First characterization of physicochemical and biological variables of the salt wetland dayat Morsli in Oran (Algeria)

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Abstract

Known to be on the outskirts of the city of Oran, 'dayat Morsli' is an endoreic wetland in western Algeria, and has suffered from many years of anthropogenic pollution (industrial and waste water). Dayat Morsli pool had never been characterized before, and the aim of this work is to understand the hydrological functions and the dynamic of this closed wetland, by monitoring biological, physical and chemical parameters for one year (2017). Water samples were collected monthly all around the lake. Measured parameters consisted of water level, pH, salinity, temperature, organic matter and phytoplankton abundance, in addition to the concentration of organic pollutants, nitrates and phosphates. The concentration of five heavy metals - cadmium, lead, iron, zinc and copper - was also determined. The results show that

dayat Morsli is characterized as a salty to moderately salty wetland. The pH and salinity vary with the temperature and water level throughout the months. The phytoplankton cell concentration decreases with decreasing depth and increasing salinity. In parallel, during the second period of the year (June - December), organic matter accumulates and sediments out, while it decomposes during the first period. Moreover, nitrates and phosphates, essential elements for phytoplanktonic development, are found at concentrations above the standards with respective concentrations of 150 mg/L (NO₃) and 6 mg/L (P), maybe causing the eutrophication of the wetland. We have shown that the average concentrations of Cd and Pb in water were higher than the allowed values. This study provides a better understanding of the functioning of dayat Morsli over one year, but also of the physicochemical and biological interactions in this small closed ecosystem. Moreover, these results could be used as a basis for the rehabilitation project of this wetland.

1. Introduction

Wetlands are the most productive and diverse ecosystems on the planet ([Sieben et al., 2018](#)). There are distinct and extremely diverse ecosystems in form, size, formation and geographical location ([Teixeira et al., 2014](#)). They include natural and artificial marshes, filled by fresh, brackish or salt water. Various categories exist: marine and coastal wetlands, coral reefs, estuarine waters and salt marshes, inland wetlands with rivers, streams, freshwater lakes, salt lakes, brackish lakes and artificial wetlands such as agricultural ponds, salt marshes and dams ([Ennabili and Ater, 1996](#); [Hammer, 1986](#)). They can also be described in terms of salinity, and subdivided into fresh (1 - 3 g/L of salt), hyposaline or brackish (3 - 20 g/L), mesosaline (20 - 50 g/L) and saline and hypersaline (> 50 g/L) water ([Hammer, 1986](#); [Semeniuk and Semeniuk, 1997](#)). Wetlands represent inundated ecosystems, where complex ecological processes occur due to interactions between water, vegetation and soil ([Beaumais et al., 2008](#)). Vegetation in wetlands is an essential component of this ecosystem and plays an important role in the ecological functions ([Ennabili and Ater, 1996](#); [Bouldjedri et al., 2011](#)). They are also a reservoir of biodiversity and a paradise for waterbirds ([Merken et al., 2015](#); [Al-Obaid et al., 2017](#); [Andreotti et al.,](#)

2018; Cherkaoui et al., 2018). During the last centuries, these environments have been subjected to an important degradation due to anthropization effects. Indeed, in wetlands, human actions are the main factors of such a degradation (Shengjie et al., 2017).

In this article, we study a wetland in Northwestern Algeria. Dayat Morsli, or ‘small lake’ of Oran, is the name given to this natural endoreic wetland. The term “dayat” refers to a closed depression in the shape of a basin, more or less vast (a few meters to several hundred meters in diameter). Dayats are located between the Mediterranean and Saharan regions. According to Köppen's classification, northern Algeria has a semi-arid climate characterized by a long dry season and a wet season with low rainfall. From the climatic data over the last 25 years (<https://www.infoclimat.fr/observations-meteo/temps-reel/oran-es-senia/60490.html> (last access: June 22 2019)), it was found that 2017 was an exceptional year, with the lowest rainfalls (247 mm) and the highest average temperatures (19.1 °C). Moreover, over the last 25 years, Es-Senia precipitation was higher than the year 2017, with a mean of 386 mm and mean annual temperatures of 17.8°C which is 1.3°C below those registered in 2017 (<https://fr.climate-data.org/> (last access: July 19 2019)). The dayats are periodically flooded; rainwater and runoff water flow and concentrate in these environments. The accumulation of water in the dayat allows the formation of a relatively deep soil (more than one meter deep) and functions as evaporation pans (Kaabeche, 2012). The proportions of dissolved ions are affected by the natural geochemical composition of aquifer rocks. In fact, the major ions in salt water are the same as those in freshwater, Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Cl^- , SO_4^{2-} and CO_3^{2-} , but the ionic proportions are different. In salt lakes, Na^+ and Cl^- are the dominant ions, while HCO_3^- is the dominant ion in freshwater lakes (Kuşcu et al., 2017).

