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ASSESSMENT OF URBAN DEVELOPMENT IMPACT ON LIMNOLOGICAL SYSTEMS

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Abstract

The aim of this study is to evaluate the human impact, in terms of organic matter distribution and chlorophyll found in representative lakes from Bucharest city. The water quality of these lakes was evaluated using fluorescence spectroscopy together with conductivity and pH. Fluorescence data, in the form tryptophan/humic acid ratio, was used to evaluate the humification degree and to evidence the level of microbial contaminations of water lakes. Graphical representation of fluorescence ratio, Chl-*a* intensity, conductivity and pH was used to divide the analyzed samples in two groups. A quality score of 0 or 1 was introduced to delimitate between good or poor water quality using threshold values. The use of quality scores was helpful in realisation of a water quality map with Bucharest's lakes, indicating the limnological systems' ecological state. The results showed that the analysis of chromophoric organic matter can be useful in identifying the negative human influence on urban lakes.

Keywords: urban lake, water quality, dissolved organic matter, fluorescence spectroscopy

1. INTRODUCTION

Human society depends on water to sustain all of life's aspects: domestic, agricultural, industrial and recreational. That is why, since the beginning of mankind, human settlements were formed around some type of water body. The process of urbanization is defined by the continuous growth of the population and, along with it, the need for more resources and the desire for utilities. Irrational consumption and discharge patterns leave a negative mark on the environment, including on the water and soil systems.

Urban lakes' water quality can be altered through the input of surface runoff, through diffuse pollution coming from wastewater discharges or through industrial pollution (Le et al., 2010, Howell et al. 2012, Thevenon et al., 2011). Despite from surface runoff, which is has a seasonal trend, the human influence generated by wastewaters has a permanent character.

Evaluating the quality of natural resources is an important aspect in maintaining their proper state and insuring they do not become a threat to human health. Fluorescence spectroscopy is widely used nowadays as a tool to check the quality of natural water resources. Many studies have been performed, proving fluorescence spectroscopy's ability to accurately detect water quality and features, based on the dissolved organic matter (DOM) content (Fu et al., 2010, Fellman et al. 2010, Korak et al., 2014). The major fluorescent bands of DOM are given by the protein-like (tryptophan, tyrosine) and humic-like substances (humic acid), each of them having specific fluorescence excitation-emission wavelengths (Coble, 1996). High levels of tryptophan and tyrosine are indicators of microbial DOM from allochthonous sources (Baker & Inverarity, 2004). Humic acid is related to the organic matter formed through the natural decomposition of plant tissues (Bieroza et al., 2010).

The aim of this paper was to evaluate the DOM and chlorophyll-*a* (Chl-*a*) distribution found in lakes from Bucharest city and to create a "hot map", pointing out the areas where lake water quality does not attain the imposed standards.

2. METHODS

For the purpose of the study, eight urban lakes from Bucharest city were investigated, hereafter named L1 - L8, as listed in Table 1. The lakes are situated within the city limits and mainly serve as recreational facilities (Ioja, 2008). The type and main geographical features of the lakes are different. Some of the lakes are semi-natural (L3, L7, L8), while others are entirely anthropic, with pure concrete basins (L1, L4, L5), or partially dammed borders (L6). Lake L2 is an anthropic lake, created on the course of Dambovita River, to prevent floods. Table 1 also reflects the major possible contamination sources of the lakes.

