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Short-term dynamics and growth parameters of cyanobacteria and microcystins in freshwater from the Sidi-Yacoub dam, North-east of Algeria

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Abstract. *Boudjellab ZE, Ghannam M, Chaib N, Chekroud Z. 2023. Short-term dynamics and growth parameters of cyanobacteria and microcystins in freshwater from the Sidi-Yacoub dam, North-east of Algeria. Biodiversitas 24: 5598-5609.* The study aimed to establish the inventory of the blue-green algae species and monitoring the monthly evolution of their specific and total cell biovolume in Sidi-Yacoub dam, located northwest of Algeria from February 2021 to January 2022. At the same time, a monthly assessment of particulate and dissolved microcystin concentrations, chlorophyll pigment concentrations, and certain physicochemical parameters has been conducted. Eight species were listed, cited in descending order of their average relative abundance are: *Microcystis aeruginosa* (54.05%); *Oscillatoria limosa* (23.68%); *Merismopedia* sp. (8.34%); *Anabaena cylindrica* (3.[illegible]%); *Aphanizomenon* sp. (2.41%); *Microcystis botrys* (2.66%); *Woronichinia* sp. (2.95%) and *Chroococcus minimus* (2.34%). The maximum value of the total biovolume, was recorded during December (27.4x106 $\mu m^3.L^{-1}$). The maximum concentration of chlorophyll-a and phycocyanin were respectively 55.26 and 47.46 $\mu g\ L^{-1}$, recorded in September 2021. The microcystins detected where mainly in the cell-bound form, reaching a maximum concentration of 0.134 $\mu g\ L^{-1}$ in October 2021. The principal component analysis shows a strong positive correlation between the total monthly cell biovolume, particulate microcystins (MCP) and some physicochemical parameters. *M. aeruginosa* has been identified as the primary producer of microcystins found in the eutrophic waters of the dam, with these microcystins being predominantly maintained in intracellular form throughout most of the year.

Keywords: Cell biovolume, cyanobacteria, microcystins, physicochemical parameters, Sidi-Yacoub dam

INTRODUCTION

Water pollution significantly affects human health worldwide (Haider and Islam 2015; Bassem 2020), and continues to be the subject of several recent studies (Nexhdet et al. 2018; Boudeffa et al. 2020; Lambert et al. 2020; Rita et al. 2020; El-Kalliny et al. 2021; Haied et al. 2021; Krumova-valcheva et al. 2021; Boulgueraguer et al. 2022; Filho et al. 2023). Toxic algae bloom in aquatic environments such as lakes and reservoirs, constitute a real risk to public health, mainly when water bodies are used for many human activities (e.g., drinking water supply, fishing, aquaculture, aquatic leisure, etc.) (Vinçon-Leite et al. 2005; de Lima Pinheiro et al. 2023).

Cyanobacteria are among the most incriminated microalgae in the poisoning of freshwater: They include 150 genera and more than 2,000 species (Bourrelly 1985). Generally, cyanobacteria are aquatic organisms, in planktonic state, letting themselves to transported by water movements. Other benthic species are fixed on submerged supports (e.g., periphytic organisms) (Prasertsin et al. 2021). Cyanobacteria usually have low growth rates and most prefer high temperatures and low light conditions (Whitton and Potts 2000). They are very efficient in assimilating and storing nutrients (Wanigatunge et al. 2014; Hassan et al. 2022). They often occur in a colonial form in a mucilaginous gel matrix or filamentous with no cellular nucleus individualized by a membrane (Catherine et al. 2013), which allows them to be weakly subjected to predation by zooplankton. Thus, they can multiply massively when the environmental conditions favor them (Vinçon-Leite et al. 2005). Some species of these microorganisms can produce a diverse range of toxins called cyanotoxins. These species belong to the genera *Anabaena*, *Microcystis*, *Oscillatoria*, *Planktothrix* and *Aphanizomenon* (Ettoumi et al. 2014). These toxins constitute a hazard to human and animal health (Kurmayer et al. 2016; Mazard et al. 2016; Buratti et al. 2017; Humbert et al. 2017; Salmaso et al. 2017; Chorus and Welker 2021; Hendrayanti et al. 2023).

The hepatotoxic microcystins are the most prevalent cyanotoxins of those currently recognized. These cyclic heptapeptides have more than 80 structural variations (Umehara et al. 2017), and are strong targeted inhibitors of protein phosphatases. The most of their activities are hepatotoxic and tumor-promoting, making them one of the most dangerous categories (Li et al. 2017). They can accumulate in various aquatic organisms, and travel up the

food chain to reach organisms at higher trophic levels (Pham and Utsumi 2018).

In this regard, guidelines and recommendations from the World Health Organization (WHO) have existed since 1999 (Chorus and Bartram 1999). It must have a microcystin-LR equivalent concentration of less than 1µg.L^{-1} for distributed drinking water. For chronic exposure, a value of 0.1 µg.L^{-1} has been proposed (Vinçon-Leite et al. 2005).

Monitoring includes determining the species present and measuring two biomass indicators, chlorophyll-a and the number of cells.mL^{-1}. From these parameters, the WHO established recommendation levels for swimming water and drinking water supply (Figure 1).

In Algeria, water is threatened in its quality and quantity due to the increase of industrial, agricultural, and urbanization development, and the urbanization. This has made monitoring and managing phytoplankton growth, especially the presence of potentially harmful species in water sources used for drinking water production, increasingly significant (Amrani et al. 2014). Managing these toxic blooms is based on scientific knowledge of the environmental variables that control them (Vinçon-Leite et al. 2005).

In this context, this study focused, firstly, on the short-term dynamics of the cyanobacteria and their specific and global monthly cell biovolume in the Sidi-Yacoub dam, Algeria. Second, to study the influence of certain environmental parameters on their growth dynamics. Finally, monitor the variations in microcystin levels in the dam's raw by comparing the results obtained with the wate quality threshold concentrations set by the WHO.

MATERIALS AND METHODS

Study area

The Sidi-Yacoub reservoir is a fre water reservoir constructed in 198 situa approximately 20 kilometers south of Oued Sidi Abdallah villag with the Chlef city in the north-western regio of Alge It is built on the Ardjem wadi which fee the with an average annual water contribution of 2 9 x10^6 m^3. This wadi is a tributary of the Chlef wadi flowing into the Mediterranean Sea. The dam was commissioned in 1986 (Chenaoui and Remini 2014) (Figure 2).

This reservoir is located in a region characterized by a semi-arid climate where the average range of temperature recorded from 1975 to 2016 is from 7.4 to 26.4°C. The annual average rainfall was less than 400 mm during these last decades (ONM 2014) and an average annual relative humidity in the watershed region of the reservoir is estimated at around 62%. At the same time, the average daily insolation in the same region is estimated at 7.9 hours/day (4.9 hours.day^{-1} in December; 11.0 hours.day^{-1} in July and August). This reservoir provides drinking water for the city of Chlef. It is also used to irrigate a perimeter of around 10 thousand ha (ANBT 2005). The main hydro-morphologic features of the Sidi-Yacoub reservoir are summarized in Table 1.

Sample collection

From February 2021 to January 2022, sampling was conducted monthly at the mid-point in the reservoir (Figure 2). Integrated samplers were used to collect whole water grab samples from the euphotic zone. The sampler was used to transfer water into a rinsed 5L container, and this procedure was carried out again until the container was filled. Then, subsamples were obtained from the container to study microcystin, cyanobacteria, and nutrients. A triplicate aliquot from the main integrated raw water sample was kept in 500 mL polyethylene bottles for nutrient analysis. These bottles were rinsed previously for 12 hours in a Nitric acid bath at 10% (v/v) to eliminate all traces of minerals, then completely washed with distilled water and dried. The bottles were rinsed with the reservoir water. Labeled sample bottles were maintained in a coolbox and moved the same day to the lab. Another 1000 mL subsample for phytoplankton was preserved with formaldehyde at a 5% (v/v) final concentration (Beaver et al. 2018). Immediately after collection, a 500 mL subsample for microcystin analysis was frozen. In the laboratory, all samples (except those d to determine cyanobacterial cells) were stored a freezi temperature of -18°C until subsequent anal s.