As mentioned above, dayat Morsli is a natural closed depression (35°40' N; 0°36' W), with a kidney circle shape, a flat bottom and a 150 ha area, with average dimensions of 1.78 km length and 1.09 km width (Fig. 1). It is part of the Oran plateau, which is located in the Chelif basin extension. The plateau is bounded to the north by the Mediterranean Sea, to the west by the mountain side of Mount Murjadjou, and to the south by a salt flat-bottomed depression called ‘The Big Sebkhah’ of Oran (Fig. 2) (Benziane, 2013). The topographic depression of dayat Morsli is filled with soft sedimentation: alluvium and loam. The open water is about 2 m depth in the centre

with diverging flow in the south. Dayat Morsli is located in the municipality of Es-Senia which has nearly 97 500 citizens. Salt lake is delimited in the east by unused agricultural lands, and by the urban agglomeration of Oran in the north, comprising 1.5 million inhabitants. It is surrounded by an industrial area and a railway in the west and the south. This area includes about ten industries, a foundry, wallpaper and plastic processing plants, as well as an agro-food plant and raw material storage sites. The depression has suffered from many years of industrial pollution and urban waste. Since 2010, dayat Morsli has been a biosphere reserve protected by the city's environmental protection authorities, and the municipality has decided to stop all rejections by court order. Now, dayat Morsli is only fed by rainwater and road drainage water (channels which can be partially closed). Since 2017, a project for the rehabilitation and transformation around the site has been underway, to make it a place of entertainment, resorts, and leisure site for the citizens. Before the rehabilitation project, the area was contaminated by industrial and urban wastes, and about 360 families lived close to the wetland in precarious dwellings. In February 2016, the dismantling of the city slums was carried out in this area. Dayat Morsli has never been explored before and the aim of this work is to understand the functioning and dynamic of this wetland by studying some physicochemical and biological parameters all along a year.

2. Materials and methods

2.1. Sampling procedure

Monthly, in 2017, at each sampling point ([Fig. 1 C](#)), water samples (triplicates) were collected using three polyethylene bottles of 1 litre each one, which was rinsed with water to be sampled, filled, stored in an icebox and then transported to the laboratory. Sampling was performed on seven points at the border around the study site. The middle area was not accessible due to the deep mud and could not be explored.

According to the seasons, the collection was done in the water surface, from the surface to 6 cm depth in the wet season, when the wetland is filled, and 2 cm to the

upper surface of the sediment in the hot season, when the wetland is dry, avoiding as much as possible stirring the water and resuspending sediments.

For this purpose, a monthly monitoring of the physicochemical parameters was carried out throughout 2017: pH, temperature, water levels, salinity, organic matter concentration, phosphates and nitrates concentrations and the concentrations of five heavy metals: cadmium (Cd), lead (Pb), zinc (Zn), iron (Fe) and copper (Cu) were measured. A monthly microphytoplankton and microzooplankton count was also carried out to quantify the living part of the dayat.

2.2. Analysis of physical, chemical, and biological parameters

In situ, the level of water with a measure tape, the temperature and the pH with digital EXTECH ® 500 (Extech instruments, Boston, USA) were measured three times in each of the seven points. In the laboratory, salinity, nitrate and phosphate, organic matter and heavy metals were measured in triplicate on water sampled.

The salinity was determined from chloride concentration, using chloride precipitation titration (Rodier et al., 2009). 10 mL water samples were titrated with a silver solution (0.2 N), in the presence of potassium chromate indicators (5%). The end point was indicated by the persistence of the orange silver chromate colour. The total nitrate and phosphate concentrations were measured according to the instructions of test kits HANNA-HI 93728-0 nitrate reagent and HANNA-HI 93717 (A, B) phosphate HR reagent (HANNA Instruments Inc, Rhode Island, USA). The results were expressed in mg/L. The organic matter weight was determined after filtration of 50 mL of water samples, using Whatman GFC filters and drying at 70 °C during two hours to remove the residual water, after heating at 450 °C during four hours to burn organic matter. The results were expressed in g OM/L.

