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Crenotherapy using Spring Thermal Water in Western Algeria and its Effectiveness Against Kidney Stones

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ABSTRACT

Water is a natural resource with multiple uses. It is precious and important; therefore, it must meet the standard criteria. The goal of this project is to verify and estimate the physicochemical and bacteriological quality of water from the Dar Bentata source and its therapeutic benefits in medical diseases. These analyses covered several physicochemical water parameters. These parameters are temperature, hydrogen potential, MO, electrical conductivity, total dissolved solid (TDS), turbidity, O_2, total hardness, alkalinity, color, Cl^- ; SO_4^{2-} ; NO_3^- ; NO_2^- ; HCO_3^- ; Ca^{2+}, Mg^{2+} ; K^+ ; PO_4^{-3} , and Na^+... ,and a certain number of bacteriological parameters such as total germs, total fecal coliforms, fecal streptococci, and Clostridium sulfitor. Three water points were sampled for five days during December 2021. The different hydrochemical facies of the Dar Bentata were used to determine the quality of the water. The results show that this water source is sodium chloride in nature and has therapeutic properties for calcium lithiasis.

KEYWORDS

Bacteriological, chemical facies, physicochemical analyses, quality, saline, source water

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1. Introduction

Health issues associated with the formation of urinary stones are frequent. It is a complication of urinary divers' ion and is now a cause of increasing concern. In addition, the mechanism of lithogenes is still to be clearly understood in the therapeutic process (Vani *et al.,* 2021; Birowo*et al.,* 2020; Patankar*et al.,* 2020; Song*et al.,* 2022; Lu *et al.,* 2022).

Nephrolithiasis or renal stones are mineral deposits in the renal calyces and pelvises that are either affixed to or free of the kidney papillae. Stone formation is the result of complex biochemical processes involving proteins and is facilitated by the supersaturation of ions in urine. Stone samples are composed of crystalline inorganic, organic, and elemental species. Inadequate water intake is the primary cause of stone formation. Other risk factors, such as family history, diet, and systemic diseases, have also been identified as contributors to these processes (Deshpande *et al.,* 2022; Han*et al.,* 2015; Siener, 2021).

Common minerals found in stones include calcium oxidalate monohydrate (COM, whewellite), calcium oxidalate dihydrate (COD, weddellite), magnesium ammonium phosphate hexahydrate (MAPH, struvite), calcium hydrogen phosphate dihydrate CHPD, brushite), penta calcium hydroxy triphosphate (PCHT, hydroxyapatite), and other rare substances. Uric acid (UA) is another uncommon organic compound responsible for stone formation. Stone samples are typically composed of more than one mineral type, with COM and/or COD predominating in terms of occurrence and relative abundance. Other minerals include MAPH, CHPD, PCHT, and organic matter (Tonannavar*et al.*, 2016; Grases *et al.*, 1996 ; Siener*et al.*, 2002).

Crenotherapy, or the therapeutic use of thermo mineral waters for treating a variety of maladies (rheumatic, dermatological, renal, genital), is supported by a large body of scientific research and clinical studies (Maarmri*et al.*, 2012; Mohim*et al.*, 2022; Dubois, 2009; Karunakaran *et al.*, 2022). Hydration also plays a crucial role in preventing these small kidney stones. Our kidneys are incredible organs that filter our blood to remove waste and produce urine. When we do not enough drink, urine becomes more concentrated, which promotes the formation of these famous stones. Therefore, drinking to evacuate the stones is the key to keeping our kidneys healthy. According to several studies, the chemical composition of drinking water plays an important role in the dissolution of kidney stones (Ricciardi *et al.*, 2016; Lieske*et al.*, 2014). For example, calcium, an essential element for bone health, also plays a role in the formation of kidney stones. However, if we have calcium-related kidney stones and, already consume enough calcium in our diet, we may want to opt for low-calcium water to avoid excessive intake. However, uric acid kidney stones can be a real source of discomfort. Gaseous water rich in bicarbonates can help reduce the acidity of urine and thus prevent the formation of uric acid stones. Knowing that several thermal sources in the world are known for the treatment of kidney diseases, the thermal springs of Pithecusa, Evian, Volvic, Badoit, La Salvetat...

The source after having been approved by the State may take the designation of a natural mineral water. Dar Bentata village is located 60 km from Tlemcen, between Nedroma and Ghazaouet in the Algerian region. On a national scale, this fountain is known for its miraculous therapeutic effectiveness. Our work consisted of studying the physicochemical and bacteriological properties of Dar Bentata thermal spring water located west of Algeria with the aim of comparing the properties to other drinking water and discussing its effects on kidney stones.

