The Assessment of Content and Dynamics of Nutrients in Water and Sediments from the Plumbuita Lake, Bucharest

I. Study on Phosphorous Content and Distribution

ECATERINA MARCU[1]*, GYORGY DEAK[1], IRINA ELENA CIOBOTARU[1], ALEXANDRU ANTON IVANOV[1], PETRA IONESCU[1], CARMEN TOCIU[1], ELENA DIACU[2]

[1]National Institute for Research and Development in Environmental Protection, 294 Splaiul Independentei, 060031, Bucharest, Romania
[2]University Politehnica of Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Polizu Str., 011061, Bucharest, Romania

Nutrient pollution of surface waters is a challenge of the modern society, leading to the occurrence of the eutrophication phenomenon which limits the uses of the aquatic resources for various purposes. The aim of this study was the evaluation of water and sediment status of the Plumbuita Lake (Bucharest-Romania), focusing on phosphorous speciation (phosphorous bonded to iron and aluminium, phosphorous bonded to calcium, and soluble and loosely sorbed phosphorous bonded to carbonate) and dynamics as this element has a significant contribution to algal bloom. The results reported herein will allow the understanding and control of the processes that take place within the water body and support the appropriate techniques for the mitigation of water polluted mitigation with phosphorus-based compounds.

Keywords: lake water, phosphorus dynamics, sediment characterisation

Human activities and natural processes are the main sources of water pollution. Among the effects of water pollution, accelerated eutrophication of surface water bodies is an undesirable phenomenon that may occur, and has not been fully understood and managed yet [1,2]. The effects of water eutrophication are numerous, including excessive algae growth, increase of organic matter production, and occurrence of hypoxic/anoxic conditions [3,4].

The causes of water eutrophication are diverse and numerous aspects of this issue have been addressed in the literature [4-15]. Among the factors that contribute to water eutrophication, nutrient content in sediments and the exchange processes that take place at the sediment-water interface play an important role and their assessment contribute to a better characterisation of these processes [5,6,10,12-15,17,19, 20-25,27-32]. Attention has been granted to nutrients speciation and dynamics in the water body as they have a significant contribution to the understanding of eutrophication phenomenon and furthermore to facilitate the development of mitigation techniques. In this context, the reduction of nutrients from wastewater discharged into the aquatic environment is required in order to ensure the protection of water quality and human health [5-10,12-36].

This study aims the characterisation and the dynamics of several quality indicators for the evaluation of eutrophication of Plumbuita Lake. This lake is located in the northern part of Bucharest, Romania, and was formed through Colentina riverbed management and development. The lake has a maximum depth of 4.5 m, with an average depth of 2.5 m. The lake is aerated during summer by means of intermittent fountains. An island (with an area of 1.92 ha) is located on the lake surface [37].

The results of the study regarding the eutrophication process of Plumbuita Lake are reported in two parts: the first part is focused on assessment of phosphorous species and distribution in water and sediments, the second part being devoted to nitrogen contribution to eutrophication.

* email: ecaterina.marcu@incdpm.ro; Phone: (+40)213052681

Experimental part

Samples of water and sediments were taken from the Plumbuita Lake at the geographic coordinates 44°272 57.43 -44°282 16.63 N, 26°072 49.23 -26°072 57.63 E, where an islet is formed at the end of the lake and determines the occurence of hypoxic conditions. Water sampling was conducted during the year 2015 on points P1, P2, and P3 shown in figure 1. The sampling points P1 and P3 were located on both sides of the inlet, while the sampling point P2 was located at the end of the inlet. The samples were taken from the near-bottom water at a distance of 1.5 m from the lake shore.

For a comprehensive evaluation of the eutrophication process of Plumbuita Lake, together with phosphorous species other significant physicochemical parameters were evaluated that are necessary for the characterisation of the status of the water lake, such as temperature, *p*H, oxygen consumption (quantified as biochemical and chemical oxygen demand).

