

# INACTIVATION OF PHOSPHORUS IN THREE SHALLOW LAKES IN POLAND, USING AN INNOVATIVE TWO-UNIT DEVICE.

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## ABSTRACT

Many Polish shallow lakes are over-eutrophied. Some of them indicate symptoms of stable cyanobacteria dominated state. In their sediments concentration of phosphorus is reaching 3.0-4.0 mg P g<sup>-1</sup> d.m. In 2006 an extensive investigations of water and sediment were conducted on three such lakes - Zdworskie, Jelonek, and Winiary. Tests of three coagulants efficiency (FeCl<sub>3</sub>, Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>, and Phoslock) were made in every lake in 4.0 sq.m. enclosures. The innovative two-unit device was used to inactivate phosphorus directly in sediment, during its controlled resuspension. In deepest parts Phoslock was applied, while in shallow regions FeCl<sub>3</sub> was used. During next year the best results, no release of phosphorus, was observed in lakes deepest parts.

## MATERIAL AND METHODS



Fig. 1. Lakes - Zdworskie, Jelonek, Winiary

Tab. 1. Lakes main features

Lake	Area ha	Max depth m	Mean depth m	Phytoplankton dominants	Zooplankton dominants
Zdworskie	350.0	4.0	2.5	Cyanobacteria Diatoms, Greens	Rotatoria Ciliata!
Jelonek	12.0	3.0	2.0	Cyanobacteria	Rotatoria
Winiary	14.0	4.0	2.0	Cyanobacteria	Rotatoria

## Water and sediment analysis

**Sampling stations:** Lake Zdworskie - 9; Lake Jelonek - 7 reduced to 3; Lake Winiary - 3.  
Water: standard analysis including N and P forms

### Sediments:

selected elements - water content, OM %, SiO<sub>2</sub>, Ca, Mg, Mn, SO<sub>4</sub>, N-NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup>, P-PO<sub>4</sub><sup>3-</sup>, P-tot, Fe, Al

### P fractions:

NH<sub>4</sub>Cl - P: - P in interstitial water, loosely adsorbed on particles surface, bioavailable  
BD - P: - (bicarbonate/dithionite): bond with FeOOH and Mn, redox sensitive, P released at anoxia  
NaOH - P: - bond to metal oxides, mainly Al and Fe, OH-exchangeable, soluble in bases, partly organic  
HCl - P: - bond to carbonates and Ca, apatite P, trace hydrolysed organic  
Residual - P: - organic and refractive, resistant to release  
P - Total: - sum of all fractions  
Sediment phosphate sorption capacity - EPC-0

## Laboratory and in situ measurements of coagulants efficiency



Fig 2 - from the left:  
- phosphate inactivation with FeCl<sub>3</sub> during sediment resuspension- proper dose.  
- application of Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>, FeCl<sub>3</sub>, Phoslock, and FeCl<sub>3</sub> + Ca(NO<sub>3</sub>)<sub>2</sub> into water, and into sediment.  
-enclosures in lake Jelonek

## The two-unit device for coagulants application during controlled sediment Resuspension



Fig 3. Surface unit, and underwater module in docking place.

## THE RESULTS

### Searching for proper coagulants doses

Tab.2. Lake Zdworskie. Jar tests of coagulants efficiency in different oxygen and pH conditions during sediment resuspension. FeCl<sub>3</sub> or Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> were added in a volume of 5.0 cm<sup>3</sup> of working solution (50.0 g /l). Phoslock was added in proportion of 290.0 mg for every 1.0 mg of PO<sub>4</sub>

Coagulant	pH 5.0		pH 7.0		pH 9.0	
	Oxic	Unoxic	Oxic	Unoxic	Oxic	Unoxic
	18 June		18 June		18 June	
Control	1,173	1.566	1.210	0.778	1.267	1.064
FeCl <sub>3</sub>	0.063	0.186	0.152	0.235	0.159	0.034
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	0.063	0.155	0.102	0.120	0.272	0.006
Phoslock 2h	0.309	0.585	0.499	0.549	0.841	0.663
Phoslock 72 h	0.247	0.462	0.329	0.076	0.557	0.292
	15 July		15 July		15 July	
	Oxic	Unoxic	Oxic	Unoxic	Oxic	Unoxic
Control	1.106	1.198	1.011	1.092	1.523	1.321
FeCl <sub>3</sub>	0.063	0.063	0.210	0.034	0.386	0.206
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	0.063	0.063	0.102	0.034	0.102	0.149
Phoslock 2h	0.861	0.585	0.386	0.292	1.295	0.349
Phoslock 72 h	0.523	0.401	0.256	0.120	0.528	0.235
	12 August		12 August		12 August	
	Oxic	Unoxic	Oxic	Unoxic	Oxic	Unoxic
Control	1.362	1.290	0.983	0.721	1.295	1.035
FeCl <sub>3</sub>	0.074	0.063	0.114	0.006	0.102	0.046
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	0.074	0.063	0.114	0.006	0.187	0.006
Phoslock 2h	0.810	0.922	0.471	0.558	0.613	0.864
Phoslock 72 h	0.564	0.646	0.256	0.120	0.414	0.292

