Asian Journal of Water, Environment and Pollution, Vol. 20, No. 4 (2023), pp. 19-26.
DOI 10.3233/AJW230047

Evaluating Water Quality of Beni-Haroun Dam (Northeastern Algeria) Before and After Treatment Procedures

Sabri Bousbia* and Noureddine Bouchareb[1]

Laboratory of Natural Sciences and Materials, Abdelhafid Boussouf University Center, Mila, Algeria
[1]Department of Natural Sciences and Life, Abdelhafid Boussouf University Center, Mila, Algeria
✉ sabri.bousbia@centre-univ-mila.dz

Received February 1, 2023; revised and accepted March 5, 2023

Abstract: Water treatment plants are of great importance in order to provide drinking water to the population. The present work aimed to study the quality of treated water from the Beni-Haroun dam (northeastern Algeria) through the analysis of its physicochemical and bacteriological parameters in order to ensure they conform to international standards. Physicochemical and bacteriological parameters of untreated water were also analysed and then compared to the same physicochemical and bacteriological parameters obtained after applying treatment procedures in order to evaluate the efficiency of these procedures on the water quality. As a result, the physicochemical parameters of treated water Beni-Haroun dam were revealed in concordance with the established international standards. Concerning bacteriological results, despite the presence of certain microorganisms in some analysed samples, their loads remained very low and do not constitute a major health risk. Based on our analyses, treated water from Beni-Haroun Dam remains generally of good quality.

Key words: Beni-Haroun dam, water treatment plant, water quality, physicochemical and bacteriological parameters.

Introduction

Water is the main constituent of living beings and the essential element for all forms of life. Its availability as well as its abundance play a fundamental role in the development and evolution of societies. Moreover, it is the key element for life, agriculture and industry (Festy et al., 2003). Habitually considered as a problem in third-world countries, access to drinking water is frequently affected by its poor distribution in the world as well as by the pollution of water resources by industry, agriculture and urban waste (Pal et al., 2018). Assessment of the quality of drinking water in a distribution network is mostly made by considering the physicochemical and microbiological standards as recommended by national and international institutions (Aghaarabi et al., 2014). Drinking water must be free of chemical and biological elements that may affect the health of individuals (Petraccia et al., 2006). It must also be clear, colourless and have no unpleasant taste or odour. In addition, drinking water must contain, without excess, a number of mineral elements that give it a satisfying taste (Crittenden et al., 2012). The World Health Organization (WHO) guidelines for drinking water quality are the benchmark for drinking water safety. Therefore, depending on the characteristics of the raw water drained to be treated, the implementation of specific treatments is mostly necessary to provide

*Corresponding Author

drinking water of good quality (Van der Bruggen et al., 2003). These treatment procedures are carried out by plants dedicated to this purpose. The effectiveness of the adopted treatment procedure depends on how the operation of the treatment plant will be conducted (Bertanza et al., 2022). In the present work, we analysed essentially physicochemical and bacteriological parameters to determine the quality of the water drained from Beni-Haroun dam in northeastern Algeria before (raw water) and after treatment (treated water). Physicochemical and bacteriological parameters of raw water were also compared to these obtained after treatment procedures (obtained from treated water) in order to evaluate the efficiency of water treatment procedures on the quality of the water.

Materials and Methods

Water Treatment Plant

This work is carried out within the treatment station belonging to the Algerian water company located in 'Douar Ben Zakri' in Mila district, northeast of Algeria (geographical location, 36°24'10.4"N 6°18'52.1"E). The plant has a treatment capacity of 64,500 m³/day based on a raw water supply of 67,725 m³/day. This water treatment plant uses a modern processing chain. Its mode of operation is briefly shown in Figure 1.

