STUDY OF THE PHYSICO-CHEMICAL PROPERTIES OF THE BASEMENT AQUIFER IN THE RURAL COMMUNE OF AMPANGABE; AMBOHIDRATRIMO DISTRICT

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ABSTRACT

As the rural commune of Ampangabe is an agricultural zone, the use of chemical fertilizers could have an impact on the quality of well water in the surrounding area. In addition, the general environment of the wells is unsanitary, despite the fact that 50% of the population consume well water in the commune.

This study involves the physico-chemical characterization of well water in the fokontany of the rural commune of Ampangabe, as the water table is drying up. Hence the research question: is the water table in the Ampangabe rural commune vulnerable to external pollutants?

The results showed that only one of the five wells analyzed complied with sanitary standards. The obsolete and unhealthy state of the infrastructure is one of the main causes of this situation; but other factors can also be considered, such as the use of chemical fertilizers and the presence of a processing industry, which are sources of pollution. Short-, medium- and long-term priority actions need to be identified to avoid the various diseases that are one of the sources of poverty among the population.

Key words: *Well, Drinking water, PH, Parameters, Analysis.*

INTRODUCTION

Water is essential for life, but it can also be a source of disease. According to a report by the World Health Organization, five million infants and children die every year from diarrhoeal diseases caused by contaminated food or drinking water (Kassim Coulibaly, April 20, 2005).

In Madagascar, less than 60% of the urban population and less than 10% of the rural population have access to drinking water (S. POSTEL, 1992). In an attempt to overcome this shortfall, the government has set itself the target of achieving a drinking water coverage rate of 80% in rural areas and 100% in urban areas by 2015, according to the 2003 Poverty Reduction Strategy Paper (PRSP).

As the commune of Ampangabe is an agricultural zone, wastewater from agricultural activities, via pesticides, could have an impact on the surrounding environment. Moreover, the general environment of the wells is not healthy, even though well water is the primary source of water supply in the commune. (V. RASOAZANAMANANA, Etude de la qualité des eaux de surface dans la ville d'Antsirabe, D.E.S.S. thesis, 2003).

The aim is to determine the physico-chemical characteristics of the water (measurements of temperature, turbidity, pH, conductivity, oxygen demand, calcium, magnesium, iron, chloride and nitrate) for consumption by means of a concise analysis of the origin of pollution, and to be able to provide well owners and the relevant authorities with suggestions and/or recommendations for improving water quality in the commune of Ampangabe.

METHODOLOGIES

Geographical location of the study area

The study area lies in a north-westerly direction at a distance of 20 km from Antananarivo.
Its location lies between the following geographical coordinates:

- 18°51'58.58" south latitude and 47°24'0.87" east longitude

Location map of Ampangabe Rural Commune

ANALYSIS METHODS FOR PARAMETERS STUDIED

I- ORGANOLEPTIC PARAMETERS

These include taste, color, odor and clarity. These parameters have no health significance, but their deterioration may indicate pollution, giving consumers an early indication of water quality.

- **Color**: the color of the water can be explained by the presence of foreign matter; for example, water with a high iron content has a reddish tint (DEGREMONT, 1985).

- **Odor**: in most cases, natural waters are odorless. The existence of a specific odour can be explained by the decay or degradation of organic matter or by the presence of certain chemical combinations (DEGREMONT, 1985).

- **Taste**: the type and intensity of taste are assessed by tasting. Taste is conditioned by the different bodies in solution. For example, salty taste is felt when water contains more than 300 mg/l of chloride, and bitter taste is felt when the sulfate content of the water is between 400 and 450 mg/l. (F Dinert, Paris 1972)

II- PHYSICO-CHEMICAL PARAMETERS

1. Temperature

Water temperature is a comfort parameter for users. It can also be used to correct analysis parameters whose values are linked to temperature.
The temperature of the water affects its physical characteristics and, above all, its treatment processes:

Water conductivity depends on the temperature at the time of measurement. If the temperature is different from 20°C, the following formula gives the correction to be made:

$$C_T = C_{20°C}[1 + 0,25(T - 20)] \quad \text{C en µS/cm}$$

With :

T: temperature of the water to be rectified
CT: conductivity at temperature T (in degrees Celsius)

2. Turbidity

Turbidity represents the transparency of water. This transparency can be affected by the presence of suspended particles and colloidal matter in the water (silt, clay, micro- organisms, etc.). Turbidity is an important parameter in the various standards governing drinking water quality.