For measuring heavy metals, 20 mL of water samples were filtered under vacuum through Millipore filters of 0.22 µm (Filtropur S, SARSTEDT, Numbrecht, Germany), to eliminate suspended solids. Then, 0.5 mL of concentrated nitric acid was added for preservation (Yazidi et al., 2017). Then, the samples were analysed for cadmuim, lead, zinc, iron and copper metals, using an atomic absorption spectrometer (AAS), (Analytikjenna, novAA® 350, Germany). The results were expressed in ppm.

Changes in a wetland volume during the annual cycle were calculated from the monthly water levels measured at the sampling points and from the Landsat 8 satellite imagery on March 1, 2017 (when water levels reach the highest point) and September 15, 2017 (when water levels are at the lowest peak). From the image of March 1, 2017, where the total surface of the wetland is visible and from the image of September 15, 2017, where it is possible to distinguish the water levels according to the colour levels, a manual segmentation was performed using the QGIS version 3.4 software to determine three depth ranges of the wetland (deep zones, mid-depth zones and shallow areas). Variations in the volume of the wetland during the annual cycle were then determined from the water depths measured monthly on the sampling points (shallow areas) and on the basis of the maximum known depth of 2 m of the wetland (deep zones). The mid-depth zones corresponded to the difference between the two ranges.

Each month, three replicates per site were biologically analyzed. The living cells were prefixed instantly after collection by mixing 10 mL of water samples with 40 μ L of Lugol. During cell counting, the microphytoplankton was determined according to the morphological criteria described by Prescott (1970). The microphytoplankton and microzooplankton cell abundances were carried out under the optic microscope, using a counting cell. Cell counts were performed on 10 cells of a Malassez cell slide.

2.3. Statistical Analysis

Statistical analyses were performed with the software R_{3.4.1} (R., 2005). All measurements were made in triplicates, except for cell counting and organic matter quantification. The repeatability of the values obtained was verified by a simple linear model. The result showed that all measurements were highly repeatable ($F_{83-168} > 120$ and $p < 10^{-3}$). The means of the three measurements were used thereafter.

To analyse the difference between the sites and the temporal variation, a Principal Component Analysis (PCA) was created with the FactoMineR package. The global PCA showed that there was no difference between the sites; we decided to make mixed linear models with the site named as random factor with the *nlme* package and the *lme* function. For chemical characteristics, the fixed variables were temperature,

water level and months. For biological characteristics, the variables were the same with chemistry added.

Before analyzing the data, a correlation between the variables was checked (Sup. data S1). For the correlated variables (chemical data) a PCA was performed to output uncorrelated variables that summed correlated variables. Indeed, nine correlated variables (salinity, pH, Cd, Fe, Zn, Cu, Pb, P and NO₃) were replaced by two uncorrelated variables ChiPC1 and ChiPC2. Two dimensions were chosen. The choice was supported by 5 (out of 9; 55.56%) methods (Optimal Coordinates, Parallel Analysis, Eigenvalues (Kaiser Criterion), Velicer MAP, VSS Complexity 1) according to the psycho package method (Makowski, 2018). The both uncorrelated variables did not represent a chemical measure but a global variation supported by the nine correlated variables.

3. Results

3.1. Seasonal variation of parameters

Concerning the physicochemical and biological parameters, PCA showed that there was no difference between the seven sites, but a difference is observed between the months of the year (Fig. 3). Two periods were clearly identified, on the one hand, the period 1 including January to May, and on the other hand, the period 2 from June to December. All corresponding physicochemical analysis graphs are presented in Figures 4, 5 and 6.

