Antropic influence on lakes water quality – case study of Bucharest city

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Abstract

Bucharest is one of largest cities in Romania and disposes of natural and artificial lakes, which are utilized for different economical and leisure purposes. Water samples collected from lakes within the urbanized area were characterized by oxygen indicators (dissolved oxygen, chemical oxygen demand), nutrients related indicators (ammonia, nitrates) and spectroscopic response (fluorescence spectroscopy). The standard parameters were correlated with the fluorescence measurements and with pollution sources situated in the proximity of lakes. Degradation of water quality was noted for lakes which have individual residential areas in the proximity, in comparison with lakes surrounded by green spaces, collective residential or industrial areas, and even open fields.

Keywords

Urban water; waste water; ecosystem; discharges; eutrophication.

INTRODUCTION

Water, as an environmental component, is essential for the life quality and the sustainable development of human settlements. Besides its value as a resource, urban water is a receiver of the environmental problems, specific to the urbanized areas: waste waters with different levels of biochemical charging, solid wastes, various organisms, and heat excess (Iojă, 2008). All these problems can reduce the economical utility of water resources and convert them into means of propagation and attraction of urban issues, like insalubrity, excessive growth of various animal and plant species, poverty, and loss of economical attractiveness of an area. Due to the continuous pressure human life puts on the natural water resources, several legal mechanisms have been developed in the European Union. Amongst these there is the Framework Directive 2000/60/EC, which has been transposed into the Romanian legislation by the Water Law and stipulates that all water ecosystems, must achieve good ecological status by 2015.

Bucharest is one the largest Romanian cities and the capital of the country. It has several lakes, used for different economical or leisure activities, which have a key role in maintaining the territorial balance of their locations. Conservation and preservation of these urban lentic ecosystems is important both from an economical and an environmental point of view and can be done by the rapid, accurate evaluation and monitoring of their state of health.

Lately, fluorescence spectroscopy has the method of choice for many water-related scientific studies (McKnight et al., 2001; Jaffé et al., 2004; Liu et al., 2007; Cârstea et al., 2009; Ghervase et al., 2010), because it has several advantages over standard techniques: it represents a rapid pre-analysis method, it does not need high sample quantities or complicated pre-preparation steps and, moreover, it offers the possibility of *in situ* measurements. Water quality can be assessed through fluorescence spectroscopy, because of its dissolved organic matter (DOM) content. DOM is present in all natural waters in various proportions, and it comprises two chromophoric fractions: 40 – 60 % is given by humic-like substances (humic acid – A, fulvic acid – C, recent humic substances – M) and the rest is represented by protein-like substances (amino acids, mainly tryptophan, T and tyrosine, B). Each of these components has specific excitation and emission wavelengths domains (Coble, 1996; Parlanti et al., 2000), which helps identify them in a fluorescence excitation – emission matrix (EEM).

The aim of the paper was to determine the ecological status of urban lentic systems, based on standard chemical analysis and optical techniques. For this purpose, several urban lakes were selected, with similar or different geo-morphological characteristics and impacted by various degradation sources. The characteristics of these lakes were correlated with the pollution sources by which each of them are affected.

MATERIAL & METHODS

A total of 16 urban lakes were included in the study: lakes situated along a river which runs near the city border (P1 – P8, “external lakes”) and lakes situated inside the city (P9 – P16, which will be called from now on “internal lakes”), as illustrated in fig. 1. The water samples were collected in spring 2010. Based on the type of water supply, they can be divided into lakes with partial natural water supply and lakes with predominant artificial water supply (from medium and high depth groundwater sources and from the water supply network).

