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Communication

Physicochemical and Algal Study of Three Dams (Algeria) and Removal of Microalgae by Enhanced Coagulation

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Abstract: The Boukerdène, Lakhel and Ghrib Dams, located in northern Algeria, are used for both drinking water supply and irrigation. Microalgae (MA) and phytoplankton are able to proliferate when environmental conditions are favorable. These phases of proliferation can have harmful consequences on the functioning of aquatic ecosystems but also on their use. The objective of this work is to acquire a better knowledge on the proliferation of these MA in these three Dams, to describe and quantify their species, as well as to study their impact on a physicochemical treatment, namely conventional coagulation and enhanced coagulation. In addition, a physicochemical study is developed to assess the water quality of these Dams. Laboratory analyses have shown that the levels of MA in these waters are high, and jar tests have proven that the application of enhanced coagulation under controlled conditions (coagulant dose, acidification of the medium) leads to better performance compared to conventional coagulation. Enhanced coagulation is not fully effective in removing micropollutants and needs always to be aided by additional treatment technologies, such as ozonation and activated carbon adsorption. The SEM analysis carried out clearly shows the changes that took place in the morphology of the collected flocs thus binding the AM debris. As a perspective, the future studies have to focus on other physicochemical parameters such as alkalinity.

Keywords: Conventional Coagulation, Enhanced Coagulation, Boukerdène Dam, Lakhel Dam, Ghrib Dam

1. Introduction

Like other Mediterranean countries, Algeria is characterized by rare water resources, which must be managed with a delicate care to guarantee their sustainable use [1]. Indeed, these water resources are dams, which, through the wadis, receive on the one hand the discharges of several agglomerations and on the other hand agricultural fertilizers [2, 3]. In recent years, these wastewater discharges of urban and industrial origin have increased in wadis. This poses a threat to the water quality of the dams. If the phenomenon persists, dams will be polluted resulting in nutrient enrichment causing a disruption of this lacustrine system [3]. Sediment deposition in dam reservoirs generates eutrophication of the water. Eutrophication is the enrichment of a water with mineral salts (nitrates and phosphates in particular) resulting in ecological imbalances such as the proliferation of aquatic vegetation and the depletion of dissolved oxygen. The eutrophication process develops a proliferation of green algae and microalgae (MA) going to the depletion of oxygen reserves in deep water and changes in the chemical composition of water [1]. This proliferation of unicellular algae and cyanobacteria, mainly represented by several species whose toxic nature is well established [4], is the most characteristic manifestation of this dysfunction. Indeed, the proliferation of algae and the metabolites they secrete can cause serious disturbances in water treatment systems and thus degrade the quality of water intended for human consumption [5, 6]. Therefore, the treatments used must be suitable for algae removal [7-9]. Different treatment processes have been proposed [10, 11]. In general, these treatments are distributed as follows [12]: (1) Physicochemical processes such as coagulation [13, 14] followed by neutralization with lime, (2) electrochemical processes such as electrocoagulation/electroflotation [15, 16],

(3) adsorption processes such as adsorption on activated carbon.

This work deals with the study of MA and their elimination of water from different dams by coagulation, which constitutes the primordial stage during which the conventional treatment of water is realized. In addition, this study aims to identify the algal populations, encountered during the year 2011, in the water of Ghrib Dam [17]. Another objective is to have a thorough knowledge of the ecology of the different classes of MA seen their serious problems of toxicity to human health [18]. The results of the various experiments carried out, based essentially on the test jar, as well as their interpretations and the applications that may result are presented.

2. Materials and Methods

2.1. Sampling and Analyses

The water samples were taken monthly from February to August 2011 according to standardized methods [19, 20]. In fact, 24 variables were subject to physicochemical monitoring. Dissolved oxygen is measured by the Winckler method. Additional adaptations (Alsterberg) made it usable in the presence of certain interferences. Nitrates (NO_3^-), nitrites (NO_2^-), ammoniacal nitrogen (NH_4^+) and sulfates (SO_4^{2-}) are determined by colorimetric assay using a spectrophotometer. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) are determined by the volumetric method using ethylenediaminetetraacetic acid (EDTA). Sodium (Na^+) and potassium (K^+) are determined by a flame photometer varying [19, 20]. The organic matter is determined by hot oxidation in acidic medium [21]. Turbidity is measured by a turbidimeter. It should be noted that water samples were taken at the surface of the water (dams). In parallel with the abiotic data, the samples of the MA were made. These samplings were carried out using a 20 to 100 µm mesh plankton net, the samples were fixed and stored in a Lugol solution. On these samples, the species were identified and counted under an inverted microscope according to the method of Utermöhl [22], modified by Legendre and Watt [23].

2.2. Removal of Microalgae (MA) from Ghrib and Lakhel Dams Water Through Enhanced Coagulation

Jar tests were carried out on the waters of the Ghrib Dam as well as on the Lakhel Dam, which have noticeable physicochemical parameters, especially those concerning water pollution. The coagulants tested are aluminum sulfate (alum) and ferric chloride [24, 25]. The experiments were performed on a jar test consisting of a battery of four beakers operating simultaneously. Coagulation testing is employed to determine the optimal dosage of coagulants to meet contamination removal especially in terms of turbidity and MA elimination [26, 27]. A particular attention is accorded to study the influence of the dose of the coagulant used. In the enhanced coagulation procedure, the effect of pH is more examined. The treatment method is briefly explained in Table 1.

