Study of Physico-chemical and Bacteriological Quality of Water from Ain Mkbrta Source in Morocco

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Abstract. Springs water is underground water, considered purer than surface water. Its nature depends on the rocks and soils through which it flows. They can be highly charged with specific minerals, which explains why these waters do not meet drinking water standards, but they are widely used for therapeutic properties. In this current work, we investigated the physico-chemical and bacteriological analysis of a water source known for its therapeutic effects, particularly in dermatology. We also examined the geological characteristics to understand the origin of the mineralization of these waters, with the aim of making better use of them on both a medical and economical levels. Ain Mkbrta source, 60 km from Fez city. It belongs to the Rif external domains (Rif Chain), and given its chemical composition, this spring is similar to the Moulay Yacoub hydrothermal spring, with a very pronounced odor due to the presence of hydrogen sulfide. The outcome of physico-chemical analysis of Ain Mkbrta spring showed a very high conductivity, a high hydrogen sulfide content and a wide variety of minerals in significant quantities, such as calcium, magnesium, bicarbonate, sulfate, sulfide, and chloride. Furthermore, Bacteriological analysis is moderately satisfactory, with low concentrations of fecal coliforms and revivable germs.

Key words: Natural springs, Ain Mkbrta, Therapeutic benefits, Geological characteristics, Physico-chemical quality, bacteriological, Morocco.

1 Introduction

Spring water is generally considered to be very pure filtered naturally through rocks and soil, since it comes from underground water tables. However, its quality can vary according to many factors, such as local geology, weather, and surrounding human and animal activities. It is widely used for therapeutic purposes.

Numerous scientific studies have been carried out on mineral waters in different parts of the world. In Turkey, for example, numerous studies have examined the geochemical properties and chemical quality of thermal mineral waters [1]. In China, a geochemical study was carried out on thermal waters in Jiangxi province [2]. In Spain, the study focused on geochemical characterization and health problems of bottled mineral waters in Catalonia [3]. In Morocco, there are several thermal springs with excellent therapeutic properties, including Moulay Yacoub spring [4], Ain Hamra spring [5] and Sidi Hrazem spring [6].

Studies on thermo-mineral waters in Morocco have mainly focused on well-known springs such as Moulay Yacoub, Sidi Harazem and Ain Allah. Numerous quantitative and qualitative studies have been carried out, as well as studies on curative benefits, but there are still many unknown and unexploited therapeutic sources, which is why our aim is to identify and develop this invaluable wealth.

In this work, we studied the therapeutic spring located 60 km from Fez city. It belongs to the Rif external domains (Rif chain), and given its chemical composition, it is like the Moulay Yacoub hydrothermal spring, with a very pronounced odor due to the presence of hydrogen sulfide.

A bacteriological study was investigated in parallel with a physico-chemical analysis, in order to prevent the health risk associated with contamination of the water spring, particularly by pathogenic microorganisms. However, a geological study was also carried out, to understand the origin of the mineralization of this water, which is known to have therapeutic effects, notably in dermatology.

Sampling campaigns, physico-chemical and bacteriological analysis of the water have been examined periodically at the spring according to standardized protocols.

In this research, we began with a general introduction. Then, we described the approved materials and methods, and we went through the results and discuss them. Finally, our paper concluded with a summary and a list of references.

2 Geographic and geological setting

Ain Mkbrta spring situated in Fez-Meknes region, exactly 1 km from Karia Ba Mohamed town. GPS coordinates are X= 03°21'14"W and Y=34°29'50"N. It is locally called Ain Mkbrta because of its sulfur content.

Our study section is in the external Rif, that is belongs to the Rif Chain which is part of the Western Mediterranean Alpine chain whose specific history extends from the Triassic to the Upper Miocene (fig. 1).

The source of Ain Mkbrta is in the limit of the rides and the pre-Rifan Nappes, on the extension of the Moulay Yacoub fault (fig. 2).

Fig. 1. (A) Geographical location of Ain Mkbrta source from Google Earth pro.

