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Physico-Chemical Characterization of the Waters of a Lake System of the: Case of Andraikiba

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A B S T R A C T

Madagascar has 175 thermal springs listed in its national territory. The city of Antsirabe located at 170 km in the South of Antananarivo by following the RN7, is known and becomes popular by the presence of its thermal springs, from where its name "the city of waters". A bibliographic synthesis was set up to inventory the thermal springs on the site. These natural underground resources are part of the natural heritage of the big island. These hot springs have attracted several scientific disciplines for a long time to carry out various studies. The valorization of these riches brings enormous incomes for the State but the recognition of their values remains still insufficient by the lack of sensitization. The exploitation of these riches contributes to a sustainable development of the country and brings many advantages in the scientific, educational, economic, tourist, therapeutic and socio-cultural fields.

Keywords: Valorisation - thermal springs – wealth therapeutic - Antsirabe

1. Introduction

Water is the source of life, every creature living on this planet Earth, each one following its own life cycle, needs water in general to flourish and to dehydrate. Water is essential to the body. Indeed, 60% of water constitutes the body mass of an adult in human beings. Water has its origin and its source, each of which brings great opportunities to its surroundings and to the plant or animal organisms that use it. Precisely, Madagascar has 175 thermal springs with temperatures over 25°C, listed on its national territory (H. Besairie, 1959). In the region of Vakinankaratra, where there is the city of Antsirabe, has thermal springs that have been exploited for years. The city of Antsirabe became popular in the Indian Ocean, in the South-East of Africa and in Europe by the presence of its thermal springs and its benefits in the social, economic and cultural life; hence its nickname: "the city of waters". Numerous foreign and Malagasy researchers have made studies since a long time until today and have given information about its thermal springs of Antsirabe.

1.1 Geological setting

1.1. Location of the study area

Madagascar has 22 regions in its territory of which the region of Vakinankaratra is part and which is geographically located on the middle west of the Highlands. The Vakinankaratra region is bordered to the west by the Menabe region; to the east by the Alaotra Mangoro and Atsinanana regions; to the north by the Analamanga, Itasy and Bongolava regions; to the south by the Amoron'i Mania region. It is located between 18°59' and 20°03' South latitude, and between 46°17' and 47°19' East longitude. It is located on the southern plateau of the great massif of Ankaratra, the third highest peak in Madagascar.
The city of Antsirabe is located 170 km south of Antananarivo following the RN7, and is attached to the region of Vakinankaratra in the province of Antananarivo.

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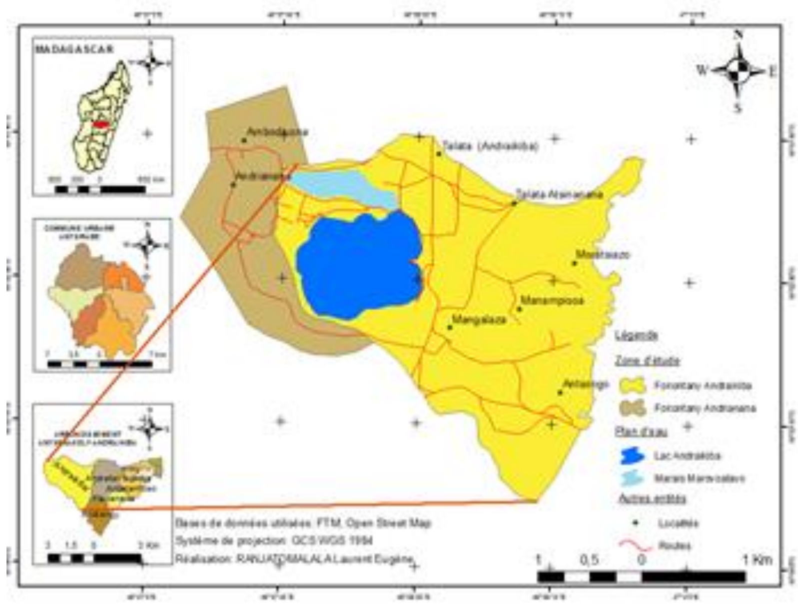


