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THE TRENDS OF DEVELOPMENT OF PHOSPHATE REGIME IN WESTERN BUG SURFACE WATERS ON THE TERRITORY OF UKRAINE

TENDENCJE ROZWOJU EUTRIFIZACJI FOSFORANOWEJ W WODACH POWIERZCHNIOWYCH ZACHODNIEGO BUGU NA TERENIE UKRAINY

ТЕНДЕНЦИИ ФОРМИРОВАНИЯ ФОСФАТНОГО РЕЖИМА ПОВЕРХНОСТНЫХ ВОД Р. ЗАПАДНЫЙ БУГ НА ТЕРРИТОРИИ УКРАИНЫ

Abstracts

The article stipulates that one of the primary issues regarding surface waters of Western Bug river, specifically eutrophication, is caused by influx of excessive amount of biogens (which include phosphates).In order to study the dynamics of change of phosphate regime in Western Bug river basin, analysis of phosphate concentrations change alongside river bed has been performed, season-related features of phosphate contents in representative observation points have been determined, main phosphates influx sources and most polluted sections of the river have been identified.Finally, the attention has been focused on the necessity to restore and guard the "good" ecological state of transboundary rivers.

Keywords*:biogenic elements, phosphate, eutrophication, water quality, control point.*

Streszczenie

W artykule opisano tendencje rozwoju eutrofizacji fosforanowej w wodach powierzchniowych Zachodniego Bugu na terenie Ukrainy. Autorzy wyjaśnili, że jednym z podstawowych zagadnień dotyczących wód powierzchniowych rzeki Zachodni Bug jest proces eutrofizacji, który jest spowodowany napływem nadmiernej ilości substancji biogenicznych, tj. składników odżywczych w tym fosforanów dla glonów i innych organizmów żyjących w rzece Bug. W celu zbadania dynamiki zmian zawartości fosforanów w dorzeczu Zachodniego Bugu, przeprowadzono analizę koncentracji fosforanów wzdłuż koryta rzeki, zidentyfikowano zmienność sezonową zawartości fosforanów w reprezentatywnych punktach obserwacyjnych, główne źródła napływu fosforanów i zidentyfikowano najbardziej zanieczyszczone sekcje rzeki Bug. Na koniec zwrócono uwagę na konieczność przywrócenia i ochrony właściwego stanu ekologicznego rzek transgranicznych.

Słowa kluczowe:*odżywki, fosforany, eutrofizacja, jakość wód, punkty monitoringu.*

Аннотация

В статье, указано, что причиной одной из основных проблем поверхностных вод р. Западный Буг – эфтрофикации, является поступление избыточного количества биогенов (среди них фосфатов).С целью исследования динамики изменений фосфатного режима в бассейне реки Западный Буг проанализировано изменения концентраций фосфатов по руслу реки, сезонные особенности их содержания в репрезентативных пунктах наблюдения, установлены основные источники его поступления и наиболее загрязнённые участки реки.Как итог, акцентировано внимание на необходимости восстановления и охраны "хорошего" экологического состояния трансграничных рек.

Ключевые слова:*биогенные вещества, фосфаты, эфтрофикация, качество воды, пункты наблюдения.*

Introduction.

Western Bug river (first-order tributary of Vistula river) is a border-crossing river which flows through territories of three states:Ukraine, Belarus and Poland; it belongs to the Baltic Sea basin.Its length is about 772 km (404 km on the Ukrainian territory, of which during 220 km it constitutes the state border between Poland and Ukraine); basin area is 73 470 km^2 (of which 11 205 km^2 are within Ukrainian borders).Ukrainian part of basin is situated in Lviv and Volyn districts.

At the place where Western Bug meets Narew, on the Polish part of river basin there is a reservoir (Zegrze Reservoir) which serves as a throughway between Bug, Narew and Vistula as well as a source of drinking water for Warsaw and other settlements.The issue of water quality in Western Bug, Narew and Vistula is topical due to potential pollution of Baltic Sea waters by these rivers.