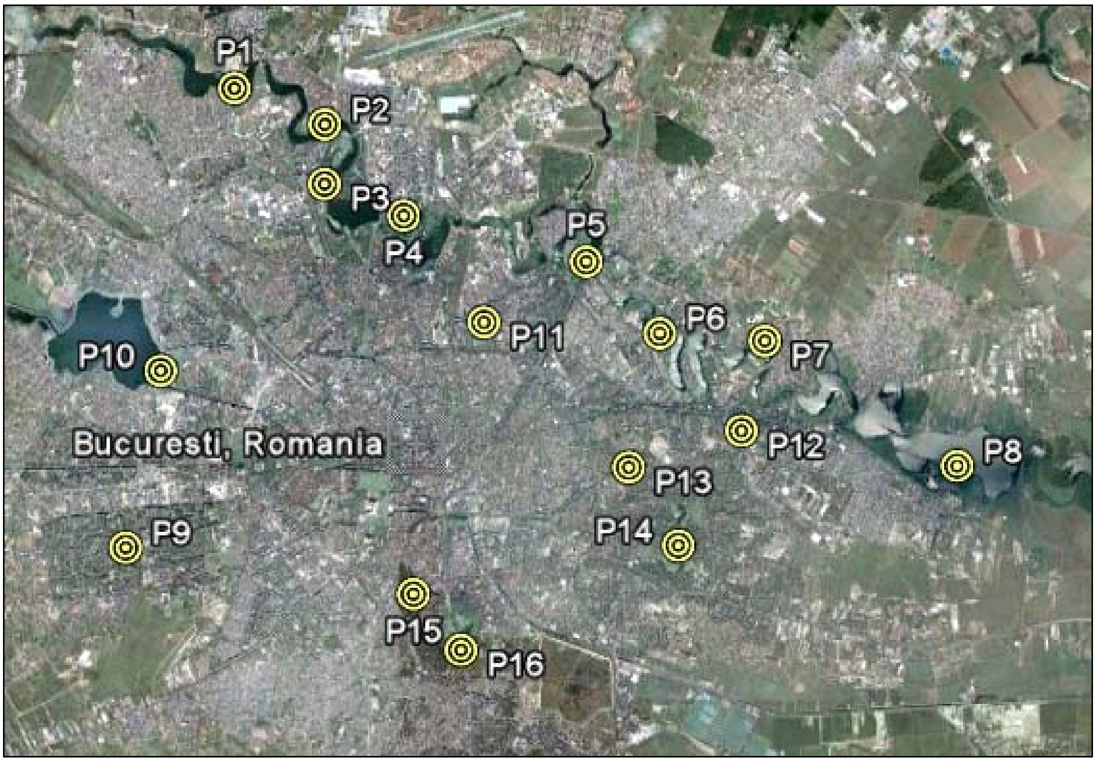

Figure 1: Map with sampling locations

These lakes are used for different economical and leisure purposes and are subjected to various degradation sources, as can be seen from Table 1. As can be seen, all of them are arranged for leisure activities and are used for fishing, even if the lake water is not very qualitative. Lakes P1 – P9 are affected by uncontrolled wastewater and dump discharges, as opposed to lakes P9 – P16 which are mostly affected by surface runoff.

TABLE 1: Description of lakes' use and degradation sources

Lake	Use	Degradation sources
P1	Fishing, recreation	Household discharges, industrial wastewaters, nutrients loading, pluvial waters, vegetation
P2	Fishing, irrigation, flooding mitigation, recreation	Household discharges, industrial wastewaters, nutrients loading, petroleum products, pluvial waters, vegetation
P3	Fishing, irrigation, flooding mitigation, recreation	Household discharges, industrial wastewaters, nutrients loading, petroleum products, pluvial waters, vegetation
P4	Fishing, flooding, mitigation, recreation	Household discharges, nutrients loading, solid wastes, pluvial waters
P5	Fishing, irrigation, flooding mitigation, recreation	Household discharges, industrial waste waters, solid wastes, nutrients loading, pluvial waters
P6	Fishing, irrigation, flooding mitigation, recreation	Household discharges, industrial wastewaters, nutrients loading, pluvial waters
P7	Fishing, irrigation, flooding mitigation, recreation	Household discharges, industrial wastewaters, nutrients loading, pluvial waters
P8	Fishing, irrigation, flooding mitigation, recreation and industrial water supply source	Household discharges, industrial wastewaters, nutrients loading, pluvial waters
P9	Fishing, recreation	Pluvial waters
P10	Fishing, recreation	Household discharges, solid wastes and waste waters
P11	Fishing, recreation	Pluvial waters, vegetation, sediments from lake bottom, aquatic birds
P12	Fishing, recreation	Pluvial waters, vegetation
P13	Recreation	Pluvial waters, vegetation
P14	Fishing, recreation	Pluvial waters, vegetation, sediments from lake bottom, restaurants, aquatic birds
P15	Fishing, recreation	Vegetation, aquatic birds, pluvial waters
P16	Fishing, recreation	Sediments from lake bottom, vegetation, birds, restaurants, pluvial waters

