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Influence of climatic conditions on cyanobacteria blooms in a tropical water supply river (Rio das Velhas, Brazil)

E. von Sperling & F.A. Jardim, Brazil

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The paper presents a discussion about the striking influence of climatic conditions on the onset of cyanobacteria blooms in a warm water river in Brazil. An unusual drought period has been observed in the second half of 2007 in Rio das Velhas, Brazil, which led to an unexpected bloom of blue-green algae (cyanobacteria). Cyanobacteria blooms constitute a special concern in Brazil, since the first human deaths caused worldwide by cyanotoxins have been reported in this country. The Brazilian legal framework restricts the water abstraction under such conditions and imposes a special monitoring programme to be carried out by water supply companies. The results of water quality analysis point out the conjunction of two factors as the main cause of the mentioned cyanobacteria blooms: nutrients input from treated and untreated sewage as well from diffuse sources and the extended dry period in 2007.

Introduction

Blue-green algae or cyanobacteria are primitive microalgae with plant chlorophyll. These ancient and remarkable organisms may inhabit quite diverse environments. They have long been recognized as a water quality problem in lakes and reservoirs due to their potential toxicity and to their capacity to impact off-flavours to drinking water. Consequently many water utilities are concerned about controlling cyanobacteria input to the treatment plant. A special relevance is dedicated to this topic in Brazil, since this was the first country in the world to register human deaths in a dialysis unit caused by the presence of cyanoprocaryota toxins (Azevedo et. al., 1996). Most cyanobacteria have maximum growth rates above 25^0C and are therefore favoured by higher temperatures. Cyanobacteria present a range of characteristics that give them a clear competitive growth advantage over planktonic algae in certain environmental conditions. They are not favoured by high light intensity and require little energy to maintain cell structure and function. Moreover some species present a buoyancy regulation capacity due to the possession of gas vacuoles within their cells. This is important in avoiding light damage in high-light environments, such as tropic lakes, or in gaining access to light in turbid or low-clarity water (Haider et. al., 2003). Cyanobacteria are also able to store phosphorus (luxury uptake), which is useful to allow continued growth under conditions of fluctuating nutrient concentrations. They are also poorly grazed by the zooplankton, since they are not a preferred food for this aquatic community (Chorus & Bartram, 1999).

Material and methods

River Velhas is located in the state of Minas Gerais, Brazil, in the southeastern part of the country. Its length is 801 km, with a mean slope of 0.08 % (1100 m at the sources and 464 m in its mouth). The river drains a total area of 27,868 km^2 with around 4.5 million inhabitants, which are distributed over 51 municipalities. Around 70% of this population is concentrated in the metropolitan area of the city of Belo Horizonte. The mean flow of the river is around 300 m^3/s. Annual average precipitation is 1500 mm and the rainy season extends from October/November to March/April.

The drainage basin of River Velhas is mostly occupied by agricultural use and cattle breeding. Urban areas, which extend at around just 2% of the total surface, are however a relevant concern regarding water quality. The water course, which is partially navigable, is scarcely used for recreational purposes. Several municipalities, including Belo Horizonte, abstract water from River Velhas.

A regular monitoring programme is being carried out since 10 years at several sampling points in River Velhas. In order to optimize the water quality evaluation, some sampling stations have been selected as the most representative ones:

BV-067 → 083 → 105 → 153 → 137 → 156 → 141 → 142 → 152 → 146 → 148 → 149

These points follow here the downstream direction. Water samples are colected 4 times in the year (January, April, July and October) and the main physico-chemical, bacteriological and hydrobiological parameters are analysed according to *Standard Methods for Water and Wastewater Analysis* (APHA/WEF, 2005).

Results and discussion

The main results of the monitoring programme carried out in the last 3 years is presented in the next figures. Emphasis is given here to the most relevant parameters that may explain the complex dynamics of cyanobacteria blooms in tropical waters. For the sake of a better understanding of the figures, average monthly values are shown instead of the time evolution of each parameter, which would concentrate too many data in a limited graphical space.

Figure 1 shows the mean water temperatures in River Velhas along the year. It can be seen that the highest values are registered in October (spring season) and not in January (summer season), as usually assumed for most tropical waters in the region. This feature has a striking influence on the onset of algal blooms, since October is exactly the very end of dry season, when all climatic factors contribute to eutrophication problems, as will be discussed at the end of this topic.