One of the most important ecological problems of contemporary Baltic at the present time is *eutrophication.*State of the Baltic Sea and the Gulf of Finland in particular is a cause for common

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concerns.The Gulf of Finland itself is one of the most polluted parts of the Baltic Sea.Excess of biogenes causes eutrophication of high sea as well as coastal areas [1, 2, 3].

Processes of accumulation of phosphate ion and nitrogen group compounds (nitrites, nitrates and ammonium nitrogen) bring into existence one of the most ecologically dangerous technogenic phenomena– water bodies eutrophication – enrichment of waters with biogenes which stimulate phytoplankton growth [4,5]. This state of water bodies establishes conditions for growth of decomposer organisms (reducers) population. These reducers feed on dead organic material and mineralize such materials. During their vital processes reducers intensely consume oxygen. As the final result of such phenomena, aerobic conditions are replaced with anaerobic, due to which H_2S, CH_4 and toxic pollutants enter the waters and lower water quality, cause "water blooming", lower water clarity and oxygen content; this, in turn, causes mass fish mortality, inhibits growth of other hydrobionts and leads to gene pool loss, decreasing ecosystem's capacity for homeostasis and self-regulation. Thus, water enrichment with biogenic elements or element-containing compounds incurs secondary negative ecological and sanitary-hygienic effects. Fresh water becomes nonpotable and dangerous for hydrobionts' vital functions [6].

Due to man-made technogenic activity amounts of phosphates in the Baltic Sea basin have grown eightfold, while nitrogen content has quadrupled. Therefore issues of examining dynamics of phosphate content in Western Bug basin represent a current problem in ecology and are of elevated importance to specialists in practical and theoretical ecology both in Ukraine and abroad [5, 6, 7].

Biogenic substances are amongst the most important indicators of water quality and state of water ecosystem.Analysis of spatiotemporal dynamics of biogenic elements and phosphorus in particular is important in the context of their importance in formation of water quality.Primary sources of influx of biogenic substances into Western Bug waters from Ukrainian territory are wastewaters of housing and utilities (they contain polyphosphate as a component of detergents as well as photography reactants and water softeners), wastewaters of industrial plants and precipitation.Mineral phosphorus compounds get into natural waters when they are washed from farmland [7, 8], from watershed surface as ortho-, meta-, pyro- and polyphosphate ions from anthropogenic objects as well as a result of natural biological transformation of animal and plant remains.High concentration of phosphorus compounds in natural and waste waters is currently one of main ecological problems for many countries of the world, including Ukraine [3, 4].

Phosphates within waste waters which reach sewage biological treatment plants with concentration of more than 5 g/t do almost completely suppress biological functions of active sludge microorganisms; they degrade treatment plants and reach the natural environment untreated [9, 10].

Results and discussion.

This scientific effort used results of research studies performed by authors

during participation in the international project "Clean Baltic" in 2001–2011 [11, 12], as well as research library materials of Western Bug water resource basin authority for 2005–2015 [13].We had studied peculiarities of phosphate regime development in the Ukrainian segment of the Western Bug on the network of approved state basin water quality monitoring points:in the Lviv district:river Western Bug – Kamyanka-Buzka city; Dobrotvirske reservoir (lower pond); river Western Bug – Sokal city; in the Volyn district:river Western Bug – Lytovezh city; river Western Bug – Ambukiv village 500 m dopwnstream from r. Huchva influx; Ustilug city 500 m downstream from r. Luga influx; river Western Bug – Zabuzhzhya village (Fig . 1).

Pic.2 shows a graph representing distribution of yearly average phosphate concentrations in the specified points in 2005, 2010, 2015.