The usual turbidity class is :

- NTU < 5: clear water
- 5 < NTU < 30: slightly cloudy water
- NTU > 50: cloudy water

NTU = Nephelometric Turbidity Unit

Scattered and transmitted light must be compared between the water sample and a range of standards made up of formazine solutions. Scattered light is significant for waters with low turbidity that is not visible to the naked eye (drinking water). Transmitted light is significant for turbid water containing substances that do not scatter.

3. pH (HYDROCURE METHOD)

The pH is used to determine the hydrogen potential of water, and therefore whether you're in one of the following three zones:

- alkaline water if pH>7 [OH] > [H+]
- neutral pH=7 (this is the point of equilibrium between hydrogen ions (H+) and hydroxide ions (OH-)
- acid pH<7 [H+] > [OH]

pH is measured in the laboratory using a digital pH meter at 25°C.

4. Electrical conductivity

The conductivity of a solution is measured by applying an alternating voltage between two electrodes immersed in an electrolyte. At each instant, the ions move towards the electrode with the opposite charge, creating a resistance that depends on the number of ions and their mobility, which in turn depends on the charge and size of the ion, the temperature and the nature of the electrolyte. Applying a voltage between two electrodes in an aqueous solution causes an electric current to flow between the two electrodes, and the resistance R of the solution is given by the relationship (according to Ohm's law). (DIONEX CORPORATION, September 1998)

$$\mathbf{R} = \frac{\mathbf{E}}{\mathbf{I}}$$

Or **R** resistance (in Ω)

E voltage between the two electrodes (in volts)
I is the current intensity (in Ampere)

III- CHEMICAL PARAMETERS

1. Organic materials

Organic materials are organic compounds derived from plant and animal metabolism, as well as chemical substances that pass into solution in water as a result of the incomplete decomposition of plant waste.

The operation consists in measuring, in an alkaline environment, the quantity of oxygen removed from permanganate by organic matter of animal or vegetable origin contained in the water.

The oxidizability of organic matter to permanganate, expressed in mg.L-1 of oxygen, is equal to V1 -V2.

- Let V1 be the volume of $KMnO_4$ used for this determination. Repeat with distilled water.
- Let V2 be the final volume poured.

2. Hydrotimetry or hardness

Water hardness or TH is the sum of metal cation concentrations, with the exception of alkali metal cations and hydrogen ions. In most cases, hardness is mainly due to Ca and Mg ions (to which Fe and Al ions are sometimes added).

In limestone, calcium is found in the form of calcium carbonate. It is the main constituent that determines water hardness. The human body's calcium requirements vary between 700 and 900 mg per day. The maximum admissible concentration in drinking water is 400 mg.L-1.

Magnesium is one of the constituents of water hardness. The human body needs around 420 mg per day. The maximum admissible concentration for drinking water is 50 mg.L-1 of magnesium.

If V is the volume of E.D.T.A. poured for a 100 ml test sample, Total hardness, expressed in °F = Vml (TH)
Calcium hardness, expressed in °F = Vml (THCa)

3. Total iron

Iron is an essential element of human nutrition. Daily requirements are 1 to 2 mg. The presence of iron in water in excess of 0.1 mg.L-1 is a cause for concern, as it will give the water a yellow to orange color and cause ferric hydroxide deposits, giving the water an unpleasant metallic taste.

In ammonia, dimethylglyoxime, in the presence of iron Fe^{2+}, produces a pink complex whose intensity increases with concentration.
Dissolved iron is a key factor in determining corrosion, and can occur in industrial circuits.

4. Chloride

Chloride is one of the ions classified as a major ion in natural water. Its content varies enormously, depending mainly on the nature of the terrain through which the water flows.
A high chloride content in drinking water leads to an unpleasant taste, especially when sodium chloride is involved, and also causes corrosion in pipes and water tanks.