Water indicators were analysed using adequate standardised methods and validated similar to procedures described elsewhere [38,39].

Sediment core samples consisting of two distinctive layers were taken from each sampling point. Sediment preparation included drying at room temperature, milling and sieving through a 90 μm-sieve. Phosphorus species were analysed according to a procedure (fig. 2) starting from the extraction procedures described in literature [17,20,26,29]. The analysed phosphorous species from

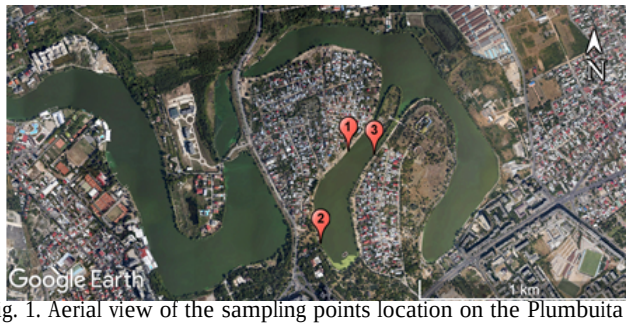

Fig. 1. Aerial view of the sampling points location on the Plumbuita Lake [37]

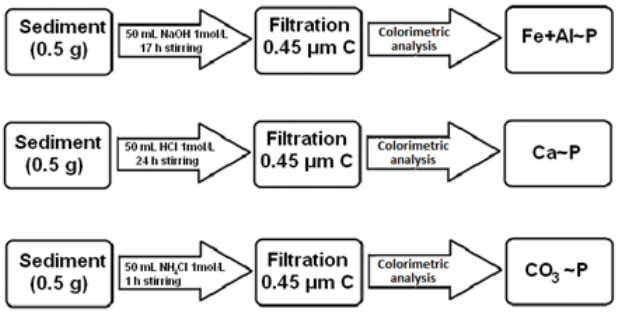

Fig. 2. The extraction procedure used for the analysis of nitrogen species from the sediment [29]

The phosphorus species were analysed starting from a mixture of dried sediment and extraction agent which was subjected to magnetic stirring followed by filtration through a 0.45µm cellulosic filter prior rinsed with boiled doubly distilled water. The filtrate was further subjected to direct colorimetric analysis.

Results and discussions

The results of the water quality indicators monitored within this study (table 1) were compared to those included in the Romanian Ministry Order no. 161/2006 [41].

The results highlighted *p*H values exceeding the domain provided by [41] during July. As to the other indicators, their values fall mainly in the first and second quality class, with few exceptions, as follows: the biochemical and chemical oxygen demand and total phosphorous during July and September fall in the fourth and third quality class.

Table1
WATER QUALITY PARAMETERS FOR PLUMBUITA LAKE

Indicator	Unit	Minimum value - maximum value (mean value)
Temperature	°C	8.8-31 (20.8)
pH	pH units	7.5-9.43 (8.32)
Dissolved oxygen (DO)	mg O_2/L	7.58-13.07 (10.64)
Biochemical oxygen demand (BOD_5)	mg O_2/L	3.39-8.73 (6.84)
Chemical oxygen demand (COD-Mn)	mg O_2/L	4.56-13.94 (9.23)
Chemical oxygen demand (COD-Cr)	mg O_2/L	14.38-97.91 (40.67)
Phosphates (PO_4^{3-})	mg/L	0.01-0.05 (0.02)
Total phosphorus (TP)	mg/L	0.07-0.46 (0.20)

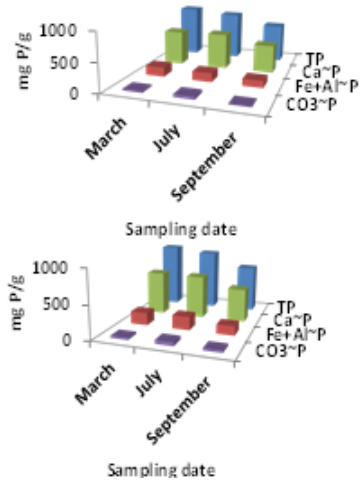

Fig. 3. Total phosphorous and phosphorous species in: (a) the upper layer and (b) the lower layer of sediment samples from the P1 sampling point: TP - total phosphorus content; Ca~P - phosphorus bonded to calcium; Fe+Al~P - phosphorus bonded to iron and aluminium; CO_3~P - phosphorus bonded to carbonate