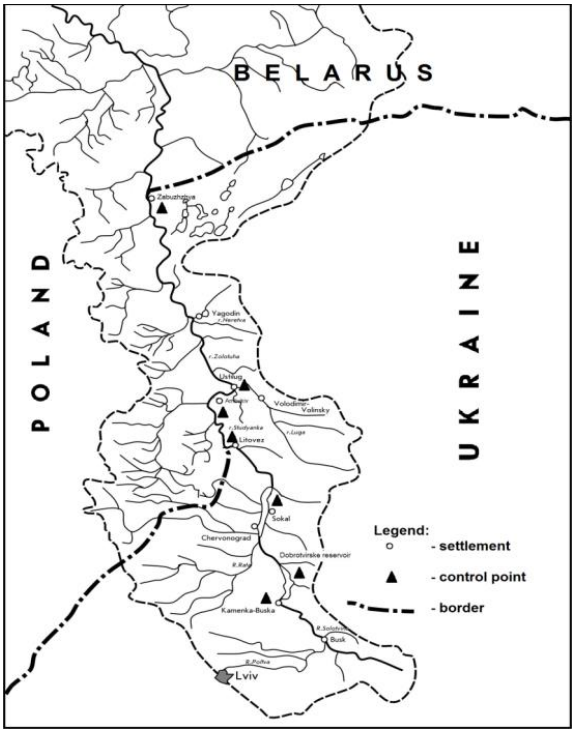

Fig. 1. Location map of surface water quality control points in Western Bug river basin [4]
(1 - Kamenka-Buzka city; 2 - Dobrotvirske reservoir, w/t; 3 - Sokal city; 4 - Lytovezh city; 5 - Ambukiv village, 500 m downstream from r. Huchva influx; 6 - Ustilug city, downstream from r. Luga influx; 7 - Zabuzhzhya village)

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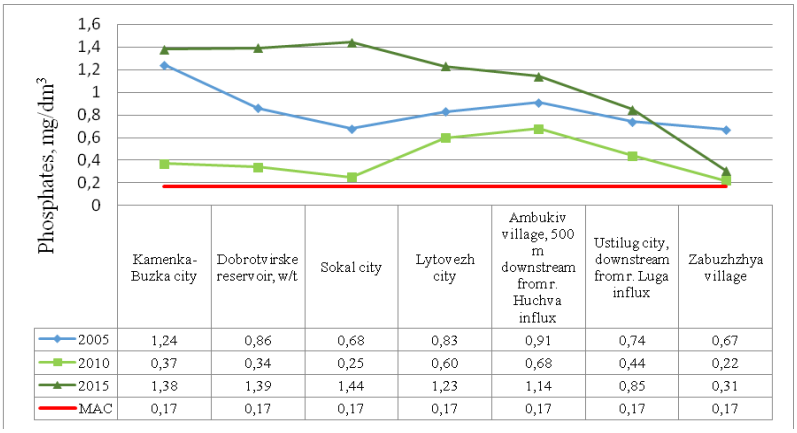

	Kamenka-Buzka city	Dobrotvirske reservoir, w/t	Sokal city	Lytovezh city	Ambukiv village, 500 m downstream from r. Huchva influx	Ustilug city, downstream from r. Luga influx	Zabuzhzhya village
2005	1,24	0,86	0,68	0,83	0,91	0,74	0,67
2010	0,37	0,34	0,25	0,60	0,68	0,44	0,22
2015	1,38	1,39	1,44	1,23	1,14	0,85	0,31
MAC	0,17	0,17	0,17	0,17	0,17	0,17	0,17

Fig. 2. Dynamics of phosphate contents in the channel of Western Bug river during the period of 2005, 2010, 2015

Analysis of obtained results has indicated that phosphate content is above the norm (exceeds maximum allowable concentration for commercial fishing waters) during the whole examined period.The situation was worst in 2015:largest average yearly phosphate concentrations during the whole examined period were observed alongside the whole riverbed. Highest pollution level is observed in the upper, urbanized part of the riverbed – 1.44 mg/dm^3 (8.5 MAC) (observation point Western Bug river – Sokal city, Lviv district). The content of phosphates gradually lowered downstream, and at the observation point Western Bug river – Zabuzhzhya village their registered concentration was almost three times lower (1.8 MAC) compared to Western Bug river – Ustilug city point (Volyn district).

In 2005 and 2010 a trend of lowering average yearly phosphate concentration from the upper riverbed part to Western Bug river — Sokal city observation point was observed, while on Lytovezh city – Ambukiv village segment the concentration increased.