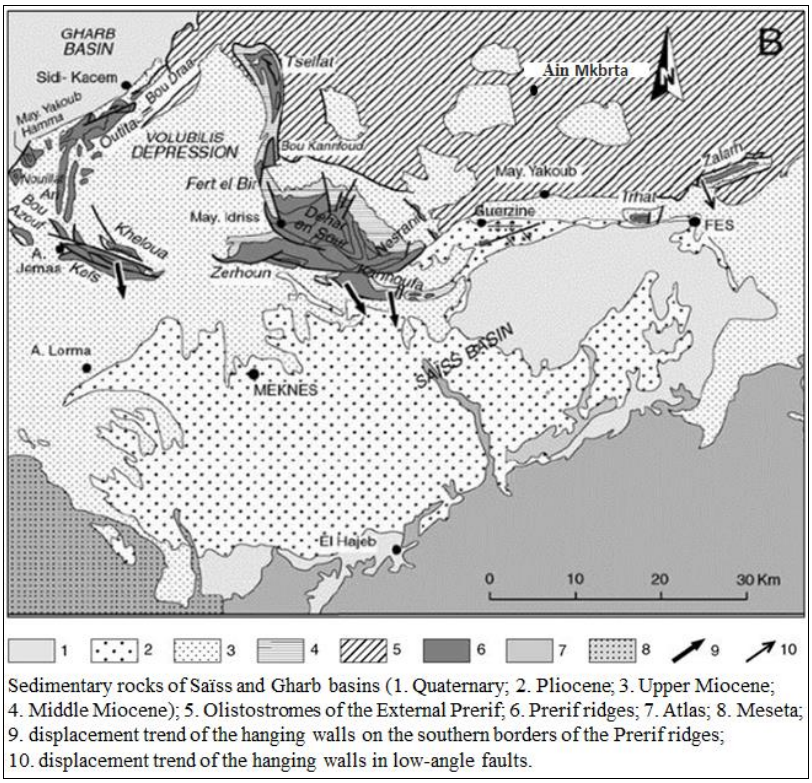

Fig. 2. (B) Geological map of the Prerif ridges, according to Bargach et al.**[7]**

3 Materials and methods

3.1 Sampling

For the physico-chemical parameters, the water samples, taken from the source in 1.5 L bottles according to Rodier standards [8]. After, these bottles were labeled and put in a cooler at a temperature of 5 ± 3 °C. Then, they were sent to the laboratory for analysis.

For the bacteriological parameters, the samples were taken aseptically in sterile bottles of 500 mL from Ain Mkbrta source, then the samples were transported to the laboratory in an isothermal enclosure at 5 ± 3 °C and analyzed within eight hours follow the sample.

3.2 Physico-chemical analysis

The physico-chemical study focused on the measurement of pH, electrical conductivity, water temperature on site using a multi-parameter analyzer Type HANNA Instruments. Also, on the determination of other parameters: Turbidity, Hardness, Dissolved Oxygen, Dry Residues, Ammonium, Nitrite, Nitrate, Chloride, Sulfate, Phosphate, Total Sulphur, Sulfide, Hydrogen Sulfide, Calcium, Magnesium, Bicarbonate in the laboratory.

3.3 Bacteriological analysis

Bacteriological analysis; focused on the counting of coliforms at 37 °C, Revivable Germs at 37 °C and 22 °C, *Escherichia Coli* at 44 °C, intestinal Enterococci, *Staphylococcus aureus* at 37 °C, sulphite-reducing anaerobic *clostridium* spores, *Pseudomonas aeruginosa* at 42 °C; and was conducted according to the analysis methods described in Moroccan standards.

4 Results and discussion

4.1 Physico-chemical parameters

Variations in the levels of several physico-chemical parameters in water from Ain Mkbrta spring are shown in Table 1.

The temperature of Ain Mkbrta spring water is below 20 °C, so we can classify it as cold water. Compared with other thermal springs in Morocco, Ain Mkbrta spring water is characterized by lower temperatures.

The pH value, which is close to neutral with an average of 7.1, is comparable to that of water from Moulay Yacoub spring [9]. These values are acceptable according to Moroccan potability standards (NM 03.07.001), while the average electrical conductivity is very high at 13705 µS/cm, exceeding national and international standards for human consumption water. This shows that the mineralization of water from Ain Mkbrta spring is excessive, like the water from Moulay Yacoub spring [4] and Ain Salama spring [10], which may be linked to the crossed geological formations. [11]

The average turbidity level recorded is 46.40 NTU, well above the acceptable limit for water intended for human consumption (NM 03.7.001). The turbidity values recorded at Ain Mkbrta are in the turbid water range (>50 NTU). [12]

Water hardness is the total concentration of calcium and magnesium ions dissolved in water. In the water from the spring studied (Tab. 1), its value is 125.1 °F, so the water from this spring is hard TH>30 °F. The hardness of groundwater is generally linked to the nature of the sedimentary rocks it flows through, and is essentially due to the presence of Calcium and Magnesium.

