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Chemical Analysis of Well water in the District of Ambilobe and Water from JIRAMA of Antsiranana-I by Atomic Absorption Spectrometry (AAS)

MAMIZARA Michéa^{1*}, RAZAFINDRAPATA Augustin², RAVOMANANA Georgial³,
ANDRIAMAHENINA Njaka Namelantsoa⁴, RAKONDRAMANANA Hery Tiana⁵,
ASIMANANA Frédéric⁶

Associate Professor, Physics, University of Antsiranana, Madagascar ^{1*}

Doctor, Water and Environmental Engineering, University Institute of Environmental and Social Sciences, University of Antsiranana, Madagascar ²

Student, Physics, University of Antsiranana, Madagascar ³

Research Professor, National Institute of Nuclear Science and Technology, University of Antananarivo, Madagascar ⁴

Professor, Physics, University of Antananarivo, Madagascar ⁵

Full Professor, Physics, University of Antsiranana, Madagascar ⁶

ABSTRACT: Well water in the district of AMBILOBE and JIRAMA water of ANTSIRANANA I remains a relevant research topic related to water consumption in Madagascar, concerning both its quality and quantity. It is then the importance of rational management of water resources in all regions of the island. The DIANA region is one of them. Very few people have benefited from drinking water, which is necessary to assess their potential impact on public health. This study aims to assess the quantity of mineral elements contained in well water in some DIANA regions, more precisely in the district of AMBILOBE and ANTSIRANANA-I. The analysis was carried out by atomic absorption spectrometry (AAS) at the INSTN-Madagascar laboratory. Well water and tap water samples were taken at different sites, including the district of AMBILOBE and JIRAMA water of ANTSIRANANA I. Several categories of mineral elements were identified in the samples: essential nutrients (magnesium and calcium), as well as potentially undesirable elements such as copper, cobalt, nickel, manganese, zinc, lead, and iron. Concentrations vary significantly depending on the water sampling points. This study highlights the presence of trace heavy metals in some well waters, highlighting the importance of vigilance on the part of consumers and regulatory authorities. Recommendations regarding the consumption of these waters could help limit exposure to potentially toxic elements.

KEYWORDS: Well water, Tap water, Mineral elements, Heavy metals, and AAS.

I. INTRODUCTION

In Madagascar, 90% of the population lives in rural areas where the water sources used in daily life are mainly sources of different origins but simply called "natural sources" and traditional wells [11]. The Malagasy population is still faced with a low rate of access to drinking water [1]. For this reason, the Malagasy State has adopted for several years the policy of supply and conveyance of drinking water for the population, especially for rural areas which do not have access to water from JIRAMA [3]. It is seen through the ramifications of numerous projects which affect water management [13]. In this case, the study of the quality of the water is necessary to guarantee its potability [7]. Only about 10% of the population of the ANTSIRANANA agglomeration have a private connection to the drinking water network, the rest mainly draws from the various public standpipes installed in all the districts of the city [4]. A large part of the population therefore uses wells to meet their daily water needs [2]. The main problem related to water consumption in Madagascar concerns both its quality and its quantity [6]. Then comes the importance of rational management of water resources in all regions of the island. The DIANA region is one of them [8]. Very few people have benefited from drinking water [9].

II. METHODOLOGY

1. Study scope

Samples will be collected in two districts of the DIANA region: ANTSIRANANA I district and AMBILOBE district. The purpose of this study is to identify the levels of elements present in these well waters at the sampling points. Our study was conducted at the National Institute of Nuclear Science and Technology (INSTN-Madagascar), located in the capital of Madagascar, at the University of Antananarivo ANKATSO, in the ANALAMANGA region. The analysis results must be comparable to the standards established by the World Health Organization and the Malagasy Ministry of Public Health.

2. Sampling Strategy

The sampling strategy plays an important role in conducting a given research project. Generally speaking, there are two types of quantitative sampling methods: probabilistic and non-probabilistic. Between these two methods, we chose probabilistic methods. This probabilistic method aims to collect samples that are as representative as possible of the study population. Water will be sampled from 10 sites in November 2024.