Table 1. *Jar test procedure followed to monitor turbidity and MA removal.*

Step	Description
Step #1	Agitate the water to be treated properly before taking a sample for analysis or for a coagulation jar test.
Step #2	Measure temperature, pH, turbidity as well as the conductivity of the dam water.
Step #3	Identify existing MA in the raw water before treatment with the Utermhöl method [22].
Step #4	Pour 1 L of sample into each one of the beakers, and place them on the stirring bench.
Step #5	Start agitation until a speed of 140 rpm to homogenize the sample for 5 min.
Step #6	Prepare the solutions of the coagulant. Inject the coagulant at different concentrations simultaneously into each beaker. Continue stirring at 140 rpm for 2 min (coagulation), and reduce stirring at 40 rpm for 20 min (flocculation) and then stop agitation. Allow to settle for 30-60 min.
Step #7	During this time, observe the flocs formed (time of appearance, size, and appearance). At the end, simultaneously take a sample of supernatant water (treated) in each of the beakers and analyze it (turbidity, pH, conductivity, and MA).

2.3. Scanning Electron Microscope (SEM) Analysis

The SEM analysis makes it possible to describe all the aspects of the solid more precisely its topography. Used for its observation functions, the SEM was then developed in association with other analytical techniques, and thus found its many applications in metallurgy, in the field of geology, and biology [28]. The SEM observations of a sample of alum flocs, for example, make it possible to specify the morphology of the flocs and the modifications that took place after treatment with enhanced coagulation through acidifying the medium pH with the acid injection, which gave better results, after drying at 105°C during 4 hrs.

3. Results and Discussion

3.1. Algal Enumeration for Lakhel Dam and Boukerdène Dam

The Lakhel Dam and Boukerdène Dam are of a medium algal diversity, it is explained by the results of physicochemical and algological analyzes carried out on the waters of these two Dams. Indeed, the results showed that these two Dams are relatively not very loaded and the concentrations of nutrients (nitrogen (N) and phosphorus (P)) are not very important. However, the factors that lead to a phytoplankton bloom or high biomass and its persistence are mainly nutrient growth, low N/P ratio, and favorable temperature and sunshine conditions.

Figure 1 presents the variation in the count of MA contained in the waters of the Lakhel Dam and Boukerdène Dam from January to August. As shown in Figure 1, for Boukerdène Dam, the number of MA shows a peak of a maximum value in winter (February). Then, it decreases in March; then, there is the appearance of a second maximum value in April but higher than that reached in February. These changes can be explained by the fact that in winter, under the effect of rain and runoff, Boukerdène Dam water can be relatively enriched with nutrients that will be used by different species; and with the increase in temperature late spring and especially in the summer, the nutrient sources decrease, as well as other factors can influence this decrease such as competition, predation and parasitism. On the other hand, by analyzing the algological community in the water of the Lakhel Dam, the maximum peak was recorded in summer (June and August); this refers to what has already been explained previously and by the difference of the climatological characteristics of the two regions. The dominance of the classes of chlorophyceae and bacillariophyceae as well as diatoms is explained by their ability to adapt to all environmental conditions, as is the case for the genus *Cyclotella sp.*, which was met in all the months studied even in the Ghrib Dam water analysis.

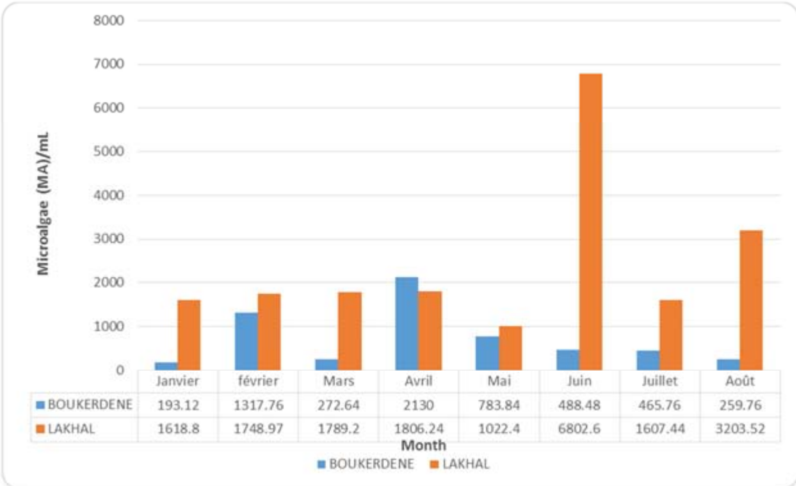

Figure 1. *Variation in the count of MA contained in the waters of the Lakhel Dam and Boukerdène Dam from January to August.*

The low charge of the two Dams in cyanophyte is due to the low phosphorus content of the medium and the temperature that was favorable for a very limited number of species encountered. The results obtained, for which the samples were taken from the surface of the Dams (0 m depth) on the periphery and nearing the center of the Dams, also revealed the presence of two dominant classes: chlorophyceae and bacillariophyceae: *Scenedesmus quadricauda*, *Scenedesmus ecornis* as well as *Tetraedron* and *Pediastrum simplex*. These are among the genera encountered in both dams, and are reported as responsible for the unpleasant taste and smell of water. This is directly related to the substances they develop during the growth phase, or indirectly to certain cyanophyceae that release phenolic substances, which during chlorination give chlorinated compounds (chlorophenols) making the water extremely unpleasant to the consumption [29-31].

3.2. Elimination of Microalgae (MA) from Ghrib and Lakhel Dams Water by Enhanced Coagulation

The results of coagulation tests using both coagulants (alum and ferric chloride) are illustrated in Figures 2-5 for Lakhel Dam, and Figures 5-9 for Ghrib Dam. The gradual addition of ferric chloride causes a significant drop in pH and electrical conductivity compared to alum [32, 33]. The decrease in pH, in both cases, is explained by the phenomenon of charge neutralization by the cationic species of aluminum (Al^{3+}, $Al(OH)^{2+}$, and $Al(OH)_2{}^{+}$); and, if the dose of the coagulant is increased, the charge of the colloids is reversed and becomes positive [34, 35].