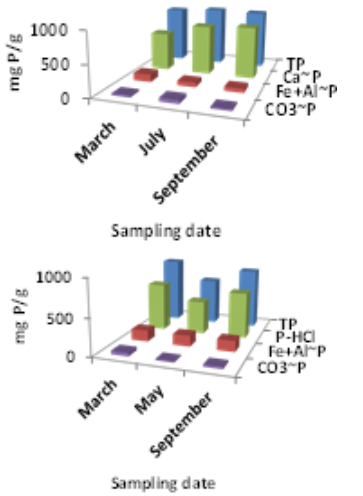

Fig. 4. Total phosphorous and phosphorus species in: (a) the upper layer and (b) the lower layer of sediment samples from the P2 sampling point: TP - total phosphorus content; Ca~P - phosphorus bonded to calcium; Fe+Al~P - phosphorus bonded to iron and aluminium; CO_3~P - phosphorus bonded to carbonate

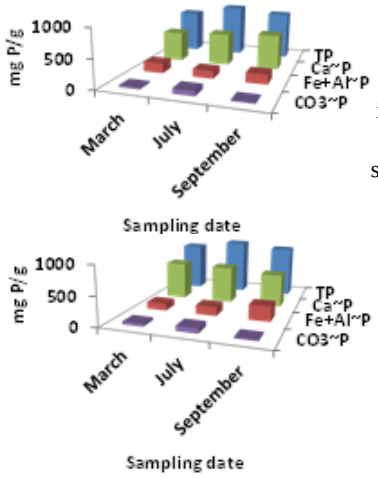

Fig. 5. Total phosphorous and phosphorus species in: (a) the upper layer and (b) the lower layer of sediment samples from the P3 sampling point: TP - total phosphorus content; Ca~P - phosphorus bonded to calcium; Fe+Al~P - phosphorus bonded to iron and aluminium; CO_3~P - phosphorus bonded to carbonate

sediments include phosphorous bonded to iron and aluminium (Fe+Al~P), phosphorous bonded to calcium (Ca~P), and soluble and loosely sorbed phosphorous bonded to carbonate (CO_3~P).

Total phosphorous has an increasing tendency during July together with a decrease of dissolved oxygen and the occurrence of anoxic conditions.

The spatial and seasonal variability of sediment samples (figs. 3-5) with the lowest nutrients concentrations during July is due to the abundant vegetation and to a decrease of dissolved oxygen content, as the occurrence of hypoxic conditions may cause the release of nutrients in the near-bottom water.

Results show that sediments are characterised by high contents of phosphorous bonded to calcium (Ca~P), representing as much as 88% of the total phosphorous content of the sediments, regardless of the core depth, followed by phosphorous bonded to iron and aluminium (up to 30% of the total phosphorus content of the sediments). According to the available literature data, the fraction of phosphorous bonded to calcium consists mainly of apatite and releases phosphorous at low *p*H values [26,29].

The lowest concentrations were observed for the phosphorous fraction bonded to carbonates (CO_3~P),

which represents only up to 10% of the total phosphorous content of the sediments. This is the loosely adsorbed phosphorous and is prone to desorption. Its low values may be attributed to a continuous dissolution process that takes place at the sediment-water interface.

Results show an increase of the content of loosely adsorbed phosphorous during July followed by a decrease during September. The results also highlighted a slight difference (up to 16% of the total phosphorous content) between the total phosphorus and phosphorous species, which was attributed to organic phosphorous.