Prior to the spectroscopic measurements, the samples were analyzed for several standard chemical quality indicators: oxygen indicators (dissolved oxygen and chemical oxygen demand) and nutrients related indicators (ammonia and nitrates). The dissolved oxygen level was measured with HANNA HI 9145 oxygen meter, the nitrogen compounds with spectrophotometer with sulphanilamide and N-(1-naphtol)-ethylenediamine for nitrates, and for the chemical oxygen demand the US EPA 410.4 method was used.

Fluorescence was recorded in the form of emission spectra using spectrofluorimeter FLS-920 Edinburgh Instruments, equipped with 450 W Xenon flash lamp and double monochromators. The emission was detected in the range of 250 – 500 nm, with 1 nm step, for different excitation wavelengths, between 230 – 400 nm. Both emission and excitation slits were set at 2 nm and the integration time was 0.2 s. The recorded data were processed using the Origin 7 software.

RESULTS AND DISCUSSION

The standard water quality parameters recorded for the lake water samples are presented in figure 2. The level of dissolved oxygen in natural waters is a balance between the oxygen depleting (respiration and decomposition) and the oxygen generating (photosynthesis) processes. Organic wastes may overload a natural water system, leading to depletion of the oxygen supply but for the investigated lakes, the organic loading did not seem to have a direct influence over the dissolved oxygen values for eutrophic lakes, due to the photosynthesis process. The values of dissolved oxygen varied unevenly from 4.17 (P12) to 10.2 (P1). The smallest value, detected for sample P12 can be related to the presence of more bacteria or animal populations using dissolved oxygen in excess.

As for the nitrogen compounds, high content of nitrates was found in samples P1, P2, P6, P7, P13 and P16, which are included in the fourth general quality class (Official Monitor of Romania, 2006), as opposed to samples P9 – P11 and P15 which had the lowest values. The ammonia content registered in the lakes varied from 0.03 (P9) to 5.89 (P7). Ammonia, as nitrogen source, is also nutrient for the aquatic vegetation and it can contribute to the overloading of natural waters. The high ammonia values found in lakes P1, P2, P7 and P8 could be related to the presence of larger fish communities.

The chemical oxygen demand (COD) represents the capacity of a water system to consume oxygen for the decomposition of organic matter or for oxidation of inorganic substances and it is a measure of the degree of water pollution with organic matter. The highest levels of COD were registered for samples P1, P5 and P8, over 40, probably indicating highly eutrophic lakes.

Lakes P1 – P8 are more subjected to the antropic influence, because there are more individual residential areas in their proximity. Many of them are not connected to the city’s sewage system and part of their wastewaters is released into the lakes, contributing to their degradation. On the other hand, lakes P9 – P16 are surrounded by parks and some collective residential locations, therefore mostly affected by surface runoff.