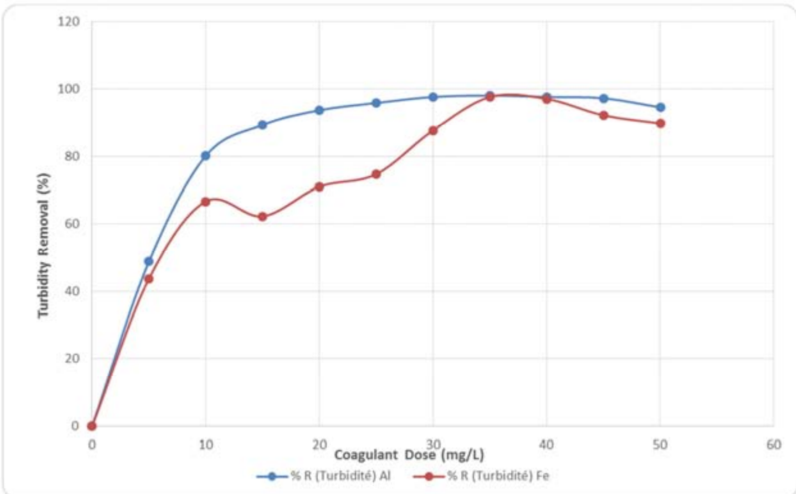

Figure 2. *Variation in turbidity reduction of Lakhel Dam water as a function of coagulant dose (alum and ferric chloride).*

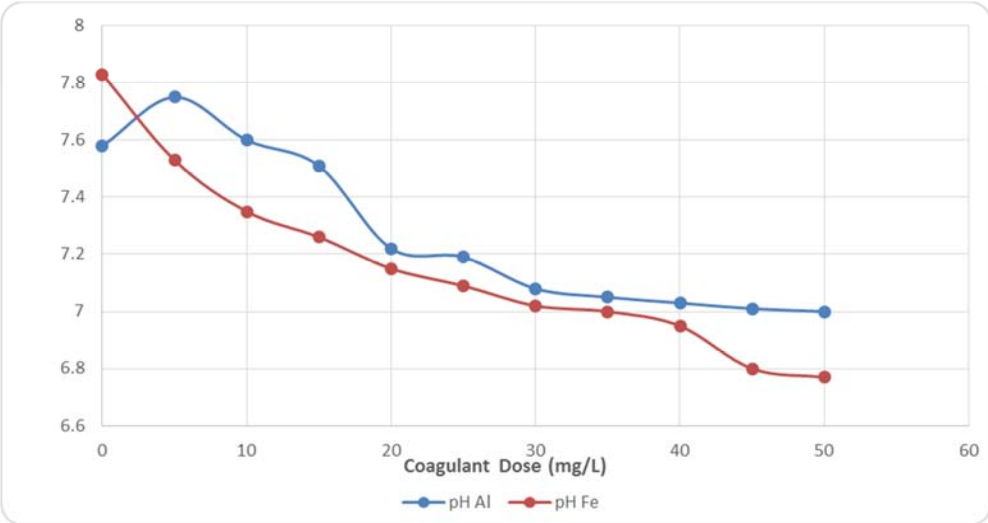

Figure 3. *Variation of the pH of the Lakhel Dam water as a function of the dose of the coagulant (alum and ferric chloride).*

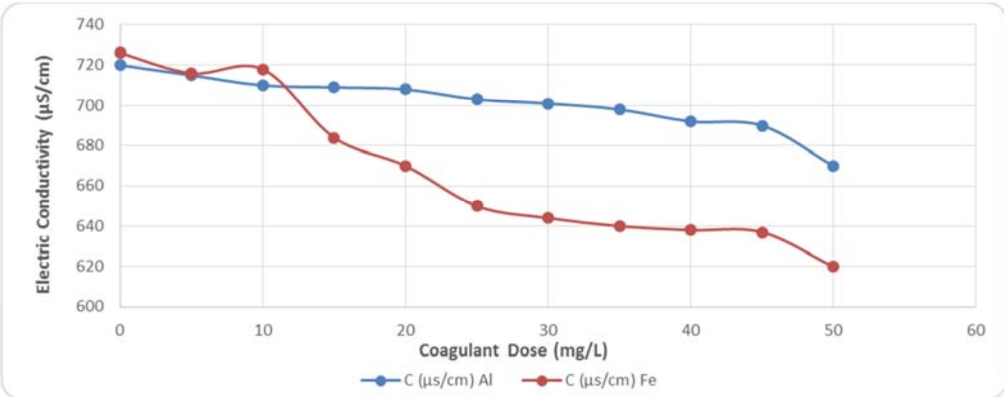

Figure 4. *Variation of the electrical conductivity of the Lakhel Dam water as a function of the dose of the coagulant (alum and ferric chloride).*