Dar Bentata is a small village located 60 km from Tlemcen city, between Nedroma and Ghazaouet cities, in the Tlemcen province, west of Algeria (Fig. 1).

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Figure 1: Study area.

Urinary lithiasis is characterized by the development of kidney stones. There are five types of kidney stones. Seventy-five percent of stones are calcium oxalate that affects the human body in cases of obesity, diabetes, and hypertension. An excess of calcium oxalate will precipitate in the form of crystals. 15 % of these have calcium phosphate due to overconsumption of Na^+ sodium combined with a low potassium K^+ ratio. 5 % of stones comprise phosphatoammoniacomagnesium caused genetically. Uric acid calculations account for 5%–10% of lithiasis cases, but in the Mediterranean countries, they are thought to account for almost 30% of cases. Uric acid precipitates after the terminal breakdown of purines. The purine-rich foods are offal, shrimp, liver, red meat, and anchovies. Cystine stones affect less than 2% of all lithiases and comprise cystine (Deepika *et al.*, 2018).

Kidney stones are considered very small solids of hard material that form in the kidneys. In most cases, 90% of patients suffer from calcium stones. In general, patients are asked to have a calcium intake of approximately 1 g/ day. For Lithiasis, the orientation of choice of drinking water is made according to the mineral composition and its chemical nature in addition to the minimum amount of drink recommended for patients depending on the type of Lithiasis. The type of water consumed must be considered in the overall treatment strategy for Lithiasis.

2. Materials and Methods

The samples were taken at three different sites (P1, P2 and P3) in Dar Bentata village for five days during December 2021 at 10 o'clock. Points (P1) and (P2) are located upstream of the main source of Dar Bentata (P3). Sampling was performed in plastic bottles rinsed with distilled water. Sampling for bacteriological analysis was performed in glass bottles tempered at 220°C. The analyses were carried out under a cold regime (4°C) in the laboratory of the Hammam boughrara drinking water production plant of the Algerian Water Company in Maghnia, located in the Tlemcen province of Algeria. Several physicochemical water parameters, including temperature, hydrogen potential, electrical conductivity, total hardness, Cl^-, HCO_3^-, Ca^{2+}, Mg^{2+}, K^+, and Na^+ ions, and bacteriological parameters such as: total microorganisms and fecal, microorganisms were analyzed. The chemical analyses were carried out in reference to (Rodier *et al.*, 2016).

3. Results and Discussion

The diverse analyses performed on samples of Dar Bentata spring water have enabled the determination of descriptive parameters of the physicochemical and bacterial quality of the water. The results of the analysis were compared with Algerian and World Health Organization (WHO) standards.

3.1. Physicochemical Parameters:

3.1.1. Temperature

Because water temperature regulates nearly all physical, chemical, and biological reactions, it is an important factor in aquatic environments (Chapman, 1996). In the study area, the results obtained show that the degree of this temperature does not present great variations from one source to the other (Fig.2a), with a minimum of 13°C and a maximum of 16.8°C.

3.1.2. Turbidity

Turbidity is a parameter of potable water quality and an indicator of groundwater well stabilization. The clarity of water is a physical characteristic of turbidity. The turbidity of natural waters is caused by suspended matter, such as clay and sediment particles, organic matter, microscopic organisms, and colloids. Water turbidity is measured optically as a property of light dispersion (Popek, 2017). For turbidity, we found low values due to the absence of organic and inorganic matter (groundwater) (Fig. 2b). By combining our results with Algerian and WHO standards, we can say that the Dar Bentata waters are clear waters.

3.1.3. Organic Matter

Organic matter is an index of pollution that comes from the decomposition of bacteria in addition to giving an unpleasant smell to the water. For the different sampling points, the median values of organic matter did not exceed 1.5 mg/L and sometimes were equal to 0 and with their absence. Dar Bentata water is inodeur (Fig.2c).

3.1.4. pH and color of Dar Bentata water

The pH depends on the origin of the water, the geological nature of the substrate, and the watershed traversed. This parameter determines numerous physicochemical balances between water, dissolved carbon dioxide, carbonates, and bicarbonates, which provide favorable conditions for the development of aquatic life (Belghiti, 2013). The pH values ranged from 7.4 to 7.7 (Fig.3d). Therefore, the source appears to be neutral. According to the values of the color in Fig. 2e, we can say that the waters of Dar Bentata are transparent.

