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Evaluation of the Physico-Chemical Quality of Well Water in the Analamanga Region (Antananarivo), Madagascar

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Abstract: *The study made in some sites of the Analamanga Region, which are the Fokontany of Mandroseza, Ampanefy, Isaingy, Antalata and Malaho, shows the deterioration of the physico-chemical quality of the water of well. Elements that can cause illnesses for the beneficiaries are detected. The result is marked firstly by the acidity of the well water in all the Fokontany studied, secondly, by the rise in the rates of ammonium and organic matter in the wells which are located in the vicinity of several houses and those of nitrites in samples from wells located in the slums, near fields and rice paddies. Finally, for the Fokontany of Isaingy which is characterized by a very high number of hearths compared to other Fokontany, the waters of the wells are turbid and contain high levels of organic matter, total iron and nitrites.*
Keywords: *wells; groundwater; physico-chemical; pollution, diseases*

I. Introduction

At the national level, the improvement of drinking water and sanitation services is one of the priorities of the Madagascar Action Plan (MAP) (Champetier & Grodin, 2009). JIRAMA (Jiro sy Ranon'ny Malagasy), a public company responsible for the production, treatment and distribution of drinking water in urban areas of Madagascar, has limited geographical coverage of services. Subsidies and own resources do not meet the financial needs to extend the distribution network. As a result, in addition to significant population growth (about 3% per year), the poor performance of JIRAMA has a strong impact on access to drinking water in urban areas (RAN'EAU, 2011). Faced with this problem, the inhabitants resort to groundwater through wells to meet their daily needs. Generally, groundwater originates from the accumulation, in the soil and subsoil, of rainwater loaded with carbon dioxide dissolved in the atmosphere. During its infiltration, it is charged with ions and acquires physical and chemical properties that characterize the water of the water table that it forms. The contribution of mineral elements depends on the nature of the rocks crossed, the contact time and the time of renewal of the water by a new infiltration (Beauchamp, 2006). In addition, the highlands have good water resources that are poorly mineralized but exposed to pollution (Rakotondrainibe, 2016). The present work focuses on the study of the physico-chemical quality of well water in the city of Antananarivo and its periphery.

II. Research Methods

2.1 Study Areas

Our study was carried out in five districts of the Analamanga region. First, an urban area, the district or fokontany of Mandroseza located in the District of Antananarivo Renivohitra, second arrondissement. Enclosed in this Fokontany, Lake Mandroseza is located

at an altitude of 1,313 meters, with geographic coordinates of 18°55'60" S and 47°33'0" E in DMS (degrees, minutes, seconds) or -18.9333 and 47.55 (in decimal degrees) East. Then, the Fokontany of Ampanefy, Antalata, Isaingy and Malaho belong to the commune of Ampanefy which is a rural area, located 5km from the capital, situated in the District of Antananarivo Atsimondrano and located at an altitude of 1.123 meters. The geographical coordinates are 21°28'0" S and 47°13'0" E in DMS (degrees, minutes, seconds) or -21.4667 and 47.2167 (in decimal degrees) (UPDR, 2003).

Due to the use of the well as a source of water in the above-mentioned sites, the study concerns the measurement of the following physico-chemical parameters: temperature, pH, turbidity, conductivity, nitrite and iron levels, and organic matter content and ammonium level.

2.2 Sample Collection

Sample collection was done in February 2019 (rainy season) in all the fokontany studied (Mandroseza, Ampanefy, Antalata, Isaingy and Malaho). Four different wells were sampled in each fokontany:

- Well 1 (P1): located near fields and rice fields and surrounded by several houses (less than 5m from a house);
- Well 2 (P2): located near fields and rice fields but far from dwellings (more than 15m from a house);
- Well 3 (P3): located on the hillside, in the vicinity of several homes (less than 5m from a house);
- Well 4 (P4): located on the hill but far enough from the houses (more than 15m from a house).

Physical parameters such as temperature, pH, conductivity and turbidity are measured immediately after each field sample. On the other hand, the organic matter, ammonium, total iron and nitrite contents are determined upon arrival at the laboratory.