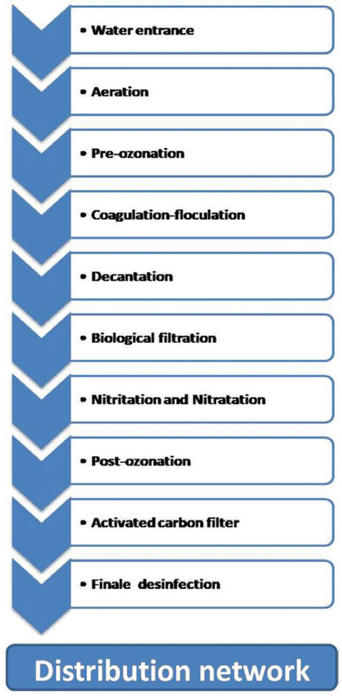

Figure 1: Schematic representation of different steps of water treatment at Ain Tin station.

The station is supplied water from the Beni-Haroun dam which is among the largest dams in Africa with a storage capacity of more than 900 million m^3/year (Figure 2).

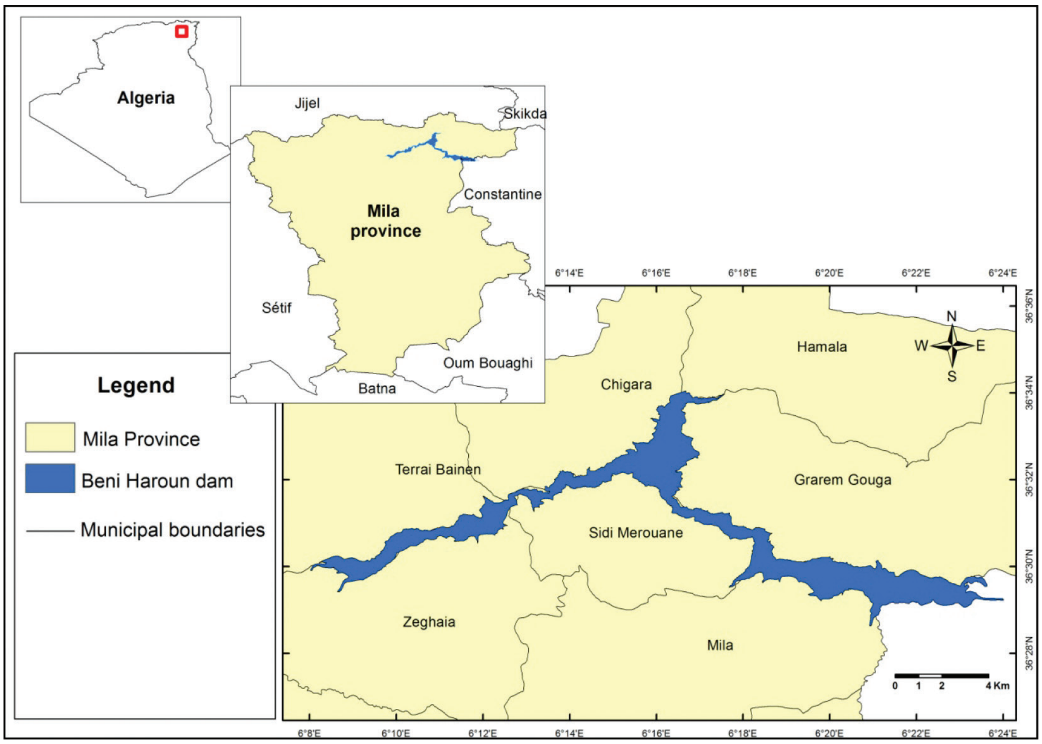

Figure 2: Location of Beni-Haroun Dam in Mila District (Northeastern Algeria).

