Available online at www.worldnewsnaturalsciences.com

World News of Natural Sciences

WNOFNS 1 (2015) 1-9 EISSN 2543-5426

Total alkaline phosphatase activity (ALP-EC 3.1.3.1) of water in the River Odra estuary (North-West Poland)

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ABSTRACT

The Odra estuary includes, as its major part, the brackish Szczecin Lagoon. This consists of two parts: the Kleines Haff (located in Germany) and the Wielki Zalew located in Poland. The Lagoon receives the River Odra water supplied from the south; prior to being discharged into the Lagoon, part of the Odra flow passes through Lake Dąbie. In its northern part, the Lagoon connects – via three straits (the Peene, Świna and Dziwna) - with the Pomeranian Bay, a Baltic embayment. Water in the lakes of the River Odra estuary were the subjects of a five-year study (2008-2012). Total alkaline phosphatase activity was determined seven times a year in these environments. The zonal study demonstrated that the top sub littoral layer (1 m) featured the highest alkaline phosphatase activity among all the analyzed zones. A study of seasonal fluctuations showed that a maximum total alkaline phosphatase activity occurred in spring (May) and summer (July, August). Basing on this parameter, no increase in eutrophication process in the River Odra estuary was determined in the course of a 5-year study.

Keywords**:** total alkaline phosphatase activity, lake water, River Odra estuary

1. INTRODUCTION

To address the increasing degradation of surface waters in the European Union, the approach to the evaluation and protection of water resources was changed. This approach was formulated in the European Union Water Framework

Directive (2000/60/EC), which calls for the protection of water, as well as an environment- friendly and comprehensive approach to water assessment.

The ecological status of surface waters and groundwater is assessed on the basis of the ecological potential of the biological and physico-chemical and hydromorphological indicators. Phosphorous plays a key role in biological production and thereby in the eutrophication of the water environment. One of the important processes impacting on the level of available mineral phosphorous is enzymatic hydrolysis of organic bonds of this element.

Phosphatase enzymes are attached to cell surfaces or are freely dissolved in the water column resulting from cell lysis or excretion. Upon enzyme hydrolysis, PMEs release inorganic phosphate into thewater, along with their organic moiety, thereby increasing inorganic P availability for planktonic, as well as benthic organisms in shallow marine systems].

A majority of previous studies shows that alkaline phosphatase is chiefly responsible for the rate of organic phosphorous mineralization, both in the pelagic zone and in the bottom sediment of water bodies with pH > 7.

However, some authors report, e.g. Yiyong[15], that abiotic factors can also play a part in the process. Jones suggests that the level of phosphatase activity in the water is linked to the degree of lake trophicity. The objective of this paper was to observe in the course of a 5-year period the level and dynamics of annual oscillations and seasonal activity of total alkaline phosphatase in the River Odra estuary. The assumption for this cycle of study was also to demonstrate the usefulness of the applied enzymatic test as a biological indicator of the degree of lake trophicity and possibly of progressing eutrophication of the analyzed water bodies.

2. EXPERIMENTAL

The Odra estuary includes, as its major part, the brackish Szczecin Lagoon which consists of two parts: the Kleines Haff (located in Germany) and the Wielki Zalew located in Poland (Figure 1). The Lagoon receives the River Odra water supplied from the south; prior to being discharged into the Lagoon, part of the Odra flow passes through Lake Dąbie.

In its northern part, the Lagoon connects – via three straits (the Peene, Świna, and Dziwna) - with the Pomeranian Bay, a Baltic embayment. The Odra (German: Oder) estuary is located at the southern Baltic Sea (German - Polish border). It consists of the Szczecin (Oder-) Lagoon and the Pomeranian Bay. The Szczecin Lagoon (687 km2) can be subdivided into the “Large Lagoon” (Polish: Wielki Zalew) on the Polish territory and the “Small Lagoon” (German: Kleines Haff) on the German side. The Lagoon is connected to the Pomeranian Bay via 3 outlets.

The entire estuary is dominated by the discharge of the River Odra (Oder) into the Lagoon. With its length of 854 km and basin area of 120,000 km², the Odra is one of the most important rivers in the Baltic region. The average annual Odra discharge is 17 km^3 (530 m^3 s 1) and it contributes at least 94% to the lagoon's water budget.