2.3 Physical-Chemical Analysis

a. Physical Parameters

pH and temperature are measured with a pH meter (Mettler Toledo), turbidity is measured with a turbidimeter and the conductivity meter (LF 538) is reserved for measuring conductivity.

b. Chemical Parameters

The determination of the content of chemical parameters, such as organic matter, ammonium, total iron and nitrite was carried out by the method recommended by Rodier (2009).

III. Results and Discussion

3.1 Results

a. Fokontany of Mandroseza

The rates of physico-chemical parameters measured in the water samples taken from the 4 wells of the Fokontany of Mandroseza are represented in Table 1.

Table 1. Physico-chemical characteristics of water of wells (P1, P2, P3, P4) located in the Fokontany of Mandroseza in February 2019

PARAMETERS	UNIT	P1	P2	P3	P4	STANDARDS
TEMPERATURE	°C	21,9	22	21,7	21,3	20 à 25
TURBIDITY	NTU	1,65	0,92	0,79	3.81	<5
pH		**5,95**	**5,6**	**6,31**	**5,74**	6,5 à 9
CONDUCTIVITY	µS/cm	430	233	408	159	<3 000
ORGANIC MATERIALS	$mg.l^{-1}$	0,4	0,6	0,8	0	<2
AMMONIUM	$mg.l^{-1}$	**0,77**	0,3	**0,77**	0,05	<0,5
TOTAL IRON	$mg.l^{-1}$	0,02	0	0	0	<0,5
NITRITES	$mg.l^{-1}$	0	0,03	0	0,01	<0,1

The results show temperature, turbidity, conductivity, organic matter, total iron and nitrite levels for all wells within the norms. However, the pH is slightly lower than normal for wells P1, P2, P3 and P4 (Result/reference; 5.6 to 6.31/ 6.5 to 9) in the Fokontany of Mandroseza. For wells P1 and P3, which are located in the vicinity of several houses, ammonium levels are high (0.77$mg.l^{-1}$) compared to normal (<0.5).

b. Fokontany of Ampanefy

The investigation of the levels of physico-chemical elements in the Fokontany of Ampanefy leads to the results described in Table 2.

According to the results, the water samples taken from all the wells studied in the Fokontany of Ampanefy have a slightly lower pH than normal (Result/reference; 5.01 to 6.3/ 6.5 to 9). In well P1, turbidity with a high value (28.2NTU) compared to the reference (<0.5) is noted as well as ammonium (Result/Reference; 0.7/<0.5) and total iron (Result/Reference; 0.9/<0.5) levels higher than normal.

Table 2. Physico-Chemical Characteristics of Water of Wells (P1, P2, P3, P4) Located in the Fokontany of Ampanefy in February 2019

PARAMETERS	UNIT	P1	P2	P3	P4	STANDARDS
TEMPERATURE	°C	21	20	21	22	20 à 25
TURBIDITY	NTU	**28,2**	2,17	3,45	2,83	<5
pH		**5,1**	6.5	**5,01**	**6,3**	6,5 à 9
CONDUCTIVITY	µS/cm	158	25.7	304	195	<3 000
ORGANIC MATERIALS	$mg.l^{-1}$	1,6	0,7	**3**	0,6	<2
AMMONIUM	$mg.l^{-1}$	**0,7**	0	0,05	0	<0,5
TOTAL IRON	$mg.l^{-1}$	**0,9**	0	0	0	<0,5
NITRITES	$mg.l^{-1}$	0,03	0.02	0,09	0,03	<0,1

In well P3, the rate of organic matter (3$mg.l^{-1}$) is clearly higher than the reference (<0.1). The temperature, conductivity and nitrite rates are within the norms for the 4 wells considered in the Fokontany of Ampanefy.

c. Fokontany of Antalata

Table 3 illustrates the results of the quantitative determination of physico-chemical elements in well water samples from the Fokontany of Antalata.