Figure 1: Location map of the study area

1.1. Location of the Antsirabe basin

Speaking of the Antsirabe basin, there are contrasting landscapes between remarkable fault escarpments, rectilinear and with strong command, and also flat areas (Figure 2), however frequently dissected by rivers (Razafimahefa R.R, Nicoud G, Mietton M and Paillet A (2012). Quaternary. reinterpretation of the Pleistocene surficial formations of the Antsirabe basin, 23, 339-353). To the North and West, the high watersheds are supported by the volcanic massifs of Ankaratra and Vakinankaratra, culminating at more than 2300 m altitude (Battistini, 1964). From a hundred meters in the western part of the basin, there is domination of volcanic cones of strombolian type like Ivohitra. In the East, the limit is determined by the great escarpment of rectilinear fault of Betampona affecting the crystalline base.

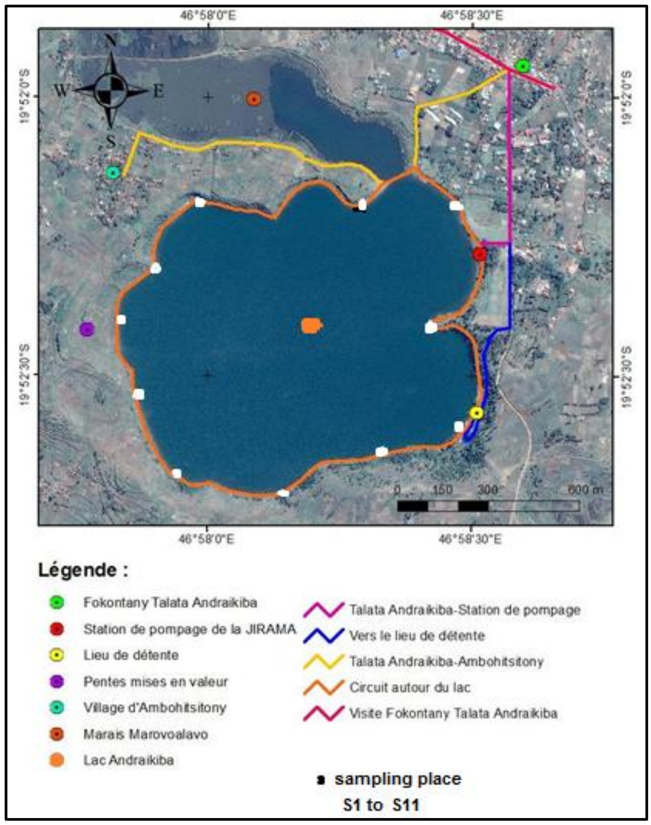
Figure 2: Photo of Andraikiba lake

1.2. Spatio-temmporal analysis

The spatio-temporal analysis of the physicochemical parameters of the waters of Lake Andraikiba in the Antsirabe basin system was tackled in the context of climate variability. The objective is to characterize the physico-chemistry of the waters during the climatic seasons. To achieve this, a hydrological analysis was carried out using in situ measurement of the parameters pH, temperature, electrical conductivity, dissolved oxygen, suspended matter, transparency and turbidity. These parameters were measured using a multi-parameter. It is launched and the results are displayed on the screen. Only transparency was measured using the Secchi disk. The temperature (31 °C) indicates relatively warm waters. As for the pH, it varies from neutral (6.79) to alkaline (8.99). The average conductivity on the lake is 40 µS / cm. The waters are well oxygenated (7 to 8 mg / L) andhave little suspended matter. The principal component analysis shows a strong correlation (r> 0.7) between the variables temperature, oxygen, pH and conductivity. These results highlight two (02) mechanisms which are at the origin of natural and artificial forcings. This is the mechanism of photosynthesis causing good oxygenation of water and the pollution mechanism reflecting high turbidity.

1.3. Sampling station

The sampling of physico-chemical parameters was carried out on eleven (11) stations during four (02) climatic seasons including 01 dry seasons (January and September 2019 and 01 rainy seasons (June and November 2019). These samplings were done on the surface and then in the water column on each station.



Sampling station

2. Materials et methods

2.1. Equipment

The equipment used is essentially composed of a multi-parameter, a GPS and a Secchi disk. Composed of a probe and a screen, the multi-parameter was used to measure in situ the physico-chemical parameters (pH, temperature, dissolved oxygen, conductivity, suspended matter, turbidity). The GPS was used to locate the sampling stations. As for the Secchi disk, it allowed the measurement of the transparency.