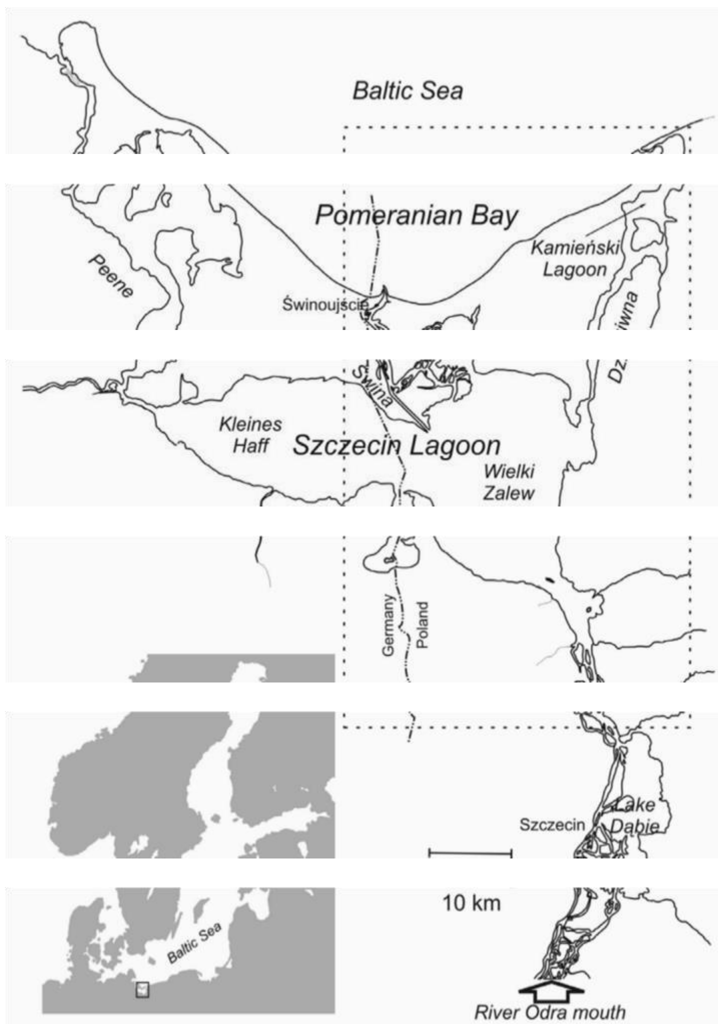

Figure 1. River Odra estuary and sampling Figure sites location.

Samples of littoral and sublittoral water were taken with a Ruttner sampler with a capacity of 2 dm^3. Water were stored for 24 hours at 4 °C. After that time total alkaline phosphatase activity in water was determined with the use of Jones's method[15], which involves detecting coloured p-nitrophenol formed from p-nitrophenol phosphate dissolved in a buffered solution (0.1 M Tris-HCl of pH 8.5).

The study was conducted during 2008-2012. The analyses were carried out 7 times a year (April, May, June, July, August, September and October), in three repetitions. The results presented in the paper constitute mean value calculated from the repetitions.

3. RESULTS AND DISCUSSION

The experimental data on activity of total alkaline phosphatase in water samples collected along the in lakes of the River Odra estuary from the month of 2008 – 2012 (April to October) is presented in Table 1.

The results presented in table 1 demonstrate that total alkaline phosphatase activity in the waters of River Odra estuary over the three-year period of study oscillated between 234.4 – 623.8 nmol p-NP·dm^{-3}·h^{1}. The oscillation range in both zones of the analyzed water body was similar. In the littoral it ranged from 314.8 to 623.8 nmol p-NP·dm^{-3}·$h^{1}$and in sublittoral from 234.4 to 549.6 nmol p-NP·dm^{-3}·h^{1}. The annual average concentration of total alkaline phosphatase (littoral) in the water samples was observed to be 437.5 nmol p-NP·dm^{-3}·h^{1} in 2008 of the year, 443.6 nmol p-NP·dm^{-3}·h^{1}ppm in 2009 of the year, 491.3 nmol p-NP·dm^{-3}·h^{1} in 2010 of the year, 482.8 nmol pNP·dm^{-3}·h^{1} in 2011 of the year and 463.4 nmol p-NP·dm^{-3}·h^{1} in 2012 of the year. The annual average concentration of total alkaline phosphatase (sublittoral) in the water samples was observed to be 358.1 nmol p-NP·dm^{-3}·h^{1} in 2008 of the year, 375.3 nmol pNP·dm^{-3}·h^{1}ppm in 2009 of the year, 410.1 nmol p-NP·dm^{-3}·h^{1} in 2010 of the year, 410.4 nmol p-NP·dm^{-3}·h^{1} in 2011 of the year and 392.2 nmol p-NP·dm^{-3}·h^{1} in 2012 of the year.