The results show a similar variation in the case of phosphorous for all three sampling points, with lower values in September, when the lake is characterised by low values of dissolved oxygen. The decrease of this indicator may be associated with the hypoxic conditions that occur in the lake during summer and at the beginning of autumn that may lead to the desorption of loosely adsorbed phosphorous from the sediment due to a continuous dissolution process that takes place at the sediment-water interface [12, 42]. These results are consistent with the results reported in [43], which proved that the phosphorous may be released from the sediment as a result of the decrease of dissolved oxygen in water due to high organic matter content and to a phosphorous sedimentation process.

Conclusions

This study showed the results of the monitoring of quality of water and sediments together with the dynamics of phosphorous from the Plumbuita Lake (Bucharest, Romania). According to the results of this research, the physicochemical indicators of water quality fall in the first and second water quality class as regulated by the Romanian legislation, with few exceptions.

The evaluation of sediment quality highlighted a significant spatial and seasonal variability as regards to phosphorous content, with the lowest concentrations during summer and at the beginning of autumn due to abundant vegetation and to a decrease of dissolved oxygen content, as the occurrence of hypoxic conditions may cause the release of nutrients in the near-bottom water. The results showed high contents of phosphorous bonded to calcium (up to 88% of the total phosphorous content of the sediments) which is prone to release at low *p*H values, followed by phosphorous bonded to iron and aluminium (up to 30% of the total phosphorus content of the sediments) and phosphorous bonded to carbonates (up to 10% of the total phosphorous content of the sediments).

Local authorities may also take advantage of the results reported herein regarding the content of phosphorous in their efforts to identify the most appropriate remediation techniques for the Plumbuita Lake. For an overall image of the assessment of lake eutrophication, the contribution of nitrogen-based compounds has been investigated and is to be presented in a subsequent report.

Acknowledgments. This work was funded by the National Authority for Scientific Research and Innovation through Contract 6N/February 2009, Additional Contract 1/2015, project PN 09.06.02.40. The authors acknowledge the ongoing support given by the National Institute for Research and Development in Environmental Protection management and staff members throughout the entire project.