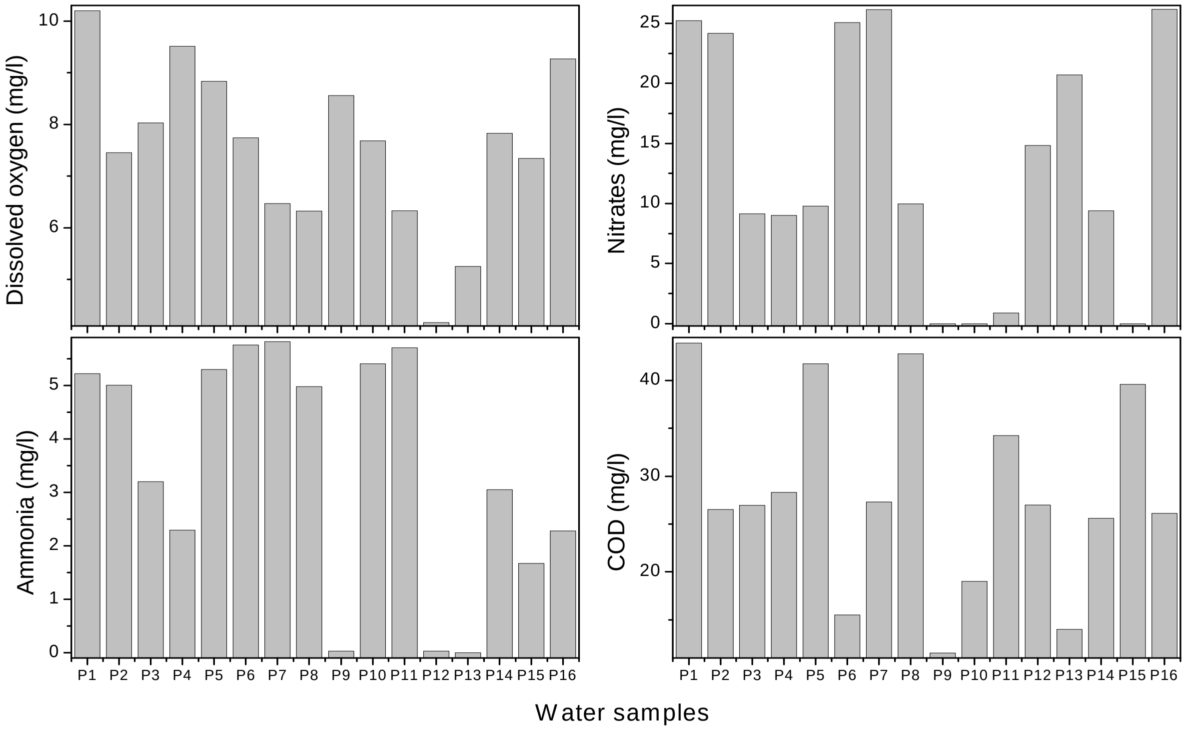

Figure 2: Standard chemical parameters of the lake water samples

Figure 3 illustrates the fluorescence intensities of the principal fluorophores encountered in the lake water samples. The humic acid A, showed maximum fluorescence signal between 380 – 480 nm, when excited with 260 nm wavelength. The sample that had the highest A peak was P3, followed by P2 and P1. At the opposite end, samples collected from the lakes inside the city had the lowest humic-like substances concentrations, with a minimum recorded for P9, P13 and P15. The maximum fluorescence emission of the fulvic acid (C) was detected in the wavelength domain of 420 – 480 nm, for excitation with 340 nm. The samples with the highest concentrations of fulvic acid were P8 and P2 and the lowest intensities were detected for samples P9, P13 – P15. The high concentration of humic substances found in sample collected from the external lakes can be correlated with the input from surface runoff, bringing into the lakes the impurities from the shores and probably also, with excess vegetation.

The M component displayed the highest fluorescence signal in the emission range of 380 – 420nm, when excited with 310 nm wavelength. This maximum is associated with the recent production of humic substances and often appears as a small "shoulder" of the fulvic-like component. This was evidenced here by the fact that C and M peaks showed the same tendency (an increase of the C maximum lead to an increase of M, also). The highest contribution of the M peak was found in samples P8, P2 and P1, possibly due the fresh production of organic matter deriving from the decay of aquatic vegetation. Once more, sample P9 had the lowest concentration, followed by P15 and P13.