Table 1. Characteristics of selected lakes

Lake / Type	Main geographical features	Possible environmental sources
Moghioros (**L1**) Anthropic	•located in Drumul Taberei Park •1.64 ha surface; low depth •100% concrete basin	• pluvial water • garden wastes
Morii (**L2**) Reservoir lake	•located along Dâmbovita River •for flood control •239 ha surface •banks are dammed	• residential areas • unorganised landfills
Circului (**L3**) Semi-natural	•located in Circ Park •0.8 ha surface •banks are not dammed •anthropic water source, pumped from groundwater	• pluvial waters • garden wastes • aquatic birds and plants
Morarilor (**L4**) Anthropic	•located in Morarilor Park •1.17 ha surface; low depth •100% concrete basin	• pluvial waters • garden wastes
National Park (**L5**) Anthropic	•located in National Park •2.05 ha surface; low depth •100% concrete basin	• pluvial waters • garden wastes
IOR (**L6**) Anthropic	•located in Titan Park •18 ha surface •partially dammed borders	• pluvial waters • garden wastes • restaurants • aquatic birds
Carol (**L7**) Semi-natural	•located in Carol Park •1.53 ha surface •dammed banks •water surplus discharged to sewage network	• vegetation • birds • restaurants • pluvial waters
Tineretului (**L8**) Semi-natural	•located in Tineretului Park •13 ha surface •dammed banks in order to reduce the sediments input from the slope •clogging is an important issue, especially due to biological compounds accumulation	• sediments from lake bottom • vegetation • birds • restaurants • pluvial waters

Pluvial waters and garden wastes represent the predominant water degradation sources for lakes situated in the Northern, Eastearn and Western parts of the city. Lakes which are most subjected to the anthropogenic influence are L6, L7 and L8, influenced by inputs of organic and inorganic matters from the slopes, communities of birds living on the shores and by some urban functional areas (e.g. the restaurants, residential area, located on the borders).

For each site, water from the middle of the lake, from the epilimnion, was collected during summer period. The samples were filtered using 0.45 µm PFTE filter, in order to remove the insoluble organic matter and then analyzed through fluorescence spectroscopy, using Edinburg Instruments FLS 920 spectrofluorimeter. Fluorescence was recorded as emission spectra between 250-500 nm, for excitation with 230 nm, 240 nm and 285 nm wavelengths. The Chl-*a* content was evaluated based on the fluorescence emission maximum registered at approximately 680 nm, for excitation with 420 nm wavelength. Additionally, pH and conductivity of the samples were measured with conductivity/pH meter Consort C352.

The spatial distributions were created using the ArcGIS 10.2, based on ortophotoplans from 2008.

3. RESULTS AND DISCUSSION

From the fluorescence data, the DOM components in water samples were evaluated by means of the excitation/emission wavelength pairs ($\lambda_{ex}/\lambda_{em}$) corresponding to their maxima, as follows: 285/335 nm for tryptophan (T), 230/325 nm for tyrosine (B) and 240/445 nm for humic acid (A). The values of these parameters for all lakes are presented in Figure 1. High values of T and B are connected with intense microbial activity due to anthropic activities, while A indicates the humification degree of the dissolved organic matter. Anthropic lakes, L1, L4 and L5, which have concrete basins, appear to have good quality, with the lowest intensities of DOM fractions. The highest fluorescence intensities were found for samples L3, L6 and L8, which have common degradation sources coming from garden wastes and the bird communities. The static nature of lakes gives rise to the appearance of both protein-like components, tryptophan and tyrosine, in the samples, which does not generally occur in the case of more ventilated systems, such as rivers.