Table 3. Physico-chemical characteristics of water of wells (P1, P2, P3, P4) selected in the Fokontany of Antalata in February 2019

PARAMETERS	UNIT	P1	P2	P3	P4	STANDARDS
TEMPERATURE	°C	20	20,5	21	21	20 à 25
TURBIDITY	NTU	4,21	2,08	3,31	1,18	<5
pH		**5,7**	**5,02**	**5,7**	**5,9**	6,5 à 9
CONDUCTIVITY	µS/cm	29,2	24,3	18,9	47,2	<3 000
ORGANIC MATERIALS	$mg.l^{-1}$	0,9	1,3	1,2	0,8	<2
AMMONIUM	$mg.l^{-1}$	0	0	0	0	<0,5
TOTAL IRON	$mg.l^{-1}$	0	0	0	0	<0,5
NITRITES	$mg.l^{-1}$	**0,33**	**0,21**	0	0,03	<0,1

In this Fokontany, the water from the 4 wells (P1, P2, P3 and P4) is clear. The temperature and conductivity are within the norms as well as the levels of organic matter, ammonium and total iron. However, in wells P1 and P2, high nitrite levels are to be noted (Result/Reference; 0.21 to 0.33/<0.1). The pH values are lower than normal for all samples collected (Result/Reference; 5.02 to 5.9/6.5 to 9).

d. Fokontany of Isaingy

The results of the rates of physico-chemical elements sought in the Fokontany of Isaingy are represented in Table 4.

Table 4. Physico-Chemical Characteristics of Water of Wells (P1, P2, P3, P4) in the Fokontany of Isaingy in February 2019

PARAMETERS	UNIT	P1	P2	P3	P4	STANDARDS
TEMPERATURE	°C	20,5	21	22	22	20 à 25
TURBIDITY	NTU	**36,2**	**30,8**	4,19	3,12	<5
pH		**5,2**	**5,07**	**5,01**	**6,01**	6,5 à 9
CONDUCTIVITY	µS/cm	132	121	120,3	160	<3 000
ORGANIC MATERIALS	$mg.l^{-1}$	**2,4**	**2,1**	**4,1**	**3,2**	<2
AMMONIUM	$mg.l^{-1}$	0	0	0,09	0,12	<0,5
TOTAL IRON	$mg.l^{-1}$	**1,2**	**1,06**	0	0	<0,5
NITRITES	$mg.l^{-1}$	**0,8**	**0,6**	0,04	0,02	<0,1

In the Fokontany of Isaingy, the results evoke a slight acidity of the water (Result/Reference; 5.01 to 6.01/6.5 to 9) and the content of organic matter is high for each well studied (Result/Reference; 2.1 to 4.1/<2$mg.l^{-1}$). In wells P1 and P2, turbidity (Result/Reference; 36.2 and 30.8/<0.5NTU), total iron levels (Result/Reference; 1.2 and 1.06/<0.5$mg.l^{-1}$) and nitrite levels (Result/Reference; 0.8 and 0.6/<0.1$mg.l^{-1}$) reach high value compared to normal respectively. Temperatures, conductivities and ammonium levels show normal values in this research.

e. Fokontany of Malaho

Table 5 shows the results obtained after measuring the content of each of the physico-chemical parameters studied in the Fokontany of Malaho.

Table 5. Physico-Chemical Characteristics of Water of Wells (P1, P2, P3, P4) Located in the Fokontany of Malaho in February 2019

PARAMETERS	UNITS	P1	P2	P3	P4	STANDARDS
TEMPERATURE	°C	21	20	20,5	20	20 à 25
TURBIDITY	NTU	**8,2**	**7,4**	3,66	2,13	<5
pH		**6,31**	**6,15**	**6,23**	**6,46**	6,5 à 9
CONDUCTIVITY	µS/cm	19.3	17,2	80,6	17,2	<3 000
ORGANIC MATERIALS	$mg.l^{-1}$	0,9	0,7	**3,4**	0,7	<2
AMMONIUM	$mg.l^{-1}$	0	0	0,08	0	<0,5
TOTAL IRON	$mg.l^{-1}$	**0,8**	**0,6**	0	0	<0,5
NITRITES	$mg.l^{-1}$	**0,21**	**0,23**	0,06	0,01	<0,1

The results express a slight decrease in pH (Result/Reference; 6.15 to 6.46/6.5 to 9) for all wells studied. The increase in organic matter content for well P3 which is 3.4mg/l (reference: <2) is noticed. The water is slightly turbid for wells P1 and P2 (Result/Reference; 8.2 NTU and 7.4NTU/<5) and contains total iron (Result/Reference; 0.8 and 0.6 $mg.l^{-1}$/< 0.5) and nitrite (Result/Reference; 0.21 and 0.23 $mg.l^{-1}$/< 0.1) contents respectively high compared to the references. Temperatures and conductivities are within the norms in the 4 selected wells.