The protein-like fraction, represented by the amino acids tryptophan, T and tyrosine, B was excited with 280 nm and exhibited the greatest fluorescence signal between 300 – 350 nm. The amino acids are indicators of the microbial activity within a water sample, the high fluorescence intensity of this fraction generally signifying bad water quality. Lakes P2 and P1 had the most intense protein-like signal, which can be explained by the household and industrial discharges being released into the waters. Samples P14 and P16 also had higher concentrations of protein-like substances, probably related to the presence of restaurants and larger aquatic birds communities.

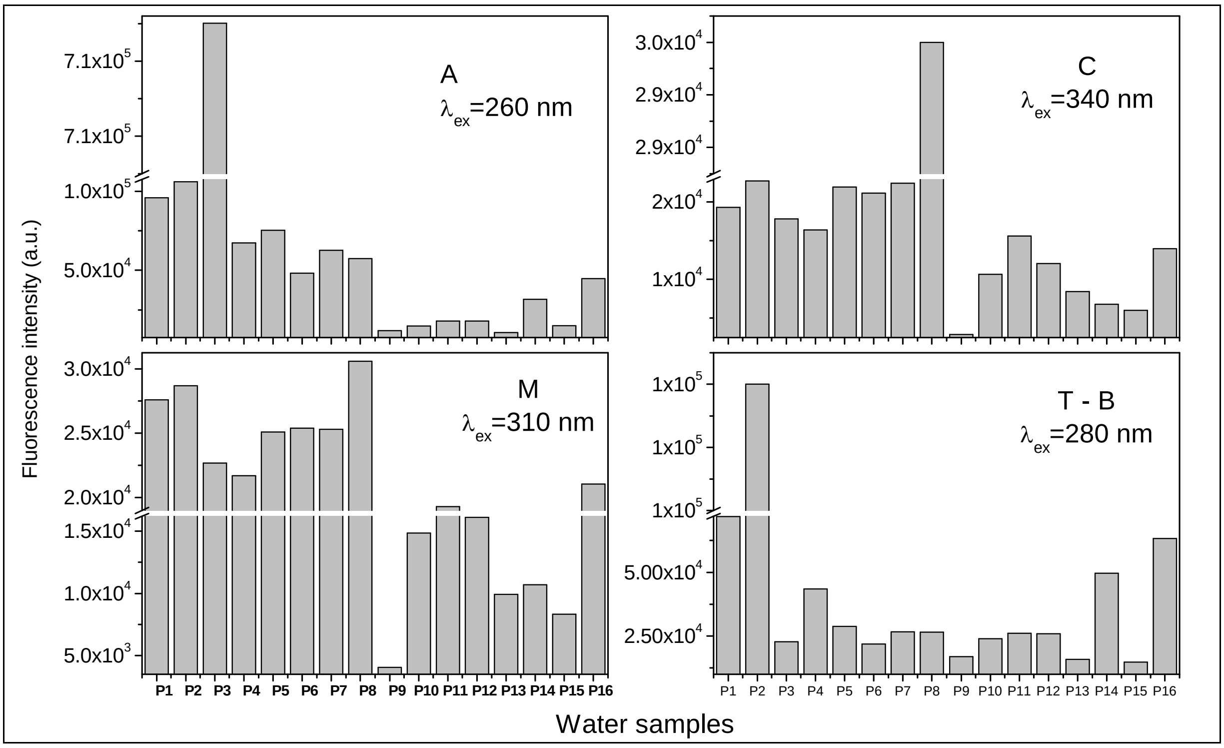

Figure 3: Standard chemical parameters of the lake water samples

From the acquired fluorescence spectra, several indices were calculated, in order to describe the nature of DOM in the chosen lake water samples. The humification index, HIX (Zsolnay, 2003) classifies DOM as a function of the relative proportions of humified and bacterial material. The biological index, BIX (Huguet et al., 2009) indicates the biological activity of aquatic DOM. The f_{450}/f_{500} index (McKnight et al., 2001), is an indicator of the organic matter source in water systems, differentiating between microbially and the terrestrially-derived DOM.