Out of the network of approved state basin water quality monitoring points for Western Bug we have distinguished three representative points, these being:Western Bug river – Kamyanka-Buzka city, located in the upper urbanized part of the riverbed (after the influx of Poltva river, in Lviv district); Western Bug river – Lytovezh city point is located at the border between Lviv and Volyn districts; Western Bug river – Zabuzhzhya village observation point is a cross-border one (last observation point on the territory of Ukraine).Those points alongside the Western Bug were selected so that collected data which characterize the phosphate regime would allow tracking

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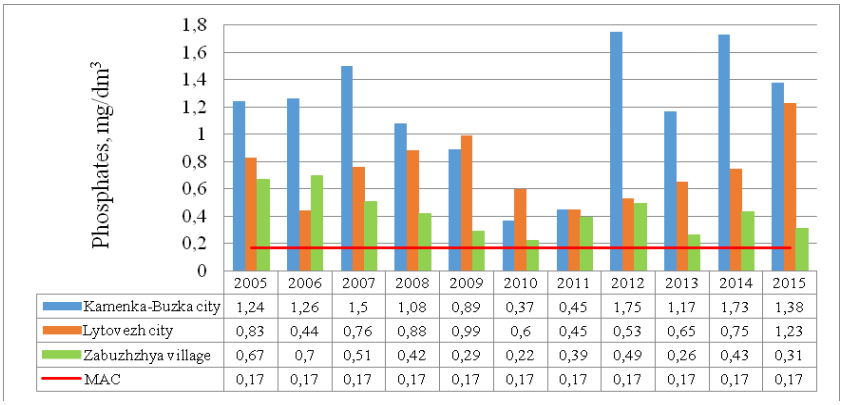
the regime dynamics on typical segments (Fig. 3).



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kamenka-Buzka city	1,24	1,26	1,5	1,08	0,89	0,37	0,45	1,75	1,17	1,73	1,38
Lytovezh city	0,83	0,44	0,76	0,88	0,99	0,6	0,45	0,53	0,65	0,75	1,23
Zabuzhzhya village	0,67	0,7	0,51	0,42	0,29	0,22	0,39	0,49	0,26	0,43	0,31
MAC	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17

Fig. 3. Dynamics of phosphates contents by observation points in Western Bug river basin in 2005, 2010, 2015

There is no clear trend towards improvement, while pollution growth at the Western Bug river — Lytovezh city causes concerns.

This lets us conclude that main contribution to phosphate pollution of basin surface waters is made by public utility companies and industrial enterprises of the Lviv district.Due to inefficient operation of waste treatment plants at those enterprises polluted, not sufficiently purified wastewaters flow into Western Bug river and its tributaries.River Poltva, into which polluted return waters of the "Lvivvodokanal" (water utility company) are dumped, remains the most polluted river in the basin.

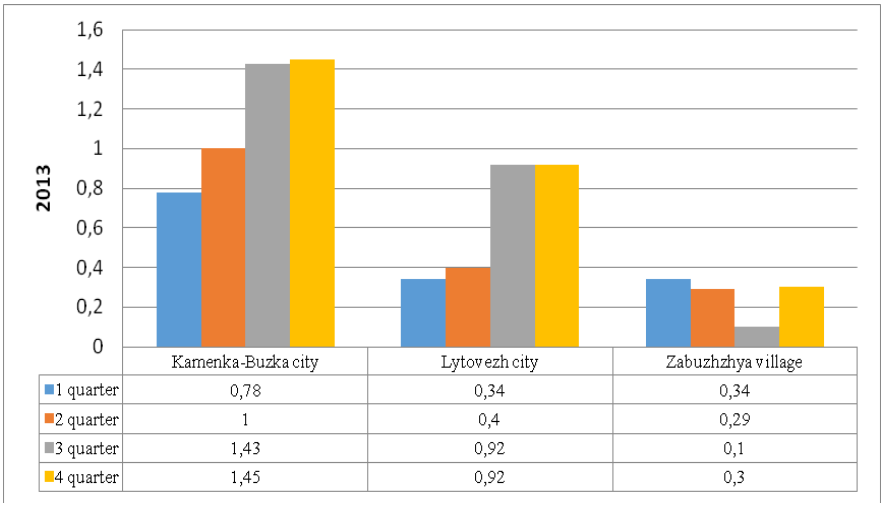
At the district border, where river leaves the Lviv district, phosphate content lowers somewhat (MAC exceeded sevenfold).This is due to inefficient operation of wastewater purification facilities in the Lviv district.