3.1.5. Conductivity

The electrical conductivity of water is the conductance of a column of water between two platinum electrodes with a 1 cm^2 surface area and a 1 cm separation. The opposite of the electrical resistivity. Conductivity indicates the mineralization of water and is an excellent indicator of the water's origin (Beyaitan-Bantin *et al.*, 2020). In fact, measuring conductivity permits estimation of the number of ions dissolved in water and, consequently, its mineralization. The values recorded during the study period vary from 884 to 1441. The increase in the values at the 3rd station (P3) determines the high mobility of the ions in the water (Fig.2f).

3.1.6. Hydrometrical Title

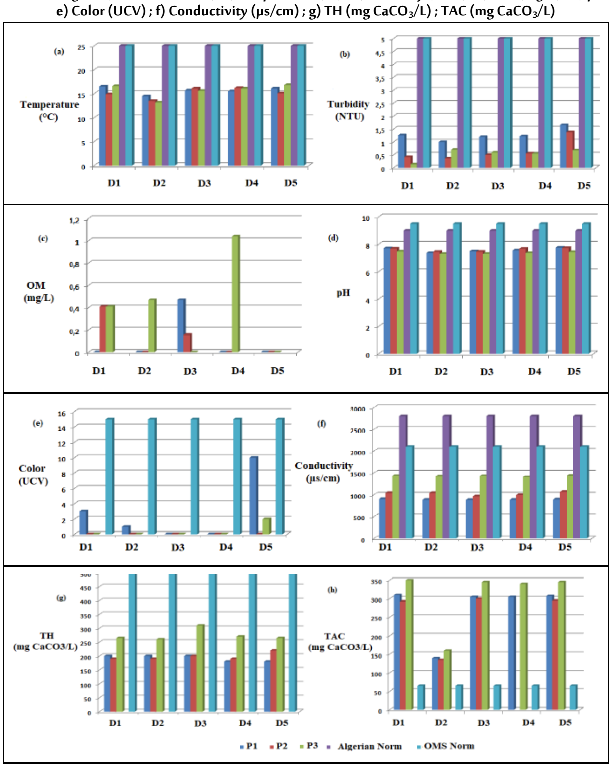
The hydrometrical title is the total concentration of Ca^{2+} and Mg^{2+} ions. Magnesium concentrations recorded at the studied sources were between 180 and 310 mg $CaCO_3$/L (Fig.2g). They stay clearly below the allowable limit for hydrometrical title, i.e., 500 mg $CaCO_3$/L.

3.1.7. Full Alkalinity Title

Alkality is due to the presence of hydroxides, carbonates, and bicarbonates. TA measures hydroxides and carbonates, and TAC measures OH^-, CO_3^{-2}, HCO_3^-. The bicarbonates in the water aid digestion and soothe heartburn because of the antacid properties of sodium bicarbonate. As a result, bicarbonate waters are good for athletes to fight against the acidity produced by the muscle during exercise (Labadi and Hammache, 2016).

The TAC values by the Algerian standard must be greater than 65 mg $CaCO_3$/L. According to the results expressed in Fig. 2h, we find that the TAC values are approaching the standard in the waters of DAR BENTATA, which are also characterized by low alkalinity (< 1000 mg/L) (Pierre, 2000).

Figure 2: Spatial distribution of the values of physicochemical parameters of Dar Bentata water, Tlemcen; Algeria (December; 2021). a)Temperature (°C) ; b) Turbidity (NTU) ; c) OM (mg/L) ; d) pH ; e) Color (UCV) ; f) Conductivity (µs/cm) ; g) TH (mg $CaCO_3$/L) ; TAC (mg $CaCO_3$/L)



3.1.8. Other physicochemical analyses

The following table (Table.1) shows the average value of the five-day pollution parameters in December 2021: NO_3^-, NO_2^- and PO_4^{-3}, and chemical parameters such as: K^+, SO_4^{-2}, Na^+ and Cl^- in relation to the water structure for the main source of Dar Bentata (P3) used for the treatment of kidney stones. The obtained results were compared with World Health Organization and French standards. In contrast to nitrate, the levels of nitrite, potassium, sulfates, phosphate, sodium, and chlorine are extremely low. Nitrate, however, marginally exceeds the standards. Consequently, the study waters are susceptible to nitrate contamination.

Table 1: Physicochemical parameters.