*2.2. **Methods***

- *Acquisition of physico-chemical data*

The in situ measurements of the parameters were made immediately in the lake using a multi-parameter. For the measurement of these parameters (pH, Temperature, Dissolved Oxygen, Conductivity, Turbidity), the multi-parameter was calibrated from the boat and then put into the water at each sampling station. The values obtained are displayed on the screen where they are carefully read by the operator. For the measurement of transparency, the principle consists in lowering the Secchi disk into the water with a graduated rope until it disappears. The height of water from which the disc is no longer visible to the operator is noted in meters (m).

- *Correlation of physico-chemical parameters by Principal Component Analysis*

The data collected during the sampling campaign were subjected to statistical analysis with the Statistica 7.1 software for a better interpretation of the results. The principal component analysis (PCA) is an exploratory tool, which consists in searching for linear combinations of quantitative variables in order to form factorial axes to detect similar individuals, then to highlight a typology of individuals and finally to detect the relations between the different variables. The PCA will be done on eleven (11) statistical units for six (06) variables (pH, Temperature, Dissolved oxygen, Electrical conductivity, Turbidity and Transparency

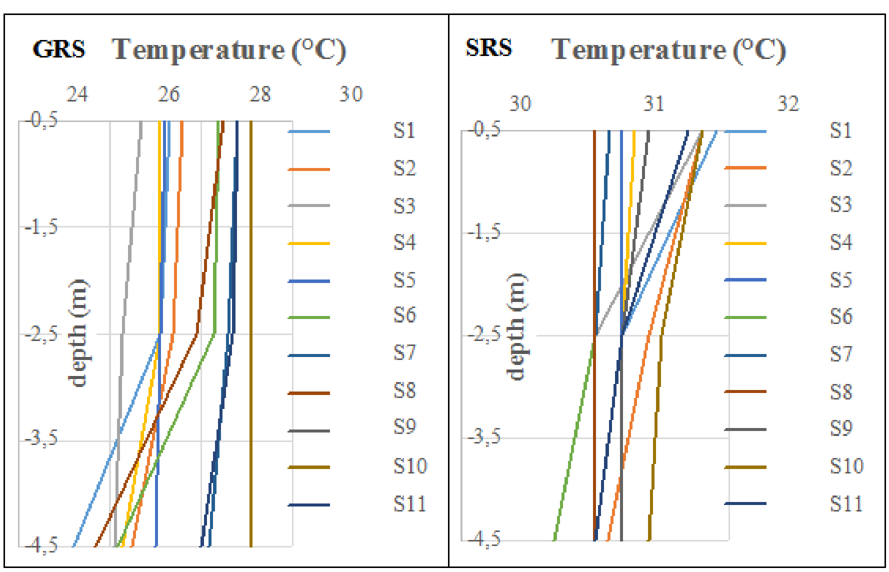
4.Results

4.1 Spatial and temporal distribution of hydrogen potential

- *Dry season (January and September)*
  The spatial distribution of pH on the lake water body is not homogeneous during the long and short dry seasons. Indeed, during the long dry season, the pH varies from 6.7 to 9.7 while during the short dry season, it ranges from 6.88 to 8.36 . The surface evolution of the pH shows basic areas (Center) (pH 7) during the long dry season that become acidic during the short dry season.
- *Rainy season (July and November)*
  During the long rainy season, the waters of Lake Labion are quasi-acidic with pH values mostly below 7 (Figure 5) while during the short rainy season , it varies from neutral (7.84) to alkaline (9.15). However, it shows a heterogeneous spatial distribution over the two (02) seasons . The SouthWest of the lake has a basic pH (8.09) during the main rainy season. This same area has an almost neutral pH (7.84) during the short rainy season.