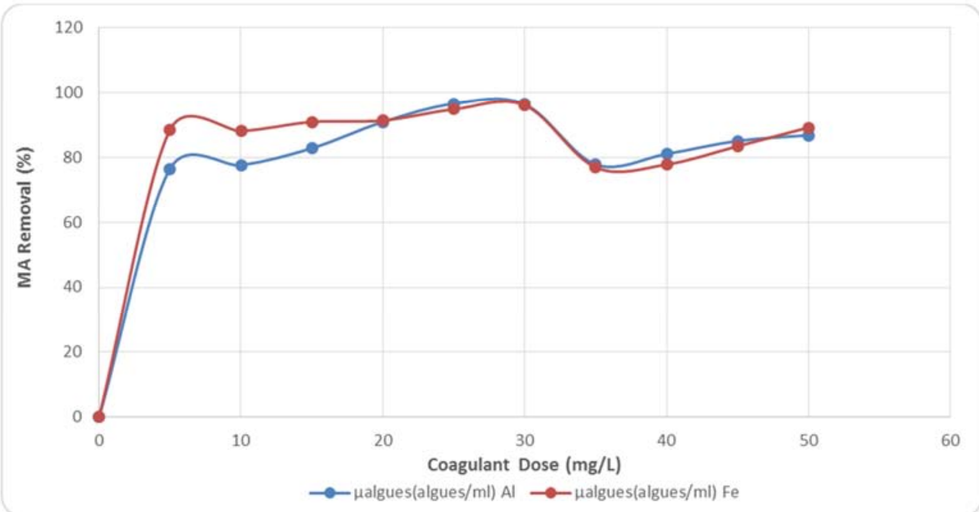

Figure 5. *Variation in the MA removal from the Lakhel Dam water as a function of the dose of the coagulant (alum and ferric chloride).*

According to Van Benschoten and Edzwald [36], the pH of coagulation and the temperature of the treated water affected residual aluminum concentrations.

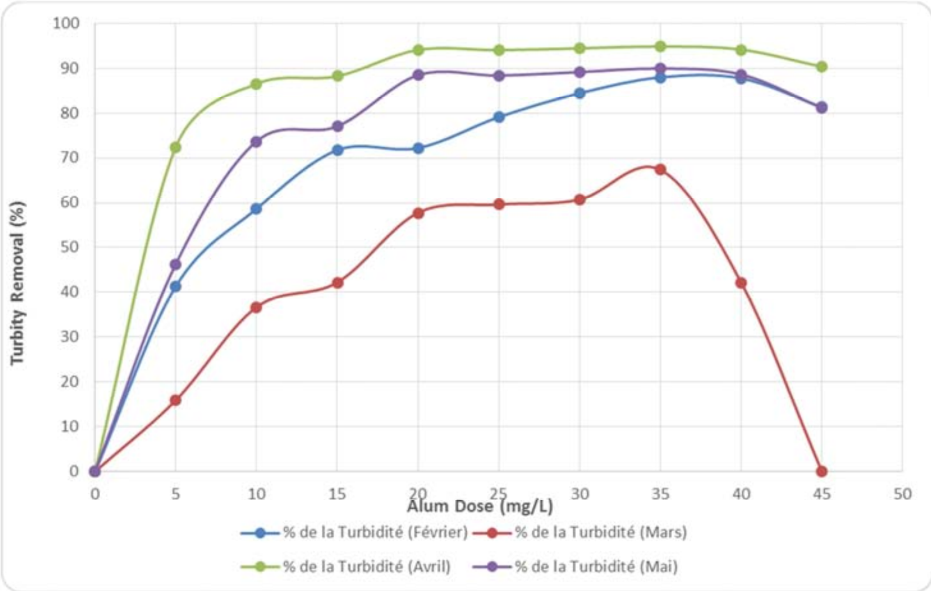

Figure 6. *Reduction of the turbidity of the Ghrib Dam water following the concentration of alum by conventional coagulation (from February to May).*

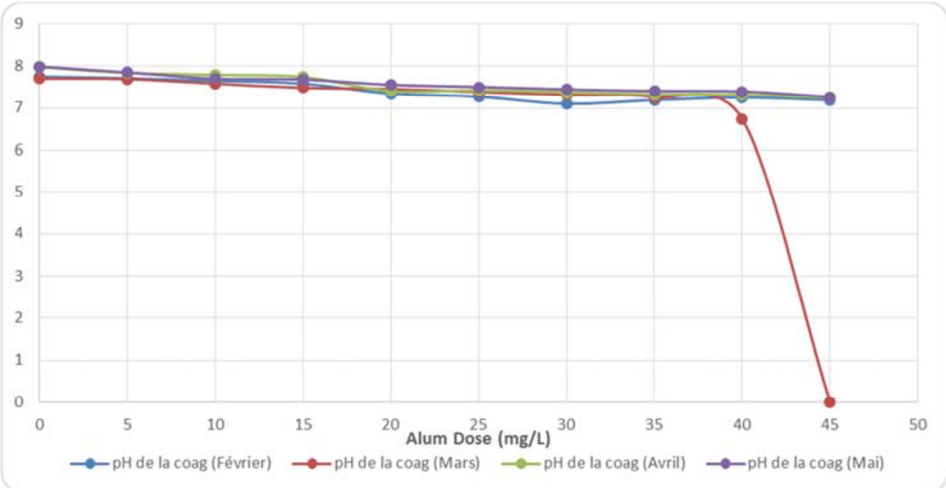

Figure 7. *Variation of the pH of the water of the Ghrib Dam following the dose of alum by conventional coagulation (from February to May).*