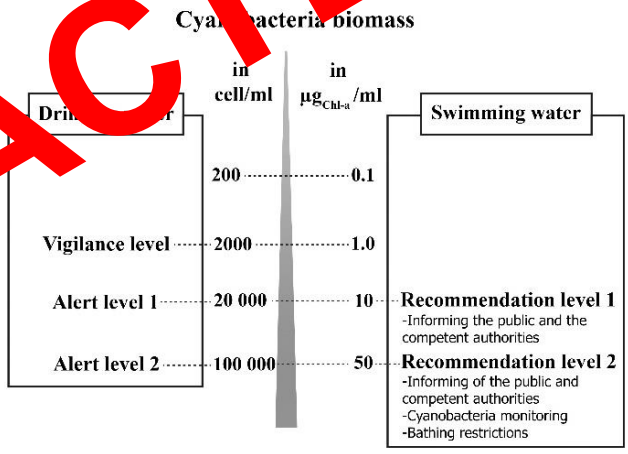

Figure 1. Alert thresholds defined by WHO concerning cyanobacteria biomass in freshwater (Chorus and Bartram 1999)

Table 1. Main characteristics of the Sidi-Yacoub reservoir, Algeria (ANBT 2005)

Characteristics	Measurements
Average altitude	245 m
Surface area	8.369 km^2
Shoreline	24.98 km
Maximum length	5.75 km
Mean depth	24 m
Total capacity	285 Hm^3
Dead volume	39 Hm^3
Average annual siltation	0.17 Hm^3

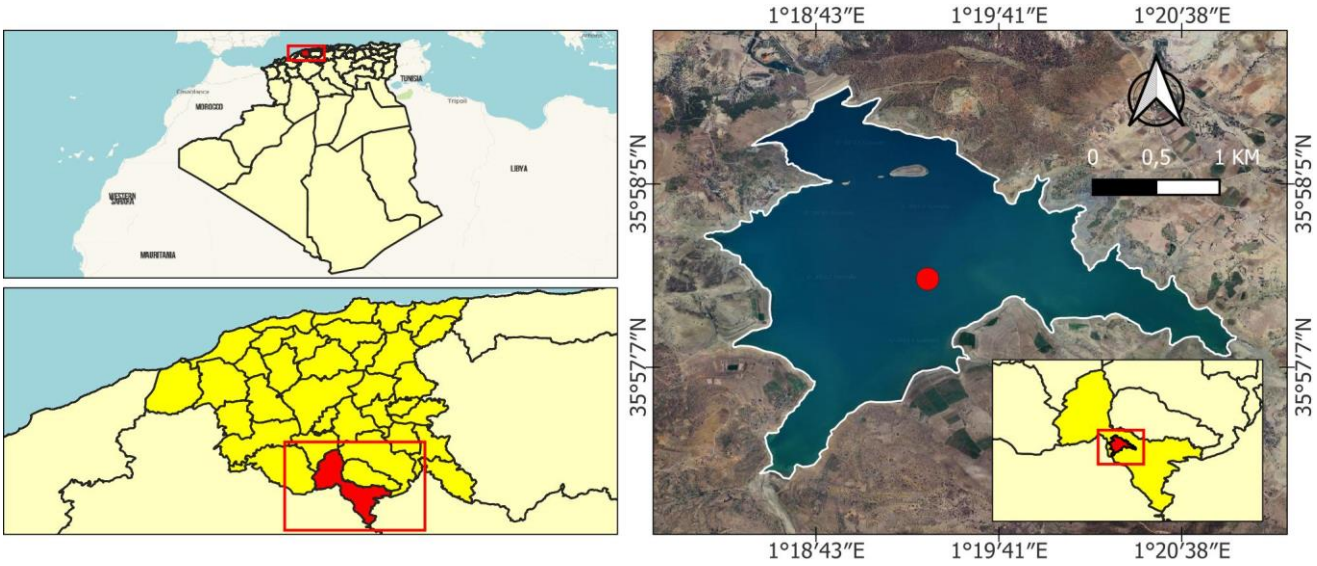

Figure 2. Geographical location of the Sidi-Yacoub reservoir and the sampling station: 35°57′35″N 1°19′18″E, Algeria

Field measurements

The in situ measurements of the water temperature (Temp, °C), oxygen saturation rate (OSR, mg L^{-1}), pH, and electrical conductivity (EC, µs cm^{-1}) were monthly measured directly in the reservoir with a portable multi-parameter provided with probes (Multi 340i/WTW®, Germany). Secchi depth (SD, cm) Measurements were taken with a conventional Secchi disk on the boat's shadowed side, and the values were recorded. These values were multiplied by a factor of 2.5 to obtain the depth of the euphotic zone (Borowiak and Borowiak 2016).

Laboratory analyses

Determination of the nutrient's concentration in freshwater

For monthly nutrient analyses, collected raw water samples were shaken vigorously and filtered through a GF/C filter (1.2 µm) before being analyzed for dissolved nutrients. Aliquots were then used for nitrate (NO_3-N) and nitrite (NO_2-N) analyses using sulfosalicylic acid and Zambelli reaction methods. Orthophosphate concentrations (PO_4^{3-}-P) are dosed with Ascorbic acid and total phosphorus (TP) using a spectrophotometer after digestion with persulfate. Kjeldahl nitrogen (KN) was determined using oxidative mineralization with peroxodisulfate methods. The sum of the three forms of Nitrogen concentrations (NO_3, NO_2 and KN) allowed the calculation of total dissolved nitrogen concentration. Dry residue (DR) was quantified through the evaporation of water samples at 105°C, followed by the weighing of the residues. Magnesium (Mg^{2+}) and calcium (Ca^{2+}) content were assessed using a titrimetric approach with EDTA. Potassium (K^+) and sodium (Na^+) concentrations were measured utilizing an atomic absorption spectrophotometer with a flame (model: Sherwood-410). The sum of total iron (Fe) and ferric ions (Fe^{2+} + Fe^{3+}) was determined through a spectrophotometric method, involving oxidation by potassium peroxodisulfate and subsequent coloration with 1,10-phenanthroline. Chloride (Cl^-) levels were assessed using the silver nitrate titration method described by Mohr. Sulfate (SO_4^{2-}) concentrations were determined through the gravimetric method involving precipitation with barium salts. These methods are described in Aminot and Chaussepied (1983); Rodier et al. (2009).

Determination of the microcystin concentrations in water

The quantification of microcystin concentrations is performed on duplicate aliquots of each water sample and analyzed using the PP2A inhibition assay with a commercial ELISA kit (Envirologix Inc., USA; lower limit of detection: 0.1 µg/L) following the manufacturer's recommendations. After three freeze-thaw cycles, total microcystins (MCT) are quantified in water samples to lyse cyanobacteria cells and release toxins (Stefanelli et al. 2017). Meanwhile, the dissolved fraction of microcystins in water (MCD) is quantified on pre-filtered water samples through a 0.45µm porosity membrane. The concentration of toxins associated with cyanobacteria cells and/or adsorbed on particles (MCP) is calculated by subtracting the MCD concentration from the MCT.

Determination of the Cyanobacteria pigment concentrations

Moreover, to determine phycocyanin pigment (PhC), water samples, in three replicates were filtered one hour after being collected; the filters were then put in 20 mL of 0.05 M phosphate buffer (pH = 6.6) and then frozen for subsequent pigment determination. Phycocyanin content was extracted by 15 seconds of sonication after thawing at 9 ± 1°C in the water bath, causing cell walls to rupture. After acid digestion, samples were filtered through the Whatman GF/C filter to eliminate cellular debris from the extracts. Samples were stored at 4°C in the dark to prevent pigment degradation.

The concentration of PhC was measured by a Shimadzu UV-1601 spectrophotometer (Melco Technorex Co. LTD, Kyoto, Japan) according to equation (1) and expressed in $\mu g.L^{-1}$:

PhC ($\mu g\ L^{-1}$) = (A615 - 0.474 * A652)/5.34Eq.1 (Lorenzen 1967)

Where, A615 is the absorbance at 615 nm and A652 is the absorbance at 652 nm.

In addition, concentrations of chlorophyll-a were also measured. Water samples were shaken vigorously and an aliquot of 300 mL was filtered through 0.45 µm membrane filters (47 mm diameter, Whatman GF/CTM, Germany). Pigments were extracted in 90% aqueous acetone and measured by spectrophotometry (Shimadzu UV-1601, Japan) according to the Equation (2):

Chl-a ($\mu g\ L^{-1}$) $= 27 \frac{v}{l \cdot V}$ [(A_0665 - A_0750) - (A_a665 - A_a750)] Eq.2 (Lorenzen 1967)

Where, $A_0\lambda$ is the absorbances before acidification; Aaλ: is the absorbances after acidification. The acidification is carried out directly in the spectrometer tank by adding a few drops of 1 N hydrochloric acid. The spectrophotometer cell is then carefully capped and stirred); v: the volume (in mL) of acetone used; V: the volume (in L) of the filtered sample and l: the length of the optical path of the measuring cell. (l = 1 cm) (Rodier et al. 2009).

Quantitative and qualitative analysis of the cyanobacteria

Phytoplankton was examined under inverted li microscopes (model: Olympus® CKX31) at magnificati x400, using Utermöhl sedimentation chambe sta for 8 h. Phytoplankton taxa was then cou d at ast 4 algal units with intact structure ells, an colonies) resulting in a counting r f abou 0%.

Cyanobacteria identi ation wa perfor ed using recognized and accept taxon mic key based essentially on the structure l ce mension, colony morphology, mucilage also on t presence of certain specific cellular str ures such a akinetes, gas vacuoles and heterocyst (B relly 85; Castenholz 2001; Leitão and Couté 2005).

More than 30 units for each taxon observed, its dimensions were measured (µm) using a micrometric eyepiece. These dimensions are used to calculate the specific cell biovolume (SBv) using formulas specific to geometric shapes closely resembling each recorded taxon (Hillebrand et al. 1999).

The total monthly specific cell biovolume (TMSBv) for each taxon was calculated by multiplying mean specific biovolume by its cell abundance (N), according to the following equation:

TMSBv (μm^3) = SBv.N Eq.3

Statistical analysis of data

A descriptive statistical analysis, allowing for the calculating of the median, the mean, and quartiles (25%, 50%, and 75%), was applied to the results of the monthly physicochemical study conducted on the reservoir water. On the other hand, a Principal Component Analysis (PCA) was applied to the entire dataset, including physicochemical parameters, TMBV, MCT, MCD, MCT, and the monthly biovolume specific to each identified species. This analysis will primarily serve to: (i) Highlight the type of correlation existing between the various parameters and their strength, and (ii) Group the months and establish periods of the year when the results of the different parameters are similar. These statistical analyses using SPSS Statistics 27.0.