Table 1. The total alkaline phosphatase activity in water River Odra estuary (nmol p-NP·dm^{-3}·h^{1})

No	Analysis terming	Litoral	Sublitoral
2008		**1 m**	**4 m**
1.	April	348.3	266.1
2.	May	382.1	324.9
3.	June	478.9	367.5
4.	July	558.6	472.6
5.	August	527.4	449.4
6.	September	452.5	374.7
7.	October	314.8	251.5
Annual mean		**437.5**	**358.1**
2009		**1 m**	**4 m**
1.	April	364.9	234.4
2.	May	382.3	367.6
3.	June	452.6	403.9

4.	July	572.1	521.6
5.	August	519.7	477.1
6.	September	463.5	449.7
7.	October	343.2	272.9
Annual mean		**443.6**	**375.3**
2010		**1 m**	**4 m**
1.	April	386.1	281.5
2.	May	443.5	334.8
3.	June	481.8	431.7
4.	July	607.3	549.6
5.	August	563.7	484.2
6.	September	527.2	467.5
7.	October	429.6	321.7
	Annual mean	**491.3**	**410.1**
	2011	**1 m**	**4 m**
1.	April	364.7	317.1
2.	May	466.9	379.5
3.	June	498.1	434.8
4.	July	623.8	527.4
5.	August	586.7	473.1
6.	September	491.3	432.8
7.	October	348.1	307.9
	Annual mean	**482.8**	**410.4**
	2012	**1 m**	**4 m**
1.	April	341.5	285.7
2.	May	426.8	371.2
3.	June	483.9	437.5

4.	July	590.2	516.9
5.	August	559.4	489.1
6.	September	472.6	327.0
7.	October	369.5	318.3
Annual mean	**463.4**	**463.4**	**392.2**

Comparing 5-year average values of the analyzed activity in the waters of selected of River Odra estuary zones, it was established that it was lower in the sublittoral than in the littoral. Among the analyzed litoral and sublittoral layers, the surface layer (1 m) featured a higher total alkaline phosphatase activity than the deeper layer (4 m), where an average value of the parameter was only slightly lower than the one recorded in the littoral. Results of more extensive research conducted in the reservoir of River Odra estuary (conducted by the author) demonstrate that algae phosphatase was chiefly responsible for the high level of total alkaline phosphatase activity in the top sublittoral zone, while bacterial and free phosphatase were much less so. It appears that the participation of another group of heterotrophic microorganisms in the activity, namely that of fungi, was also insignificant.

Both in the water a higher level of the activity was determined in spring (May) and in full summer period (July and August). What is noteworthy is the fact that higher values of the studied activity were not always accompanied by larger number of bacteria and saprophytic fungi, which would confirm the importance of algae affecting its level.

4. CONCLUSIONS

Comparing 5-year average values of the analyzed activity in the waters of selected lakes of the River Odra estuary zones, it was established that it was lower in the sublittoral than in the littoral. Among the analyzed litoral and sublittoral layers, the surface layer (1 m) featured a higher total alkaline phosphatase activity than the deeper layer (4 m), where an average value of the parameter was only slightly lower than the one recorded in the littoral. Results of more extensive research conducted in the reservoir of lakes of the River Odra estuary (conducted by the author) demonstrate that algae phosphatase was chiefly responsible for the high level of total alkaline phosphatase activity in the top sublittoral zone, while bacterial and free phosphatase were much less so. It appears that the participation of another group of heterotrophic microorganisms in the activity, namely that of fungi, was also insignificant.