4.2 Spatio-temporal evolution of temperature

- *Dry season (January and September*)
  The temperature during the dry season is almost constant at the surface because it varies little (Figure 7). It ranges from 30.3°C to 32°C during the long season and from 29.1 to 30.6°C during the short dry season. In the water column, the evolution of temperature varies slightly during the short dry season. Values drop to a minimum of 28 °C at depth.
- *Rainy season (July and November*)
  Temperatures recorded during the long rainy season vary from 26.7 °C to 29.1 °C at the surface. In the water column, they reach a minimum of 25 °C. In contrast, station 10 remains constant over the entire water column. During the short rainy season, the temperature values rise slightly at the surface and vary from 31 °C to 21.9 °C. The temperature varies little in the water column during this season .



(GRS: Great rainy season ; SRS : Small Rainy Season)

Spatio-temporal evolution of temperature

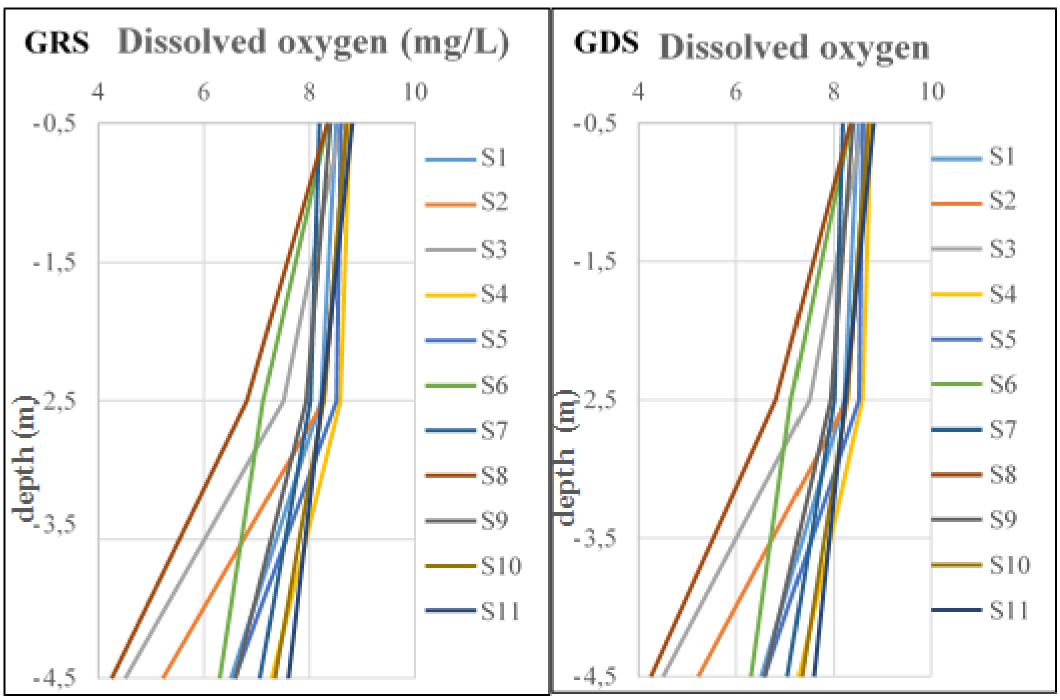
4.3 Evolution of dissolved oxygen

- *Dry season (January and September)*

Dissolved oxygen levels at the lake surface during the long dry season vary little (8.2 mg/L to 8.85 mg/L) with an average of 8.5 mg/L. During the short dry season, dissolved oxygen levels range from 8.33 mg/L to 9.01 mg/L. In the water column, these different values fall and reach a minimum value of 4.5 mg/L during the long dry season

- *Rainy season (July and November)*

During the rainy season, dissolved oxygen ranges from 6.14 mg/L to 8.27 mg/L during the long season and from 8.5 mg/L to 8.7 mg/L during the short season . Dissolved oxygenvaries very little at the surface during the shortrainy season. In the water column, oxygen remains constant over the first few meters of the lake and then decreases at the bottom.



Evolution of dissolved oxygen

4.4 Evolution of the electrical conductivity

- *Dry season (January and September)*

Electrical conductivity during the long dry season shows an uneven distribution over the lake surface It varies from 40.55 µS/cm to 42.3 µS/cm with an average of 41.44 µS/cm and a standard deviation of 0.64. The eastern part of the lake records the highest values during the two (02) seasons studied

- *Rainy season (July and November)*

Conductivity during the rainy season varies little and shows an uneven spatial distribution across the lake. During the large rainy season, conductivity varies from 40 µS/cm to 45 µS/cm with a mean of 43.12 µS/cm and a standard deviation of 1.69 (Figure 13). During the short rainy season, there is a slight decrease in these values. They vary from 40.55 µS/cm to 41.65 µS/cm with an average of 41.25 µS/cm and a standard deviation of 0.28. The high conductivities are observed in both the western and eastern parts of the lake during the large rainy season and in the eastern part during the small rainy season (Figure 14).