The period 1, from January to May, was marked by a high water level 32 ± 12 cm, a high pH 9 ± 0.5 and a large number of living cells in the water $249 \times 10^3 \pm 208 \times 10^3$ cells/mL, with the occurrence of a bloom between March and April including several species such as a dominant microalgae *Dunaliella salina*. Two macroalgae species *Ulva* sp. and *Mougeotia gracilis* were generally detected on the studied sites. In parallel, a low salinity 30 ± 1.7 mg/L and a variable temperature, as well as low nitrate 90 ± 7 mg/L, phosphate 4.4 ± 0.3 mg/L and stable organic matter 2.3 ± 0.3 g/L concentrations (Fig. 4 and 5) were registered in this period 1. In contrast, the period 2, from June to December, a decrease of the water level 9.8 ± 3.2 cm, pH 8.3 ± 0.6 and of the numbers of cells at $1.8 \times 10^3 \pm 0.6 \times 10^3$ cells/mL was observed. On the

contrary, the remaining parameters showed higher values than previously: temperature and salinity with a maximum of 40 °C and 56 mg/L in August. Nitrate and phosphate show a maximum between July and October before decline (Fig. 5). The organic matter varies from a maximum of 10 ± 0.01 g/L in September to a minimum of 0.06 ± 0.01 g/L in October (Fig. 4). Concerning the variations in the volume of the wetland, it was evolving with the same seasonal trends and had a volume of 1.95×10^6 m³ in March to 1.47×10^6 m³ in September, which represented important variations in the year.

During the first three months of the year, in the water, a decrease is observed in cadmium 0.04 ± 0.02 ppm (Fig. 6a), in copper 0.09 ± 0.01 ppm (Fig. 6b) and in zinc 0.07 ± 0.03 ppm (Fig. 6c). For iron and lead, the months of April and May were relatively linked as shown by the green circle in Figure 3, and an increase in iron 2.1 ± 0.1 ppm (Fig. 6d) and lead 1.3 ± 0.2 ppm (Fig. 6e) is observed. During the period 2, the concentration of heavy metals remained relatively stable, with concentrations of 0.71 ± 0.05 ppm for Cd, 0.2 ± 0.03 ppm for Cu, 0.04 ± 0.02 ppm for Zn, 0.2 ± 0.07 ppm for Fe and 1.1 ± 0.2 ppm for Pb (Fig. 6).

3.2. Physicochemical and Biological Parameters Relationship and Influence

The result of the chemical principal correlation analysis showed that: 1) Dimension 1, named ChiPC1, was positively correlated with salinity, nitrate, phosphate, and lead and negatively with pH and zinc (Sup.data S2). This dimension could be assimilated to 'salinity' since chemical elements evolved in different ways over time with salinity being the most influential element in the remaining chemical variables 2) Dimension 2, named ChiPC2, was positively correlated with iron and lead, and negatively correlated with copper (Sup. data S2). ChiPC2 corresponded to the iron concentration and the absence of copper.

To provide a better understanding of the evolution of physicochemical parameters, mixed linear models were performed in order to see the influence of temperature and water height over the months on the chemical parameters, named ChiPC1 and ChiPC2. The results showed that ChiPC1 varied according to months ($F_{11,84} = 3\,929$, $p < 10^{-3}$, Fig.7 a) and temperature ($F_{1,84} = 7$, $p = 0.001$). When the temperature

increased the salinity increased (Fig.7 b), whereas ChiPC2 only depended on months ($F_{11,84} = 3\,929$, $p < 10^{-3}$, Fig. 8).

Abundance of cells varied with the months, it was higher and more variable during the first months than the rest of the year ($F_{11,84} = 111$, $p < 10^{-3}$) (Fig. 9 a). However, cell number also varied with increasing water height ($F_{1,84} = 5$, $p = 0.02$) and to some extent with a decreasing salinity ($F_{1,84} = 3$, $p = 0.08$) (Fig. 9 b). During the last 6 months the concentration of organic matter has varied enormously with two peaks at 7.5 g/L in September and December ($F_{11,84} = 156$, $p < 10^{-3}$). The increase in heavy metals (ChipC2) and temperature influenced the concentration of the organic matter ($F_{1,84} = 15$, $p < 10^{-3}$, Fig. 10 a; $F_{1,84} = 13$, $p < 10^{-3}$, Fig. 10 b).