References

[1] Cao X., Song Ch., Zhou Y., 2009. Limitations of using extracellular alkaline phosphatase activities as a general indicator for describing P deficiency of phytoplankton in Chinese shallow lakes. J Appl Phycol DOI:10.1007/s108110099422-0

[2] Chróst RJ, Siuda W, Halemejko GZ, 1984. Longterm studies on alkaline phosphatase activity (APA) in a lake with fishaquaculture in relation to lake eutrophication and phosphorus cycle. Arch Hydrobiol 70, 1-32

[3] Furczak J. (2000). Acta Agrophysica, 4(2), 291-299.

[4] Furczak J., Bielińska E. J. (2001). Acta Agrophysica, 56, 125-135.

[5] Górniak A. (1993). Composition of the organic matter in lakes bottom sediments. Procc. IHSS Ins. Meeting, Barii, ed. Senesi N., Miano T.M., Elsevier Publisher, Amsterdam.

[6] Jansson M., Olsson H., Pettersson K. (1988). Hydrobiol. 170, 157-175

[7] Jones J.G. (1972) J. Ecol., 60, 777-791.

[8] Kobari H., Taga N. (1979). Deep-Sea Res., 26A, 799-808.

[9] Koch M.S., Kletou D.C., Tursi R. 2009. Alkaline phosphatase activity of water column fractions and seagrass in a tropical carbonate estuary, Florida Bay. Estuarine, Coastal and Shelf Science, 1-11.

[10] Korniłłowicz T. (1994). Acta Mycol., 29, 23-31, 159-168.

[11] Tabatabai M.A., Bremner J.M. (1969). Soil Biol. Biochem., 1, 301-307.

[12] Cao X, Štrojsová A, Znachor P, Zapomělová E, Liu G, Vrba J, Zhou Y, 2005. Detection of extracellular phosphatases in natural spring phytoplankton of a shallow eutrophic lake (Donghu, China). Eur J Phycol 40: 251-285 doi:10.1080/09670260500192760

[13] Feuillade J, Feuillade M, Blanc P, 1990. Alkaline phosphatase activity fluctuations and associated factors in a eutrophic lake dominated by Oscillatoria rubescens. Hydrobiologia 207:233–240 doi:10.1007/BF00041461

[14] Gage MA, Gorham E, 1985. Alkaline phosphatase activity as an index of phosphorus status of phytoplankton in Minnesota lakes. Freshw Biol 15: 227-233 doi:10.1111/j.1365-2427.1985.tb00195.x

[15] Gillor O, Hadas O, Post AF, Belkin S, 2002. Phosphorus bioavailability monitoring by a bioluminescent cyanobacterial sensor strain. J Phycol 38: 107-115 doi:10.1046/j.1529-8817.2002.01069.x

[16] He Z.L., Alva A.K., Li Y.C., Calvert D.V., Banks D.J., 1999. Sorptiondesorption and solution concentration of phosphorus in a fertilized sandy soil. Journal of Environmental Quality 28, 1804-1810.

[17] Hedley M.J., Stewart J.W.B., Chauhan B.S., 1982. Changes in inorganic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. Soil Science Society of America Journal 46, 970-976.

[18] Hino S, 1988. Fluctuation of algal alkaline phosphatase activity and the possible mechanisms of hydrolysis of dissolved organic phosphorus in Lake Barato. Hydrobiologia 157: 77-84. doi:10.1007/BF00008812

[19] Jamet D, Amblard C, Devaux J, 1997. Seasonal changes in alkaline phosphatase activity of bacteria and microalgae in Lake Pavin (Massif Central, France). Hydrobiologia 347: 185-195. doi:10.1023/A:1003044008455

[20] Jamet D, Amblard C, Devaux J, 2001. Size-fractionated alkaline phosphatase activity in the hypereutrophic Villerest reservoir (Roanne, France). Water Environ Res 73: 132-141. doi:10.2175/ 106143001X138787

[21] Jones JG, 1972. Studies on freshwater bacteria: association with algae and alkaline phosphatase activity. Ecol 60: 59-75. doi:10.2307/2258040

[22] Krystyna K, 1997. Eutrophication processes in a shallow, macrophyte dominated lake - alkaline-phosphatase activity in Lake Łuknajno (Poland). Hydrobiologia 342-343: 395-399 doi:10.1023/A:1017051726211