Enterprises in the Volyn district do not significantly influence the water quality of Western Bug river.At the final point, where river flow leaves Ukrainian territory (Zabuzhzhya village), insignificant exceedance of regulatory values regarding phosphates content is observed (1,8 MAC).

According to Polish scientists [18], quality of surface waters in Polish tributaries of Western Bug (i. e. Bukova, Guchva, Velnyanka, Ugerka and Vlodavka) is also unsatisfactory due to high concentrations of phosphates and ammonium nitrogen; these conditions are also typical for tributaries in Ukrainian part of river basin.

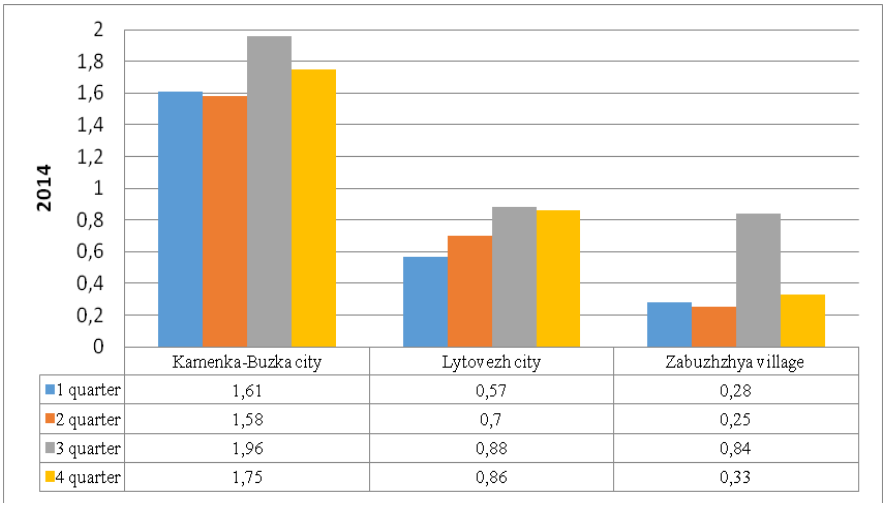
To study the seasonal specifics of phosphate regime formation we have analyzed data of Western Bug water resource basin authority (located in Lutsk city) for years 2013-2015 taken in representative points. Picture 4-6 shows dynamics of season (quarter) mean phosphate concentrations in representative points: river Western Bug - Kamyanka-Buzka city; point at Western Bug river -

Lytovezh city; Western Bug river - Zabuzhzhya village in years 2013 – 2015.



	Kamenka-Buzka city	Lytovezh city	Zabuzhzhya village
1 quarter	0,78	0,34	0,34
2 quarter	1	0,4	0,29
3 quarter	1,43	0,92	0,1
4 quarter	1,45	0,92	0,3

Fig. 4. Dynamics of season (quarter) mean phosphate concentrations in representative points: Western Bug river in 2013



	Kamenka-Buzka city	Lytovezh city	Zabuzhzhya village
1 quarter	1,61	0,57	0,28
2 quarter	1,58	0,7	0,25
3 quarter	1,96	0,88	0,84
4 quarter	1,75	0,86	0,33

Fig. 5. Dynamics of season (quarter) mean phosphate concentrations in representative points: Western Bug river in 2014