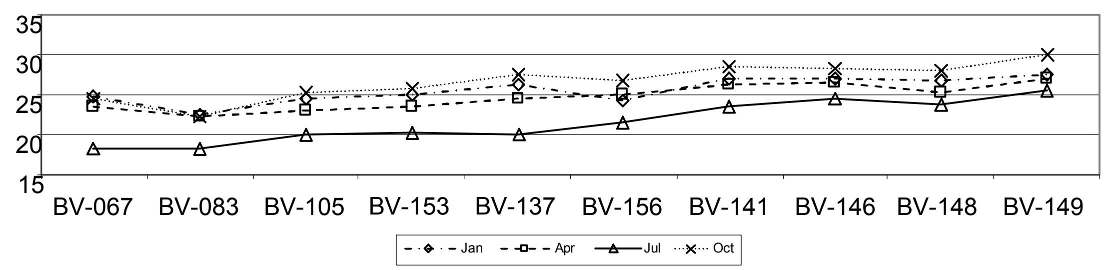

Figure 1. Average water temperatures (0C) in River Velhas

The influence of sewage discharge from the metropolitan area of Belo Horizonte can be observed in the behaviour phosphorus and nitrogen concentrations. Figure 2 depicts the average values of phosphorus concentrations in the several sampling stations in River Velhas. Points 83 and 105, located downstream the two main tributaries of River Velhas, receive high loads of treated and untreated sewage. It can be seen a clear depuration (cleansing) process in the river, which takes place downstream point 153.

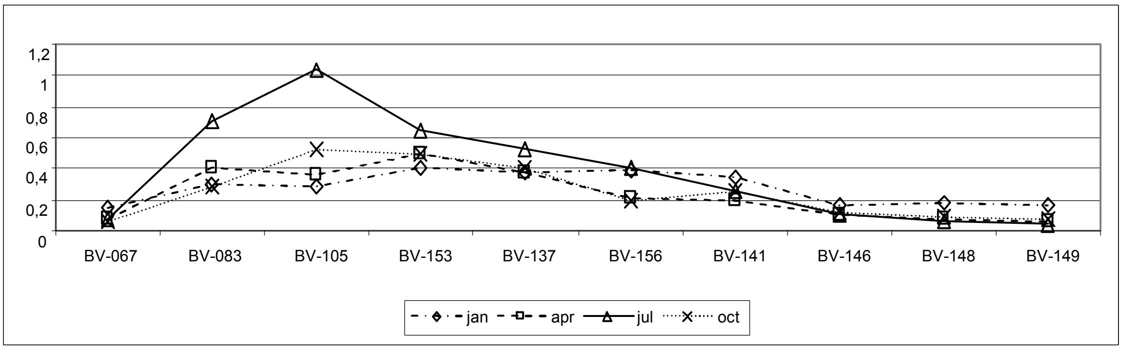

Figure 2. Average phosphorus concentrations (mg/L) in River Velhas

A very similar pattern is also observed with nitrogen concentrations (Figure 3), showing a clear rise in the values at the sampling stations which are more influenced by nutrients discharge. The long term monitoring of nitrogen and phosphorus in River Velhas indicates that the element phosphorus acts as a limiting nutrient for phytoplankton growth, since most of the N/P values are over 10. A mass balance estimation of phosphorus loads in the drainage basin of River Velhas has been also carried out considering point (sewage discharge) and diffuse (run-off, cattle breeding, rain, agriculture) sources. The results show that point sources contribute with about 70 % of the total load to River Velhas. This number indicates however that actions developed to limit point sources may not be sufficient to restore the ecological integrity of the river. Diffuse sources, mainly those related with activities that take place close to the water course, such as cattle breeding and use of fertilizers for agricultural purposes, should be efficiently tackled to minimize the intensity of algal blooms.

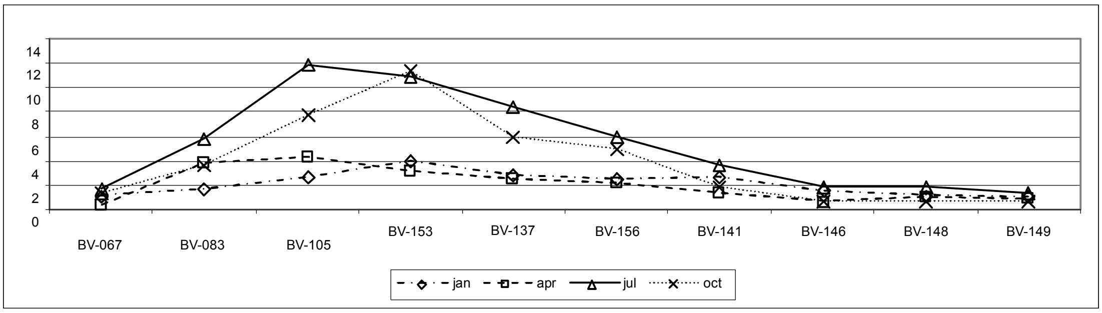

Figure 3. Average nitrogen concentrations (mg/L) in River Velhas

With respect to the dissolved oxygen concentrations (Figure 4) there is a logical inverse trend in comparison with the nutrients pattern, i.e., the values fall down at the vicinity of the city of Belo Horizonte and then rise again downstream sampling point 137. It can be infered from Figures 2 to 4 that River Velhas has a quite satisfactory self –depuration capacity, recovering its initial characteristics after crossing a high density urban area. It should be stressed that most of the algae blooms take place not in the impacted area but far downstream, mainly in the stations 148 and 149. It can be hence hypothesized the influence of resuspended nutrients as one of the key factors in the development of algal blooms in the lower reach of River Velhas.

