of faecal contamination: Escherichia coli, total coliforms, thermotolerant coliforms, Enterococcus faecalis, sulphite-reducing anaerobic bacteria (SRA) represented by Clostridium perfringens.

2.5.5. Data Processingt

The benchmarks used for comparing chemical and bacteriological results are the WHO 2011 guidelines for drinking water [11]. A water sample is declared non-potable when it has at least one non-compliant parameter

3. Results and Discussion

3.1. Results

3.1.1. Presentation of Some Water Sources

Thirty samples are collected from 27 wells, 2 boreholes (Agnébi Tiassa) and 1 surface water (Nawa). Precarious hygiene and sanitation conditions were observed in the villages (Figure 2).

Figure 2. Water sources in different localities: A) Gripazo; B) Bakro; C) Mabehiri II; D) Krindjabo; E) Andepo; F) Ekissi Ho.

3.1.2. Synthesis of Physicochemical Analyzes

Physicochemical data are summaries in Table 1. The main parameters concerned by the non-compliance are turbidity greater than 5 NTU (37%), color greater than 15 TCU (30%), iron greater than 0.3 mg/L (20%) and higher nitrites at 0.1 mg/L (17%) (Figure 3). Five samples (17%) are physicochemically compliance. They were from the two boreholes of Agnébi Tiassa and three wells of Gontougo. All samples from the South Comoé region had a pH below 6.5.

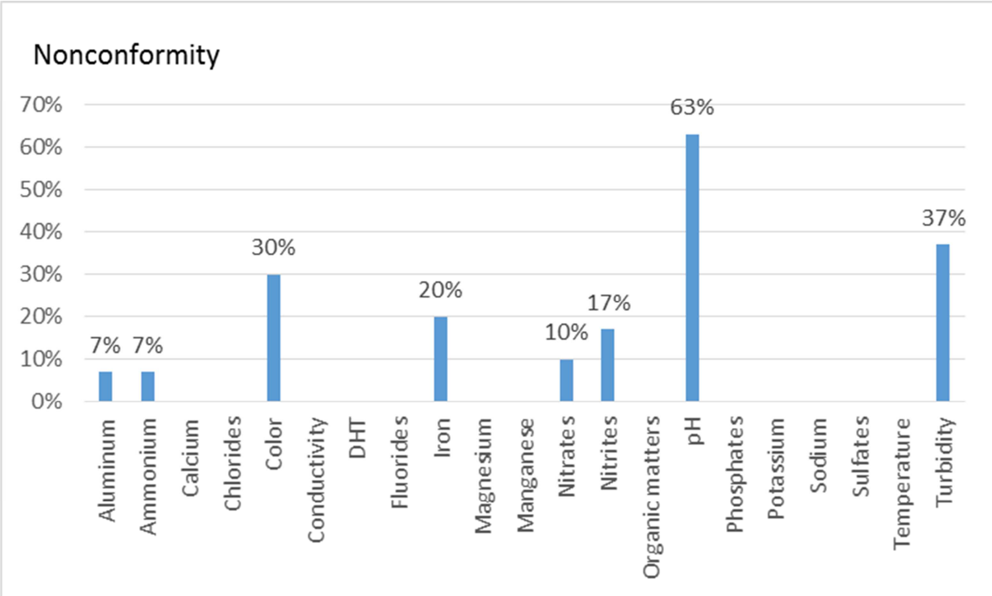

Figure 3. *Assessment result of organoleptic and physicochemical analyzes.*

All South Comoé samples had a pH below 6.5.