Chlorine is a disinfectant added to drinking water to reduce or eliminate the presence of microorganisms such as bacteria and viruses. The addition of chlorine to drinking water has significantly reduced the risk of waterborne disease transmission. Silver nitrate precipitates chlorides in the form of AgCl. The end of the reaction is marked by the appearance of the brick-red hue of silver chromate Ag_2CrO_4 (beginning of the turn).
Excessive chlorine in the water may increase chloride ion levels in the water, following the reaction:

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$$

5. Nitrate (sodium salicylate method)

In the form of a salt derived from nitric acid (HNO_3), nitrates are used in agriculture as a fertilizer and are highly soluble in water. This compound poses a threat to groundwater quality, especially in shallow catchments.
The maximum admissible concentration for drinking water is 50 mg.L-1 (expressed as NO_3^-).

Nitrate ions are the final stage in the bacterial degradation of nitrogen (N). Its presence in water indicates that the water is polluted with organic matter. This oxidation reaction is catalyzed by bacteria in soil and water.

The chain reaction is:

$$\underset{\text{ammonium}}{NH_4^+} \rightleftharpoons \underset{\text{nitrite}}{NO_2^-} \rightleftharpoons \underset{\text{nitrate}}{NO_3^-}$$

Or

$$\underset{\text{ammonium}}{2NH_4^+} + \underset{\text{oxygène}}{3O_2} \longrightarrow \underset{\text{nitrite}}{2NO_2^-} + \underset{\text{eau}}{2H_2O} + \underset{\text{hydrogène}}{4H^+}$$

Finally

$$\underset{\text{nitrite}}{2NO_2^-} + \underset{\text{oxygène}}{O_2} \longrightarrow \underset{\text{nitrate}}{2NO_3^-}$$

Nitrates are waste products of low toxicity. Plants help regulate this level, which is why fertilizers containing nitrates or phosphates should not be used.
In the presence of sodium salicylate, nitrates give sodium paranitrosalicylate, colored yellow and suitable for colorimetric determination.

Several processes can lead to the presence of nitrates in the soil:

- nitrogen fixation by bacteria (nitrogen cycle);
- decomposition of organic matter;
- spreading commercial fertilizers or animal manure on fields;
- leaks from domestic septic fields, municipal sewage systems, animal waste storage structures and livestock housing facilities.

Through the oxidation of organic nitrogen compounds (proteins, amino acids, urea) into ammonia, then nitrites and finally nitrates.

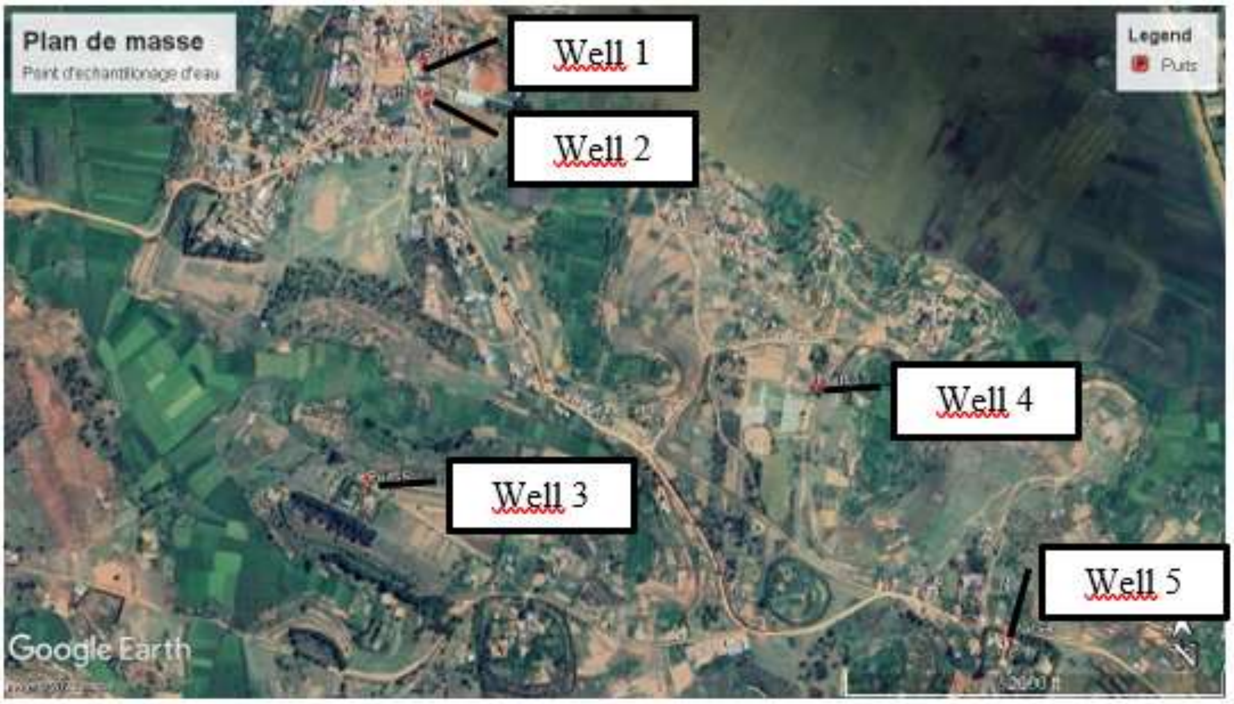
$$\text{Urea} \Rightarrow NH4^+ \rightarrow NO2 \rightarrow NO3$$