References

1. DEAK, Gy., DAESCU, V., HOLBAN, E., MARINESCU, P., TANASE, G., CSERGO, R., DAESCU, A.I., GAMAN, S., J Environ Prot Ecol., **16**, 2015, p.304.
2. CIRTINA D., MITRAN R.V., Annals of Constantin Brâncuºi University of Târgu Jiu, Engineering Series, **3**, 2011, p.338.
3. YANG, X., WU, X., HAO, H.-I., HE, Z.-L., J Zhejiang Univ-Sc B, **9**, 2008, p.197.
4. QIN, B.Q., GAO, G., ZHU, G.W., ZHANG, Y.L., SONG, Y.Z., TANG, X.M., XU, H., DENG, J.M., Chinese Sci Bull, **58**, 2013, p.961.
5. NÜRNBERG, G.K., Limnetica, **10**, 1994, p.1.
6. CARPENTER, S.R., P Natl Acad Sci USA, **102**, 2005, p.10002.
7. KHAN, F.A., ANSARI, A.A., Bot Rev, **71**, 2005, p.449-482.
8. LUKKARI, K., HARTIKAINEN, H., LEIVUORI, M., Limnol Oceanogr-Meth, **5**, 2007, p.433.
9. SEN, S., HAGGARD, B.E., CHAUBEY, I., BRYE, L.R., COSTELLO, T.A., MATLOCK, M.D., Water Air Soil Poll., **179**, 2007, p.67.
10. CHAO, W., JIN, Q., ZHI-YONG, G., LI, Z., XIAO-CHEN, L., Pol J Environ Stud, **17**, 2008, p.155.
11. WANG, H., WANG, H., Prog Nat Sci., **19**, 2009., p.1445.
12. WANG, Q., LI, Y., J Soil Sediment, **10**, 2010, p.1159.
13. GAO, L., Procedia Environ Sci, **13**, 2012, p.2077.
14. ZHANG, K., CHENG, P.-D., ZHONG, B.-C., WANG, D.-Z., J Hydrodyn, **24**, 2012, p.589.
15. ZHU, Y., ZHANG, R., WU, F., QU, X., XIE, F., FU, Z., Environmental Earth Sciences, **68**, 2012, p.1041.
16. KEMP, A.L.W., MUDRUCHOVA, A., Limnol Oceanogr, **17**, 1972, p.855.
17. OLILA, O.G., REDDY, K.R., HARRIS, W.G., Hydrobiologia, **302**, 1995, p.147.
18. AUER, M.T., TOMASOSKI, K.A., BABIERA, M.J., NEEDHAM, M.L., EFFLER, S.W., OWENS, E.M., HANSEN, J.M., Lake Reserv Manage, **14**, 1998, p.278.
19. HOUSE, W.A., WARWICK, M.S., Hydrol Process, **13**, 1999, p.1103.
20. RYDIN, E., Water Resour, **34**, 2000, p.2037.
21. GOLTERMAN, H.L., Limnetica, **20**, 2001, p.15.
22. HU, W.F., LO, W., CHUA, H., SIN, S.N., YU, P.H.F., Environ Int, **26**, 2001, p.369.
23. FYTIANOS, K., KOTZAKIOTI, A., Environ Monit Assess, **100**, 2005, p.191.
24. HAGGARD, B.E., SOERENS, T.E., Ecol Eng, **28**, 2006, p.280.
25. MOOSMANN, L., GACHTER, R., MULLER, B., WÜEST, A., 2006, Limnol Oceanogr, **51**, p.763.
26. KAPANEN, G., Est J Ecol, **57**, 2008, p.244.
27. DA SILVA, I.S., TERRAE, **6**, 2009, p.52.
28. MIDDELBURG, J.J., LEVIN, L.A., Biogeosciences, **6**, 2009, p.1273.
29. SAHIN, Y., DEMIRAK, A., KESKIN, F., Lakes, reservoirs and ponds, **6**, 2012, p.139.
30. WANG, X., Procedia Environ Sci, **12**, 2012, p.379.
31. KANGUR, M., PUUSEPP, L., BUHVESTOVA, O., HALDNA, M., KANGUR, K., Est J Earth Sci, **62**, 2013, p.171.
32. TOPCU, A., PULATSU, S., J Agr Sci, **20**, 2014, p.63.
33. IONESCU, P., RADU, V.-M., DIACU, E., Rev Chim (Bucharest), **66**, 2015, p.1725.
34. JINGFU, W., JINGAN, C., DALLIMORE, C., HAIQUAN, Y., ZHIHUI, D., Lake Reserv Manage, **31**, 2015, p.214.
35. RADU, V.-M., DIACU, E., IONESCU, P., DEAK, Gy., Rev Chim (Bucharest), **66**, 2015, p.601.
36. TOCIU, C., DIACU, E., U Politeh B Ser B, **77**, 2015, p.29.
37. Administratia Lacuri, Parcuri si Agrement Bucuresti, https://www.alpa.ro.
38. SR EN ISO 6878-2005, Water quality standard, Determination of the total phosphorous by means of the spectrophotometric method and ammonium molybdate, Romanian Association for Standardization (ASRO), 2005.
39. IONESCU, P., DIACU, E., RADU, V.-M., U Politeh B Ser B, **76**, 2014, p.23.
40. Google Earth, https://earth.google.com.
41. Order 161/16.02.2006 on the approval of the Normative regarding the classification of the quality of surface water in order to establish the ecological status of water bodies.
42. KATSEV, S., TSANDEV, I., L'HEUREUX, I., RANCOURT, D.G., Chem Geol, **234**, 2006, p.127.
43. GACHTER, R., WEHRLI, R., Environ Sci Technol, **32**, 1998, p.3659.

Manuscript received: 11.05.2017