Table 1. *Summary physicochemical data of the thirty sample.*

Parameters	MIN	MAX	WHO [11]
Alkalinity (mg/L)	5	140	
Aluminium (mg/L)	0	3.5	<0.2
Ammonium (mg/L)	0	10	<1.5
Calcium (mg/L)	2	69	
Chlorides (mg/L)	0.9	40	<250
Color (TCU)	5	40	<15
Conductivity (mg/L)	23.8	650	<1000
DHT (mg/L)	5	245	
Fluorides (mg/L)	0	1.11	<1.5
Iron (mg/L)	0	1.25	<0.3
Magnesium (mg/L)	1	22	
Manganese (mg/L)	0.002	0.036	<0.1
Nitrates (mg/L)	0.62	90	<50
Nitrites (mg/L)	0	0.93	<1
Organic matters (mg/L)	0.31	4.8	<5
pH	4.1	7.2	6.5-8.5
Phosphates (mg/L)	0	51.4	
Potassium (mg/L)	0.2	50	
Sodium (mg/L)	0.6	28	
Sulfates (mg/L)	0	39	
Temperature (C)	24.1	30.3	
Turbidity (NTU)	0.03	59.4	<5

3.1.3. Indicator Parameters of Faecal Pollution of Water Sources

In total, 93% of these waters contained *E. coli* and 100% *Enterococcus faecalis* (Figure 4).

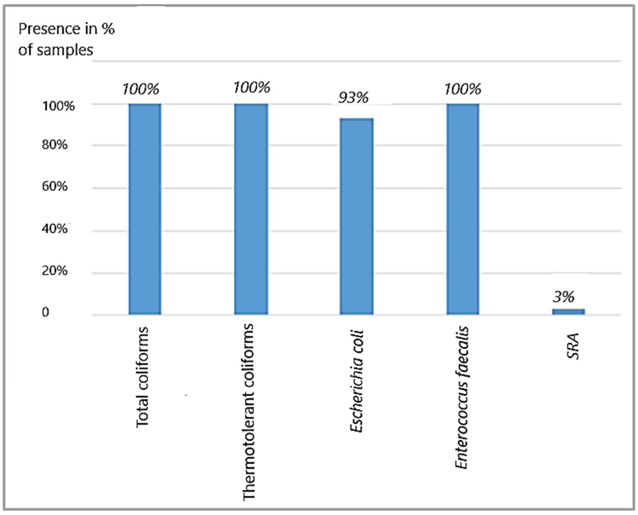

Figure 4. *Outcome of microbiological analysis.*

3.1.4. Pesticide

A pesticide named terbucarb (Phenol, 2,6-bis (1,1-dimethylethyl) -4-methyl-, methylcarbamate) and a nitrobenzene derivative were detected by GC / MS (Figure 5). Analysis of the water samples revealed the presence of terbucarb in 67% of the samples and the nitrobenzene derivative in 50% of the samples. Ten samples were free of pesticides.

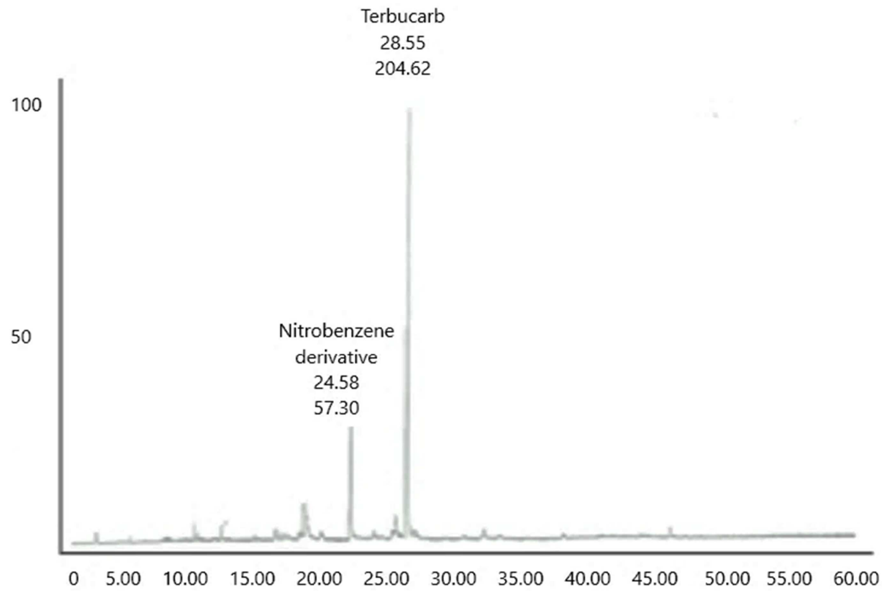

Figure 5. *Identification of terbucarb pesticide in a drinking water sample (GPS: Longitude 05°56.601 'Latitude 004°17.382') using GC/MS in full scan mode.*

3.2. Discussion

Pollution of environment is a major public health problem in developing countries. It reaches more and more groundwater like surface water. While people without access to public water supply, use well water, drilling water and surface water. The problem of this study was to evaluate the quality of these waters in several localities of Côte d'Ivoire.