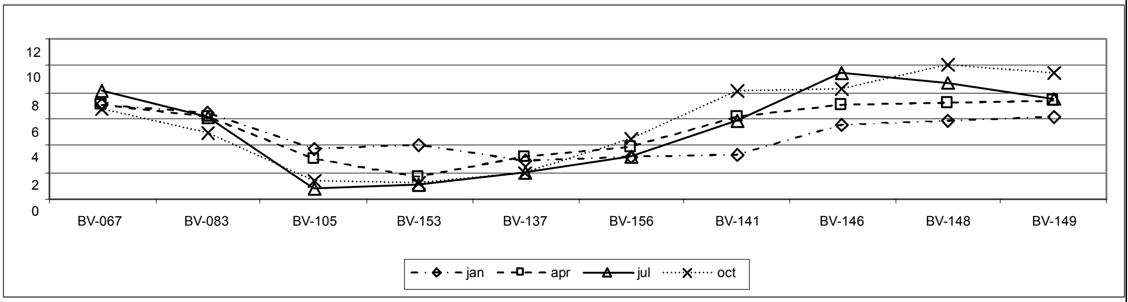

Figure 4. Average dissolved oxygen concentrations (mg/L) in River Velhas

The hydrobiological results from the monitoring programme point out a massive algal bloom in October/07, with cyanobacteria densities in the range of 340000 to 6 million cel/mL. The possible reasons for this unusual numbers are associated with peculiar climatological conditions, as will be discussed in the next topic. In the year 2008 (until September) the cyanobacteria populations reached a maximum value of 600000 cel/mL. The prevalent cyanobacteria species are from genus *Microcystis* (*M. aeruginosa* and *M. novacekii*), together with *Sphaerocavum brasiliense* and *Chroococcus disperses.*

Brazilian federal regulations regarding drinking water supply (Act 518/04 from Ministry of Health) determine a monthly sampling frequence when cyanobacteria densities lie under 10000 cel/mL. If the populations exceed this value a weekly monitoring programme should be then implemented.

As pointed out previouly, the climatological aspects play a relevant role in the onset of phytoplankton blooms in River Velhas as well as in most tropical water courses. At the dry period (here usually from May to October) a series of forcing factors contribute to a massive algae growth, specially cyanobacteria:

1) Higher air temperatures ⇨ Higher water temperatures → higher phytoplankton growth

2) Low precipitations ⇨ Low water velocity → less shoreline erosion → higher water transparency → higher phytoplankton growth

⇨ Lower dilution capacity → higher nutrients concentrations → higher phytoplankton growth

⇨ Higher water residence time → higher phytoplankton growth

⇨ Lower air humidity → higher phytoplankton growth

3) Stronger solar radiation ⇨ higher phytoplankton growth → favour cyanobacteria

It can be seen that most of the forcing factors that predominate at the dry season clearly favour the onset of algal blooms. The stochastic nature of these climatic phenomena complicates the configuration of reliable predictions regarding phytoplanktonic blooms. The striking role played by climatology on the dynamics of algal growth has been recently confirmed also in temperate water bodies (Phlips, 2007; Sobafer, 2008).

Conclusions

The main conclusion to be drawn from this paper is the striking influence of climatological conditions on the onset of algal blooms in tropical water courses. Together with the presence of nutrients, the conjunction of dry periods and low water velocity are the basic causes of eutrophication processes in warm waters. The spatial distribution of algal populations shows a concentration at the lower reaches of the river. This pattern does not coincide with the nutrients distribution, indicating a possible resuspension of phosphorus trapped in the sediments. The amount of diffuse pollution should be taken into account for a sound restoration of the water body. One of the relevant learning points of the paper is the need of the correct identification of those diffuse sources, considering that the point pollution is already known and the construction of waste water treatment plants is currently planned for several municipalities outside the metropolitan region of the capital city.

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Contact details

Eduardo von Sperling
Av. Contorno 842, Belo Horizonte, Brazil
Tel: 55 31 34091880
Fax: 55 31 34091879
Email: eduardo@desa.ufmg.br

Fernando A. Jardim
Mar de Espanha 525, Belo Horizonte
Tel: 55 31 32502013
Fax: 55 31 34091879
Email: fernando.jardim@copasa.com.br