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Sanitary and Agronomic Significance of the Trophic Levels of Two Reservoirs from Cordoba (Argentina)

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Abstract

Algal blooms occur when starts the multiplication and accumulation of microalgae that live freely in aquatic systems, causing a significant increase in the biomass of one or a few species, in very short periods of time. When it comes to Cyanobacteria, it is common for them to produce toxins, which are highly risky when reservoirs are used as reservoirs. This problem has been aggravated with the passage of time, since in general for several decades concrete and effective measures have not been taken to prevent it. The situation is particularly serious when lakes are used as water reservoirs for purification, since in many cases the health of the population they supply is compromised by the effect of cyanotoxins. In this research, a data update was made based on the monitoring of the San Roque and La Quebrada Reservoirs, considering results of samplings carried out between 2019 and 2020 together with previous information. The results showed that the biomass of cyanobacteria rises in the warm months due to the massive influx of nutrients as a result of the discharge into the water body of sewage tributaries with little or no treatment. It is suggested the manufacture of sewage treatment plants in the basins of both reservoirs, and also to apply aeration systems such as those installed in the San Roque Reservoir as a temporary palliative.

Keywords: Cyanobacteria, Blooms, Reservoirs, San Roque, La Quebrada.

1. Introduction

The reservoirs of the Province of Córdoba have been supporting for several decades a strong and continuous process of pollution of anthropic origin, mainly organic matter, which has led them to a general state of quite advanced eutrophication [1-3]. Lentic water bodies can be classified according to their trophic status, that is, according to the load of organic nutrients that they contain

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in dilution and that are fundamental for the development of the flora of algae and photosynthetic micro-organisms, which in turn, as primary producers, they start the food chain that continues with primary and secondary consumers [4]. Different criteria can be adopted to determine the trophic status of lakes, which can put into practice the use of, for example: trophic indices or load of phosphorus, or nitrogen and phosphorus balance, as well as the use of biological techniques by observing indicator organisms such as algae, zooplankton, fish and organisms from the bottom of the lake [5]. For this reason, it is always convenient to consider both aspects as a whole, that is, the chemistry of water and biodiversity, in order to be able to establish the trophic state of the environments under study [6]. Those aquatic environments with a low nutrient load are considered oligotrophic, those with intermediate values mesotrophic, and those with high loads eutrophic. In some extreme cases the term hypertrophic or hypereutrophic is used [7]. The population growth of phytoplanktonic microorganisms is generally measured as the number of cells per unit volume of water or as the quantity of chlorophylls per unit, since chlorophylls are directly proportional to the biomass of photosynthesizing organisms [8]. When these blooms occur, the release of cyanotoxins happens at the same time, as a defense mechanism against herbivorous organisms. They can be peptides, alkaloids or lipopolysaccharides that affect the nervous system or the digestive system and cause harmful effects on mucosa and skin [9]. The World Health Organization has estimated the maximum concentration allowed for drinking water of potentially toxin-producing Cyanobacteria (Table 1) [4, 10].

SPECIES	(Cel. / Ml)
Microcystis aeruginosa	2,000-6,500
Anabaena circinalis	20,000
Cylindrospermopsis raciborskii	1,500
Nodularia spumigena	40,000

Table 1: Maximum concentration of potentially toxin-producing Cyanobacteria, allowed by the World Health Organization.

In order to monitor the biomass of cyanobacteria and algae, chlorophyll-a levels must be taken into account. For oligotrophic lakes the values are: 1 to 10 μg / l, while for eutrophic lakes they can be 300 μg / l or more. Algal blooms generally peak and then die rapidly as toxin levels in the water decline over days or weeks [11, 12]. Toxin-producing cyanobacteria are not only important from the sanitary point of view, when the reservoir is used for drinking water, but also from the agronomic point of view, when it is used for irrigation. If the water used for irrigation is applied to edible vegetable crops, toxins can bioaccumulate, thereby adding another important health risk, which of course prevents the consumption of such crops. The objective of this research was to update the data based on the monitoring of the San Roque and La Quebrada reservoirs, considering results of samplings carried out between 2019 and 2020 together with previous information.

2. Materials and Methods

The study covered two bodies of water in Córdoba, Argentina, which present serious risks of cyanobacterial blooms, and which are involved in the provision of water for human consumption to the City of Córdoba (about 1.5 million of inhabitants) and its surroundings. The San Roque Lake is the main drinking water reservoir for the city of Córdoba and because it receives a high contribution of nutrients mainly from anthropic activity, it constitutes a very favorable ecosystem for the development of algal communities, especially Cyanophytes [13]. The other reservoir, which supplies peripheral localities, is the La Quebrada Reservoir, located in Río Ceballos, 32 km northwest of the city of Córdoba, it is the only reservoir for the provision of drinking water for approximately 30,000 people who live in the surroundings, in the towns of Río Ceballos, Unquillo and Mendiolaza. The samples were collected in 2-liter hermetic containers, washed with distilled water, and sub-surface samples were taken on the margins of the two reservoirs. After being concentrated by decantation, they were fixed in 3% formaldehyde. The taxonomic study of the species was carried out following the specific identification keys and manuals [14, 15]. The counting of the samples was carried out by direct counting using photon microscopy [16, 17, 18].