Water from Ain Mkbrta spring generally has very low dissolved oxygen concentrations (below 0.01 mg/L), which are acceptable according to Moroccan standards (NM 03.7.001).

Levels of phosphorus-based nutrient (ortho-phosphates and total phosphorus) and nitrogen (nitrate, ammonium, and total nitrogen) were very low in the spring water studied (Tab. 1), indicating the absence of any source of pollution.

Overall, the levels of these elements, with the exception of ammonium, remain well below the maximum values permitted by Moroccan drinking water standards. Knowing that this spring is positioned in an agricultural zone, the low concentrations of these elements justify its very deep origins.

Dry residues are the elements that remain after water evaporation. The average dry residue value in Ain Mkbrta spring is very high at 9290.75 mg/L. This value is higher than 1500 mg/L, making it mineral-rich water.

Concentration of sulfur, sulfide and hydrogen sulfide are very high at 42 mg/L, 57.95 mg/L and 6.55 mg/L, respectively, which explains the strong odor of the water. Furthermore, Ain Mkbrta waters are not drinkable due to their high salinity, but they are recommended by the local population for the treatment of dermatological diseases, as sulfurous waters are known to have an anti-inflammatory action.

Hydrogen sulfide has numerous therapeutic applications, including heart failure, cancer, organ transplantation, peripheral arterial disease, and inflammatory bowel disease. [13-14]

Table 1. Physico-chemical parameters of Ain Mkbrta spring water.

Sample	Min	Max	Average
pH	6.94	7.10	7.01
Electrical Conductivity	9910	15630	13705.00
Turbidity (NTU)	21.10	113.00	46.40
Ammonium (mg/L)	1.58	3.22	2.40

Nitrates (mg/L)	<0.1	<0.5	<0.5
Nitrite (mg/L)	<0.0	<0.01	<0.01
Phosphate (mg/L)	0	0.84	0.42
Hardness (F)	100.40	140.00	125.10
Dry residue (mg/L)	7400.00	10843.00	9290.75
Dissolved oxygen (mg/L)	0.0	<0.1	<0.1
Sulfure (mg/L)	56.70	59.20	57.95
Hydrogen sulfide	5.20	7.90	6.55
Total sulfur (mg/L)	39.20	44.80	42.00

Two cations were analyzed in this study: calcium ions (Ca^{2+}) and Magnesium ions (Mg^{2+}). The results of analyzes of these two cations showed that Ain Mkbrta water spring are rich in calcium (average = 370.34 mg/L) and magnesium (average = 71.56 mg/L). (Fig. 3). The high content of calcium contributes to the treatment of certain diseases; the percentage of calcium present in Avène thermal water has revealed its therapeutic benefit due to this element in the treatment of certain dermatological pathologies, through the regulation of intracellular calcium in the keratinocyte. [15]

The results of anion analysis show that the waters of Ain Mkbrta spring have much higher values of chloride ions (average of 4888.96 mg/L). This value exceeds Moroccan standards (750 mg/L). The trend in chloride concentrations over the study period is like that for conductivity. This could be due to the regional geological nature. [16]

Concerning bicarbonates, the levels are lower in the spring studied (mean = 435.40 mg/L) (Fig. 3). Generally, spring waters rich in bicarbonates have a great therapeutic effect on certain diseases. [17]

The amount of sulfate in Ain Mkbrta spring is 380.50 mg/L, reflecting the geological nature of the region. The recorded sulfate concentration in these waters does not exceed the acceptable limit values for water intended for human consumption (Fig. 3).