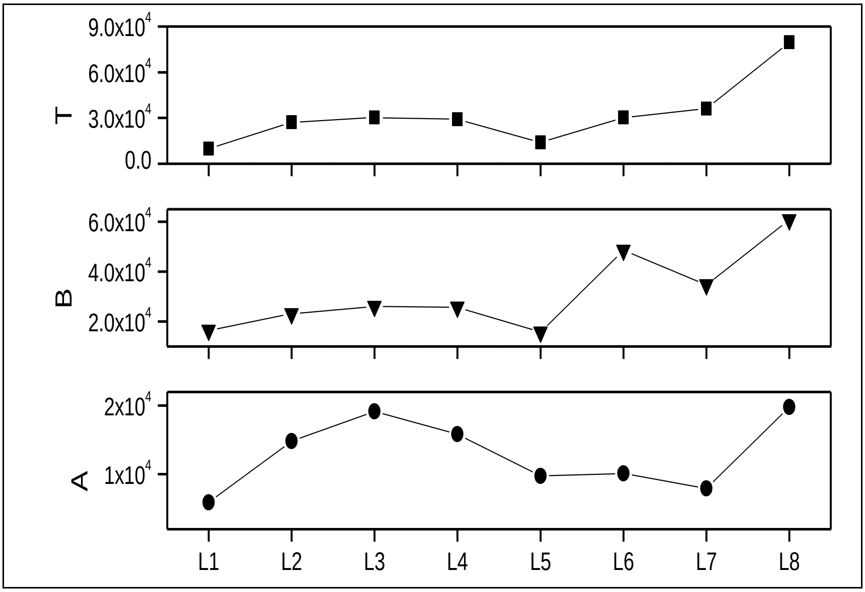

Figure 1. Fluorescence intensities associated with DOM components and Chl-*a*

The values of Chl-*a*, pH and conductivity of the samples, and the general classification of the lakes water quality, according to Romanian regulations (Law 310/2004), are included in Table 2. From the fluorescence data, the ratio between tryptophan and humic acid maxima, T/A has been calculated for all lakes (Table 2). Deriving fluorescence ratios can eliminate some of the uncertainty associated with the performed measurements and the inter-sample variations. The T/A relationship is useful for determining the degree of humification of samples and can point out potential microbial contaminations. The fluorescence ratio was suitable for identifying lakes with poor water quality. The calculated values were high for samples L6, L7, L8, signifying a higher influence of the bacterial DOM. These lakes are eutrophic, and subjected to specific degradation sources, such as restaurants discharges and the input from the large aviary communities. Lakes L1, L2, L3, L4 and L5 had lower T/A values, suggesting the presence of more humified organic matter, formed through the conversion of plant and animal products (Ohno, 2002). Clean lakes usually have higher content of humic-like material as compared with the protein-like.

Conductivity and pH measurements showed that lakes L1 and L2 have good water quality, with low values, given by the lack of degradation sources, the high water volume (L2) and by the input of chlorinated water from urban water supply network, used to control the water level (L1). Lakes L6, L7 and L8 are definitely affected by the anthropic activities, through low rate of water change in the lakes correlated with illegal wastewaters discharges from the border functions, the geomorphological features (high slope that favors the drain of organic and inorganic sediments) and the border vegetation inputs (especially in the autumn season).

High Chl-*a* values are representative for the excessive growth of phytoplankton, which is associated with poor water quality. This is often the result of organic matter rich sediments, nutrients inputs from anthropogenic activities and surface runoff (Ghervase et al. 2011; Novoa et al. 2012). Fluorescence measurements of Chl-*a* indicated that lakes L6, L7 and L8 have eutrophication problems, probably arising from the specific degradation sources.

The ecological status classification of water quality, according to the Romanian legislation, categorizes waters as very good (I), good (II), moderate (III), weak (IV) and poor (V). Quality classes I-III include waters without or with minor to medium anthropogenic influence on the physico-chemical, biological and hydromorphological quality elements. Classes IV and V are assigned to waters with status below moderate (Law 310/2004).

Table 2. Measured and calculated parameters for the selected limnological systems

Lake	L1	L2	L3	L4	L5	L6	L7	L8
T/A	1.64	1.84	1.57	1.83	1.42	3.00	4.56	4.02
Chl-*a* intensity (a.u.)	200	2100	6500	5900	520	9950	5700	7600
Conductivity (μS/cm^2)	730	713	726	753	691	981	1270	1309
pH	7.53	7.39	7.57	7.89	7.42	7.82	7.70	7.78
Ecological status classification	I	II	III	III	III	IV	IV	IV