The graphical representation of the fluorescence indices is given in figure 4. HIX values ranged from 0.59 to 2.48, while BIX values varied between 0.76 and 1.31. These are very small variations and not enough to separate the samples into different classes. Both indices indicated the predominance of autochthonous DOM of microbial origin. Unlike HIX and BIX, the f_{450}/f_{500} values obtained (below 1.4) indicated terrestrially-derived DOM, probably due to a high input of organic matter coming from the slopes. This confirms previous statements that f_{450}/f_{500} might not be very suitable for all types of water samples (Huguet et al., 2009). The reason behind this seems to be that this index was created to describe the fulvic-like substances, and could not describe very accurately water samples in which DOM derives from a variety of sources and samples which could contain important quantities of non-humic substances.

The fact that HIX and BIX indicated generally a low contribution of humified material and a stronger, predominantly bacterial origin of DOM in lakes is not surprising. Lakes are not very ventilated systems; most of them have a flow of only 1-2 m/s, which favours an increased activity of the protein-like components of DOM. Also, most of these lakes are influenced by surface runoff, aquatic vegetation and birds and illegal waste waters dumping, which increase the microbial degradation of the water bodies.

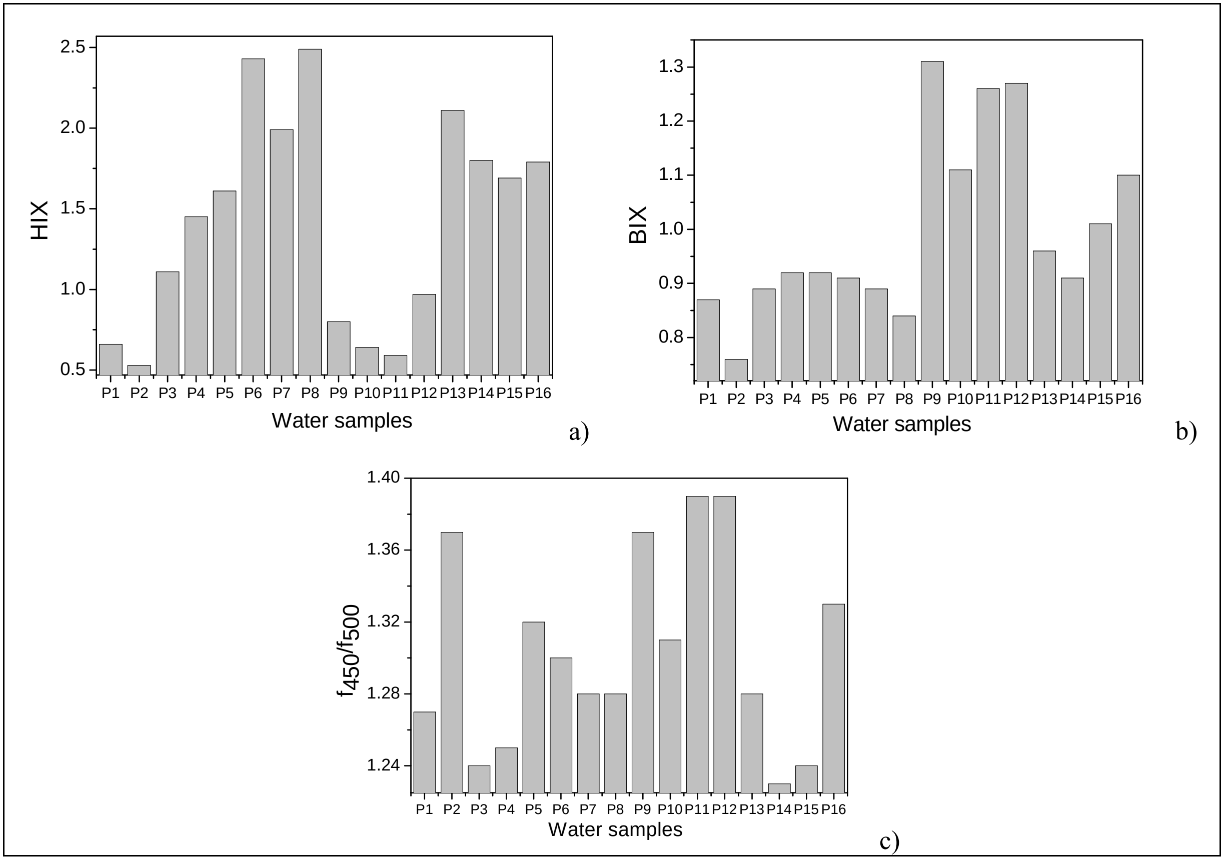

Figure 4: Variation of the fluorescence indices: a) the humification, b) the biological and c) the f_{450}/f_{500} index

Another indicator of the lake water quality is the chlorophyll-a production. This is related to the eutrophication level of a lentic system, which can be influenced by antropic inputs (mainly waste water discharge) and surface runoff. The fluorescence signal of chlorophyll-*a* can be detected at

680 nm emission, when using an excitation wavelength of 420 nm. Figure 5 illustrates the fluorescence intensity of chlorophyll-*a*, for all 16 lakes analyzed. According to this graph, the most eutrophic lakes are P1, P3, P2, P4, P8 and P14. This was also suggested earlier by the high concentrations of humic-like substances found for these samples.