IV- RESULTS, DISCUSSION AND TREATMENT TRIAL

Physico-chemical analysis reveals the concentrations of chemical elements present in water, as well as their physical properties. This is very important, as water used for human consumption contains components that need to be totally or partially eliminated, such as suspended solids, organic matter, organic and/or mineral micropollutants and micro- organisms (bacteria, viruses, etc.). It also contains elements beneficial to health, such as calcium, magnesium and mineral salts. It is therefore necessary to precisely characterize its composition in order to know which parameters need to be corrected and to be able to treat it correctly.

1. Data presentation

The following figure shows the sampling points:



Source: Google Earth

Well 1: S18°51'57", E47°24'0.4"
Well 2: S18°51'59", E47°24'0.3"
Well 3: S18°52'15", E47°24'24
Well 4: S18°52'28", E 47°24'34
Well 5: S18°52'20", E 47°23'59

2. Temperature

Table 01: Temperature measurements for the various samples

WELL	T (°C)
Well 1	20,7
Well 2	20,7
Well 3	20,6
Well 4	20,6
Well 5	20,6
WHO standard	**< 25**
EU standard	**< 25**
Standard according to MALAGASY STATE	**< 25**

The temperature of the water sampled is between 20.6°C and 20.7°C. In-situ measurements are required before each well can be adequately treated.
Any change in water temperature causes its saturation pH to vary inversely, and thus the saturation index. It should be noted that water pH tends to decrease with increasing temperature.

Dosages need to be adjusted according to temperature variations, as the water temperature in the community can reach up to 5°C, especially in winter, which reduces the effectiveness of the disinfectant.

3. Turbidity [NTU]

Turbidity influences other water quality parameters, both bacteriological and chemical.

Table 02: Turbidity measurement

WELL	Turbidity [NTU]
Well 1	1,95
Well 2	0,74
Well 3	1,1
Well 4	1,2
Well 5	1,69
WHO standard	**< 5**
EU standard	**< 5**
Standard according to MALAGASY STATE	**< 5**

A comparison of the turbidity values of the samples with the standards required by the WHO, the European Union and the Malagasy government shows that: the concentration levels of each well in our case are compliant.

Turbidity in water is due to the presence of particles of various origins: soil erosion, dissolution of mineral substances or decomposition of plant and/or animal organic matter.
Turbidity is a parameter used to measure the effectiveness of the treatments applied to produce water for human consumption (the best organoleptic parameter).

Turbidity removal by filtration method
The essential process for eliminating turbidity is sand filtration. Its effectiveness depends on the level of turbidity at the filter inlet, in the case of conventional sand filtration. Compliance with current regulations (1 NTU maximum) means that water turbidity at the filter inlet must not exceed 6 NTU.

4. pH

The pH is determined by the quantity of ions present in the water. Similarly, when a basic substance dissociates, it releases OH- ions, which increase the pH and therefore the basicity of the water.