[23] Mhamdia BA, Azzouzib A, Elloumic J, Ayadic H, Mhamdia MA, Aleya L, 2007. Exchange potentials of phosphorus between sediments and water coupled to alkaline phosphatase activity and environmental factors in an oligo-mesotrophic reservoir. C R Biol 330:419–428 doi:10.1016/j.crvi.2007.02.009

[24] Nedoma J, Garcia JC, Comerma M, Simek K, Armengol J, 2006, Extracellular phosphatases in a Mediterranean reservoir: seasonal, spatial and kinetic heterogeneity. Freshw Biol 51: 1264-1276. doi:10.1111/j.1365-2427.2006.01566.x

[25] Newman S, Mccormick PV, Backus J, 2003. Phosphatase activity as an early warning indicator of wetland eutrophication: problems and prospects. J Appl Phycol 15: 45-59. doi:10.1023/A:1022971204435

[26] Nicholson D, Dyhrman S, Chavez F, Paytan A, 2006. Alkaline phosphatase activity in the phytoplankton communities of Monterey Bay and San Francisco Bay. Limnol Oceanogr 51: 874-883

[27] Olsson H, 1990. Phosphatase activity in relation to phytoplankton composition and pH in Swedish lakes. Freshw Biol 23: 353-362. doi:10.1111/j.13652427.1990.tb00277.x

[28] Pettersson K, 1985. The availability of phosphorus and the species composition of the spring phytoplankton in Lake Erken. Int Rev Gesamten Hydrobiol Hydrograph 70: 527–546. doi:10.1002/ iroh.19850700407

[29] Pick FR, 1987. Interpretations of alkaline phosphatase activity in Lake Ontario. Can J Fish Aquat Sci 44: 2087-2094. doi:10.1139/f87-258

[30] Rengefors K, Pettersson K, Blenckner T, Anderson DM, 2001. Species-specific alkaline phosphatase activity in freshwater spring phytoplankton: application of a novel method. J Plankton Res 23: 435-443 doi:10.1093/plankt/23.4.435

[31] Rengefors K, Ruttenberg KC, Haupert CL, Taylor C, Howes BL, 2003. Experimental investigation of taxon-specific response of alkaline phosphatase activity in natural freshwater phytoplankton. Limnol Oceanogr 48: 1167-1175

[32] Sebastian M, Aristegui J, Montero MF, Niell FX, 2004. Kinetics of alkaline phosphatase activity, and effect of phosphate enrichment: a case study in the NWAfrican upwelling region. Mar Ecol Prog Ser 270: 1-13. doi:10.3354/meps270001

[33] Smith RIH, Kalff J, 1981. The effect of phosphorus limitation of algal growth rate: evidence from alkaline phosphatase. Can J Fish Aquat Sci 38: 1421-1427. doi:10.1139/f81-188

[34] Spijkerman E, Coesel PFM, 1998. Alkaline phosphatase activity in two planktonic desmid species and the possible role of an extracellular envelope. Freshw Biol 39: 503-513. doi:10.1046/j.1365-2427.1998.00299.x

[35] Štrojsová A, Vrba J, Nedoma J, Komárková J, Znachor P, 2003. Seasonal study on expression of extracellular phosphatases in the phytoplankton of an eutrophic reservoir. Eur J Phycol 38: 295-306 doi:10.1080/09670260310001612628

[36] Štrojsová A, Vrba J, Nedoma J, Šimek K, 2005. Extracellular phosphatase activity of freshwater phytoplankton exposed to different in situ phosphorus concentrations. Mar Freshw Res 56: 417-424 doi:10.1071/MF04283

[37] Taga N, Kobori H, 1978. Phosphatase activity in eutrophic Tokyo Bay. J. Mar Biol (Berl) 49: 223-229. doi:10.1007/BF00391134

[38] Vrba J, Komárková J, Vyhnálek V, 1993. Enhanced activity of alkaline phosphatases-phytoplankton response to epilimnetic phosphorus depletion. Water Sci Technol 28: 15-24

[39] Yu S., Hea Z.L., Stoffellaa P.J., Calverta D.V., Yanga X.E., Banksa D.J., Baligar V.C., 2006. Surface runoff phosphorus (P) loss in relation to phosphatase activity and soil P fractions in Florida sandy soils under citrus production. Soil Biology & Biochemistry 38, 619-628.

(Received 04 June 2015; accepted 20 June February 2015)