3.2 Discussion

a. The Acidity

The pH conditions the physico-chemical equilibrium of the water. It is said to be acidic in the waters of sandy or granitic aquifers when its value is less than 7, and alkaline or basic in the waters of limestone aquifers when its value is greater than 7 (Mouhamadou et *al.*, 2020).

The results obtained indicate the acidity of well water (Result/Reference; 5.01 to 6.46/6.5 to 9) in all the Fokontany studied (Mandroseza, Ampanefy, Antalata, Isaingy and Malaho). This acidity is very close to that measured by Lagnika et *al*. (2014) in the commune of Pobè, Benin (between 5.17 and 6.88) as well as that found by Safougne et *al*. (2020) south of Douala, Cameroon (5 to 6.1). In the present study, the acidity of the well water may come from the infiltration of runoff water during the summer into the water table because rainwater is slightly acidic due to its dissolved CO_2 content (Beauchamp, 2006). Indeed, the dissolution of CO_2 will generate dissolved carbonic acid. This one dissociates and thus releases protons which modify the pH of natural water by making it acid (Humez, 2012). However, the consumption of water that is too acidic (< 5.5) is potentially dangerous for the digestive tract and urinary tract (diarrheal syndromes and renal and urinary disorders) (El ALLAOUI and *al.*, 2016). Decree No. 2.914/2011 of the Ministry of Health recommends that the pH of the water be maintained in the range of 6.0 to 9.5 in the distribution system (National Health Foundation, 2013). Ould Cheikh et *al*. (2011) found that the pH of water in the city of Tijikja (Mauritania) is very close to neutrality (7.1 to 7.6).

b. The Temperature

The temperature is between 20 and 22°C for all the wells consulted. Compared to the reference values (20 to 25°C), it is normal and similar to the study made by Kahonin et *al*. in 2017, in Bingerville, "the temperature does not show great variations from one well to another and remains close to the average annual temperature of the region." The temperature values obtained are between 28 °C and 32 °C, in 2 locations in Benin: Cotonou and Dassa-Zoumè (Gbohaida et *al*., 2016). This temperature is quite high compared to the one obtained in the present study. Practically, the variation in water temperature does not have a direct impact on

human health. However, a temperature higher than 15 °C favors the development of microorganisms in the pipes at the same time that it can intensify the flavors and odors (Degremont, 1989).

c. The Ammonium

The high levels of ammonium (Result/Reference; 0.7 to 0.77/<0.5mg.l^{-1}) in wells P1 and P3 of the Mandroseza fokontany and in well P1 of the fokontany were noted. It should be noted that these wells are located in the vicinity of houses. In water, ammonium generally comes from the incomplete degradation of organic matter. It is a reaction of minerals containing iron with nitrates. Its presence is an excellent indicator of water pollution by organic discharges of agricultural, domestic or industrial origin. Ammonium does not have harmful effects on human health, but in the natural environment, on plants, it causes an imbalance in their nutrition and increases their fragility (Portejoie et *al*., 2002). This is harmful to the crop. Moreover, it must be eliminated because it is a food that can allow certain bacteria to proliferate (Degremont, 1989). Moreover, ammonia characterizes the concentration of $NH4^{+}$, $NH3^{-}$ ions. These elements are found in trace amounts in water. The presence of ammonia in the water table is related to the infiltration of nitrogenous material (of anthropogenic or natural origin) in the soil (Heriarivony et *al*., 2015). The use of fertilizers in the treatment of agricultural land can constitute pollution factors (Maoudombaye et *al*., 2015). According to Degremont in 1989, chlorine is ineffective to eliminate ammonium.