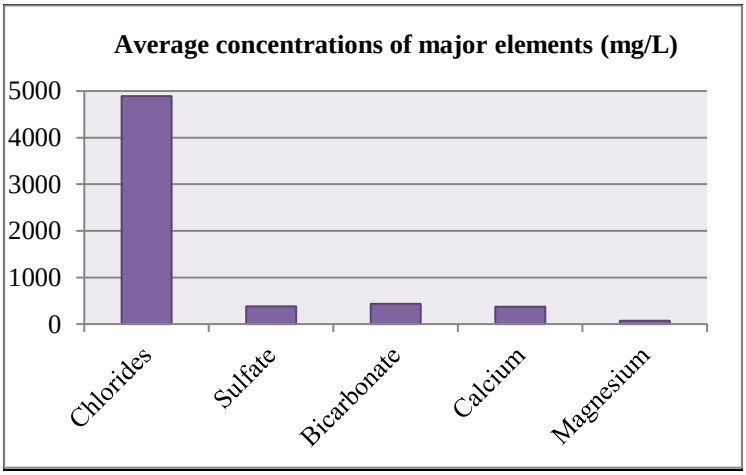

Fig. 3. Average concentrations of major elements in water from Ain Mkbrta spring.

4.2 Bacteriological parameters

The bacteriological results showed the absence of *Staphylococcus aureus* at 37 °C, which may be due to the antifungal and antibacterial activity of Ain Mkbrta and the bactericidal

action directed against *Staphylococcus aureus* germs, which may be linked to the manganese and iodide ions present in this water.

The absence of *Pseudomonas aeruginosa* germs (0 CFU/100 mL) in Ain Mkbrta water can be explained by its particular physico-chemical characteristics, such as its character (mesophilic/thermophilic) or the richness of Ain Mkbrta in H_2S elements.

The bacteriological results demonstrated a low load of Revivable germs at 37 °C and 22 °C (150 CFU/1 mL); (40 CFU/1 mL, respectively), which indicates the possible presence of bacteriological contamination with the absence of a direct effect on health.

While the waters of Ain Mkbrta have average concentrations of Coliforms at 37 °C, *Escherichia. Coli*, intestinal Enterococci (18 CFU/100 mL, 2 CFU/100 mL, 5 CFU/100 mL, respectively) which may be an indicator of the degradation of Ain Mkbrta by surface water inputs and that these waters remain unprotected against faecal contaminants, which reflect the presence of pathogenic micro-organisms in Ain Mkbrta.

The presence of sulphite-reducing anaerobic *clostridium* spores (20 CFU/100 mL) indicates that Ain Mkbrta contains a source of old contamination.

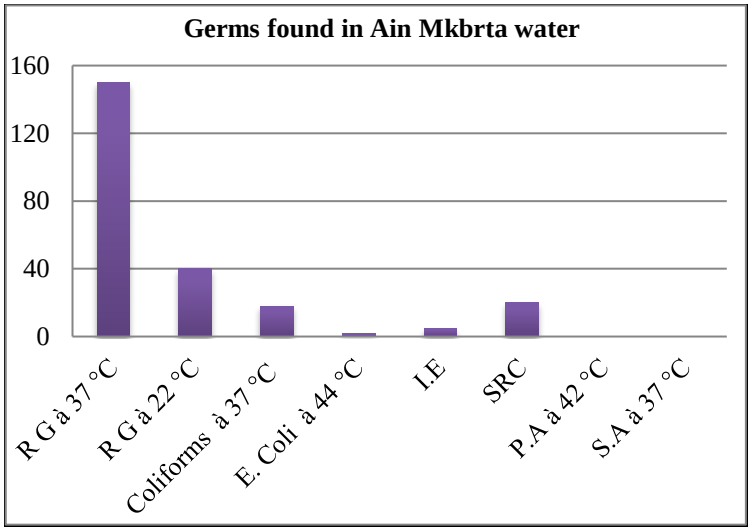

Fig. 4. Concentrations of Revivable germs (RG), Coliforms, *Escherichia coli* (E. Coli), intestinal Enterococci (I.E), anaerobic sulphite-reducing *clostridium* spores (SRC), *Pseudomonas aeruginosa* (P.A) and *Staphylococcus aureus* (S.A) in Ain Mkbrta water.

5 Conclusion

The results have shown that the water from Ain Mkbrta spring is cold water with a neutral pH. However, our analysis confirmed its very high conductivity and high H_2S content. This explains why the water is not drinkable.

The mineral composition of the spring water studied in certain major elements such as chloride, bicarbonates and calcium may give these waters therapeutic properties in the treatment of certain dermatological pathologies.

The bacteriological quality of the water at Ain Mkbrta is moderately satisfactory, with low levels of mesophilic flora and coliforms. This contamination is linked to the conditions surrounding Ain Mkbrta, mainly the presence of agricultural land and the parallel sampling period in winter. This suggests that this source should be developed and that the necessary measures should be taken to monitor and control the quality of the water.

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