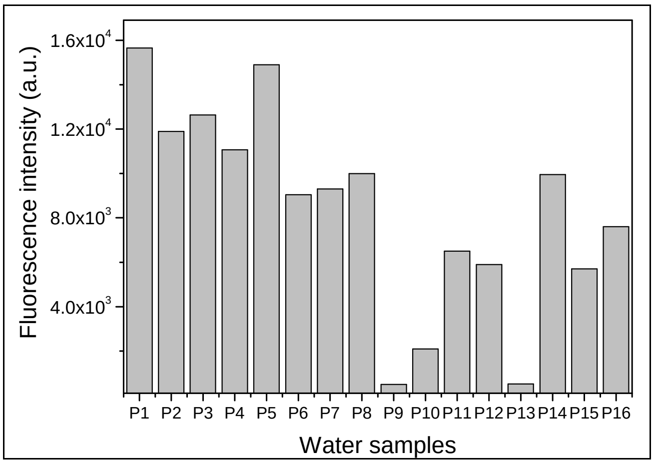

Figure 5: Chlorophyll – *a* levels in the urban lentic systems

Degradation of the water quality was observed for lakes which are close to individual residential areas (P1 – P8) as compared with lakes surrounded by green spaces or collective residential areas (P9 – P16). Generally, it could be noted that the external lakes (P1 – P8) had higher concentrations of dissolved organic matter, as opposed to the internal lakes. Sample P9, with the lowest DOM concentration was characterized by the smallest values of ammonia, COD and nitrates and also had the least degree of eutrophication. The strongest fluorescence signal, of all major fluorophores, was detected for the eutrophic lakes which are closest to the entrance to the city, P1, P2 and P3. Correlated with the facts that these lakes were characterized by high values of the chemical parameters (COD, nitrates, ammonia, dissolved oxygen) and that they were ascribed to the third general water quality (Official Monitor of Romania, 2006), it could be concluded that high concentrations of dissolved organic matter generally indicate a bad ecological status of the water body.

CONCLUSIONS

From the analysis of chemical and fluorescence data of water samples from Bucharest lakes, it was found that external lakes have worst ecological status than the internal lakes. This could be explained by the fact that these lakes are subjected to the negative influence of the individual residential areas in their proximity, not connected to the sewerage system, opposing the internal lakes, which are surrounded by parks and collective residential areas and which are arranged only for leisure activities. The obtained results are important because of the ever growing need to protect and conserve the natural resources, including urban lentic ecosystems. This task can be facilitated by the rapid, accurate assessment of the water quality of these systems. The fluorescence response of the lake water samples analyzed here revealed similar features as the standard chemical analysis, leading to the idea that fluorescence could be used as pre-analysis method for the rapid assessment of the ecological state of urban lentic systems.

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