Water sampling, physicochemical and bacteriological analyses

Raw water samples were collected from a specific faucet at the arrival of the raw water while treated water samples were collected from the faucet where the treated water is stocked prior to being distributed. The physicochemical parameters tested were temperature, pH, turbidity, total hardness (TH), calcium hardness (CaH), complete alkalimetric title (CAT) and the dry residue (DR). Temperature, pH and turbidity were daily measured over a 6 months period (from October 2015 to March 2016) while TH, CaH CAT and DR parameters were weekly measured. These parameters were performed as described elsewhere (Rodier et al., 2009). Values of physicochemical parameters of analysed samples are expressed as a monthly mean ± standard deviation (SD). To analyse bacteriological quality, water samples are monthly analysed for raw water and weekly for treated water. However, for technical reasons, the raw water is analysed during the period from January to March, 2016. These bacteriological analyses consisted of the research and loads counting of the following microorganisms: total coliforms, fecal coliforms, total mesophilic aerobic flora (TMAF), streptococci and sulphite-reducing anaerobic bacteria (SRAB). Prior to sampling, taps, where the sampling was carried out, were cleaned using cotton soaked in 70% alcohol. Taps are first opened for 1 or 2 minutes to reject old water present in the pipes. The taps are then sterilized a second time. Only the raw water was diluted to 1/10 due to its very high contamination by microorganisms. Different bacteriological analyses, were performed as previously described (Rodier et al., 2009).

Statistical Analysis

For statistical analysis, we only used the Student's t-test by using Graph-Pad software. *P*-values less than or equal to 0.05 were considered significant.

Results and Discussion

Physicochemical Analysis

Our results showed that the temperature of the treated water was always lower than that of raw water. Overall, the temperature of the raw water ranged from 10.8°C to 21°C while that of the treated water varied from 9.9°C to 18.7°C. As logic predicts, the highest temperatures, for both raw water and treated water, were shown during the autumn season and gradually decrease until the end of the winter season (Figure 3). The raw and treated water temperature values did not exceed the limits recommended by the WHO and were fixed at 25°C (WHO, 2004).

The temperature of our analysed samples varied, therefore, in concordance with the atmospheric temperature. Indeed, the change in temperature could influence the proliferation of microorganisms. High temperatures may stimulate the growth of microorganisms and may influence the taste, odour and colour of water (WHO, 2004). A temperature below 10°C may also slow the chemical reactions in the various water treatment processes (Rodier, 2005). Temperature is also an important ecological factor that may have a great influence on the physicochemical properties of aquatic ecosystems (Yung et al., 2017). Moreover, temperature variations also affect some properties of water such as the solubility of oxygen, the rate of chemical reaction of degradation and mineralisation of organic matter (Akiya and Savage, 2002).

For pH, our study revealed slightly high values for raw water especially from November to February. By examining the pH values, our results showed that they are on average above 7.8 before the treatment procedures (raw water) with peaks that may reach 8.35. The pH was always decreased after the treatment procedures (treated water). These values are within the range of the standards fixed by the WHO (from 6.5 to 8.5) which makes the water more drinkable after treatment (Figure 3).

In general, the average pH of the water after treatment in the plant is neutral to slightly alkaline. These results are similar to those obtained by Dovonou et al. in Benin in 2011, which showed pH values ranging from 6.92 to 7, which makes the treated water more drinkable. Also, the pH may influence chemical and biological processes. A high or lower pH may be revealed as toxic for living organisms (Wang et al., 2016). In addition, according to Pandey and Shweta in 2009, a pH of 8.5 can influence the effect of disinfectants such as water chlorination by reducing their effectiveness. The pH can also be influenced by other factors such as climatic conditions. Thus, the high temperature indirectly leads to the displacement of the calco-carbonic balance and leads to the formation of carbonates under the effect of photosynthesis which may increase pH (Bouaroudj et al., 2019).

Concerning turbidity, our results showed that the water samples analysed before treatment are much more turbid than after-treatment procedures. For raw water, the turbidity gradually increased from October to February with a monthly average that varied from 3.58 ± 2.69 to 6.75 ± 4.85 NTU (Figure 3).