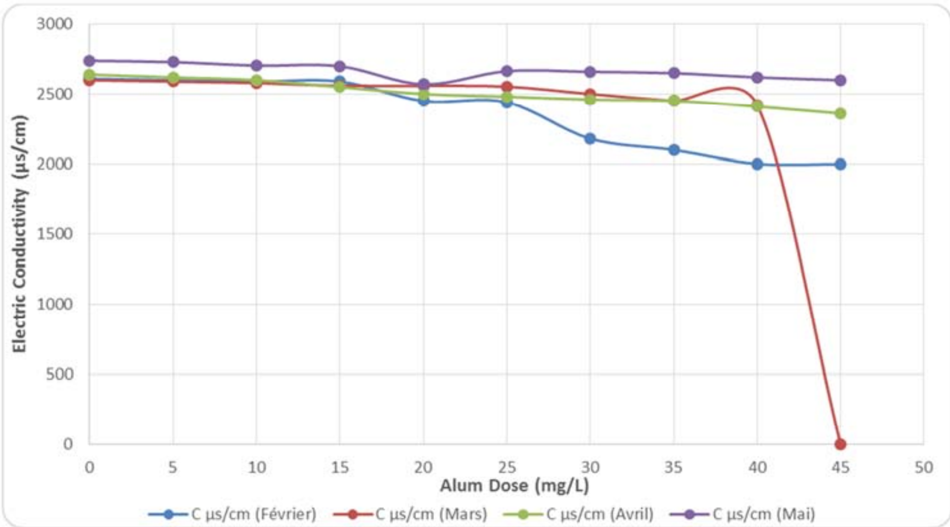

Figure 8. *Variation of the electrical conductivity of the Ghrib Dam water following the dose of alum by conventional coagulation (from February to May).*

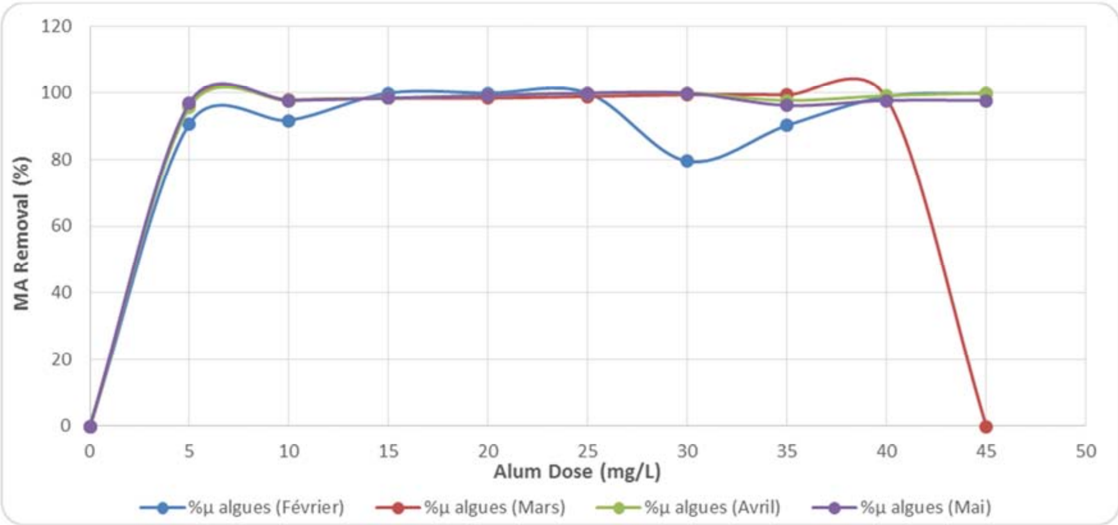

Figure 9. *Reduction of the MA contained in the Ghrib Dam water following the dose of alum by conventional coagulation (from February to May).*

For enhanced coagulation [37], the decrease in pH leads to an increase in the elimination of turbidity: up to 76.9% (HCl) and 84.52% (H_2SO_4) for February, 74,05% (HCl) and 68.88% (H_2SO_4) for March, 94.52% (HCl) and 92.5% (H_2SO_4) for April, 93.02% (HCl) and 64.19% (H_2SO_4) for May.

The results obtained clearly show that the application of HCl is better adapted to the elimination of turbidity as well as the MA than H_2SO_4.

The elimination of turbidity by conventional coagulation was close to 67.4% compared to 74.05% enhanced coagulation elimination at a pH value of 6.5 and an optimal coagulant dose of 35 mg/L.

Moreover, the electrical conductivity recorded after treatment by the two processes is decreasing and this during the 4 months of testing.

The comparison between the two processes applied concerning the elimination of MA from Ghrib Dam water makes it possible to conclude that the best treatment is that obtained by acidification of the medium by adding the two acids (improved coagulation). Indeed, rates of 100% elimination at a pH around 6-6.5 are obtained, and this during the month of February until May.

3.3. Scanning Electron Microscope (SEM) Results

Figures 10-12 showed the changes that occurred during the treatment of enhanced coagulation (using HCl). The samples selected are those with the best results for removal of MA and turbidity obtained during the four consecutive months. The aggregates formed show two different geometrical aspects: spherical and prismatic. The spherical particles have a mean diameter of 100 nm and the prismatic particles have an average diameter of 600 nm. These results may mean that the final form of precipitation has a prismatic morphology.