Phytoplankton biomass was estimated by measuring the chlorophyll concentration "a" in a spectrophotometer, after its extraction in methanol for 12 hr at -5ºC, according to Prosperi [19], and various biological indices were calculated (diversity, dominance, and others). Although emphasis was placed on the determination of Cyanophyceae, the study of some other taxa that were important due to their interactions with the former or due to their abundance was also included, such as Euglenophyceae, Chlorophyceae, Bacillaryophyceae, Dinophyceae and other taxa [20, 21]. In the evaluation of these environments, not only the data obtained recently but also the information accumulated in several decades of work on the problem were taken into account.

3. Results and Discussion

San Roque Reservoir

The number of taxa determined was 107 in total. *Microcystis aeruginosa* and *Anabaena spiroides*, (Cyanophyceae) (Fig 1), two potentially toxic species, were the cause of blooms during the warm months. During winter the Bacillariophyceae were the dominant group. The results would indicate that the Reservoir could be located in a eutrophic state with a tendency to hypereutrophic in summer given that its waters are characterized by abundant primary productivity, low transparency, greenish coloration and anoxic processes that generate odoriferous gases. In addition, it could be seen that *Anabaena spiroides* did not present heterocysts, which clearly indicates that the lake environment is rich in nutrients with nitrogen [22]. Regarding the environmental variables that were measured, such as pH and temperature, the pH values obtained oscillated around 7.5, and it is known from the literature that the optimum for cyanobacterial growth is given by an alkaline pH, with values above 6.5 to 8.5. The temperature never reaches an average lower than 10 ° C, being the optimum for Cyanobacteria between 18 and 20.

The abundance in biomass of cyanobacteria is favored by the high degree of nutrients present in the lake as a consequence of the discharge into the water body of sewage effluents without previous treatment. There were blooms of *Ceratium hirundinella*, (Pyrrophyceae) probably an invasive species from Patagonia, in southern Argentina, but at present the lake has been dominated by Cyanophyceae [23]. Observations made in the San Roque reservoir in 1948 did not mention this problem of growth of Cyanobacteria, which were present but in low quantity, with a predominance of Chlorophytes, which are generally indicative of clean and aerated waters [24]. The presence of *Anabaena spiroides*, a potential neurotoxin producer, was determined. It has not developed heterocysts, which suggests very high levels on nitogen compounds in the wáter, as far as the role of heterocysts is nitrogen fixation from the air (Fig 1). Currently, however, it can be noted that there is a period in which growth falls from May to August, coinciding with lower temperatures and with the progressive consumption of nutrients such as phosphates and nitrates. This period of the year is also consistent with the time when human populations in the basin towns decrease at the end of the tourist season.

Fig 1: Anabaena spiroides (Cyanobacteria) from San Roque Reservoir. Note the absence of heterocysts.

La Quebrada Reservoir

In La Quebrada reservoir, during summer there is a marked thermal stratification of its water layers. The superficial layer, the epilimnion, in summer registers a temperature between 27º to 29º C, which decreases in depth until reaching 19º C at 20 m in the lower layer, the hypolimnion. In the autumn, the thermal stratification is broken, observing an almost uniform temperature of 15º to 13ºC from the surface to the bottom of the reservoir [25]. In general, during the colder seasons, an increase in the populations of different diatoms was determined, the predominant ones being *Aulacoseira granulata* (*Melosira granulata*) together with *Melosira varians, Achnates inflata, Achnates linearis, Cymatopleura solea, Cymbella aspera, Cymbella cistula, Cymbella tumida, Epithemia adnata, Fragilaria capuchina, Gomphonema truncatum, Hanzschia amphioxys, Navícula cuspidata, Nitzschia sigmoidea, Nitzschia sinuata var. Tabellaria, Synedra ulna, Surirella robusta, Pinnularia divergens* and some Chlorophyceae of the genera *Cosmarium, Closterium, and Spirogyra.*

The transparency of the water measured by the Secchi Disc indicates that during the summer the lowest values of this transparency are found at the mouth of the creek Arroyo Colanchanga, coinciding with the moments of maximum values in the algal blooms [26]. The general conditions of the reservoir observed during the different seasons of the year indicated that there is a transition from a state between mesotrophic - eutrophic (spring-summer) to an oligotrophic state (autumn-winter). The predominant mesotrophic state of the reservoir, associated with the microbiological contamination of the tributaries, implies the urgent need to apply short-term measures throughout the supply basin for the preservation of water resources, since the La Quebrada Dam is the only source of water supply for approximately 30,000 permanent inhabitants [27, 28].

4. Conclusions

The characteristics of the two reservoirs considered corresponded to the mesotrophic state, although with important variations according to the season of the year and the sampling site. Regarding the concentration of chlorophyll-a, during spring and summer they were predominantly eutrophic, while during autumn and winter they were mesotrophic [26]. The need to adopt immediate sanitation measures to stop this growing eutrophication process in these water bodies is evident. The most important thing is the treatment of sewage effluents before being discharged into the basin, but fires must also be controlled, since the leaching of the ashes contributes strongly to eutrophication [29].

This sanitation must include the tertiary treatment of all sewage effluents that are discharged into the environment, and the control of diffuse organic pollution produced by agricultural-livestock activity in the affected basins. As a palliative measure for algal blooms, aeration is recommended in its different possibilities of implementation [30, 4]. Any mechanical action that contributes to breaking the thermocline of a lake and mixing both phases, or that directly oxygenates the hypolimnion, or both actions at the same time, will decrease the activity of the anaerobic organisms in the bottom and will prevent the availability of phosphorus for the Cyanobacteria of the surface. There are various aeration mechanisms for rivers and lakes, all more or less efficient, depending on the characteristics of the environment to be treated and according to a cost-benefit ratio that must be evaluated in each particular case [4].

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