Table 1: Well Depth (in meters)

Sampling locations	Depth (in meters)
MATIAKOHO	14 m
ANORONALA	15 m
ANJARIDAINA	5 m
AMBATOBÉ	10 m
AMBAKIRANO CENTRE	10 m
AMPASINDAVA	15 m
MANTALIMARO	16 m
EPP BETSIKA	5 m
CEG BETSIKA	6 m
DIEGO-SUAREZ	Tap water

3. Spectrometric Instrumentation and Analysis

This experiment used a single measuring instrument that operates on two techniques: graphite furnace and flame atomic absorption spectrometry. The VARIAN SpectrAA 240 Atomic Absorption Spectrometer is shown in its overview in the figure above: the flame spectrometer and the graphite furnace spectrometer, along with its accessories.



Fig. 1. Graphite furnace and Flame atomic absorption spectrometry

4. Sample Preparation

Before analysis, samples must be prepared in a vial and a small vial, thoroughly cleaned in acid and distilled water. This step ensures that only the dissolved forms of the metals are analyzed. To clean the vials, add a few drops of concentrated nitric acid to the water for 24 hours, then wash in water, then prepare the sample to be analyzed and fill it

into the vial. The preparations were completed on December 6, 2024. After sample preparation, we proceed directly to the analysis using a graphic and flame oven in the laboratory. Place approximately 5 ml of the samples (blank, material reference, and samples) to be analyzed in a small, clean cuvette. Place the six samples in a sampler, place the blank sample in numbers 1 and 2, the SRM sample in numbers 3 and 4 and the samples in numbers 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16. Blanks, reference materials, serve as quality assurance and control elements. These follow the same analytical protocol steps as samples. In the SAA, only 4 hollow lamps can be used because it is composed of 4 lamps. Program the analysis using the **Varian SpectraAA** software. Enter the data from the standards, blanks, reference materials, and samples into the program. Perform the qualitative analysis first before the quantitative analysis.

5. Standard by competent entities on drinking water

Standards have been established which set, in particular, the limit levels not to be exceeded for a certain number of harmful substances likely to be present in water.

Table 2: Standard for chemical parameters (mg. l⁻¹) [10] [12]

Entities	Ca	Mg	Fe	Mn	Zn	Pb	Cd	As	Ni	Cu	Cr	Co
O. M. S	400	50	0,3	0,4	3	0,01	0,003	0,01	0,07	2	0,05	0,02
Etat Malagasy	400	50	0,5	0,05	5	0,05	0,005	0,05	0,05	0,05	0,05	0,02

III. EXPERIMENTAL RESULTS

Ten (10) samples were analyzed and taken from different locations, coming from the ANTSIRANANA I district (UNA) and the AMBILOBE district (MATIAKOHO, ANORONALA, ANJARIDAINA, AMBATOBE, AMBAKIRANO CENTRE, AMPASINDAVA, MANTALIMARO, EPP BETSIKA, CEG BETSIKA) more precisely in the DIANA region. The results of these analyses using the SAA method show that they contain several elements such as:

- Trace elements: Lead, Arsenic, Chromium and Cadmium
- Undesirable elements: Copper, Cobalt, Nickel, Manganese, Magnesium, Zinc and Iron.
- Nutrients: Calcium and Magnesium.

1. Flame Atomic Absorption Analysis Results

Table 2 shows the average concentrations of mineral elements in water.

Table 2: Flame AAS analysis of the concentration (n=5) of mineral elements

Collection site	Ca (mg/L)	Cu (µg/L)	Co (µg/L)	Ni (µg/L)	Mn (µg/L)	Mg (mg/L)	Zn (µg/L)	Fe (µg/L)
Diego-Suarez (UNA)	<10	<10	<8	<10	<10	<10	<10	<10
MATIAKOHO	<10	<10	<8	<10	63,50 ± 0,36	<10	18,24 ± 2,37	12,78 ± 0,07
ANORONALA	<10	<10	<8	<10	68,28 ± 0,89	<10	209,94 ± 5,08	26,35 ± 0,02
ANJARIDAINA	<10	<10	<8	<10	<10	<10	41,51 ± 1,90	<10
AMBATOBE	<10	<10	<8	<10	<10	<10	<10	<10
AMBAKIRANO CENTRE	26,65 ± 0,5	<10	<8	<10	756,14 ± 0,14	72,81 ± 1,47	11,19 ± 0,87	<10
AMPASINDAVA	<10	<10	10,32 ± 0,8	14,76 ± 0,8	294,66 ± 6,02	17,81 ± 0,5	67,39 ± 3,36	53,24 ± 0,73