Table 03: pH measurement

WELL	PH
Well 1	4.68
Well 2	5,66
Well 3	6,09
Well 4	6,11
Well 5	6,23
WHO standard	**6,5 à 8,5**
EU standard	**6,5 à 8,5**
Standard according to MALAGASY STATE	**6,5 à 8,5**

pH is an important factor in water treatment, as certain processes need to be carried out at a specific pH to be effective. For example, reactions involving chlorine only take place at pH levels of 6.5 to 8.

The water sampled has a pH range of between 4.68 and 6.23, and these values do not comply with the WHO and EU recommended drinking water standard for Madagascar.
Increasing the pH of the water improves its quality for drinking purposes and brings it up to standard.

To solve this problem, you can add harder water, limestone or sodium bicarbonate or carbonate. Care must be taken, however, because the way in which you modify the pH also modifies the hardness.

5. Conductivity [µS/cm]

Conductivity measures water's ability to transmit an electric current.
Conductivity is directly proportional to the quantity of salts (ions) dissolved in water. Conductivity is linked to the presence of ions in solution. It increases with temperature and the concentration of dissolved salts. Water conductivity is expressed in microsiemens per centimeter (µS/cm), at 25°C.

Table 04: Conductivity measurement

WELL	EC [µS/cm]
Well 1	719,8
Well 2	39,03
Well 3	35,08
Well 4	41,9
Well 5	18,38
WHO standard	**180 à 1000**
EU standard	**180 à 1000**
Standard according to MALAGASY STATE	**< 3000**

In terms of conductivity, we can say that the water in this district is moderately mineralized, since the average conductivity value is less than 804 **µS /cm**, and some samples have a very low value, as in the case of site 5.

Compared with the recommended potability standards, these values are in line with Malagasy, WHO and EU standards, so there's no need to look for a way to modify this parameter, as the values found comply with the standard.

However, there are relationships that allow us to calculate approximate mineralization from conductivity. For a temperature of 20°C and a conductivity of between 166 and 333 µS/cm, mineralization can be estimated using the following formula:

$$M\ (mg.L^{-1}) = 0.77 \times \text{conductivity}\ (\mu S/cm)$$

The lower the conductivity, the "softer" the water, i.e. the less mineral salts it contains. Temperature plays a role in ion mobility, so warmer water will have a higher conductivity (normal value at 20°C).

6. Organic matter [mg.L-1]

Natural organic matter (NOM) comes mainly from the decomposition of plants, animals and micro-organisms. It is difficult to give a precise description of its origin in water,

but these elements play a major role in water quality parameters: color, disinfection by- products, odors, flavors, etc.

Table 05: Measurement of Organic Matter

WELL	MO [mg.L-1]
Well 1	2,68
Well 2	2,2
Well 3	2,23
Well 4	2,48
Well 5	1,05
WHO standard	**< 2**
EU standard	**< 2**
Standard according to MALAGASY STATE	**< 2**

The average MON value for groundwater is generally between 0.5 and 2 $mg.L^{-1}$

Four samples out of the eight 5 do not meet the standard, similarly to turbidity, the origin of these Organic Matter in these wells comes from the unhealthy environment of these wells.

Organic matter is at the root of water quality degradation, as it has a direct influence on the organoleptic properties of water (odour and taste) and is the cause of a certain toxicity acquired during treatment via the metabolization of certain compounds and from a bacteriological point of view, hence the need for treatment.

- ***The organic matter is removed by membrane filtration.***

Microfiltration and ultrafiltration are generally used; in some cases, prior coagulation is necessary when certain organic materials are too small to be retained by the membrane pores. Nanofiltration is used as a refining process in conjunction with hardness treatment. As a direct consequence, chlorine demand is reduced and chlorine residuals become easier to control.

- **Oxidation with ozone, chlorine dioxide or chlorine**

Ozone can be used for pre- or inter-oxidation, which promotes biological degradation of this organic matter, and thus reduces bacterial revitalization problems in the water.