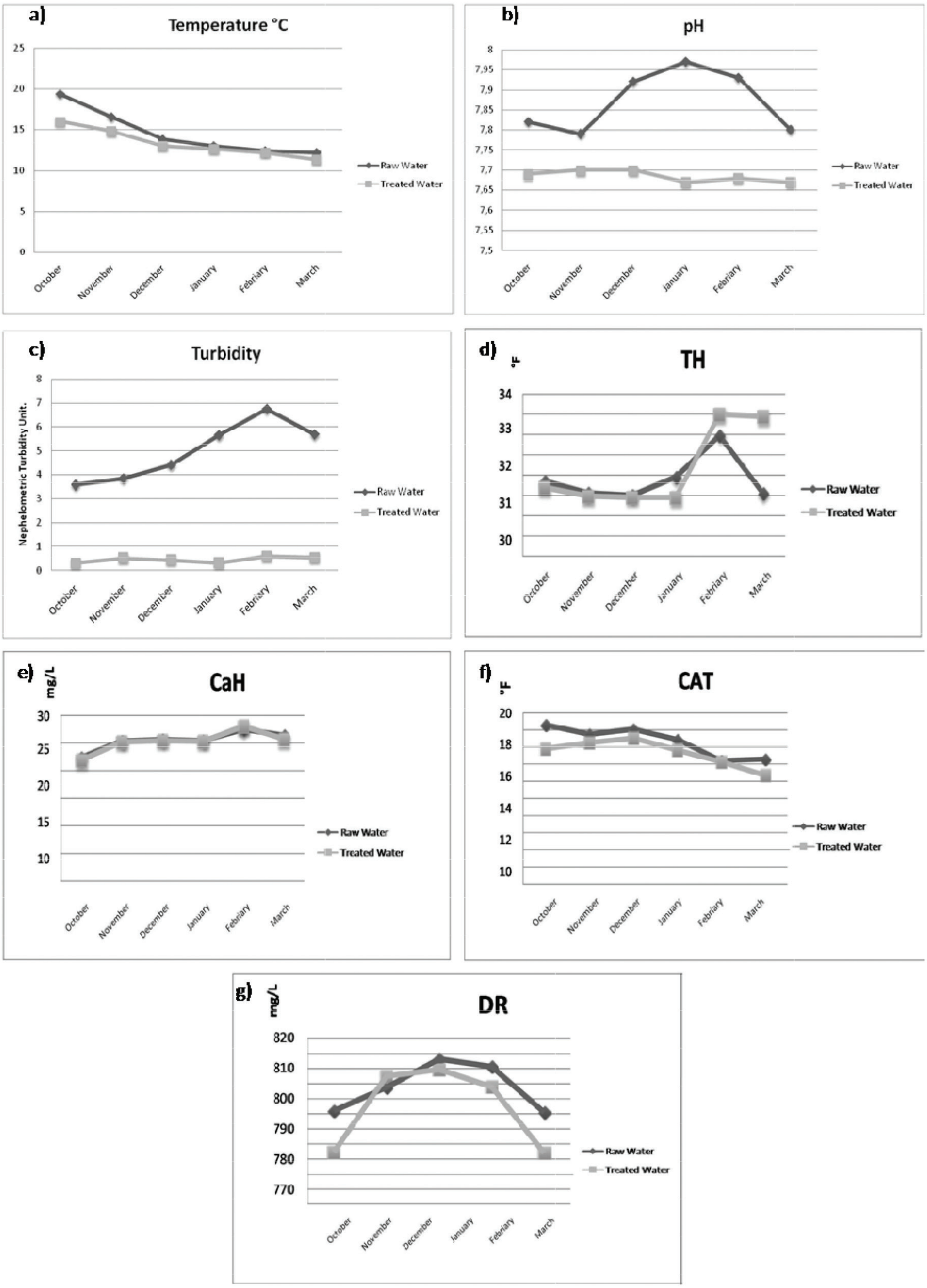

Figure 3: Variations in physicochemical parameters of raw and treated water. (a) Temperature, (b) pH, (c) turbidity, (d) total hardness, (e) calcium hardness, (f) complete alkalimetric title and (g) dry residues.