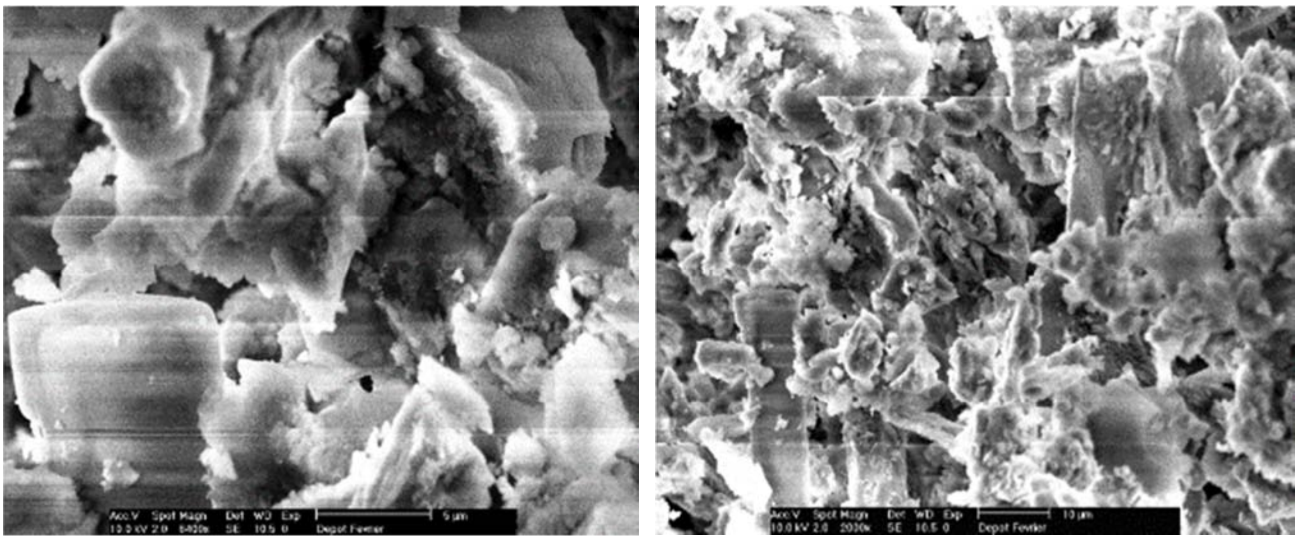

Figure 10. *SEM image of the precipitate (left 5 µm, right 10 µm) (Deposit of February).*

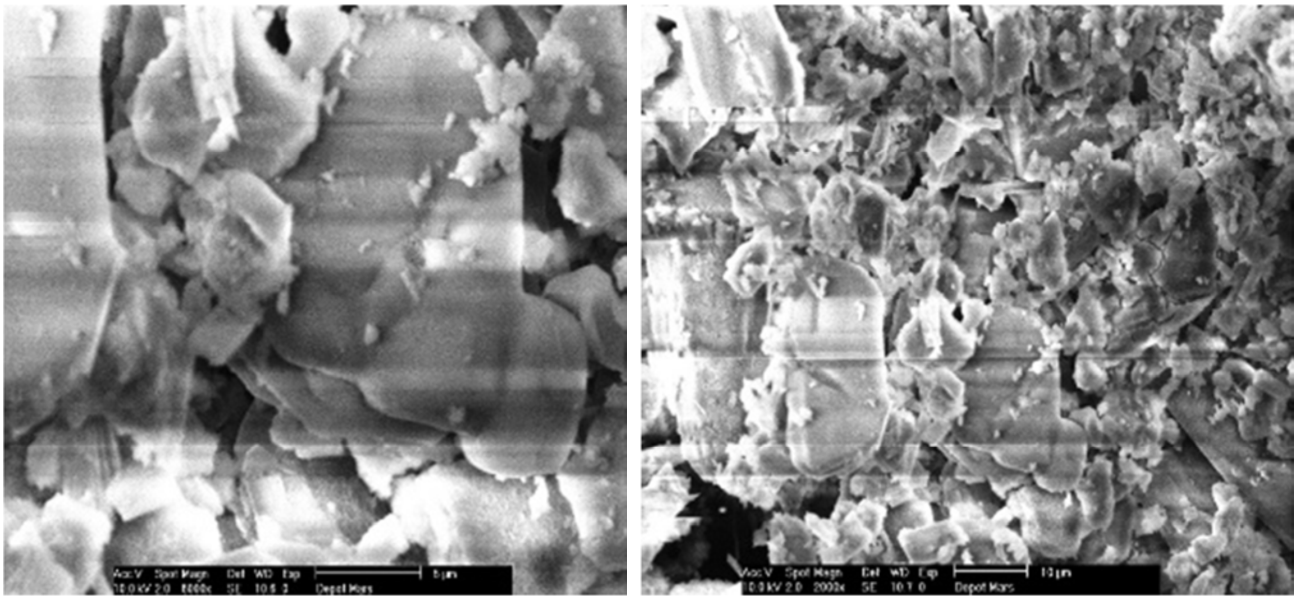

Figure 11. *SEM image of the precipitate (left 5 µm, right 10µm) (Deposit of March).*