Ozone is a very powerful oxidizing agent in the form of an unstable gas. O3 +

$$O_3 + H_2O + 2\,e^- \rightleftharpoons O_2 + 2\,OH^- \qquad E0 = 1,24\ \text{Volt}$$

The main difference between ozonation and chlorine disinfection is the effectiveness of the former in eliminating viruses.
An ozone disinfection step in a water treatment process is therefore one of the best barriers against the risk of contamination, but it is more expensive than chlorine or chlorine dioxide.

$$2ClO_2 + H_2O \rightleftharpoons ClO_2^- + ClO_3^- + 2H^+ + H_2O$$

Chlorine dioxide can lead to either an oxidation reaction (excess ClO_2) or a chlorination reaction (slight excess ClO_2).

- **Activated carbon oxidation**

The activated carbon adsorption process is used to remove dissolved organic pollutants, such as certain pesticides and hydrocarbons, after oxidation treatment. Activated carbon is used either in powder form during flocculation, or in granular form in thick filtration beds. Organic molecules, whose size has been reduced during oxidation, penetrate and bind to the pores of the activated carbon. Biological activated carbon is also sometimes used, with micro-organisms adsorbed on its walls that are major consumers of biodegradable organic matter. The advantage of such a process is that it enables organic micropollutants to be extracted without the use of chemicals.

7. Hardness (Magnesium, Calcium) [mg.L-1]

Water hardness is determined by its calcium and magnesium content. Hardness is expressed in French degrees (1° F).

Table 06: Hardness measurement

WELL	Ca [**mg.L-1**]	Mg [**mg.L-1**]
Well 1	6	10
Well 2	0,0	5
Well 3	0,0	6
Well 4	1	5
Well 5	0,0	5
WHO standard	**400**	**50**
EU standard	**400**	**50**
Standard according to MALAGASY STATE	**400**	**50**

For calcium, we found fairly low concentrations compared with the 400 mg.L-1 standard, as the maximum value was only 6 mg.L-1.
It is advisable to find a way of increasing Calcium levels in these wells to avoid certain diseases such as osteoporosis, where extremely porous bone is an essential component for bones and teeth. As the human body needs around 420 mg of Magnesium per day, and the maximum concentration in our samples is only 10 mg.L-1, it is advisable to find ways of correcting these problems, even if their concentrations are within the recommended norm.
Modifying the hardness may alter the pH, as is the case when treating samples that are too acidic. This can be achieved by mixing with harder water, adding limestone or adding bicarbonate or sodium carbonate, which raise the pH by modifying the calcium content.

8. Iron [mg.L-1]

It's a metal that's widespread underground. Food provides between 15 and 25 mg of iron per day. The maximum permissible concentration of iron in drinking water is 0.200 mg.L-1.
The following table shows the concentration of this element in our samples.

Table 07: Total iron concentration

WELL	FER [mg.L-1]
Well 1	0,52
Well 2	0,11
Well 3	0,09
Well 4	0,19
Well 5	0,1
WHO standard	**0,2**
EU standard	**0,2**
Standard according to MALAGASY STATE	**0,2**

With Iron, one sample exceeds the 0.2 mg.L-1 standard. For this reason, an oxidation step is necessary to eliminate these substances more easily.
Iron found naturally in water is either in soluble form, such as ferrous iron (bivalent iron in dissolved form Fe2+ or Fe (OH) +), or in complexed form, such as ferric iron (trivalent iron: Fe3+ found in precipitated form Fe (OH)3). For site 1, the origin of the iron in the water can also be explained by agricultural corrosion of metals.

Iron poses no danger to human health or the environment, but it does cause aesthetic and organoleptic problems. Iron gives a rusty color to water, which can stain linen, sanitaryware and food products. Iron also gives water a metallic taste, making it unpleasant to drink.