With the treatment procedures, the turbidity of the treated water was significantly lower and varied on average from 0.32 ± 0.12 to 0.61 ± 0.4 NTU (Figure 3). The monthly average turbidity of treated water remains within the range of standards fixed by the WHO (WHO, 2004). This proves the good quality of the water in the station. Moreover, the turbidity of the raw water is very high during the three winter months than during the autumn, which suggests a probable influence of climatic disturbances on the turbidity of surface waters. In addition, turbidity makes it possible to specify the visual information of water, indicating the presence of suspended particles in the water (Heriarivony et al., 2015). High turbidity is also particularly a sign of flooding leading to the overflow of rivers and streams which could result in very high water contamination by microorganisms such as bacteria and other parasites responsible for some diseases (Thayer et al., 2007).

The total hardness whether for raw or treated water, seemed to exhibit stable levels during the autumn period. It remained within the standards considered by the treatment plant (less than 50°F). Nevertheless, the total hardness of raw water like that of treated water seemed to increase during the winter period, especially after bad weather which often leads to the overflow of the river and streams feeding the dam (Figure 3). This is supported by the study of Rodier et al. in 2009 which showed that hardness is a natural character linked to the leaching of the crossed lands.

For calcium hardness (CaH), the obtained results, whether for raw or treated water, showed that CaH seemed to increase slightly over time from October to March, but could be considered stable. In addition, it is quite obvious that there are no obvious changes between the values from the raw water and those from the treated water (Figure 3). The concentration of calcium in water depends amply on the time that water takes in calcium-rich geological formations (Nechad et al., 2014). In our study, the concentration curve of the calcium titre (or calcium hardness) did not express notable variations either for the raw water or for the treated water. The treatment procedures carried out at the station level, therefore, did not seem to have an effect on the calcium titer.

Otherwise, contrary to turbidity, total hardness and calcium content that showed increasing levels over time from the beginning of autumn to the end of winter, complete alkalimetric title (CAT) showed a constant decrease over the two seasons, whether for raw or treated water and seemed to be in agreement with temperature values. On the other hand, and like the calcium titer, we did not notice a real effect of the treatment procedures on this parameter (Figure 3). The temperature is a very important ecological factor that has a great influence on the physicochemical properties of aquatic ecosystems (Yung et al., 2017). This could mean a probable role of temperature in the alkalinity of the water.

The content of raw and treated water in dry residues is on average lower in October and March but showed a remarkable rebound significantly higher from November to January. Furthermore, the content of the treated water in dry residues is often lower and consistent with that obtained from the raw water (Figure 3).

Comparison of Physicochemical Parameters Between Autumn and Winter Seasons

We also carried out a comparative analysis to study the probable variations of physicochemical parameters depending on two seasons which differ by climatic changes (between autumn and winter). The obtained results showed that for raw water, a statistically significant variation in the values of temperature, pH, turbidity and CAT between the two seasons was evident ($P = 0.001$, $P = 0.023$, $P = 0.004$, $P = 0.0147$, respectively). The values of temperature and CAT are significantly higher in autumn than in winter, while in contrast, those of pH and turbidity are significantly higher in winter than in autumn (Table 1). For treated water, only the temperature and TH values are considered to exhibit a significant variation between the two seasons ($P = 0.0001$ and $P = 0.0131$ respectively). The temperature values of the treated water are, like those of raw water, significantly higher in autumn than in winter. The TH values, for their part, are significantly higher in winter than in autumn (Table 1).

Bacteriological Analysis

Overall, raw water samples collected and analysed from January to March largely showed high contamination by different bacterial communities. The results of this analysis showed a strong presence of Coliforms as well as moderate contamination by TMAF. Streptococci, they were much more abundant in the sample analysed during March than in the samples analysed in January and February (Figure 4). The presence of *Clostridium* genus is noticeably lower.