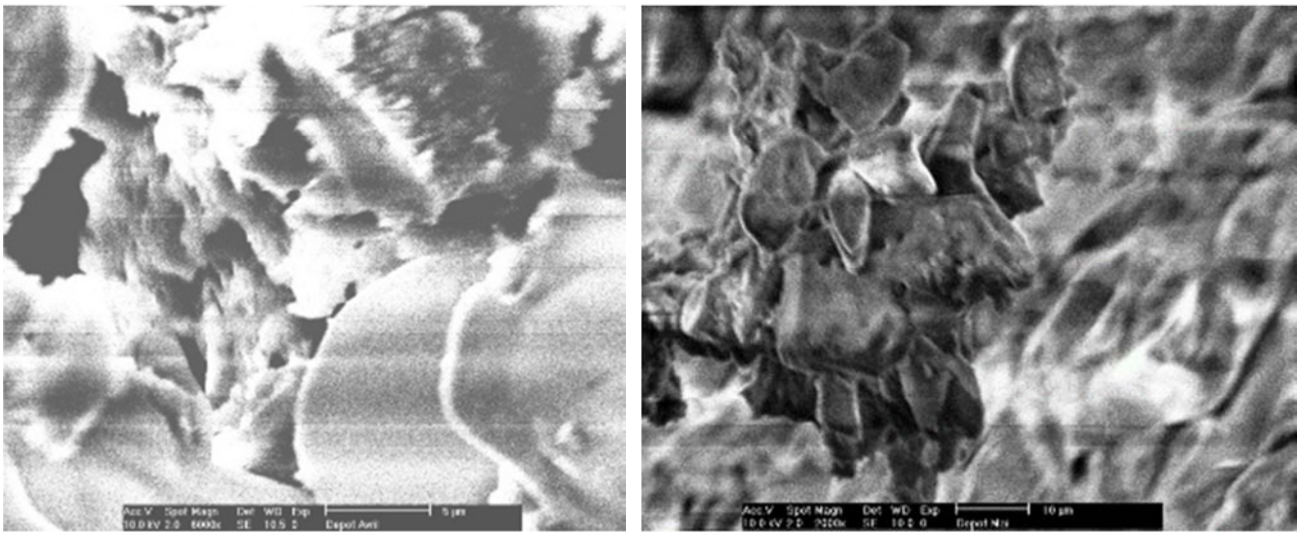

Figure 12. *SEM image of the precipitate (left 5 µm, right 10 µm) (Deposit of May).*

The powder consists of spherical particles, ranging from about ten nanometers [38]. This uniaxial shape makes it possible to avoid a preferential orientation of particles in the compact. Figures 10-12 clearly show the changes in the aggregates formed in the different samples during the period from February to May. From Figures 10-12, it is noted the existence of some debris of MA trapped in the flocs that come in different forms [d1600].

4. Conclusions

The main points drawn from this short communication may be given as:

1. The Lakhel Dam is the most heavily loaded dam in MA with a very large diversity of algal communities. As for the Ghrib Dam, it is very low in MA and this is due to the very high rate of salinity of the water of this dam.
2. The effectiveness of Ghrib Dam water treatment by the enhanced coagulation process compared to the coagulation of the conventional treatment chain is well proven. Indeed, almost total reductions of the MA and the turbidity have been demonstrated through the jar tests carried out. Although the study has yielded better results, the harmful impact of chemicals used in treatment processes will always be very important. The toxicity of chlorine and aluminum is well established.
3. Enhanced coagulation is not fully effective in removing micropollutants and needs always to be aided by additional treatment technologies, such as ozonation and activated carbon adsorption.
4. The SEM analysis carried out clearly shows the changes that took place in the morphology of the collected flocs thus binding the AM debris.
5. As a perspective, the future studies have to focus on other physicochemical parameters such as alkalinity.

References

[1] I. Bouaichi, Qualité des eaux de barrages en exploitation. Les Enjeux de la Qualité dans le Secteur de l'Eau et de l'Assainissement en Algérie, Apport des Techniques Nucléaires. EQSEAATN' 2010. http://www.semide.net/media_server/files/semide/thematicdirs/news/2010/08/les-enjeux-de-la-qualite-dans-le-secteur-de-leau/20100510_tipaza.pdf (accessed on 08/05/19).

[2] D. Ghernaout, B. Ghernaout, On the concept of the future drinking water treatment plant: Algae harvesting from the algal biomass for biodiesel production—A Review, Desalin. Water Treat. 49 (2012) 1-18.

[3] M. S. Hamaidi, F. Hamaidi, A. Zoubiri, F. Benouaklil, Y. Dhan, Etude de la dynamique des populations phytoplanctoniques et résultats préliminaires sur les blooms toxiques à cyanobactéries dans le Barrage de Ghrib (Ain Defla-Algérie). Europ. J. Sci. Res. 32 (2009) 369-380.

[4] B. Remini, La problématique de l'eau en Algérie du nord, Larhyss J. 8 (2010) 27-46.

[5] D. Ghernaout, A. Badis, G. Braikia, N. Matâam, M. Fekhar, B. Ghernaout, A. Boucherit, Enhanced coagulation for algae removal in a typical Algeria water treatment plant, Environ. Eng. Manag. J. 16 (2017) 2303-2315.

[6] Y. Alshammari, D. Ghernaout, M. Aichouni, M. Touahmia, Improving operational procedures in Riyadh's (Saudi Arabia) water treatment plants using quality tools, Appl. Eng. 2 (2018) 60-71.

[7] D. Ghernaout, B. Ghernaout, M. W. Naceur, Embodying the chemical water treatment in the green chemistry – A review, Desalination 271 (2011) 1-10.

[8] D. Ghernaout, The best available technology of water/wastewater treatment and seawater desalination: Simulation of the open sky seawater distillation, Green Sustain. Chem. 3 (2013) 68-88.

[9] D. Ghernaout, Magnetic field generation in the water treatment perspectives: An overview, Int. J. Adv. Appl. Sci. 5 (2018) 193-203.

[10] D. Ghernaout, M. W. Naceur, Ferrate (VI): In situ generation and water treatment – A review, Desalin. Water Treat. 30 (2011) 319-332.

[11] D. Ghernaout, M. Aichouni, A. Alghamdi, Applying Big Data (BD) in water treatment industry: A new era of advance, Int. J. Adv. Appl. Sci. 5 (2018) 89-97.

[12] D. Ghernaout, Disinfection and DBPs removal in drinking water treatment: A perspective for a green technology, Int. J. Adv. Appl. Sci. 5 (2018) 108-117.

[13] D. Ghernaout, A. I. Al-Ghonamy, M. W. Naceur, A. Boucherit, N. A. Messaoudene, M. Aichouni, A. A. Mahjoubi, N. A. Elboughdiri, Controlling coagulation process: From Zeta potential to streaming potential, Am. J. Environ. Prot. 4 (2015) 16-27.

[14] D. Ghernaout, Entropy in the Brownian motion (BM) and coagulation background, Colloid Surface Sci. 2 (2017) 143-161.