For samples with an iron content in excess of the 0.2 mg.L-1 standard, oxidation is required to remove these substances more easily. An oxidizing agent such as chlorine or ozone is used for this purpose. Lime can also be used for iron removal, the chemical reactions being :

$$Fe^{2+} + Ca\,(OH)^{2} \longrightarrow Fe\,(OH)^{2} + Ca^{2+}$$
$$Fe^{3+} + Ca\,(OH)^{2} \longrightarrow Fe\,(OH)^{3} + Ca^{2+}$$

Example: 2FeCl3 + 2Ca(OH)2 $\longrightarrow$ 2Ca Cl2 + 2Fe(OH)3

9. Chloride

Table 08: Chloride measurement

WELL	Cl- [mg.L-1]
Well 1	50,00
Well 2	11,00
Well 3	7,00
Well 4	9,00
Well 5	14,08
WHO standard	**250**
EU standard	**250**
Standard according to MALAGASY STATE	**250**

Chloride levels in our samples comply with Malagasy, WHO and French standards, which are below 250 mg.L-1. The highest concentration found in site 1 is 50.00 mg.L-1, so chloride ion concentration is not a problem.

10. Nitrate

High nitrate levels in drinking water can cause health problems, particularly for babies and pregnant women. Farming activities can lead to excess nitrate levels, and farmers and others involved in the agricultural sector will have to comply with applicable guidelines and regulations to avoid contamination problems.

Table 09: Nitrate concentration measurement

WELL	NO3- [mg.L-1]
Well 1	68,00
Well 2	2,10
Well 3	4,50
Well 4	2,80
Well 5	2,60
WHO standard	**44**
EU standard	**50**
Standard according to MALAGASY STATE	**50**

This table shows that of the five samples, only one meets the potability standards [WHO, EU, Malagasy State] for nitrate ($NO3^-$). Well water from the commune of Ampangabe contains high levels of nitrates in excess of 50mg.L-1.
Site 1 has a high concentration of nitrates, mainly due to domestic, public and natural pollution.

Although nitrates are necessary for plant growth, their excessive presence in the soil can contaminate water supplies.

Removal technique to neutralize Nitrate is biological denitrification

Biological denitrification is based on the use of bacteria, mainly from the Pseudomonas family, which use nitrates instead of oxygen from the air, converting them into nitrogen gas. The nitrate decomposition chain can be simplified as follows:

$$NO\text{-}3 \longrightarrow NO\text{-}2 \longrightarrow NO \longrightarrow N2O \longrightarrow N2$$

There are two types of denitrification: autotrophic and heterotrophic. Industrially, only heterotrophic denitrification is used, for reasons of reaction kinetics. This assumes the following operating conditions:

- anoxic environment (absence of O2),
- constant renewal of an organic carbon source,
- homogeneous mixture of bacteria, their carbon source and nitrates.

We mainly use fixed beds in which a granular material serves as a support for the bacteria. This technique is effective but tricky to implement, as it requires the above-mentioned conditions to be maintained in equilibrium. In addition, several factors influence denitrification: temperature, since higher temperatures favor denitrification, and biological mixing, which must be efficient to ensure that the bacteria are in contact with nitrates and carbon.

V- DISCUSSIONS AND RECOMMENDATIONS

The quality of water intended for human consumption depends both on the quality of the physicochemical analyses provided and on the interpretation of these analyses.
As previously mentioned, certain elements are naturally present in large quantities in well water in this district. As chlorine has the power to eliminate mineral and organic matter in water, and to remove undesirable tastes, odors and destroy pathogenic germs, chlorine-based treatment is recommended.

On the other hand, since surface water and groundwater are often closely linked, runoff can lead to reciprocal contamination. A protective approach is needed. For example, by introducing regulations specifying which pesticides can be used in areas near wells, or specifying how to apply these pesticides; by banning landfills or gas stations near groundwater supplying wells. It is necessary to respect distance standards between the well and livestock fields, or the confinement of animals near vulnerable groundwater, which is responsible for contamination of wells after infiltration.

VI- CONCLUSION

The study devoted to the analysis of well water in the commune of Ampangabe has enabled us to determine the chemical quality of the water. These include measurements of water temperature, turbidity, pH, conductivity, oxygen demand, calcium, magnesium, iron, chloride and nitrate.

According to the results of our analyses, some samples are deemed to be non- compliant, despite the fact that they may have a clear, limpid appearance and no particular odour or taste. Some chemical species far exceed the maximum permissible values recommended by water potability standards [WHO, EU, Malagasy government].

This work has provided some knowledge of well water quality in the commune of Ampagabe.

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