MANTALIMARO	31,51 ± 0,02	<10	<8	<10	<10	123,89 ± 4,38	<10	34,82 ± 0,9
EPP BETSIKA	11,35 ± 0,01	<10	<8	<10	4473,15 ± 10,28	<10	<10	17,51 ± 2,39
CEG BETSIKA	<10	<10	<8	<10	65,97 ± 0,02	<10	24,60 ± 1,22	<10

Considering the results of the SAA in flame, for calcium, the concentration is 26.65 ± 0.5 mg/l for AMBAKIRANO CENTRE, for MANTALIMARO it is 31.51 ± 0.02 mg/l, for the case of EPP BETSIKA it is 11.35 ± 0.01 and the other sampling sites are below the detection limit. For the case of nickel, the highest value is in AMPASINDAVA with 14.76 ± 0.8 µg/L, and the lowest one is below the detection limit in all other sites. Magnesium is among the nutrients whose concentration is 123.89 ± 4.38 mg/L in MANTALIMARO and the lowest value is found in AMPASINDAVA with 17.81 ± 0.5 and the others with contents below the detection limit. For the case of iron, it is found in AMPASINDAVA with 53.24 ± 0.73 µg/L while the lowest value is found in MATIAKHOHO with 12.78 ± 0.07 µg/L. Manganese concentrations range from 4473.15 ± 10.28 µg/L to 63.50 ± 0.36 µg/L. For Zinc, we note that the highest value is found in ANORONALA with 209.94 ± 5.08 µg/L while the lowest value is in MATIAKHOHO with 18.24 ± 2.37 µg/L. For cobalt, the highest value is in AMPASINDAVA with 10.32 ± 0.8 µg/L, and the lowest value is below the detection limit in all other sites. For copper, the minimum value is below the detection limit.

2. Graphite Furnace Atomic Absorption Analysis Results

Table 3 shows the average concentrations of mineral elements in the water.

Table 3: Graphite Furnace AAS Analysis of Mineral Element Concentrations (n=5).

Collection site	Pb (µg/L)	As (µg/L)	Cr (µg/L)	Cd (µg/L)
Diego-Suarez (UNA)	<5	<3	<10	<1
MATIAKHOHO	59,93 ± 0,98	<3	<10	1,21 ± 0,01
ANORONALA	33,34 ± 0,25	<3	<10	2,72 ± 0,08
ANJARIDAINA	16,79 ± 0,04	<3	<10	1,31 ± 0,01
AMBATOBÉ	<5	<3	<10	<1
AMBAKIRANO CENTRE	<5	<3	<10	<1
AMPASINDAVA	<5	<3	<10	<1
MANTALIMARO	<5	<3	<10	<1
EPP BETSIKA	<5	<3	<10	<1
CEG BETSIKA	6,55 ± 0,8	<3	<10	<1

Based on graphite furnace atomic absorption spectroscopy analysis, we found the presence of lead in some sampling sites such as MATIAKHOHO, ANORONALA, ANJARIDAINA and CEG BETSIKA with concentrations of 59.93 ± 0.98 µg/L, 33.34 ± 0.25 µg/L, 16.79 ± 0.04 µg/L and 6.55 ± 0.8 µg/L. Cadmium, in turn, had its highest value in ANORONALA with 2.72 ± 0.08 µg/L and the lowest content in MATIAKHOHO with 1.21 ± 0.01 µg/L. Arsenic and chromium had levels below the detection limit.