The parameters	Test results (mg/L)	WHO Standard (mg/L)	French Standard (mg/L)
Nitrite	0.027	3	0.1
Nitrate	53.3	40	50
Potassium	8	10	-
Sulphate	50	400	250
Phosphates	0	-	0.4
Sodium	88	150	-
Chlorine	5	250	-

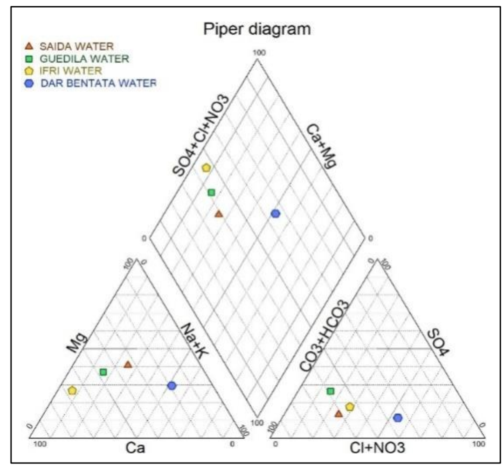
3.2. Chemical Facies:

Several methods have been defined by various authors to classify and determine the different hydrochemical facies of the waters. In our study, we used the most well-known main methods, namely Piper's classification, Schoeller and Berkaloff classification, the classification of Stiff, and the Stabler classification. All of these classifications are based on the chemical composition of the waters, from which the properties of our water of Dar Bentata (P3) can be deduced; we compared our results with those of Ifri, SAIDA, and GUEDILA mineral water.

3.2.1. Piper diagram

Piper's diagram (1994) uses the major elements to determine the different families of sources. It is composed of two triangles and a diamond. Triangles are filled with cations and anions. The transfer of the water test results to the Piper diagram shows the variability in the chemical facies. The concentrations in this diagram are expressed in % (Shah *et al.*, 2021; Das*et al.,* 2021). There are two poles in Fig. 3; the first pole is characterized by calcium and magnesium bicarbonate facies (Ifri, Saida and Guedila waters). The second pole representing the water of Dar Bentata is characterized by sodium and potassium chloride facies.

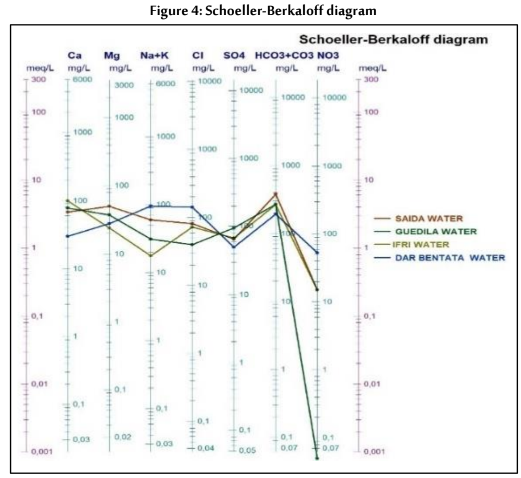
Figure 3: Piper diagram illustrating the hydrogeochemical facies of water samples from the study area



3.2.2. Schoeller-Berkaloff diagram

The semi logarithmic graphic representation is the Schoeller–Berkaloff diagram. On the axis of the abscisses, various ions are represented. For every major ion, the actual concentration in mg/L is plotted on the y-axis, and the resulting nodes are connected by straight lines (Viljoen *et al.,* 2019; Popek, 2017). The obtained graph (Figure 4) allows for visualisation of the mineral water in question. The Schoeller– Berkaloff diagram analysis revealed that the groundwater contained elevated levels of chlorides, potassium, and sodium.

Figure 4: Schoeller-Berkaloff diagram



3.2.3. Stiff diagram

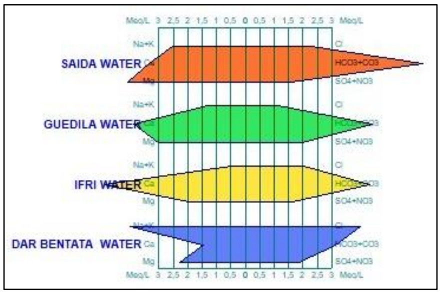
Stiff's diagram presents the analyses in two different axes, the left axis presents the cations (Na^+, K^+,Ca^{2+},Mg^{2+}) and the right axis presents the anions (Cl^-, HCO_3^-, CO_3^{-2}, SO_4^{-2}, NO_3^-). The values used are expressed in meq/L (Hounsinou, 2020). According to Stiff's diagram (Fig. 5), we observe the following facial features:

- Calcium bicarbonate: for GUEDILA and IFRI water.

- Magnesium bicarbonate: for SAIDA water.
- Sodium chloride: for DAR BENTATA water.