Graphical representation of parameters listed in Table 2, T/A ratio, Chl-*a* intensity, conductivity and pH, indicated that samples could be divided in two groups, as can be seen in Figure 2. A threshold value was established for each parameter, delimiting between good or poor water quality. The threshold values are as follows: 2.5 for the T/A ratio, 5000 a.u. for Chl-*a*, 900 μS/cm^2 for conductivity, and 7.7 for pH. For T/A, samples L1, L2, L3, L4 and L5 had values below the limit, while samples L6, L7 and L8 had higher values, denoting microbial contamination. For the fluorescence intensity associated with Chl-*a*, samples L3, L4, L6, L7 and L8 appeared to have eutrophication problems. Conductivity also demarcated samples L6, L7 and L8 from the rest. pH values were under the set limit for samples L1, L2, L3 and L5. The established thresholds appear to fairly describe the waters: lakes L6, L7 and L8, included in the IV quality class, had T/A, pH, conductivity and Chl-*a* values above the set limits

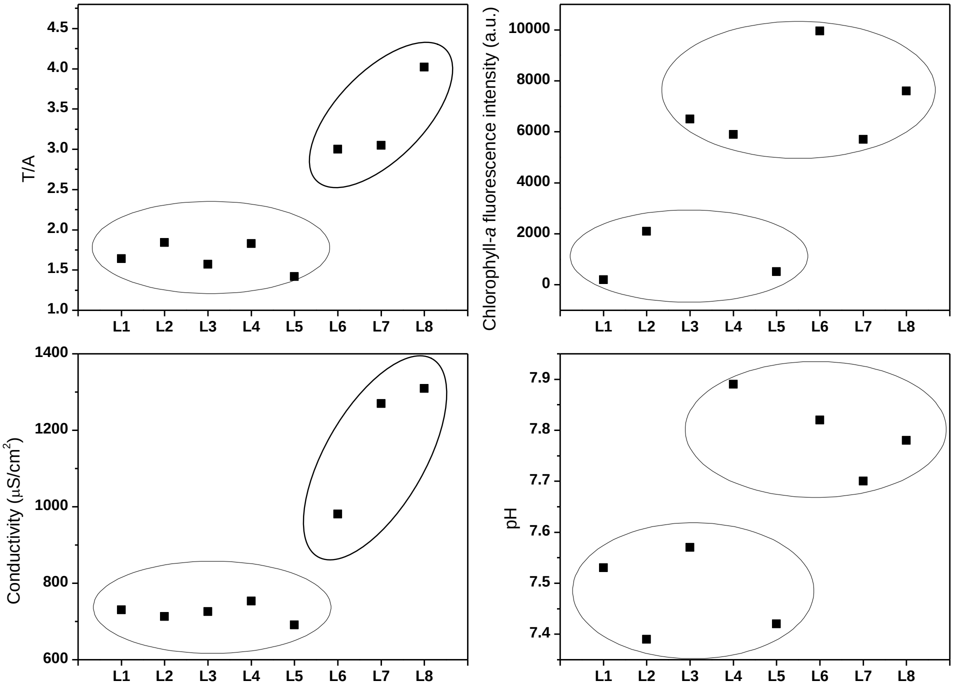

Figure 2. T/A, Chl-*a*, conductivity and pH values

For each parameter, the values below the threshold were assigned a quality score of 0, and values above the established limit were given a score of 1, as shown in Table 3. The predominant scores for each sample were attributed as general score, representative for the water quality. Lakes L1, L2, L3 and L4 received a general score of 0, meaning they have good water quality, in agreement with the current legislation, which classifies them as group I-III, with good or acceptable water quality. Lakes L6, L7 and L8 obtained general scores of 1, which is consistent with the standard ecological status classification from Table 2. However, the results for sample L4 are inconclusive, as this sample had equal scores of 0 and 1.

Table 3. Scores of the urban lakes

Lake	L1	L2	L3	L4	L5	L6	L7	L8
T/A	0	0	0	0	0	1	1	1
Chl-*a* intensity (a.u.)	0	0	1	1	0	1	1	1
Conductivity (µS/cm2)	0	0	0	0	0	1	1	1
pH	0	0	0	1	0	0	1	1
General score	0	0	0	0/1	0	1	1	1

Using the general score attributed to each lake, a map was created for Bucharest, illustrated in figure 3.