RESULTS AND DISCUSSION

Temporal variation of cyanobacteria cell density and biovolume

The monthly microscopic water analysis of the Sidi-Yacoub dam showed the presence of 8 species of cyanobacteria (Figure 3) which were omnipresent throughout the study period (Figure 4a). These species are (accompanied by their relative aver ndance - RAA): *Microcystis aeruginosa* (Kü g) K zing (54%); *Oscillatoria limosa* C. A dh e Gomo (23.7%) and *Merismopedia* sp. (8.5). O er s cies were identified such as: *Anabaen ylin* Lemmerm n; A*phanizomenon* sp.; *Microc s botrys* eilin *Woronichinia* sp. and *Chrooc us limn cus* Le ermann, had an RAA not exc d 3% as sh n in Figure 4a. This same figure ind ates that the ove all cell density of cyanobacteria takes incr singly high values from September to reach a maxi 81.75 $x10^3$ $Ind.L^{-1}$ in November. Outside this d the cell density did not exceed 33.14 $x10^3$ $Ind.L^{-1}$.

The calculation results of the average specific cell biovolume for each species (SBv) are represented in Figure 5. In contrast, the variation of the total monthly cell biovolume (TMBv), as well as its composition by the TMSBv is represented in Figure 4b from which, we can distinguish the presence of two total cell biovolume peaks, coinciding with July and December ($23.43x10^6$ and $27.4x10^6$ $\mu m^3.L^{-1}$, respectively), with a majority contribution of *Oscillatoria limosa* species in the composition of the TMBv.

Temporal variation of cyanobacteria pigment concentrations

The photometric analysis of phytoplankton pigments in the waters of Sidi-Yacoub Dam reveals that the concentrations of chlorophyll-a vary between 13.65 and 55.26 $\mu g.L^{-1}$ (Figure 6). These two limit values are recorded in February and September, respectively. Meanwhile, phycocyanin reached its maximum value of 47.46 $\mu g.L^{-1}$ in October, exhibiting a monthly evolution with a similar pattern to that observed for chlorophyll-a (the linear correlation coefficient of Pearson calculated between the two pigments, r = 0.802 with p-value = 0,00167 <0.05), indicating the significant contribution of cyanobacteria to the composition of the overall phytoplankton community in the dam's water.

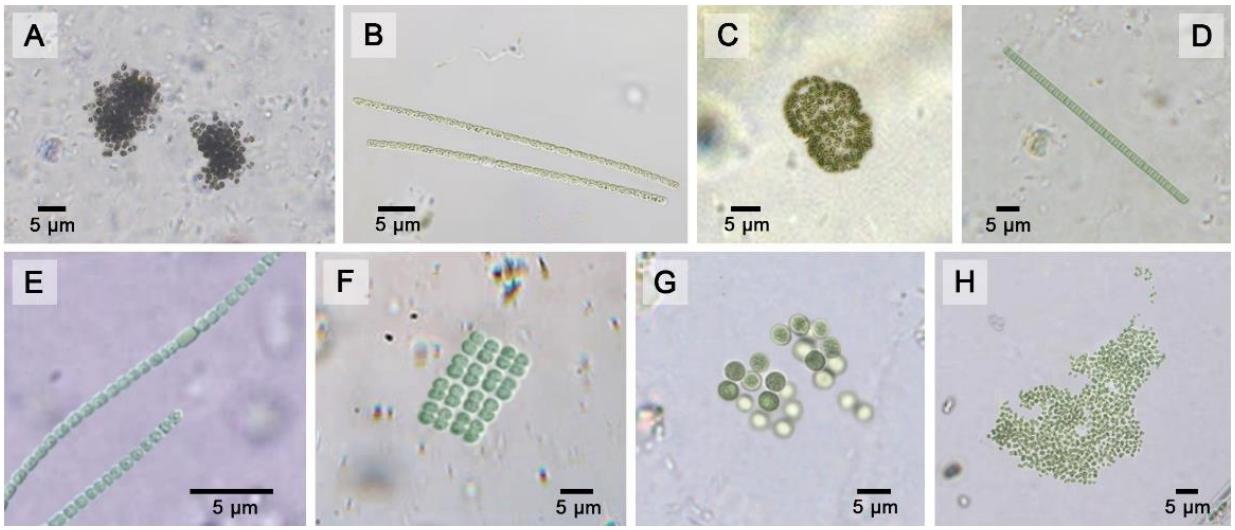

Figure 3. Photomicrographs of cyanobacteria species found in the waters of the Sidi-Yacoub dam, Algeria: A. *Microcystis botrys*; B. *Aphanizomenon* sp.; C. *Wonorichinia* sp; D. *Oscillatoria limosa*; E. *Anabaena cylindrica*; F. *Merismopedia* sp; G. *Chroococcus limneticus*; H. *Microcystis aeruginosa*

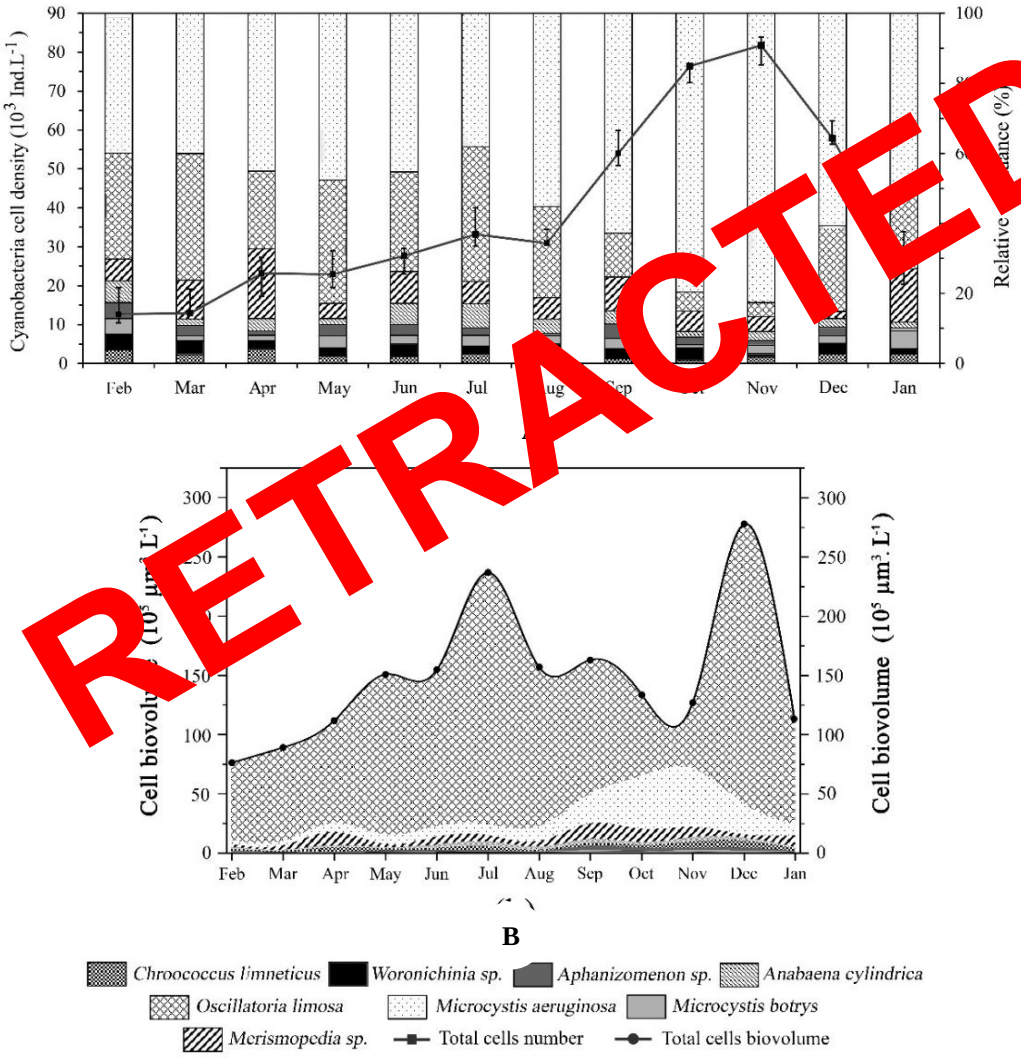

Figure 4. A. Monthly Cell density variation and the relative abundance of Cyanobacteria species; B. the variation of the total cell biovolume and its composition by the total specifics cell biovolume in Sidi-Yacoub dam freshwater, Algeria