4. Discussion

In ecosystems and particularly in wetlands, it is important to know the biogeochemical and water cycles that affect the structure and composition of this ecosystem. This cycle represents a large number of independent physical, chemical and biological processes (Reddy and Delaune, 2008). One of these processes is the climate. Dayat Morsli is under the influence of a semi-arid climate defined by the Köppen-Geiger classification, with a dry season from June to September. At the dayat, we observed two periods, different from the climatic seasons, defined from the statistical analysis of all samples and all physicochemical and biological parameters: a period 1 (January to May; Fig. 11a) and a period 2 extending over most of the year between June to December (Fig. 11b). However, the climate remains the most important factor influencing the quality of the wetland surface water through the balance of precipitation and evaporation. The impact of climatic variations on dayat Morsli, particularly between the first five and last seven months of the year, is clearly illustrated in Figure 11. The rainfall and temperature variations have induced a significant decrease in the water level with drying borders and shrinkage in the dayat area. The water volume evolution of the lake shows an important evaporation (significantly negative correlation with temperature $p < 0.05$) with a decrease in lake volume of 24% between the wettest month (March) and the driest month (September). Under these conditions, the autumn rains fill mostly the underground lack of water at the end of the summer and do not allow a significant increase in the

lake volume during this second period. Moreover, the arid regions tend to have higher salt concentrations in surface waters than in humid regions (Williams and Gosselink, 2007), a common phenomenon especially in endoreic lakes located in countries known for their warm climate where the evaporation rate is higher than precipitation, such as in the Mediterranean basin or in Central Africa (Jan and Lenka, 2008; Bouchez et al. 2016). Dayat Morsli is not immune to this phenomenon and shows very significant salinity variations over the year.

Hydrology has an effect on salinity, the decrease of water in wetlands causes the increase of salinity due to the concentration of ions in hot periods which forms a crust on the surface of the wetland (Hart et al., 1990). This has an impact on the planktonic and bacterial communities. The accumulation of organic matter in wetlands is controlled by hydrology, through its influence on primary productivity, decomposition and export of particulate organic matter. When the organic matter is decomposed, microorganisms use organic substrates as an energy source. This process is accelerated in aerobic conditions and becomes slower in anaerobic conditions (Reddy and Delaune, 2008). Actually, the decomposition of organic matters in dayat Morsli happens in period 1 in aerobic conditions while its accumulation and sedimentation occurs during the period 2 at the same time as the decrease in water level. This explains the spike of organic matter found in the Dayat during this period, the same observations as in central Asia arid lakes (Ginatullina et al., 2017; Lin et al., 2017).

Another parameter related to water quality in wetlands is the pH of the water. In wetlands, the pH is mainly regulated by the photosynthetic activity of the flooded phytoplankton and peripheral aquatic plants. This is directly related to the absence or presence of carbon dioxide, the pH can then reach higher values during the day and lower ones at night (Reddy and Delaune, 2008). In dayat Morsli, the pH is alkaline in period 1 and neutral to acid in period 2. The increase in pH is explained by a large number of phytoplanktonic cells, particularly with the occurrence of bloom in the period 1, while in the period 2 it decreases due to a drop in the water level, in the number of phytoplanktonic cells and consequently in photosynthetic activity. Actually, between March and April there was the occurrence of a bloom identified as two macroalga species *Ulva* sp. and *Mougeotia gracilis* and a microalga species *Dunaliella salina*. The favorable environmental conditions, the increase in nitrates

and phosphates and the rise of the water level in dayat Morsli contributed to these algal blooms. As the studies show, these diverse species have the ability to live in the same conditions as in the Oran dayat (Frost-Christensen and Sand-Jensen, 1990; Thakur and Kumar, 1999).

Nitrate and phosphates are essential elements for the development of photosynthetic organisms. In wetlands, they are used by microorganisms and plants as mineral sources, but at high concentrations they induce an ecosystem eutrophication and blooms (Boeykens et al., 2017). In dayat Morsli, these two elements are closely correlated, and well above the standard concentrations (Extract from the executive decree, 2011; WHO, 2004; Sup. data S3). This is mainly due to the agricultural and urban waste containing high concentrations of nitrates and phosphates, which have been accumulated over time. These two elements are also related to the organic matter decomposition and bacteria, especially the nitrificants bacteria of the water, that also increase the NO_3 production (De Wilde et al., 2015; Gómez-Alday et al., 2014). The high concentrations of nitrates, phosphates, as well as the water alkalinity, induce the eutrophication of dayat Morsli, as demonstrated in studies on polluted lakes in Kenya and Morocco (Jirsa et al., 2013; Lakhdar Idrissi et al., 2004). The eutrophication increases sedimentation and thus degrades the aquatic system, as well as problems related to different water utilizations (Heathcote and Downing, 2012; Jirsa et al., 2013; Lakhdar Idrissi et al., 2004).