Unlike raw water, treated water samples were globally significantly more pure than raw water. These samples do not express or express weak bacterial contamination (Table 2). Moreover, despite the presence of some of these microorganisms in treated water,

Table 1: Comparison of physicochemical parameters before and after treatment procedures during autumn and winter seasons (Student's t-test was used)

Parameters	*Raw water*			*Treated water*		
	Autumn	*Winter*	*P value*	*Autumn*	*Winter*	*P value*
Temperature (°C)	16.9 ± 2.36	12.64 ± 0.71	0.001	14.82±1.67	12.08±1.92	0.0001
pH	7.8412 ± 0.3	7.94 ± 0.2	0.023	7.7 ± 0.1	7.68 ± 0.16	0.39
Turbidity (NTU)	4.03 ± 2.47	6.12 ± 0.04	0.004	0.39 ± 0.25	0.68 ±1.81	0.2062
TH (°F)	29.05 ± 0.78	30.51 ± 2.79	0.1128	28.87 ± 0.85	31.64 ± 3.22	0.0131
CaH (mg/L)	24.8 ± 2.11	26.5 ± 2.52	0.1198	24.54 ± 2.48	26.47 ± 2.55	0.342
CAT (°F)	18.16 ± 2.62	15.56 ±1.36	0.0147	16.53 ±1.48	14.53 ± 1.37	0.1045

their load remains too low. This drastic decrease in contaminants after treatment is an irrefutable witness to the effectiveness of the treatment procedures. In fact, 5 samples out of the 17 analysed (29.41%) were positive for total coliforms, of which only one showed the presence of fecal coliforms identified as *E. coli* (6%). As for total Streptococci, they were detected in 5 samples with an average load of 5.82 ± 17.51 CFU. Nevertheless, in the confirmation test, 2 of these 5 samples revealed the presence of fecal Streptococci whose average load was estimated at 0.65±1.85 CFU. The total mesophilic aerobic flora, whether for species growing at 22°C or 37°C, was also present in 5 samples out of the 19 analysed (26%). For anaerobic sulphito reductive *Clostridium* species, they were detected in 3 of the 17 samples analysed (18%).

Otherwise, the presence of total coliforms in treated water or their exceeding regulatory standards does not necessarily imply a risk for public health but a degradation of water quality. Indeed, most of the species in this group are found naturally in the soil or in vegetation (Edberg et al., 2000). Moreover, the bacteriological analysis showed that raw water from Beni-Haroun is characterized by fecal coliforms and *E. coli* levels that sometimes slightly exceed the load limit (1000 copies/100 mL) recommended by the WHO for the reuse of wastewater. Nevertheless, this contamination is greatly reduced and remains within the standards after treatment. On the other hand, the average number of Streptococci was throughout the study period

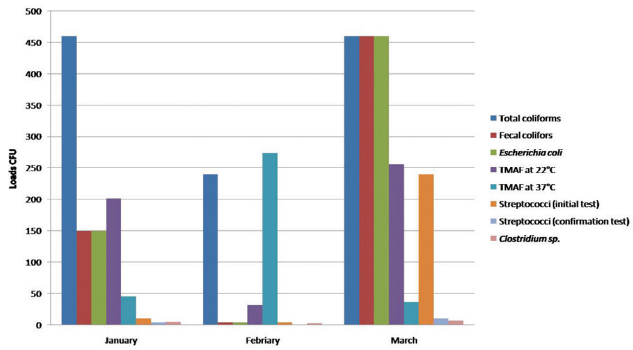

Figure 4: Bacteria isolated from raw water.