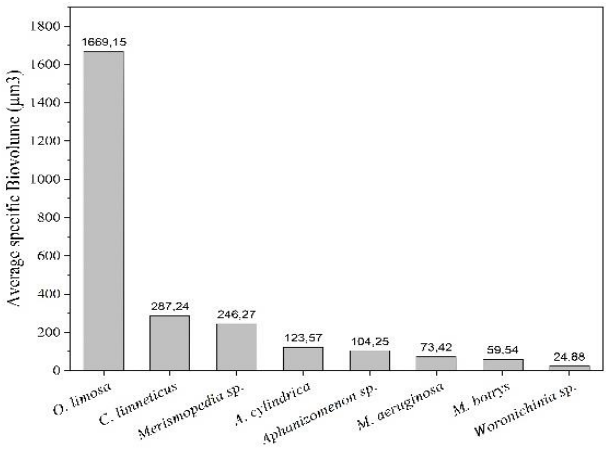

Figure 5. Specific cell biovolume (SBv) of cyanobacteria species inventoried in the waters of the Sidi-Yakoub dam, Algeria

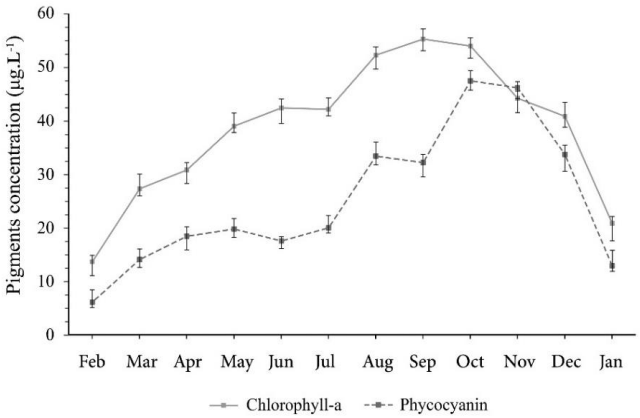

Figure 6. Monthly variation of chlorophyll-a and phycocyanin concentration

Regarding the standards applied to pigments described by Chorus and Bartram (1999) (Figure 1), the values obtained for it exceed level 1 of alert and even the second level in August, September, and October. That involves applying the second level of recommendations: informing the public and the competent authorities about the need to monitor cyanobacteria and restrict swimming regularly.

Monthly variation of freshwater physicochemical parameters

The results of the monthly physicochemical analysis of the Sidi-Yacoub dam water are represented in a boxplot graph (Figure 7), which displays the maximum and minimum value of each studied parameter, accompanied by the month corresponding to these values, quartile 25, quartile 75, the average and the average values. Compared with the threshold values obtained by Carlson and Simpson (1996), the average values obtained for TP, TN, and SD are 75.92 mg.L^{-1}; 11.61 mg.L^{-1} and 1.32 m, re[illegible]ely, indicating an eutrophic state. On another si[illegible] the [illegible]ues obtained for the ratio TN/TP (greate[illegible]an 33 [illegible]sh limitation of the microalgae g[illegible]ow[illegible] in [illegible]rticular cyanobacteria by the phosphe[illegible]s element.

Concerning the aerati[illegible] in [illegible]ter, ve[illegible] high oxygen saturation rates ar[illegible]rde[illegible]aring periods of low water temperature in [illegible]d (firs[illegible]mon[illegible] of [illegible] year), even reaching 91.6% in Febru[illegible]ever, [illegible]ese values drop rapidly in the hot season, re[illegible]ing a [illegible]inimum of 40.8% saturation in November. The o[illegible]r studied parameters relating to the water's overall cationic and anionic mineralization, record characteristic values of surface waters, and their seasonal evolution and relations will be discussed later by the principal component analysis (PCA).

Monthly fluctuation in microcystin freshwater concentrations

The monthly determination of particulate (intracellular) and dissolved (extracellular) microcystins concentrations (MCP and MCD respectively) in the water samples was carried out by the PP2A inhibition essay. The results obtained are represented in Figure 8, which shows a peak in total microcystins level (MCT) recorded in October with a concentration of 0.134 µg.L^{-1}. After October, this concentration does not stop decreasing in an almost linear way until reaching its lowest level in January (0.336 µg.L^{-1}), while during the period extending from April to September the levels of MCT do not know a significant variation, varying around a value of 0.0685 ± 0.006 µg.L^{-1}.

Concerning the composition of MC[illegible]10 months, it is mainly composed of cell-boun[illegible]microc[illegible]in (MCP) (Figure 8) reaching a maxim[illegible] MC[illegible]MCD r[illegible]io of 8 in July; except in March wh[illegible]the to[illegible]l M[illegible] is[illegible]red almost equally between M[illegible] an[illegible]CP. The[illegible]pposite of this situation is obs[illegible]ec[illegible]n Febr[illegible]y wh[illegible] the proportions are reversed[illegible] maki[illegible] the M[illegible] represent the majority fractio[illegible]ound in the d[illegible] water, with a rate of 84.56% of the tot[illegible] MCT.

Re[illegible]ionsh[illegible]etween environmental and biotic [illegible]ia[illegible]s

The relationships between physicochemical and biotic parameters were studied using principal component analysis (PCA). This multivariate analysis produced two main axes (factors), F1 and F2, explaining 50.69% and 17.43% of the variation between the different parameters (Figure 9).

The results obtained from this analysis showed that almost the total monthly cell biovolume (TMB_V) representing the sum of biovolumes calculated for each identified species per month, was positively correlated with axis 1 and MCP.

These two parameters refer to a period between September and November (Figure 9) characterized by relatively high values of the parameters: Temp, TN, TP, NO_3^-, PO_4^{3-} and SD. These parameters are known, precisely, to be stimulants of cyanobacteria growth, and therefore, of other parameters having a direct link, such as TMB_V and MCP.

The other physicochemical parameters (Ca^{2+}, Fe, K^+, Na^+, SO_4^{2-}, KN, DR and NO_2^-) showed an increase in concentration, around December and are negatively correlated with the growth of the studied microalgae.

Two other periods of the year are distinctly visible in Figure 9, the first, including January, February, March, and April, representing the year where the dissolved oxygen saturation rate (OSR) shows the highest values which also applies to the concentrations of MCD. This can be explained by the fact that at this period of the year, the cyanobacteria cells release their cellular content of microcystin, which will therefore end up in a dissolved form in water. This cessation of cyanobacteria growth and cell lysis is caused by a limitation in the nutrients required for their growth. In addition, he lowest values are recorded for the environmental and biotic parameters from May to August.

Figure 7. Boxplot graph of the monthly physicochemical parameter analysis of the Sidi-Yacoub dam freshwater, Algeria

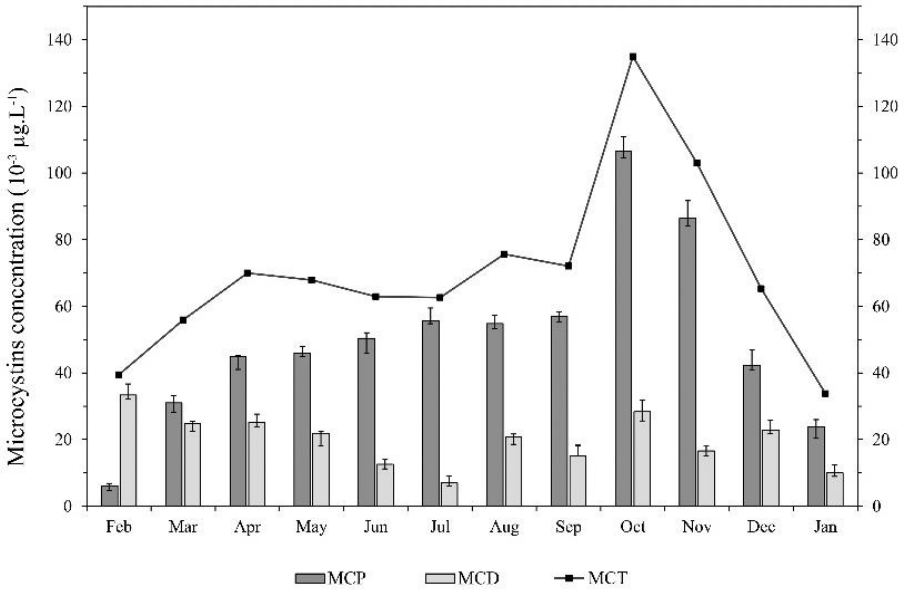

Figure 8. Monthly fluctuation in microcystin concentrations in Sidi-Yacoub freshwater dam, Algeria

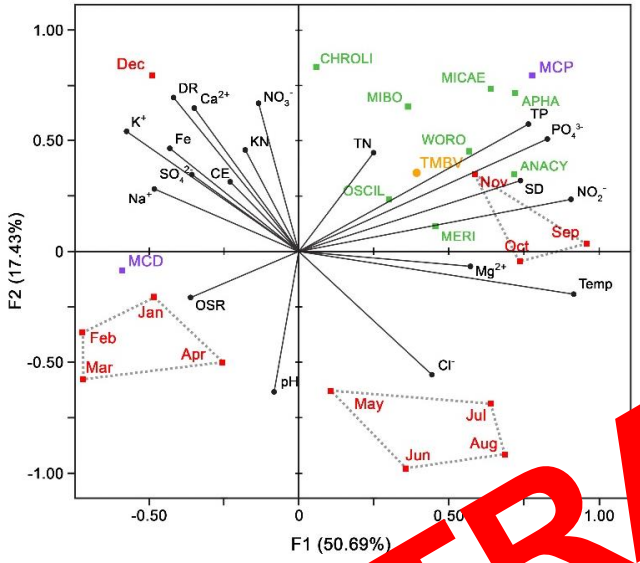

Figure 9. Principal component analysis (PCA) plot illustrating the distribution of two forms of microcystins (in purple) concerning the monthly specific cell biovolume (in green), the monthly total cell biovolume (in yellow) and the physical and chemical parameters (in black) in the waters of Sidi-Yacoub dam

Discussion

Concerning the sampling point in the middle part of the reservoir, our results indicated that the most abundant species were *M. aeruginosa* and *O. limosa* (54 and 23.7% respectively). Throughout November, *M. aeruginosa* was the most predominant (82.64%) of all microalgae inventoried during our survey. This result is congruent with other studies on numerous Algerian freshwater reservoirs (e.g., Nasri et al. 2007; Guellati et al. 2017; Touati et al. 2019).