4.5 Seasonal Evolution of Transparency and Turbidity

The transparency and turbidity parameters are originally inversely correlated. High turbidity indicates low transparency. By definition, turbidity represents the total dissolved mineral and organic matter. For this study, only the turbidity maps will be presented.

- *Dry season (January and September)*

The turbidity of the lake presents an unequal spatial distribution during the two (02) dry seasons. Turbidity concentrations vary from 4.72 NTU to 6.12 NTU with an average of 5.47 NTU during the long dry season and from 5.47 NTU during the short dry season *dry season*and from 3.73 NTU to 10.5 NTU with an average of 5.65 NTU during the short dry season . The high turbidity values are located in the center of the lake during the two (02) seasons.

- *Rainy season (July and November)*

The turbidity during the seasons, presents an almost uniform spatial distribution. Turbidities vary from 4 NTU to 10.5 NTU during the long rainy season and from 4 NTU to 7.29 NTU during the short rainy season . Low turbidities occupy almost the entire lake.

4.6 Correlation between the variables studied

- *Statistical description of the parameters*

Table 1 presents the description of the statistical parameters (mean, minimum, maximum and standard deviation) of the different variables studied (pH, T°, EC, DO, Turbidity and Transparency).

The pH varies from acidity (6.79) to alkalinity (8.99). As for temperature, the waters are relatively warm (30.3°C – 32°C). Dissolved oxygen and electrical conductivity vary very little. Oxygen varies from 8.18 mg/L to 8.76 mg/L and conductivity from 40.5 µS/cm to 42.2 µS/cm. Water transparency varies from 0.5 m to 1.05 m depth.

- *Correlation matrix*

Table 2 shows the correlation matrix for the Lake Labion variables.

The analysis of the above correlation matrix shows the following correlations:

- temperature correlates positively with the variables electrical conductivity (0.77) and pH (0.70) ;

- dissolved oxygen (DO) correlates positively with electrical conductivity in a very significant way, with a correlation coefficient of 0.83.

The existence of a significant correlation between temperature and electrical conductivity shows that there is a great chemical affinity between these variables and indicates mineralization of the waters.

Table 1: Description of physico-chemical parameters

Parameters	Mean	Minimum	Maximum	Standard deviation
pH	8.22	6.79	8.99	0.45
Temperature	31.53	30.3	32	0.98
Dissolved oxygen	8.51	8.18	8.76	0.41
Conductivity	41.42	40.5	42.2	0.64
Transparency	0.93	0.5	1.05	0.26
Turbidity	5.47	4.72	6.12	0.37

Table 2: Correlation matrix between variables

	pH	Temperature	Oxygen	Conductivity	Transparency	Turbidity
pH	1.00					
Temperature	0.04	1.00				
Oxygen	0.16	0.69	1.00			
Conductivity	0.29	**0.77**	**0.83**	1.00		
Transparency	**0.70**	-0.33	-0.41	-0.12	1.00	
Turbidity	-0.27	-0.06	-0.33	-0.45	-0.09	1.00