For heavy metals, cadmium and lead are present in high concentrations in the dayat Morsli water system (Extract from the executive decree, 2011; WHO, 2004; Sup. data s3). Toxic metals without a biochemical role for phytoplankton can have adverse effects due to their high bioaccumulation trend, and their origin is entirely anthropogenic (industrial waste) (Pavlaki et al., 2016). Cadmium in nature is a common under-product of zinc mining, which subsequently often flows into the aquatic system, and is then found in brackish and marine environments (Nazeer et al., 2014). During the first three months of the year 2017, there was a decrease in cadmium and zinc levels in the water due to favorable conditions (alkaline pH, increased numbers of cells) (Christensen, 1989; Ming et al., 2016), which may have resulted in the sorbtion of Zn and Cd by planktonic organisms present in dayat Morsli, particularly by the species that appeared during the bloom of the month of March and April. As a matter of fact, the planktonic organisms have the ability to absorb and

assimilate heavy metals from the aquatic environment (Jia et al., 2018). The cadmium is accumulated by plankton, but to a lesser extent than zinc which is absorbed and metabolised by cells (Intwala et al., 2008; Lasenby and Van Duyn, 1992). Further research revealed that the presence of cadmium increased the uptake of zinc in competitive manner and that plankton preferentially absorbed Zn (Sprenger and McIntosh, 1989).

In addition to zinc, copper and iron are also essential elements for the development of microorganisms; copper in dayat Morsli decreases in April until December. This decline suggests that dissolved Cu is removed by organic matter particles and is rapidly sedimented, due to its affinity to oxides and carbonates present in the water column (Jackson, 1978). This organic matter present in natural water plays an essential role in the transport of metals from the lake to sediments (Taher and Soliman, 1999; Van Hullebusch et al., 2003). In the same way, a correlation between heavy metals and surface organic matter has been demonstrated, as well as a geochemical association of Cu and organic matter formed in Seliger Lake (Kosov et al., 2004). For the iron analysis a marked increase in the aquatic environment between March and May has been shown. This high concentration would indicate that this metal is abundant in the soil of the wetland (Singh et al., 2007) and this iron concentration decrease in the water could be due to the increase of nitrates and phosphates in dayat Morsli. Actually, this decrease could be partly due to the iron oxidation in the water and the formation of the Fe-PO₄ complex in sediments (De Wilde et al., 2015).

In dayat Morsli the appearance and the disappearance of the algal bloom induced changes in particular for zinc, iron and copper, three essential elements for the development of microorganisms. These changes are observed before and after the bloom. The decrease of these elements before the bloom appeared between January and February and could be due to their absorption by planktonic microorganisms. After the algal bloom, the zinc and iron increase in the water, although not demonstrated, could be due to their release by planktonic cells, except for copper, which sediments at the same time as cell residues and organic matter. In June, iron and zinc sedimentation are linked to the water level decrease.

5. Conclusion

The study of dayat Morsli shows that this wetland varies in a uniform way over the year and there is no difference between the seven sampling points. The physicochemical and biological analysis in 2017 showed two successive periods characterized by three main indicators. These are physicochemical and biological parameters influencing the lake. In the wet season, the three highest indicators are water level, cell abundance and pH. These variables decrease in the period 2, when the three main indicators are the organic matter, the temperature and the salinity which are at their maximum. The dayat Morsli suffered for many years from industrial and urban waste pollution, which induced bioaccumulation of pollutants in this lake. The heavy metal analysis of the water of this wetland showed cadmium and lead pollution, with a respective average of 0.6 ppm and 0.9 ppm during the year. The measured concentration of five heavy metals evolved according to the physicochemical parameter changes, and there was a relationship between iron, nitrates and phosphates, zinc and cadmium, and copper with the organic matter in the wetland.

This first characterization of dayat Morsli provides a better understanding of the functioning of this ecosystem and a description of the physicochemical and biological parameter variations of the lake during the year 2017. All these results will make it possible to establish a bioremediation initiative of this environment for its rehabilitation.

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Sitography

<https://www.infoclimat.fr/observations-meteo/temps-reel/oran-es-senia/60490.html>

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Period 1: January – May 2017

Dunaliella bloom

Macroalgae bloom

5 μm

50 μm

200 μm

Period 2: June – December 2017