It should be noted that extended periods of stable water thermal layering give an advantage for *Microcystis* spp. and some others cyanobacterial species with floating ability due to the presence of gas-vacuol. This genus can move vertically by controlling its buoyancy in the water column (Medrano et al. 2013). This up-and-down migration is linked to changes in colony buoyancy caused by carbohydrate content, this gives to this group the advantage of migrating to the optimal depth within the stable water column. This enables them to capture solar radiation from the surface water during the day and access an adequate amount of nutrients in the lower layer at night, this is due to the variations in colony buoyancy driven by carbohydrate content (Dokulil and Teubner 2000).

The migration capacity of *Microcystis* spp. may explain the difference in cell concentration between the two observed species in the studied dam: *M. aeruginosa* and *Oscillatoria limosa*. Another factor favoring the quantitative dominance of the species *M. aeruginosa* is its increased capacity to absorb nutrients. In a similar study conducted in fish farms in Brazil, *M. aeruginosa* was found to be a constant species, showing the highest cell density among cyanobacteria species, in addition, it bloomed the most, thus generating a high ecotoxicological risks (de Lima Pinheiro et al. 2023).

In fact, according to Kromkamp et al. (1989), *Microcystis* quickly outnumbered *Oscillatoria* sp. in competition tests with a significant input of phosphorus at saturating concentrations due to the assimilation of this nutrient and its more effective usage by the organism.

The monthly calculation of the total specific biovolume (TSBv) showed a strong contribution of *O. limosa* in the composition of the total monthly biovolume (TMBv) even exceeding the total biovolume calculated for the species *M. aeruginosa;* this due, mainly, to the relatively high SBv of *O. limosa* (1669.15 µm^3) compared to other species, including that of the species *M. aeruginosa* (73,42 µm^3). It

should be noted that in October and November, the composition of the TMBv is mainly shared between the TMSBv of the species *M. aeruginosa* and *O. limosa.*

According to alert levels defined by WHO, the global biomass of cyanobacteria recorded in the studied waters of Sidi-Yacoub dam has reached only the first level of alert ($\leq 10^5$ Ind.mL^{-1}); this implies the first level of recommendations, which states: "inform the public and competent authorities on the subject of cyanobacteria proliferation in the studied water reservoir".

Wasmund (1997) reported that a massive development of cyanobacteria is marked, coinciding with water temperature values ranging between 15°C and 30°C, with alkaline pH (between 7.5 and 11), an average nitrate (up to 3.805 mg.L^{-1}) and orthophosphates (up to 0.0124 mg.L^{-1}) concentrations. All these conditions were available in the water of our studied dam. Regarding the pH value, it varied between 7.5 and 7.65, this agreed with the results obtained in several water bodies in Algeria including lakes and dams (Kahoul and Touhami 2014; Draredja et al. 2019; Chabaca et al. 2020; Heramza et al. 2021). It should be noted that the sensitivity of cyanobacteria species and the phytoplankton in general, is well known (Jose and Xavier 2022); therefore are regarded as indicators of changes in the water composition of lakes (Jiang et al. 2014; Poot-Delgado and Okolodkov 2016; Suda et al. 2016) and reflect the trophic state of water bodies (Liu et al. 2014; Taş 2016; Mangoni et al. 2017; Wasmund 2017; de Lima Pinheiro et al. 2023).

The dosage of nutrients was carried out on the upper layer of the water dam; this layer is continually mixed with the runoff recently spilled in the dam. These water courses are loaded with nutrients due to the leaching of the watershed characterized by dense vegetation. The second origin of the nutrients found in the superior layers of the water, come from substances accumulated at the bottom of the dam (sediments); these substances reach the upper layer of the water, in particular the euphotic area, by mechanical movement and mixing of water, this considerably stimulates cyanobacteria growth. These spatial and temporal dynamics of hydrological and physic-chemical parameters cause a heterogeneous distribution of phytoplankton communities in the water body (Sahl 2015; de Lima Pinheiro et al. 2023).

The recorded values of chlorophyll-a over 20 µg.L^{-1} throughout the study period are closely correlated with phycocyanin concentrations and with recorded values of water transparency (below 2 meters throughout the study period). These water parameters indicate, according to Carlson and Simpson (1996), an eutrophic state of water dam with a tendency for cyanobacteria species to dominate the water environment, particularly the genus Microcystis, which recorded the highest biomass among all the species of cyanobacteria observed in the Sidi Yakoub dam. The many human activities applied to the waters of the Sidi-Yakoub dam has a negative impact on its quality, exerts a notable influence on the progression of phytoplankton communities (Setyono and Himawan 2018; Namsaraev et al. 2020 ; Mashkova et al. 2021) and can even cause eutrophication, a natural phenomenon accelerated by human activity, impacts numerous aquatic ecosystems worldwide and is recognized as a global concern (Ansari and Gill 2014; Ismest'eva et al. 2015; Viaroli et al. 2015; Gao et al. 2020; Pratiwi et al. 2020; Kostryukova et al. 2021), leading to increase in production of phytoplankton biomass (Kostryukova et al. 2018) and its community structure (Schuster et al. 2015; Sharma et al. 2016; Suda et al. 2016; Li et al. 2018; Pratiwi et al. 2018; Song et al. 2019; Wang et al. 2020; Yang et al. 2020; Manamani and Bensouilah 2023), oxygen depletion, reduced light penetration and extensive deterioration of water quality (Rao et al. 2018).

The dominance of cyanophyte species agrees with results obtained by other researchers from reservoirs located in Algeria and a neighboring country with close climatic conditions as in Marocco. Among these climatic conditions is the temperature which is considered the most important determinant of cyanobacteria growth and metabolism of microcystins (Lv et al. 2014; Xue et al. 2016; Pham et al. 2017; Preece et al. 2017; Huang et al. 2022).

Many other studies have demonstrated that it is probably due to a combination of environmental conditions, including nutrient enrichment (Oliver and Ganf 2000), an inorganic carbon limitation (Klemer et al. 1996), a lack of rain with lower turbulence, and a zooplankton grazing (Sharpley et al. 2013).

In our case the maximum cell biovolume per liter of water dam was recorded in December (27.4x10^{6}µm^3.L^{-1}), knowing that the major part of the microcystins is intracellular as shown in Figure 8 and that in the entire study period, this should implicitly the maximum values of MCT to be recorded in December. However, the results obtained show that the maximum value of MCT was observed in October and a little less in November, the same period when the species *M. aeruginosa* recorded its maximum biovolume, this suggests that the only or the major responsible for the production of cyanotoxins in the studied dam water is the species *M. aeruginosa*.

The peak of total microcystins occurs in the months when the highest phycocyanin concentrations are recorded. While the maximum concentrations of chlorophyll-a are recorded outside the period of the maximum MCT, this could be explained that pigment is specific to phytoplankton species in general, while phycocyanin is specific to cyanophyte species. This phytoplankton group contain a wide range of toxigenic strains.

It should be noted that it is important to investigate the identification of phytoplankton beyond the species level, to determine the type of strain incriminated in toxinogenesis, because several studies report that some *M. aeruginosa* strains are far more toxic than others, often by a factor of more than 10 (Bolch et al. 1997).

In our study, the microcystins assay was performed only on samples across the entire water column representing the euphotic zone (Average from 0 to 3.29 m depth). However, Agha et al. (2014) reported that cyanotoxin biosynthesis is mainly located in surface water. Conversely, microcystins and Cyanobacteria cells are usually maintained on the top layer of water (less than 1 m);

this concerns the cell-bound toxins. But these molecules can have other forms: Toxins that are dissolved in water, accumulated in organisms, deposited in sediment, or combined with suspended particles (Song et al. 2015).

During our study period, the intracellular form of microcystins was superior to the dissolved form, only in February when the opposite was observed. This can be explained by the fact that senescence and lysis at the end of blooms cause the intracellular toxins to be liberated into the surrounding water body (extracellular), which causes an increase in the concentration of MCD in the water column (Zhang et al. 2009; de Lima Pinheiro et al. 2023).

Multiple variables, including environmental conditions, dilution, photodegradation, adsorption to solid particles, including living organisms, and biodegradation, influence the ambient concentration of MCD. However, after cell lysis, microcystins could be mixed through the entire depth of the body of water (Song et al. 2015).