Table 2: Bacteriological results of treated water

Microorganisms	*Presumptive (Initial) Test*		*Confirmation Test*	
	Positive samples /total	*Loads (CFU)*	*Positive samples /total*	*Loads (CFU)*
Coliforme totaux	5 /17	17.64 ± 56.49	-	-
Coliforme fécaux	-	-	1/17	0.24 ± 0.94
E. coli	-	-	1/17	0.24 ± 0.94
TMAF (at 22°C)	5/19	12.55 ± 24.32	-	-
TMAF (at 37°C)	5/19	13.3 ± 24.29	-	-
Streptococci	5/17	5.82 ± 17.51	2/17	0.65 ± 1.85
Clostridium	3/17	0.18 ± 0.56	ND	ND

Note: TMAF, total mesophylic aerobic flora lower than that of Coliforms. These bacteria can also multiply in media with very high pH values up to 9.6 and are therefore used as indicators of contamination by pathogens with resistance to high pH (WHO, 2004). High loads of mesophilic aerobic flora in water can indicate the presence of pathogenic germs, and as such, are considered important indicators of water quality (Sánchez-Monedero et al., 2008). In our study, of the 19 samples, 5 exhibited the presence of TMAF but at very low loads. The load of these bacteria gives an idea of the effectiveness of water treatment (Fagrouch et al., 2010). In addition, it has been shown that the storage and stagnation of water in the tanks of treatment plants could promote and revive the growth of these bacteria (LeChevallier, 1990). Finally, the presence of sulphite reducing anaerobic bacteria in natural water suggests old fecal contamination (WHO, 2004). The presence of these germs indicates the presence of iron sulphite, which causes the appearance of bad odours and can be the cause of pipe corrosion (Rodier, 2005). In our study, and like other microorganisms, the rate of sulphite-reducing anaerobes seems to decrease significantly after treatment, which once again indicates the effectiveness of the treatment.

Conclusion

To be drinkable, water needs to be treated for achieving a high quality. However, raw water does not always meet the required criteria in terms of physicochemical and microbiological qualities. This is why water must be treated before its consumption. Overall, there are several water treatment methods, each with its advantages and disadvantages. The objective of this study was to assess the physicochemical and bacteriological quality of waters from Beni-Haroun Dam and treated at the Ain Tinn treatment plant located in the Mila district, northeastern Algeria. We found that, in general, and despite some exceptions, the treatment procedures have great effectiveness, and treated water from the Beni-Haroun Dam remains of good quality. This is deduced by observing physicochemical and bacteriological parameters which most often did not exceed the thresholds recommended by international institutions. For bacteriological analysis, and despite the fact that our results showed the absence of germs which are indicators of bacterial contamination, or even their presence at low loads does not present any danger for water consumption, it is, therefore, necessary to continue to research for the presence of these germs in order to avoid any risk of infection. Evaluation of other physicochemical parameters is also recommended to preserve the quality of the water and avoid all forms of pollution.

References

Aghaarabi, E., Aminravan, F., Sadiq, R., Hoorfar, M., Rodriguez, M.J. and H. Najjaran (2014). Comparative study of fuzzy evidential reasoning and fuzzy rule-based approaches: An illustration for water quality assessment in distribution networks. *Stochastic Environmental Research and Risk Assessment*, **28(3):** 655-679.

Akiya, N. and P.E. Savage (2002). Roles of water for chemical reactions in high-temperature. *Water. Chem. Rev*., **102(8):** 2725-2750.

Bertanza, G., Boiocchi, R. and R. Pedrazzani (2022). Improving the quality of wastewater treatment plant monitoring by adopting proper sampling strategies and data processing criteria. *Science of the Total Environment*, **806:** 150724.

Bouaroudj, S., Menad, A., Bounamous, A., Ali-Khodja, H., Gherib, A., Weigel, D.E. and H. Chenchouni (2019). Assessment of water quality at the largest dam in Algeria (Ben Haroun Dam) and effects of irrigation on soil characteristics of agricultural lands. *Chemosphere*, **219:** 76-88.

Crittenden, J.C., Trussell, R.R., Hand, D.W., Howe, K.J., and G. Tchobanoglous (2012). MWH's water treatment: Principles and design. John Wiley & Sons Edition.