The figure above also shows that the water of the DAR BENTATA spring is a water of low mineralization compared to the mineral drinking waters chosen.

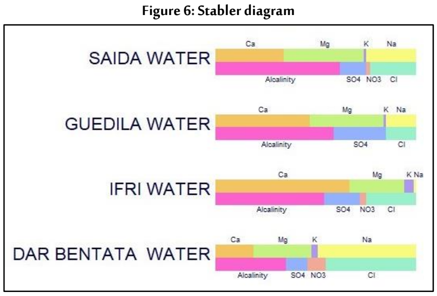
Figure 5: Stiff diagram



3.2.4. Stabler diagram

The Stabler diagram is used to quickly determine the different titles of water. For this purpose, the meq/L concentrations of anions and cations are reported on two separate bars or columns of the same length, and the concentrations are reported in % (Hans-Friedrich*et al.,* 1989). According to the Stabler diagram in Figure. 6, we observe that the dominant face is calcium bicarbonate represented by the mineral waters GUEDILA and IFRI. The other facies are magnesium bicarbonate for SAIDA water and sodium chloride for DAR BENTATA spring water.

Figure 6: Stabler diagram



3.3. Bacteriological Analyses:

The purpose of these analyses is to determine the types of microorganisms in the water because they are responsible for water-borne diseases. Several parameters were examined, including total germs, total sprouts, total coliforms, fecal coliforms, fecal streptococci, and Clostridium sulfito-reducer. The results are given in Table 2.

Table 2: Bacteriological parameters

Type of analysis	Results of the analysis (CFU/ml)	Algerian standard (CFU/ml)
Total germs at22C°(CFU/1 mL)	3	<10
Total sprouts at 37C°(CFU/1 mL)	3	<100
Total coliforms (CFU/100 mL)	12	0
Faecal coliforms (CFU/100 mL)	0	0
Faecal streptococci (CFU/100 mL)	0	0
Clostridium sulfito-reducer (CFU/100 mL)	0	0

The count of total germs is a much more general type of indicator with respect to microbiological pollution. This determines the total bacterial load. The results obtained were 3 germs/1 mL at 22°C and 3 germs/1 mL at 37°C in our sample. However, they remain compliant with the standards prescribed by Algerian regulations (<100 germs/1 mL at 22°C and <10 germs/1 mL at 37°C). The count of total coliforms in the water sample shows that the bacterial load of the water studied (12 CFU/100 mL) is higher than the Algerian standard (10 CFU/100 mL), which may be due either to septic spurs or by contamination of boreholes near the region. The regulations of our country imperatively exclude the presence of fecal coliforms, fecal streptococci, and Clostridium sulfito-reducer in 100 mL of water. The results found in the water sample analyzed are (0 CFU/100 mL), which corresponds to the Algerian standard (0 CFU/100 mL).

Finally, due to the quality of the waters of DAR BENTATA and according to their nature and chemical compositions (low mineralization, low calcium content, etc.), it is recommended for the treatment of patients who suffer from calcium lithiasis (Pierre, 2000).

4. Conclusion

The various analyses carried out on the samples of water from the source of DAR BENTATA have made it possible to determine the behavior of certain descriptive parameters of the physicochemical and bacteriological quality of the waters. In the field of hydrochemistry, there are several types of chemical facies. Our study shows that the waters of DAR BENTATA are classified as sodium chlorinated water and the low mineralization claim its effectiveness on calcium renal stones.

Finally, we conclude by proposing the following perspectives:

- The improvement of the source by the renewal of the pipes and placement of hydraulic accessories (e.g.: valve, etc.) to protect these waters in a quantitative and qualitative way by the State.
- The State must take advantage of this natural wealth and provide opportunities for investors.
- Nationally recognize DAR BENTATA as source waters to maintain healthy glass bottling while protecting the water.
- The quality monitoring of this thermal source for one year to determine its chemical stability will be carried out in the future.

We have concluded that this source has therapeutic virtues.

Biography

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Mrs. Amara-Rekkab, Algerian, obtained his PhD from ABU BEKR BELKAID University, Tlemcen, in Algeria in 2015. Since this year, she has been an Algerian lecturer in the Department of Chemistry. She has published over ten articles in highly regarded journals. His research focuses on environmental pollution, the extraction of heavy metals, and their toxicity. She has participated in and presented at several conferences in Algeria, Paris, Spain, and Dubai. She also teaches desalination, water treatment, and wastewater treatment. ORCID: 0000-0002-0014-3066

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