In the end, at the cellular level, the species *M. aeruginosa* turned out to be the most abundant. In contrast, in terms of cellular biovolume, the species *O. limosa* records the highest levels in the eutrophic waters of the Sidi-Yakoub reservoir. The dynamics of cyanobacteria do not differ from other reservoirs in Algeria and neighboring Mediterranean countries with similar climatic conditions. This dynamic has led to the conclusion that *M. aeruginosa* is the only or the major responsible species for producing cyanotoxins in the studied dam water. These microcystins reach their highest levels in October followed by November, in the intracellular form and predominantly transform into the dissolved form around February.

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REFERENCES

Agha R, Lezcano MA, Labrador MdM, Cires S, Que[illegible] A. [illegible]14. Seasonal dynamics and sedimentation pa[illegible]s of [illegible] oligopeptide based chemotypes reveal su[illegible] p[illegible]tions wi[illegible] different ecological traits. Limnol Oc[illegible]nogr [illegible] (3): [illegible]1-871. DOI: 10.4319/lo.2014.59.3.0861

Aminot A, Chausspied M. 1983. M[illegible]uel de[illegible]alyses ch[illegible]iques en milieu marin. CNEXO, Brest [illegible]ce.

Amrani A, Nasri H, A[illegible]ouz [illegible] Kadi[illegible] Bouaï[illegible] N. 2014. Variation in cyanobacteria [illegible]totoxi[illegible] Micro[illegible] content of water samples and two species [illegible] tacted from a shallow lake in Algeria. Arch Environ [illegible]Contam [illegible]Toxicol 66 (3): 379-389. DOI: 10.1007/s0024[illegible]13-9993-2.

ANBT. 2005. Agence Nationale des Barrages et Transferts: Etude de protection du bassin versant du barrage de Sidi-Yacoub. Phase II: description du milieu. Ministère des ressources en eau, Algeria.

Ansari AA, Gill SS. 2014. Eutrophication: causes, consequences and control. Volume 2. Springer, Dordrecht, The Netherlands. DOI: 10.1007/978-94-007-7814-6.

Bassem SM. 2020. Water pollution and aquatic biodiversity. Biodivers Intl J 4 (1): 10-16. DOI: 10.15406/bij.2020.04.00159.

Beaver JR, Tausza CE, Scotese KC, Pollard AI, Mitchell RM. 2018. Environmental factors influencing the quantitative distribution of microcystin and common potentially toxigenic cyanobacteria in U.S. lakes and reservoirs. Harmful Algae 78: 118-128. DOI: 10.1016/j.hal.2018.08.004.

Boudeffa K, Fekrache F, Bouchareb N. 2020. Physicochemical and biological water quality assessment of the Guebli river, northeastern Algeria. Rasayan J Chem 13 (1): 168-176. DOI: 10.31788/RJC.2020.1315255.

Bolch CJS, Blackburn SI, Jones GJ, Orr PT, Grewe PM. 1997. Plasmid content and distribution in the toxic cyanobacterial genus *Microcystis Kutzing* ex Lemmermann (Cyanobacteria: Chroococcales). Phycologia 36: 6-11. DOI: 10.2216/i0031-8884-36-1-6.1.

Borowiak D, Borowiak M. 2016. Comparative studies of underwater light regimes in lakes of the East-Suwałki Lakeland. Limnol Rev 16: 4. DOI: 10.1515/limre-2016-0019.

Boulgueraguer Z, Chaffai H, Gasmi L, Djabri L, Hani A. 2022. Impact of organic and microbiological pollution on the quality of water in Boussellam Valley and its environment, Setif City, Northeast Algeria. Biodiversitas 23: 2621-2629. DOI: 10.13057/biodiv/d230545.

Bourrelly P. 1985. Les algues d'eau douces, initiation à la systématique. Tome III: Les algues bleues et rouges. Edition N. Boubée et Cie, Paris.

Buratti FM, Manganelli M, Vichi S, Stefanelli M, Scardala S, Testai E, Funari E. 2017. Cyanotoxins: producing organisms, occurrence, toxicity, mechanism of action and human health toxicological risk evaluation. Arch Toxicol 91: 1049-1130. DOI: 10.1007/s00204-016-1913-6.

Carlson RE, Simpson J. 1996. A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society, USA.

Castenholz RW. 2001. Phylum BX, Cyanobacteria. Oxygenic photosynthetic bacteria. In: Garrity G, Boone DR, Castenholz RW (eds.) Bergey's manual of systematic bacteriology. Volume 1: The archaea and the deeply branching and phototropic bacteria. Second edition. Springer-Verlag, New York.

Catherine Q, Susanna W, Isidora ES, Mark H, Aurélie V, Jean-François H. 2013. A review of current knowledge on toxic benthic freshwater cyanobacteria Ecology, toxin production and risk management. Water Res 47: 5464-5479. DOI: 10.1016/j.watres.2013.06.042.

Chenaoui B, Remini B. 2014. Monitoring and [illegible] of sediment transport in the watershed of Oued El Ard[illegible], Algeri[illegible] Desalination Water Treat 52: 2139-2143. DOI: 10[illegible]80/19[illegible]3994.20[illegible]877852.

Chorus I, Bartram J. 1999. Toxic c[illegible]obacteria in [illegible]ter: A [illegible]ide to their public health consequenc[illegible] m[illegible]itori[illegible]nd ma[illegible]nt. E and FN Spon, London.

Chorus I, Welker M[illegible]02. Toxic cy[illegible]obact[illegible] in water, 2nd edition. CRC Press, Boca Raton, [illegible]orida. D[illegible].1201/9781003081449.

de Lima Pi[illegible]iro MM, Santos [illegible], Dantas Filho JV, Pedroti VP, Cavali J, Dos S[illegible]tos RB, Nishiyam[illegible]AC, Guedes EA, de Vargas Schons S. 2023. [illegible]irst mo[illegible]oring of cyanobacteria and cyanotoxins in freshw[illegible] from [illegible] farms in Rondônia state, Brazil. Heliyon 9 (8): [illegible]8518. D[illegible]1016/j.heliyon.2023.e18518.

[illegible]okn[illegible]T, Teubner K. 2000. Cyanobacterial dominance in lakes. Hydrobiol 438: 1-12. DOI: 10.1023/A:1004155810302.

[illegible]aredja MA, Frihi H, Boualleg C, Gofart A, Abadie E, Laabir M. 2019. Seasonal variations of phytoplankton community in relation to environmental factors in a protected meso-oligotrophic southern Mediterranean marine ecosystem (Mellah lagoon, Algeria) with an emphasis of HAB species. Environ Monit Assess 191: 603. DOI: 10.1007/s10661-019-7708-5.

El-Kalliny AS, Abd-Elmaksoud S, El-Liethy MA, Abu Hashish HM, Abdel-Wahed MS, Hefny MM, Hamza IA. 2021. Efficacy of cold atmospheric plasma treatment on chemical and microbial pollutants in water. Chem Select 6 (14): 3409-3416. DOI: 10.1002/slct.202004716.

Ettoumi A, El Khalloufi F, El Ghazali I, Oudra B, Amrani A, Nasri H, Bouaïcha N. 2014. Bioaccumulation of cyanobacterial toxins in aquatic organismsand its consequences for public health. In: Kattel G (eds.) Zooplankton and Phytoplankton. Nova Science Publishers, New York.

Filho JVD, Pedroti VP, Santos BLT, Pinheiro MMdL, Mira ABde, Silva FCd, Silva ECSe, Cavali J, Guedes EAC, Schons SdV. 2023. First evidence of microplastics in freshwater from fish farms in Rondônia state, Brazil. Heliyon 9 (4): e15066. DOI: 10.1016/j.heliyon.2023.e15066.

Gao F, Qiao Y, Wang W, Lv S. 2020. Identification and evaluation of factors affecting the eutrophication of Wuxing lake. Intl J Des Nat Ecodynamics 15 (4): 603-608. DOI: 10.18280/ijdne.150419.

Guellati FZ, Touati H, Tambosco K, Quiblier C, Humbert J, Bensouilah M. 2017. Unusual cohabitation and competition between *Planktothrix rubescens* and *Microcystis* sp. (cyanobacteria) in a subtropical reservoir (Hammam Debagh) located in Algeria. PloS One 12 (8): e0183540. DOI: 10.1371/journal.pone.0183540.

Haied N, Khadri S, Foufou A, Azlaoui M, Chaab S, Bougherira N. 2021. Assessment of groundwater pollution vulnerability, hazard and risk in a semi-arid region. J Ecol Eng 22 (10): 1-13. DOI: 10.12911/22998993/142234.

Halder JN, Islam MN. 2015. Water pollution and its impact on the human health. J Environ Human 2: 36-46. DOI: 10.15764/EH.2015.01005.

Hasna C, Faiza M, Aicha T. 2020. Diatoms diversity in Oubeïra lake, northeastern Algeria. Biodivers J 11 (2): 573-580. DOI: 10.31396/Biodiv.Jour.2020.11.2.573.580.

Hassan FM, Mahdi WM, Al-Haideri HH, Kamil DW. 2022. Identification of new species record of Cyanophyceae in Diyala River, Iraq based on 16S rRNA sequence data. Biodiversitas 23: 5239-5246. DOI: 10.13057/biodiv/d231033.

Hendrayanti D, Prihantini NB, Ningsih F, Maulana F. 2023. Next Generation Sequencing (NGS) for Cyanobacterial study in Agung and Sunter Barat Lakes, North Jakarta, Indonesia. Biodiversitas 24: 1117-1124. DOI: 10.13057/biodiv/d240251.