Dovonou, F., Aina, M., Boukari, M. and A. Alassane (2011). Pollution physico-chimique et bactériologique d'un écosystème aquatique et ses risques écotoxicologiques: Cas du lac Nokoue au Sud Benin. *Int. J. Biol. Chem. Sci.,* **5(4):** 1590-1602.

Edberg, S.C., Rice, E.W., Karlin, R.J. and M.J. Allen (2000). *Escherichia coli*: The best biological drinking water indicator for public health protection. *Journal of Applied Microbiology*, **88:** 106-116.

Fagrouch, A., Amyay, S., Berrahou, A., El Halouani, H. and H. Abdelmoumen (2010). Performances d'abattement des germes pathogènes en lagunage naturel sous climat aride: Cas de la filière de traitement des eaux usées de la ville de Taourirt. *Afrique Science*, **6(3):** 87-102.

Festy, B., Hartemann, P., Ledrans, M., Levallois, P., Payment, P. and D. Tricard (2003). Qualité de l'eau. *In:* Environnement et santé publique-Fondements et pratiques, pp. 333-368.

Heriarivony, S., Razanamparan, Y. and J. Rakotomalala (2015). Caractères physico- chimiques et bactériologiques de l'eau de consommation (puits) de la commune rurale d'antanifotsy, région vakinankaratra, Madagascar. *Larhyss Journal*, **12(4):** 7-17.

LeChevallier, M.W. (1990). Coliform regrowth in drinking water: A review. *Journal American Water Works Association*, **82(11):** 74-86.

Nechad, I., Fadil, K. and F. Fadil (2014). Qualité physicochimique des eaux des sources Ain Regrag et Ain sidi Bouali dans la région de Séfrou (moyen atlas, Maroc). *Larhyss Journal*, **20:** 137.

Pal M., Ayele Y., Hadush M., Panigrahi S. and V.J. Jadhav (2018). Public health hazards due to unsafe drinking water. *Air Water Borne Dis*, **7(1):** 1.

Petraccia, L., Liberati, G., Masciullo, S.G., Grassi, M. and A. Fraioli (2006). Water, mineral waters and health. Clinical Nutrition, **25(3):** 377-385.

Pandey, S.K. and T. Shweta (2009). Physico-chemical analysis of ground water of selected area of Ghazipur city-A case study. *Nature and Science*, **7(1):** 17-20.

Rodier, J. (2005). L'analyse de l'eau. Eaux naturelles. Eaux résiduaires. Eaux de mer, Dunod, Paris. 8ème Edition.

Rodier, J., Legube, B. and N. Merlet (2009). L'analyse de l'eau. Dunod Paris. 9éme Edition.

Sánchez-Monedero, M.A., Aguilar, M.I., Fenoll, R. and A. Roig (2008). Effect of the aeration system on the levels of airborne microorganisms generated at wastewater treatment plants. *Water Research*, **42(14):** 3739-3744.

Thayer, B.B., Riahi, K. and H. Boudhara (2007). Élimination de la turbidité par oxygénation et filtration successives des eaux de la station de Sfax (Sud de la Tunisie). *Revue des sciences de l'eau*, **20(4):** 355-365.

Van der Bruggen, B., Vandecasteele, C., Van Gestel, T., Doyen, W. and R. Leysen (2003). A review of pressure-driven membrane processes in wastewater treatment and drinking water production. *Environmental Progress*, **22(1):** 46-56.

Yung, M., Kwok, K.W., Djurišić, A.B., Giesy, J.P. and K.M. Leung (2017). Influences of temperature and salinity on physicochemical properties and toxicity of zinc oxide nanoparticles to the marine diatom *Thalassiosira pseudonana*. *Scientific Reports*, **7(1):** 1-9.

Wang, Z., Meador, J.P. and K.M. Leung (2016). Metal toxicity to freshwater organisms as a function of pH: A meta-analysis. *Chemosphere*, **144:** 1544-1552.

WHO (2004). Guidelines for drinking-water quality (Vol.. 1). World Health Organization.