[15] D. Ghernaout, A. Badis, B. Ghernaout, A. Kellil, Application of electrocoagulation in *Escherichia Coli* culture and two surface waters, Desalination 219 (2008) 118-125.

[16] D. Ghernaout, C. Benblidia, F. Khemici, Microalgae removal from Ghrib Dam (Ain Defla, Algeria) water by electroflotation using stainless steel electrodes, Desalin. Water Treat. 54 (2015) 3328-3337.

[17] D. Belhout, D. Ghernaout, S. Djezzar-Douakh, A. Kellil, Electrocoagulation of Ghrib dam's water (Algeria) in batch using iron electrodes, Desalin. Water Treat. 16 (2010) 1-9.

[18] D. Ghernaout, Environmental principles in the Holy Koran and the Sayings of the Prophet Muhammad, Am. J. Environ. Prot. 6 (2017) 75-79.

[19] AFNOR (Association Française de Normalisation), Recueil de normes françaises eaux: Méthodes d'essais, (1979), 342 p.

[20] J. Rodier, L'analyse de l'eau. Eaux naturelles, eaux résiduaires, eau de mer, 8th Ed., Dunod, Paris, 1996.

[21] D. Ghernaout, The hydrophilic/hydrophobic ratio *vs.* dissolved organics removal by coagulation - A review, J. King Saud Univ. – Sci. 26 (2014) 169-180.

[22] H. Utermöhl, Zur vervollkommung der quantitative phytoplankton-Methodik, Schweizerbart, Stuttgart, 1958.

[23] L. Legendre, W. D. Watt, On a rapid technique for plankton enumeration, Ann. Inst. Oceanogr. Paris 58 (1971-1972) 173-177.

[24] D. Ghernaout, B. Ghernaout, A. Kellil, Natural organic matter removal and enhanced coagulation as a link between coagulation and electrocoagulation, Desalin. Water Treat. 2 (2009) 203-222.

[25] B. Ghernaout, D. Ghernaout, A. Saiba, Algae and cyanotoxins removal by coagulation/flocculation: A review, Desalin. Water Treat. 20 (2010) 133-143.

[26] D. Ghernaout, A. Boucherit, Review of coagulation's rapid mixing for NOM removal, J. Res. Develop. Chem., 2015, DOI: 10.5171/2015.926518.

[27] A. Boucherit, S. Moulay, D. Ghernaout, A. I. Al-Ghonamy, B. Ghernaout, M. W. Naceur, N. Ait Messaoudene, M. Aichouni, A. A. Mahjoubi, N. A. Elboughdiri, New trends in disinfection by-products formation upon water treatment, J. Res. Develop. Chem., 2015, DOI: 10.5171/2015.628833.

[28] A. Masseboeuf, Microscopie Électronique en Transmission pour l'étude de phénomènes magnétiques à l'échelle du nanomètre, Université Joseph-Fourier - Grenoble I, 2008.

[29] D. Ghernaout, B. Ghernaout, From chemical disinfection to electrodisinfection: The obligatory itinerary?, Desalin. Water Treat. 16 (2010) 156-175.

[30] D. Ghernaout, M. W. Naceur, A. Aouabed, On the dependence of chlorine by-products generated species formation of the electrode material and applied charge during electrochemical water treatment, Desalination 270 (2011) 9-22.

[31] D. Ghernaout, Water treatment chlorination: An updated mechanistic insight review, Chem. Res. J. 2 (2017) 125-138.

[32] D. Ghernaout, A. Simoussa, A. Alghamdi, B. Ghernaout, N. Elboughdiri, A. Mahjoubi, M. Aichouni, A. E. A. El-Wakil, Combining lime softening with alum coagulation for hard Ghrib dam water conventional treatment, Inter. J. Adv. Appl. Sci. 5 (2018) 61-70.

[33] D. Ghernaout, C. Laribi, A. Alghamdi, B. Ghernaout, N. Ait Messaoudene, M. Aichouni, Decolorization of BF Cibacete Blue (CB) and Red Solophenyle 3BL (RS) using aluminum sulfate and ferric chloride, World J. Appl. Chem. 3 (2018) 32-40.

[34] D. Ghernaout, S. Moulay, N. Ait Messaoudene, M. Aichouni, M. W. Naceur, A. Boucherit, Coagulation and chlorination of NOM and algae in water treatment: A review, Intern. J. Environ. Monit. Analy. 2 (2014) 23-34.

[35] D. Ghernaout, A. I. Al-Ghonamy, A. Boucherit, B. Ghernaout, M. W. Naceur, N. Ait Messaoudene, M. Aichouni, A. A. Mahjoubi, N. A. Elboughdiri, Brownian motion and coagulation process, Am. J. Environ. Prot. 4 (2015) 1-15.

[36] J. E. Van Benschoten, J. K. Edzwald, Measuring aluminum during water treatment: methodology and application, J. Am. Water Works Assoc. 82 (1990) 71-78.

[37] S. Djezzar, D. Ghernaout, H. Cherifi, A. Alghamdi, B. Ghernaout, M. Aichouni, Conventional, enhanced, and alkaline coagulation for hard Ghrib Dam (Algeria) water, World J. Appl. Chem. 3 (2018) 41-55.

[38] A. Shui, Z. Kato, S. Tanaka, N. Uchida, K. Uematsu, Sintering deformation caused by particle orientation in uniaxially and isostatically pressed alumina compacts. J. Eur. Ceram. Soc. 22 (2002) 311-316.

[39] D. Ghernaout, B. Ghernaout, Sweep flocculation as a second form of charge neutralisation – A review, Desalin. Water Treat. 44 (2012) 15-28.