### Final coagulant doses

#### Lake Zdworskie - March 2009. Limited Phoslock and PIX application

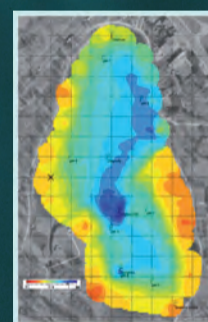
Experiments in enclosures confirmed appropriate calculation of the PIX 111 dose. Surface of 4.0 m<sup>2</sup> needs 0.976 l of PIX 111 i.e. 0.244 l of PIX111/m<sup>2</sup> or 2440 litre/ha. It is practically 50 commercial containers of 40% PIX 111 (50 litre each).

For conditions stated in the enclosures - P<sub>tot</sub> in sediments = 0.283 mg/p/g d.m. and 17% share of mobile P fractions it should be 3.6 tonnes of Phoslock for 1.0 ha. Considering the high pH - close to 9.0 stated in the lake Zdworskie, the dose should be increased by 25-30%.

The results show also that it is reasonable to implement both coagulants. In the shallow parts of the lake (about 2.0 m depth), where anoxic conditions are unlikely, cheap and efficient (even at pH 9.0) PIX 111 (FeCl<sub>3</sub>) can be used.

In the deepest parts of the lake (4.5-5.0 m), periodically unoxic, and in the regions of main inflows it is worthwhile to implement Phoslock. Due to its high cost, total surface for treatment with Phoslock would be limited to 5.0 - 10.0 ha (of total 340.0 ha).

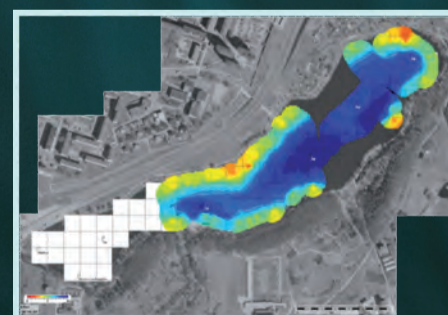
#### Lake Jelonek - October 2009. Phoslock and PIX application



Whole lake surface was treated with PIX at 0.22 m<sup>3</sup>/ha dose.  
For sediment surface of 10.3 ha - 32.75 tonnes of Phoslock were used  
For deepest parts - 0.4 ha - 7.25 t/ha of Phoslock were applied.  
For the rest - 9.9 ha - mean dose was 3.015 t/ha (2.0 - 3.625).

Fig 4 Lake Jelonek bathymetry

#### Lake Winiary - November 2009. Phoslock and PIX application



Whole water surface was treated with PIX at a dose of 0.22 m<sup>3</sup>/ha.  
The most of sediment surface (11,58 ha) was also treated with PIX at a dose of 0.15 m<sup>3</sup>/ha.  
Total surface of 3 deepest regions - 1.32 ha was treated with 7.25 tonnes of Phoslock - 5.5 t/ha.

Fig 5 Lake Winiary bathymetry

## CONCLUSIONS

In lakes Zdworskie and Winiary the best results, no release of phosphorus, were obtained in its deepest parts, where Phoslock was applied. Application of PIX in shallow regions gave ambiguous results, and no substantial improvement of sediment sorption capacity. The reason was probably small density of coagulate, and its susceptibility to re suspension, and redistribution.

In lake Winiary during spring of 2009 the distinct symptoms of regime shift were observed. In small, isolated bay macrophytes expansion was started. The expansion is progressing in 2010. Macrophytes are dominating in 2/3 of lake surface. Water transparency increased from below 1.0 m to the bottom at 4.0 m.