Heramza K, Barour C, Djabourabi A, Khati W, Bouallag C. 2021. Environmental parameters and diversity of diatoms in the Aïn Dalia dam, Northeast of Algeria. Biodiversitas 22: 3633-3644. DOI: 10.13057/biodiv/d220901.

Hillebrand H, Dürselen C-D, Kirschtel D, Pollingher U, Zohary T. 1999. Biovolume calculation for pelagic and benthic microalgae. J Phycol 35: 403-424. DOI: 10.1046/j.1529-8817.1999.3520403.x.

Huang Y, Shen Y, Zhang S, Li Y, Sun Z, Feng M, Li R, Zhang J, Tian X, Zhang W. 2022. Characteristics of phytoplankton community structure and indication to water quality in the lake in agricultural areas. Front Environ Sci 10: 833409. DOI: 10.3389/fenvs.2022.833409.

Humbert J-F, Törökné A. 2017. New tools for the monitoring of cyanobacteria in freshwater ecosystems. In: Meriluoto J, Spoof L, Codd GA (eds.) Handbook of Cyanobacterial monitoring and Cyanotoxin analysis. John Wiley & Sons, Ltd., Chichester, UK. DOI: 10.1002/9781119068761.ch8.

Ismest'eva LR, Moore MV, Hampton SE, Ferwerda CJ, Gray DK, Woo KH, Pislegina HV, Kraschuk RS, Shimaraeva SV, Silow EA. 2015. Lake-wide physical and biological trends associated with warming in Lake Baikal. J Great Lakes Res 42: 6-17. DOI: 10.1016/j.jglr.2015.11.006.

Jiang YJ, He W, Liu WX, Qin N, Ouyang HL, Wang QM, Kong XZ, He QS, Yang C, Yang B, Xu FL. 2014. The seasonal and spatial variations of phytoplankton community and their correlation with environmental factors in a large eutrophic Chinese lake (Lake Chaohu). Ecol Indicators 40: 58-67. DOI: 10.1016/j.ecolind.2014.01.006.

Jose J, Xavier J. 2022. Seasonal variation of physicochemical parameters and their impact on the algal flora of Chimmony Wildlife Sanctuary. Asian J Plant Sci 21 (4): 667-676. DOI: 10.3923/ajps.2022.667.676.

Kahoul M, Touhami M. 2014. Evaluation de la qualité physico-[illegible] des eaux de consommation de la ville d'Annaba (Algérie). Larhyss 19: 129-138. DOI: 10.4314/jab.v95i1.7.

Klemer AR, Cullen JJ, Mageau MT, Hanson K[illegible]endell R[illegible]1996. Cyanobacterial buoyancy regulation: the paradoxical roles of carbon. J Phycol 32: 47-53. DOI: 10.1111/j.0[illegible]-3646.1996.[illegible]047.x.

Kostryukova AM, Krupnova TG, Ma[illegible]ova IV, Gavrilkin [illegible]V, Nikita O. Egorov NO. 2018. Phyto[illegible] diversity in three lakes of South Ural[illegible]. Biodiversitas 19: 1459-1467. DOI: 10.13057/biodiv/d[illegible]436.

Kostryukova A, Mashk[illegible] S, Sh[illegible]elkanova E, Trofimenko V. 2021. Short C[illegible]munica[illegible] Assessing phytoplankton species structure in tro[illegible]rally different water bodies of South Ural, Russia. Biodiversitas 22: [illegible]530-3538. DOI: 10.13057/biodiv/d220853.

Kromkamp JC, Den Heuvel AV, Mur LR. 1989. Phosphorus uptake and photosynthesis by phosphate-limited cultures of the cyanobacterium *Microcystis aeruginosa*. Br Phycol J 24 (4): 347-355. DOI: 10.1080/00071618900650361.

Krumova-Valcheva G, Gyurova E, Mateva G, Milanov M. 2021. Microbiological effect of complete replacement of nitrites/nitrates with starter cultures in traditional raw-dried fermented sausage "Lukanka Panagyurska". Bulg J Vet Med 2021: 1-14. DOI: 10.15547/bjvm.2021-0043.

Kurmayer R, Deng L, Entfellner E. 2016. Role of toxic and bioactive secondary metabolites in colonization and bloom formation by filamentous cyanobacteria Planktothrix. Harmful Algae 54: 69-86. DOI: 10.1016/j.hal.2016.01.004.

Lambert N, Anirudha G, Marc N. 2020. Assessment of coliforms Bacteria contamination in Lake Tanganyika as bioindicators of recreational and drinking water quality. South Asian J Res Microbiol 6 (3): 9-16. DOI: 10.9734/sajrm/2020/v6i330150.

Leitão M, Coute A. 2005. Guide pratique des cyanobactéries du Grand Ouest de la France. Nanterre, Agence de l'Eau Seine Normandie, France.

Li D, Wu N, Tang S, Su G, Li X, Zhang Y, Wang G, Zhang J, Liu H, Hecker M, Giesy JP. 2018. Factors associated with blooms of cyanobacteria in a large shallow lake, China. Environ Sci Eur 30 (1): 1-5. DOI: 10.1186/s12302-018-0152-2.

Li J, Li R, Li J. 2017. Current research scenario for microcystins biodegradation e a review on fundamental knowledge, application prospects and challenges. Sci Total Environ 595 (Suppl. C): 615-632. DOI: 10.1016/j.scitotenv.2017.03.285.

Liu D, Morrison RJ, West RJ. 2014. Phytoplankton assemblages as an indicator of water quality in seven temperate estuarine lakes in SouthEast Australia. In: Ansari AA, Gill SS (eds.) Eutrophication: Causes, Consequences and Control 2. Springer, Netherlands. DOI: 10.1007/978-94-007-7814-6_14.

Lorenzen CJ. 1967. Determination of chlorophyll and pheopigments: Spectrophotometric equations. Limnol Oceanogr 12: 343-346. DOI: 10.4319/lo.1967.12.2.0343.

Lv H, Yang J, Liu L, Yu X, Yu Z, Chiang P. 2014. Temperature and nutrients are significant drivers of seasonal shift in phytoplankton community from a drinking water reservoir, subtropical China. Environ Sci Pollut Res Intl 21 (9): 5917-5928. DOI: 10.1007/s11356-014-2534-3.

Mangoni O, Lombardo R, Camminatiello I, Margiotta F, Passarelli A, Saggiomo M. 2017. Phytoplankton community to assess the environmental status of the Adriatic Sea via non-linear partial least squares regression: The environmental status of the Adriatic Sea. Qual Quant 51 (2): 799-812. DOI: 10.1007/s11135-016-0440-0.

Mazard S, Penesyan A, Ostrowski M, Paulsen I, Egan S. 2016. Tiny microbes with a big impact: The role of cyanobacteria and their metabolites in shaping our future. Mar D[illegible]4 (5): 97. DOI: 10.3390/md14050097.

Mashkova I, Kostryukova A, Shchelkanova E, Trofimenko V. 2021. Short Communication: Zooplankton as indicator of trophic status of lakes in Ilmen State Reserve, Russia. Biodiversitas 22 (3): [illegible]449-[illegible]455. DOI: 10.13057/biodiv/d220348.

Medrano EA, Uittenbog[illegible], Pires [illegible]D, Wic[illegible]JHvd, Clercx HJH. 2013. Coupling hydr[illegible]namics [illegible] buoyancy regulation in *Microcy[illegible]ginosa* [illegible] its vertic[illegible] distribution in lakes. Ecol Model 2[illegible]41-56. DOI: 10.1[illegible]/j.ecolmodel.2012.08.029.

Namsaraev Z, Melnikova A, Komova A, Ivanov V, Rudenko A, Ivanov E. 2020. Al[illegible] bloom [illegible]currence and effects in Russia. Water 12 (1): [illegible]0285. D[illegible]10.[illegible]0/w12010285.

N[illegible]i H[illegible]ouchaicha N, Harche MK. 2007. A new morphospecies of M[illegible]ocy[illegible] sp. forming bloom in the Cheffia Dam (Algeria): [illegible]easonal variation of microcystin concentrations in raw water and [illegible]eir removal in a full-scale treatment plant. Environ Toxicol 22 (4): 347-356. DOI: 10.1002/tox.20275.

Nexhdet S, Ibrahim H, Gafur QX, Bajram A. 2018. The microbiological quality of water, pathogenic microorganisms in food products and fecal contamination in the rivers of the Republic of Kosovo. Rasayan J Chem 11 (4): 1399-1404. DOI: 10.31788/RJC.2018.1144065.

Oliver RL, Ganf GG. 2000. Freshwater blooms. In: Whitton BA, Potts M (eds.) The Ecology of Cyanobacteria, their Diversity in Time and Space. Kluwer Academic, Dordrecht, The Netherlands.

Pham TL, Dao TS, Tran ND, Nimptsch J, Wiegand C, Motoo U. 2017. Influence of environmental factors on cyanobacterial biomass and microcystin concentration in the Dau Tieng Reservoir, a tropical eutrophic water body in Vietnam. Ann Limnol Intl J Lim 53: 89-100. DOI: 10.1051/limn/2016038.