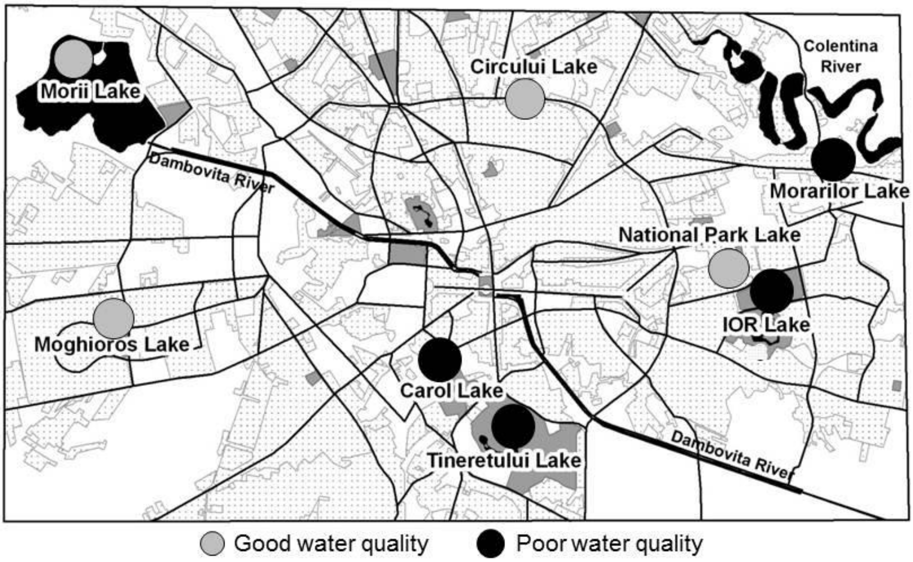

Figure 3. Water quality map of Bucharest's lakes

The represent lakes with general score of 1, lakes where there is a degradation of the water quality, arising from the uncontrolled discharge of wastewaters and from excess eutrophication. The gray marks represent lakes with good or acceptable quality, which received a 0 score. Sample L4, with equal scores of 0 and 1, was represented by a black mark, due to high values of Chl-*a* and pH.

The use of quality scores was helpful in creating water quality map of Bucharest's lakes, indicating the limnological systems that should be investigated more, so as to take the necessary remediation actions. The results showed that the spatial distribution of chromophoric organic matter can be useful in identifying the negative anthropogenic influence.

4. CONCLUSION

Dissolved organic matter (tryptophan, tyrosine, humic acid) and chlorophyll-*a* distributions were determined for lakes from Bucharest city area using fluorescence spectroscopy. Standard parameters (conductivity and pH) together with fluorescence data highlighted that the degradation of water quality was amplified by the low rate of water change in the lakes correlated with illegal wastewaters discharges from the border functions, the geomorphological features (high slope that favors the drain of organic and inorganic sediments) and the vegetation inputs (especially in the autumn season). Fluorescence data, in the form tryptophan/humic acid ratio, were used to evaluate the humification degree and to evidence the level of microbial contaminations of lakes.

Graphical representation of fluorescence ratioT/A, Chl-*a* intensity, conductivity and pH, indicated that samples could be divided in two groups. A quality score of 0 or 1 was introduced to delimitated between good or poor water quality using threshold values (2.5 for the T/A ratio, 5000 a.u. for Chl-*a*, 900 $\mu S/cm^2$ for conductivity, and 7.7 for pH). The quality score was in agreement with the standard ecological status classification of these lakes. The use of quality scores was helpful in creating a water quality map of Bucharest's lakes, indicating the limnological systems' ecological state. The results showed that the analysis of chromophoric organic matter can be useful in identifying the negative anthropogenic influence on urban lakes.

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