All thirty water samples analyzed in the five (5) regions of Agnebi-Tiassa, Sud-comoé, Gontougo, Kabadougou and Nawa contained markers of faecal pollution such as total coliforms, thermo-tolerant coliforms, *E. coli* and *Enterococcus faecalis*. They did not contain anaerobic sulphite reducer germ with the exception of a single sample from the sud comoé region. This pollution of wells and / or boreholes has been reported in several African countries including Benin [15], Cameroon [16, 17], Morocco [18], Mauritania [19] and Togo [20, 21]. These waters are therefore unfit for human consumption and a potential source of disease. The presence of these markers in the water is due to a lack of latrines and other potential sources of pollution such as open defecation, infiltration of organic matter into the soil; the shallow water table [22].

In addition to the markers of microbiological pollution often responsible for acute diseases, there are markers whose presence in drinking water is more and more worrying. In fact, the detection of terbucarb (a prohibited pesticide herbicide of the carbamate family) in more than half of the samples (67%) analyzed raises fears of the extent of environmental pollution. Similarly, pesticides have been found in tropical agricultural areas in the Marahoué watershed, Côte d'Ivoire [23], in the water of the rivers of the Werweru sub-basin in Tanzania [24], in the groundwater in agricultural sector in Quebec [25]. Carbamates having the same characteristics as organophosphorus compounds, but with less pronounced toxicity, would be used in agriculture to control insect pests, fungi and weeds, thereby promoting growth in production [26].

In fact, agriculture, the driving force of the Ivorian economy, is distributed among cash crops 61.7%, cereals, food, fruit, (2.8%), vegetable (1.7%) and industrial (0.4%). Côte d'Ivoire uses an average of four thousand (4000) tons of pesticides per year for agricultural products. The lack of mastery of the use of pesticides by manipulators, most of whom are illiterate, the deviation of pesticide use for other non-recommended purposes such as fishing or hunting, contribute significantly to the pollution of the air and water tables, soil, drinking water, the presence of pesticide residues in food [27]. The same applies to the use of empty packaging of chemicals or defective containers that leak the product.

Apart from pesticides, nonconformities were related to turbidity, color, iron, nitrates, nitrites, aluminum and ammonium. Such nonconformities have been reported by Akonguhi et *al.* who worked on the drilling water of thirty-six (36) villages in the Abidjan region [28], also by Eblin et *al.* who worked on the hydrochemistry of surface waters of the Adiake region in the coastal south-east of Côte d'Ivoire [29]. These physicochemical parameters in relation to turbidity and color are due to the content of suspended matter in water associated with materials of very diverse nature (clay, silt, sand, microorganisms), colored organic substances (products humic or humic substances) and metals such as iron. High nitrate and nitrite values have been reported by Dégbey et *al.* who have worked on the quality of well water in the commune of Abomey-Calavi in Benin [30], but also by Yao et *al.* who worked on the assessment of the chemical potability of groundwater in a tropical watershed in Côte d'Ivoire [31]. The presence of nitrates and nitrites in water has been revealed in studies in Benin [32], Morocco [33], Mauritania [19] and Burkina Faso [34].

4. Conclusion

The quality control of drinking water from 15 villages in

Côte d'Ivoire showed that in terms of microbiology, faecal pollution was objectified in all samples. Physicochemically, the non-conformities concerned pH (pH <6.5), turbidity, color, iron and nitrites. A banned pesticide, terbucarb, has been identified in some water sources. All waters analyzed in the five regions are of unsatisfactory quality and unfit for human consumption. It is therefore imperative to look for sources of good quality water. Otherwise, it is necessary to treat them before any human consumption in order to preserve the health of the population.

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