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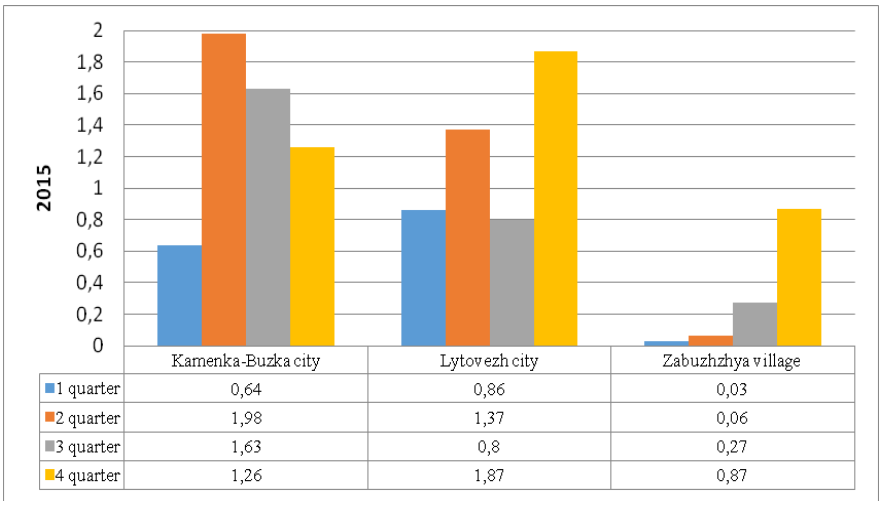

	Kamenka-Buzka city	Lytovezh city	Zabuzhzhya village
1 quarter	0,64	0,86	0,03
2 quarter	1,98	1,37	0,06
3 quarter	1,63	0,8	0,27
4 quarter	1,26	1,87	0,87

Fig. 6. Dynamics of season (quarter) mean phosphate concentrations in representative points:
Western Bug river in 2015

Chart analysis (pictures 4-6) demonstrates a clearly exhibited seasonality in phosphate content dynamics: phosphate concentration grows sharply in warm time of the year due to change of temperature regime. From time to time significant concentration jumps are observed; those might be induced by volleys of discharged domestic sewage as well as by run-offs from watershed surface during intense precipitation in summer-autumn period. Minimal phosphates concentration in water is observed during spring floods.

Conclusions.

Taking into account that surface waters of Western Bug are used as potable waters for population not only in Ukraine, but also in Belarus and Poland, and Zegzhynsky lake, into which Western Bug runs, is used for potable water in Warsaw, there must be more attention paid to issues of environmental protection and prevention of further phosphates influx from examined sources.

So, surface water quality control is performed based on state and transborder monitoring of Western bug basin waters, and it evidences that there is sufficient number of hydrochemical points, hydrological and water gauge stations within basin territory. Yet efficiency of surface water quality monitoring depends on list of analytic assay measurements in assays taken in state monitoring network as well as on optimal definition of assay count.

In Ukraine, surface water quality monitoring is performed by 35 indicators out of 39 proposed by European Union. Monthly sampling frequency is provided only at trans-border (international) observation points, and at all other stations sampling frequency is once per quarter. In order to cut economic costs and increase efficiency of monitoring observations in

Western Bug basin, in our opinion, an differentiated approach to monitoring observation is necessary. We mean that each of Western Bug tributaries has individual pollution profile which is determined by many factors of both natural and anthropogenic nature and which together form the hydrochemical and hydrological regime of river basin surface waters. During organization of surface waters monitoring in Western Bug basin, list and regime of observations should be adjusted, taking into account specifics of each monitored water object.

Thus there is no need to perform monthly observation of all indicators specified in the list. For each tributary and each hydrochemical point there should be its own substance list which would be representative for this specific waterobject or point. Taking into consideration that phosphates and nitrite nitrogen are amongst limiting polluting agents defining quality of Western Bug basin surface waters, performing monitoring of those indicators is of top priority, and water assay sampling in mentioned observation points should be performed monthly rather than quarterly.

In sum, quality of water in Western Bug river does not meet requirements of EU Water Frame Directive [16] in regard to phosphorus compounds contents, on the basis of maximum allowable concentration of 0,17 mg/dm^3. Hydrochemical regime of upper part of Western Bug river basin does not meet requirements of Ukrainian environmental law in regard to phosphate ion as well, as the MAC for fishery water bodies is exceeded.

Migration of pollutants in the river water flow from one country's territory to another's causes negative consequences for the environment, human health and safety and creates not just national, but rather an international issue.To solve this problem, the states should join their efforts and options as to restoration and protection of "good" environmental state of cross-border rivers by rapprochement and mutual coordination of national and international regulations, by cooperative environmental activity.

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