5. Discussion

- The surface hydrogen potential analysis showed the influence of photosynthesis on the lake environment (Aka, 2016). It generates neutral sometimes basic pH on Lake Andraikiba. Indeed, the pH varies from 6.79 to 8.99 during the dry season and from 6.5 to 8.09 during the rainy season. These values are within the range of the WHO (2004) guide values (6.5-8.5). The pH values obtained on Lake Andraikiba are almost close to those measured on Lake Ranomafana which varies from 7.1 to 7.8 (Konan et al., 2013). These different values are related to biological and physico-chemical reactions in connection with the presence of aquatic plants (Lynda et al., 2011). The pH of Lake Andraikiba is within the standards of potability for surface water.
- Regarding the temperature on the lake water body, it varies from 30.3°C to 32°C in the dry season and from 26.7°C to 29.1°C in the wet season. Lake Andraikiba temperatures vary little and are essentially identical to those obtained (27.48 °C to 32.45 °C). Water temperature being a very important factor for ecosystem functioning, is subject to atmospheric influences and particularly to changes in air temperature. Thus, the high water temperatures (> 30 °C), would be explained by the sunshine of the surface layers during the dry season. The rays pass through the thin water layer, heating it up evenly. On the other hand, the temperatures below 30°C on Lake Andraikiba obtained during the rainy season, would be explained by the cooling of the water due to the arrival of rainwater.
- Dissolved oxygen concentrations in Lake Andraikiba average over 8 mg/L during the dry season and 7 mg/L during the wet season.
- The origin of dissolved oxygen in natural environments would certainly be linked to the photosynthetic activity of aquatic plants but also to the dissolution from atmospheric oxygen. According to the WHO (2004), a good quality water should have an oxygen concentration higher than 7 mg/L. On Lake Andraikiba, DO concentrations range from 8.2 mg/L to 9.01 mg/L. These values are well above the WHO (2004) guideline values for surface water potability. Therefore, the water quality of Lake Andraikiba is good.
- Lake Andraikiba has a very low electrical conductivity (EC less than 100 µS/cm). It varies on average from 41.42 µS/cm to 43.12 µS/cm at the surface. The conductivity is also low (83 µS/cm and 64 µS/cm respectively). Since the nature of the bedrock is a function of the mineralization of a water, the electrical conductivity therefore reflects geological characteristics of the watershed (Clement et al., 2004; CBRSC, 2010). Thus, the low conductivities recorded on the waters of the lakes in the south of Antsirabe, could be explained by the flow of inputs due to runoff on the one hand and on the other hand by the nature of the substratum which is constituted of sandy-clay rock.
- Turbidity and transparency are markers of dissolved particles in the water. During the dry season, turbidity is low with values from 3.73 NTU to 10.5 NTU. As for the transparency during this same season, it varies from 0.5 m to 1.02 m in depth. We thus note a high turbidity for a low transparency. In the rainy season, we observe a low turbidity that varies from 4 NTU to 7.29 NTU and a high transparency that varies from 0.5 m to 1.2 m. These different values allow us to conclude that Lake Andraikiba is little loaded with dissolved particlesand organic matter during the seasons.

The principal component analysis (PCA) carried out on Lake Andraikiba during the seasons, allowed to highlight the existing correlations between the variables taken two by two. However, the correlations observed are between the variables dissolved oxygen and electrical conductivity. These variables have a common origin because they are positively correlated ($r = 0.87$). The couples of variables temperature - conductivity and hydrogen potential - temperature, also present a common evolution. Their correlation coefficients are respectively 0.77 and 0.70. The mechanism highlighted is the organic pollution of the water which would be due to the presence of suspended matter (low transparency) on the lake (Soro et al., 2010).

6. Conclusion

The main objective of the study carried out on the physico-chemical characterization of a lake system of the Ivorian coastal strip was to characterize the physico-chemistry of the waters of Lake Andraikiba. This study allowed to bring out the characteristics of the waters of the lake during the dry and rainy seasons. The physico-chemical analysis showed that the temperature (>27 °C) and dissolved oxygen (>7 mg/L) present high values. Transparency and turbidity evolve according to the same sequences of variation leading to organic pollution. On the other hand, the electrical conductivity is the dominant factor of the fresh water quality of the lake. The pH of the lake water is relatively neutral to basic (pH: 6.96 to 8.22) at the surface and acidic (< 7) at depth. The parameters electrical conductivity, temperature and dissolved oxygen have a common origin because they present a good correlation (>0,70). The waters of Lake Labion are relatively warm, rich in oxygen, very soft and have a neutral to basic pH. The hydrology of Lake Andraikiba iscontrolled by anthropogenic influences. It is therefore undeniable to reduce the input of nutrients into the lake. However, these waters could serve as a freshwater resource for drinking water supply. For a better monitoring of the lake systems that are potential sources of drinking water supply, studies on bathymetry and microbiology should be carried out.

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