IV. DISCUSSIONS

These results reveal that the waters are rich in nutrients, with some undesirable and trace elements such as significant heavy metals.

- Case of DIEGO-SUAREZ (UNA)

The calcium concentration found in the water is acceptable, although the concentration is very low for water intended for human consumption. The magnesium concentration found is acceptable for drinking water; copper, cobalt, zinc, iron, nickel, manganese, lead, arsenic, chromium, and cadmium are not present in the sample, so the water is not toxic.

- MATIAKHOHO Case

Calcium and magnesium have acceptable concentrations, although very low, for water intended for human consumption. Copper, cobalt, nickel, arsenic, and chromium are not present in the sample, so the water is not toxic. Lead has a concentration found to vary little, but it is unsatisfactory. Iron is good, compared to the drinking water standard.

- ANORONALA Case

Calcium has an acceptable concentration, although very low, for water intended for human consumption, and magnesium has an acceptable concentration for drinking water. Copper, cobalt, nickel, arsenic, and chromium are not present in the sample, so the water is not toxic. Iron has a satisfactory value, and zinc has a tolerated level compared to the drinking water standard imposed by the authorities.

- ANJARIDAINA Case

Calcium is suitable for human consumption. Magnesium has an acceptable concentration for drinking water. Copper, cobalt, nickel, manganese, iron, arsenic, and chromium are not present in the sample, so the water is not toxic. Lead has a level closer to the standards imposed by the authorities. Cadmium has a concentration that is not excessive, so the water meets the conditions required for consumption.

- AMBATOBÉ Case

Calcium has an acceptable concentration, although the concentration is very low for water intended for human consumption. Magnesium has an acceptable concentration for drinking water. Copper, cobalt, nickel, manganese, zinc, iron, lead, arsenic, chromium, and cadmium are not present in the sample, so the water is not dangerous.

- Case of AMBAKIRANO CENTRE

Calcium has a tolerable concentration, although the concentration is very low for water intended for human consumption. Magnesium has an acceptable concentration for drinking water. Copper, cobalt, nickel, iron, lead, arsenic, chromium, and cadmium are not present in the sample, so the water is not toxic. Manganese has a content that is well above the required standard.

- AMPASINDAVA Case

Calcium has an acceptable concentration, although the concentration is very low for water intended for human consumption. Magnesium has a concentration well below the standards. Copper, lead, arsenic, chromium, and cadmium are not present in the sample, so the water is not toxic. Manganese has an acceptable concentration, not compared to the standard required for drinking water. Iron has a content that is not excessive, so the water meets the conditions required for drinking water.

- MANTALIMARO Case

Calcium, the concentration found is acceptable, although the concentration is very low for water intended for human consumption. Magnesium has an excess concentration, but it is not admissible for drinking water standards. Iron has a value that is below the standards. Copper, Cobalt, Nickel, Manganese, Lead, Arsenic, Chromium and Cadmium are below the detection limit, the sample has no risk of toxicity.

- Case of the BETSIKA EPP

The calcium concentration found is acceptable, although the concentration is very low for water intended for human consumption. The magnesium concentration found is very low, but it meets the drinking water standard. Copper, cobalt, nickel, zinc, lead, arsenic, chromium, and cadmium are detected below the limit.

- Case of the BETSIKA CEG

The calcium concentration is acceptable, although the concentration is very low for water intended for human consumption. The magnesium concentration found is very low compared to the standards. Copper, cobalt, nickel, iron, arsenic, chromium, and cadmium are detected below the limit. Lead has a negligible level compared to the standard required for drinking water. Manganese poses a risk of toxicity.

V. CONCLUSION

In recent years, the Diana region has suffered from a water shortage, which is evident in the neighborhoods and surrounding areas where it is growing. In fact, this situation is the cause of population growth and the city's expansion. The manganese concentration from the BETSIKA EPP is well above the standards required by the Malagasy government and the World Health Organization (WHO). These results underscore the crucial importance of rigorous monitoring of metal contaminants in well water, particularly those intended for regular consumption. They also call for a better understanding of the sources of contamination and the implementation of effective preventive measures to protect consumer health.

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