Pham T-L, Utsumi M. 2018. An overview of the accumulation of microcystins in aquatic ecosystems. J Environ Manag 213: 520-529. DOI: 10.1016/j.jenvman.2018.01.077.

Poot-Delgado CA, Okolodkov YB. 2016. Microalgae as water quality indicators: An overview. In: Snyder M (eds.) Aquatic Ecosystems: Influences, Interactions and Impact on the Environment. Nova Science Publishers Inc, New York.

Prasertsin T, Suk-ueng K, Phinyo K, Yana E. 2021. The diversity and abundance of phytoplankton and benthic diatoms in varying environmental conditions in Kok River, Chiang Rai, Thailand as bio-indicators of water quality. Biodiversitas 22: 1853-1862. DOI: 10.13057/biodiv/d220431.

Pratiwi H, Damar A, Sulistiono. 2018. Phytoplankton community structure in the Estuary of Donan River, Cilacap, Central Java, Indonesia. Biodiversitas 19 (6): 2104-2110. DOI: 10.13057/biodiv/d190616.

Pratiwi NTM, Imran Z, Ayu IP, Iswantari A, Wulandari DY. 2020. The phosphorus load and the variation of the trophic states of cirata reservoir (West Java, Indonesia) from 1988 to 2017. Biodiversitas 21 (9): 4176-4183. DOI: 10.13057/biodiv/d210931.

Preece EP, Hardy FJ, Moore BC, Bryan M. 2017. A review of microcystin detections in estuarine and marine waters: environmental implications and human health risk. Harmful Algae 61 (Suppl. C): 31-45. DOI: 10.1016/j.hal.2016.11.006.

Rao K, Zhang X, Yi X-J et al. 2018. Interactive effects of environmental factors on phytoplankton communities and benthic nutrient interactions in a shallow lake and adjoining rivers in China. Sci Total Environ 619: 1661-1672. DOI: 10.1016/j.scitotenv.2017.10.135.

Rita A, Karoli N. 2020. Factors affecting distribution of coliforms bacteria in semi-arid groundwater sources- Tanzania. Intl J Biosci 16 (4): 487-499. DOI: 10.12692/ijb/16.4.487-499.

Rodier J, Legube B, Merlet N. 2009. L'analyse de l'eau (9ème edition). DUNOD, Paris.

Salmaso N, Bernard C, Humbert JF, Akçaalan R, Albay M, Ballot A, Catherine A, Fastner J, Häggqvist K, Horecká M, Izydorczyk K. 2017. Basic guide to detection and monitoring of potentially toxic cyanobacteria. In: Meriluoto J, Spoof L, Codd GA (eds.) Handbook of Cyanobacterial Monitoring and Cyanotoxin Analysis. John Wiley & Sons, Ltd., Chichester, UK.

Sharma RC, Singh N, Chauhan A. 2016. The influence of physicochemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: A case study. Egypt J Aquat Res 42 (1): 11-21. DOI: 10.1016/j.ejar.2015.11.004.

Sharpley A, Jarvie HP, Buda A, May L, Spears B, Kleinman P. 2013. Phosphorus legacy: Overcoming the effects of past management practices to mitigate future water quality impairment. J Environ Qual 42 (5): 1308-1326. DOI: 10.2134/jeq2013.03.0098.

Schuster KF, Tremarin PI, de Souza-Franco GM. 2015. Alpha and beta diversity of phytoplankton in two subtropical eutrophic streams in southern Brazil. Acta Botanica Brasilica 29 (4): 597-607. DOI: 10.1590/0102-33062015abb0060.

Setyono P, Himawan W. 2018. Analyses of bioindicators and physicochemical parameters of water of Lake Tondano, North Sulawesi Province, Indonesia. Biodiversitas 19 (3): 817-82[illegible]OI: 10.13057/biodiv/d190315.

Skála I. 2015. Zooplankton community composition of li[illegible] mou[illegible]in lakes in the Tatra Mts., the Alps in North[illegible]ol, an[illegible] relationship to pH, depth, organic c[illegible]and chl[illegible]ophyll-a concentration. Acta Musei Silesiae, [illegible]ntiae N[illegible]ales 64 [illegible] 175-189. DOI: 10.1515/cszma-2015-[illegible].

Song H, Coggins LX, Reichwa[illegible] ES, [illegible]hadouani [illegible] 2015. The importance of lake sed[illegible]s as [illegible]way for microcystin dynamics in shallow eutr[illegible] lak[illegible] To[illegible] Basi[illegible] (3): 900-918. DOI: 10.3390/toxins70[illegible]900.

Song Y, Qi J, Liu L[illegible]g[illegible]iu H, Bai Y, Liu H, Qu J. 2019. Eutrophication stat[illegible]and phytoplankton community structure in Chenghai Lake in sum[illegible]r and winter Huanjing Kexue Xuebao. Acta Scientiae Circumstantiae 39 (12): 4106-4113. DOI: 10.13671/j.hjkxxb.2019.0308.

Stefanelli M, Scardala S, Cabras PA, Orrù A, Vichi S, Testai E, Funari E, Manganelli M. 2017. Cyanobacterial dynamics and toxins concentrations in Lake Alto Flumendosa, Sardinia, Italy. Adv Oceanogr Limnol 8 (1): 71-86. DOI: 10.4081/aiol.2017.6352.

Suda H, Tanaka M, Oyagi M, Nobori M, Yagi A. 2016. Water quality and compositions of the phytoplankton and zooplankton before and after building construction in lake Fukami-ike, Japan. GEOMATE J 10 (22): 1983-1988. DOI: 10.21660/2016.22.5140.

Taş B. 2016. Phytoplankton community and ecological state of a highmountain lake within an important natural area (Eastern Black Sea, Turkey). Fundam Appl Limnol 189 (1): 51-61. DOI: 10.1127/fal/2016/0966.

Touati H, Guellati FZ, Arif S, Bensouilah M. 2019. Cyanobacteria dynamics in a mediterranean reservoir of the North East of Algeria: vertical and seasonal variability. J Ecol Eng 20 (1): 93-107. DOI: 10.12911/22998993/94606.

Umehara A, Takahashi T, Komorita T, Orita R, Choi J, Takenaka R, Mabuchi R, Park H, Tsutsumi H. 2017. Widespread dispersal and bio-accumulation of toxic microcystins in benthic marine ecosystems. Chemosphere 167: 492-500. DOI: 10.1016/j.chemosphere.2016.10.029.

Viaroli P, Nizzoli D, Pinardi M, Soana E, Bartoli M. 2015. Eutrophication of the Mediterranean Sea: a watershed—cascading aquatic filter approach. Rend Lincei 26 (1): 13-23. DOI: 10.1007/s12210-014-0364-3.

Vinçon-Leite B, Zervos N, Tassin B. 2005. Les proliférations de cyanobactéries dans les lacs et réservoirs: Modélisation prédictive dans un système d'alerte. Proceeding of the 16th Scientific Days of the Environment - Water: living without risks. Créteil, France, May 2005. [French]

Wanigatunge RP, Magana-Arachchi DN, Chandrasekharan NV, Kulasooriya SA. 2014. Genetic diversity and [illegible]phylogeny of Cyanobacteria from Sri Lanka based 16S [illegible]A gene. Environ Eng Res 19 (4): 317-329. DOI: 10.4491/e[illegible]014.0[illegible]

Wang J, Wu S, Fan B, Chen [illegible] 2020. Di[illegible]bution [illegible]atures of phytoplankton and its c[illegible]rela[illegible]n wi[illegible] envir[illegible] factors of Baima Lake. IOP C[illegible]fer Ma[illegible]l Eng 730 [illegible]): 012055. DOI: 10.1088/1757-89[illegible]/012055[illegible]

Wasmund N. 1997. Phytopla[illegible]on perio[illegible]n a eutrophic coastal water of the [illegible]tic Sea. Intl [illegible]ue Ges Hydrobiol 79: 259-285. DOI: 10.100[illegible]ROH.1994079021[illegible]

Wasmund [illegible] 2017. T[illegible] diatom/dinoflagellate index as an indicator of ecosyst[illegible] change[illegible]n the Baltic Sea. 2. Historical data for use in [illegible]rmina[illegible]good environmental status. Front Mar Sci 4 (153). D[illegible]3389/fmars.2017.00153.

[illegible]on B[illegible], Potts M. 2000. The ecology of cyanobacteria: Their diversity in time and space. Springer, Netherlands.

[illegible]e Q, Su X, Steinman AD, Cai Y, Zhao Y, Xie L. 2016. Accumulation of microcystins in a dominant chironomid larva (*Tanypus chinensis*) of a large, shallow and eutrophic Chinese lake, Lake Taihu. Sci Rep 6 (1): 31097. DOI:10.1038/srep31097.

Yang Y, Du C, Qian Z et al. 2020. Phytoplankton community structure and its influencing factors in Nanhan Polder Area of Dongting Lake. Res Environ Sci 33 (1): 147- 54. DOI: 10.13198/j.issn.1001-6929.2019.06.17.

Zhang D, Xie P, Liu Y, Chen J, Wen Z. 2009. Spatial and temporal variations of microcystins in hepatopancreas of a freshwater snail from Lake Taihu. Ecotoxicol Environ Saf 72 (2): 466-472. DOI: 10.3390/atmos11030231.