d. Organic Materials

In the P3 wells of the Fokontany of Ampanefy and Malaho, as well as in all the wells concerned in the Fokontany of Isaingy, the organic matter levels are clearly higher than normal (Result / Reference; 2.1 to 3.4 / < 2mg.l^{-1}). A high organic matter content would favor the progression of the bacterial load (Travel et *al*., 2007). According to the result, the high rates of turbidity of well water P1 and P2 of the Fokontany of Isaingy testify to the presence of high concentrations of organic matter that are probably from discharges related to human activity. This is confirmed by the high number of households in the fokontany of Isaingy (639 households according to the 2018 monograph of the rural commune of Ampanefy). Most of them are farmers and practice livestock around their habitat. After the rain, leached organic matter (human feces and livestock excrement) reaches the groundwater by infiltration and contributes to its pollution. In the case of the Fokontany of Ampanefy and Malaho, the increase in organic matter content may be due to urban discharges because the P3 well is located in the vicinity of several dwellings. As a result, little space is left to separate the latrines from the water point. However, the concentration of these organic materials must be reduced to prevent the development of microorganisms (Degremont, 1989).

e. Total Iron

In well P1 of Ampanefy as well as wells P1 and P2 of the Fokontany of Isaingy and Malaho, the total iron contents are higher (Result/Reference; 0.9 and 1.2/<0.5mg.l^{-1}) than normal. This may be due to the character of the soil as the Central Imerina region is characterized by red ferralitic soils (UPDR, 2003). Indeed, the iron confers to the water an unpleasant metallic taste, appearance and color (Amadou et *al*., 2014). It is much more beneficial than harmful to health. The WHO sets the maximum acceptable and admissible levels at 0.3 and 1.0 mg.l^{-1} (HANE and *al*., 2020). In contact with air, the ferrous ion Fe^{2+} (soluble) is oxidized to ferric ion Fe^{3+} (insoluble). Thus, the presence of iron oxide in water gives it its turbidity and red color (LASM et *al*., 2008).

f. Nitrites

In wells P1 and P2 of the Fokontany of Antalata, Isaingy and Malaho, nitrites are at high levels compared to the norm. (Result/reference; 0.21 to 0.8 $mg.l^{-1}$/<0.1). These values are higher than those found by Merzoug and colleagues in 2011 on well water quality in Algeria. They measured nitrite levels from 0.1 to 0.27$mg.l^{-1}$. In the case of the present study, soil nitrites are probably from fertilizers since these wells are located near rice fields. Similar to the findings of Kahoul et *al*. in the Berrahal region, nitrate pollution "would be due to the development of livestock and excessive nitrogen fertilization of the agricultural areas surrounding the study sites. The nitrate ion is reduced to nitrite by bacteria. This asserts the possible presence of bacteria in these waters. In terms of health, in an acid environment, the stomach for example, the nitrite ion gives rise to nitrous acid which generates nitrogen dioxide. The latter is able to react with nitrogenous substances called amines to form nitrosamines. High levels of nitrites, nitrates and secondary amines promote the endogenous production of powerful carcinogens, nitrosamines (Decloitre, 1992). Moreover, nitrites combine with hemoglobin and an enzyme can reconstitute Hb from MHb if the MHb content does not exceed 2 to 3%. Up to 5% there are only biological signs, from 5 to 10% there is cyanosis, from 10 to 20% there is insufficient muscle oxygenation, death can occur above 40 to 50%. MHb can cross the placental barrier and fetal deaths have been observed in animal experiments (Payment & Hartemann, 1998).

IV. Conclusion

The study of the physico-chemical qualities of well water in certain areas of the Analamanga region revealed a decrease in the pH value in almost all of the wells consulted. Organic matter, nitrite, total iron and ammonium are detected at high levels after analysis. The wells located near several houses and in the low-lying areas near fields and rice fields were the most affected. These elements deteriorate the quality of the water table by causing diseases such as digestive and urinary disorders, cancer ... for the beneficiaries. It is therefore essential to take strict measures to preserve the potability of the well water such as the construction of the well far enough away from the agglomerations, the use of filtration materials preventing the dirt from entering and especially, the treatment of the water before consumption. A bacteriological study followed by a survey will be the continuation of this study in order to confirm the suspicions of microorganisms in the well water and to know the impact of this pollution on the health of the consumers.

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