Management of litoral zone of lowland reservoir for enhancement of nitrogen removing via denitrification

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Around 60% of total nitrogen and 35% of phosphorus transported to the Baltic Sea come from agricultural sources

Typical sources of nitrogen from agriculture

7. Leaching of mineral fertilisers from arable land
8. Leaching from storage of manure from animal production
9. Atmospheric emission of ammonia from manure due to storage and field application

This is because:

- Nearly 60% of Poland area is arable land with light soils
- 38% of Polish population lives in rural areas
- Poland has 2 041 400 farms in rural areas
- 55,3% of these farms are smaller than 5 ha
- 56% of farms are connected to water supply systems
- but only 3,7% of these are connected to wastewater treatment systems
- The educational level of the farmers is low:

2,6% - graduated from universities

16,2 % - completed secondary education

Maciej Dzikiewicz (2000) Activities in non-point pollution control in rural areas of Poland.

Ecological Engineering 14, p.429-434

In Poland – 50% of dug wells located in agricultural areas have exceeded

maximum contaminant levels of $N\text{-}NO_3$ (MCLs) in drinking water

10 mg $N\text{-}NO_3$ L^{-1}

Nitrates Directive (91/676/EC)

Drinking water consumption polluted with nitrate-nitrogen at level of 10 mg/l and above may result in:

- methemoglobinemia, especially at children of nursing mothers and infants up to six months,
- birth defects (while pregnant women is exposed),
- increase of a potential cancer risk (nitrosoamine),

Using denitrification
as a biological method for water treatment

⬇

environmental and economic advantages –

simple

selective

cost effective

The aim of research was estimation of :

1. Average denitrification rate

2. Spatial variation of denitrification rate

3. The rate of annual nitrogen removal from the reservoir via denitrification

Study Area

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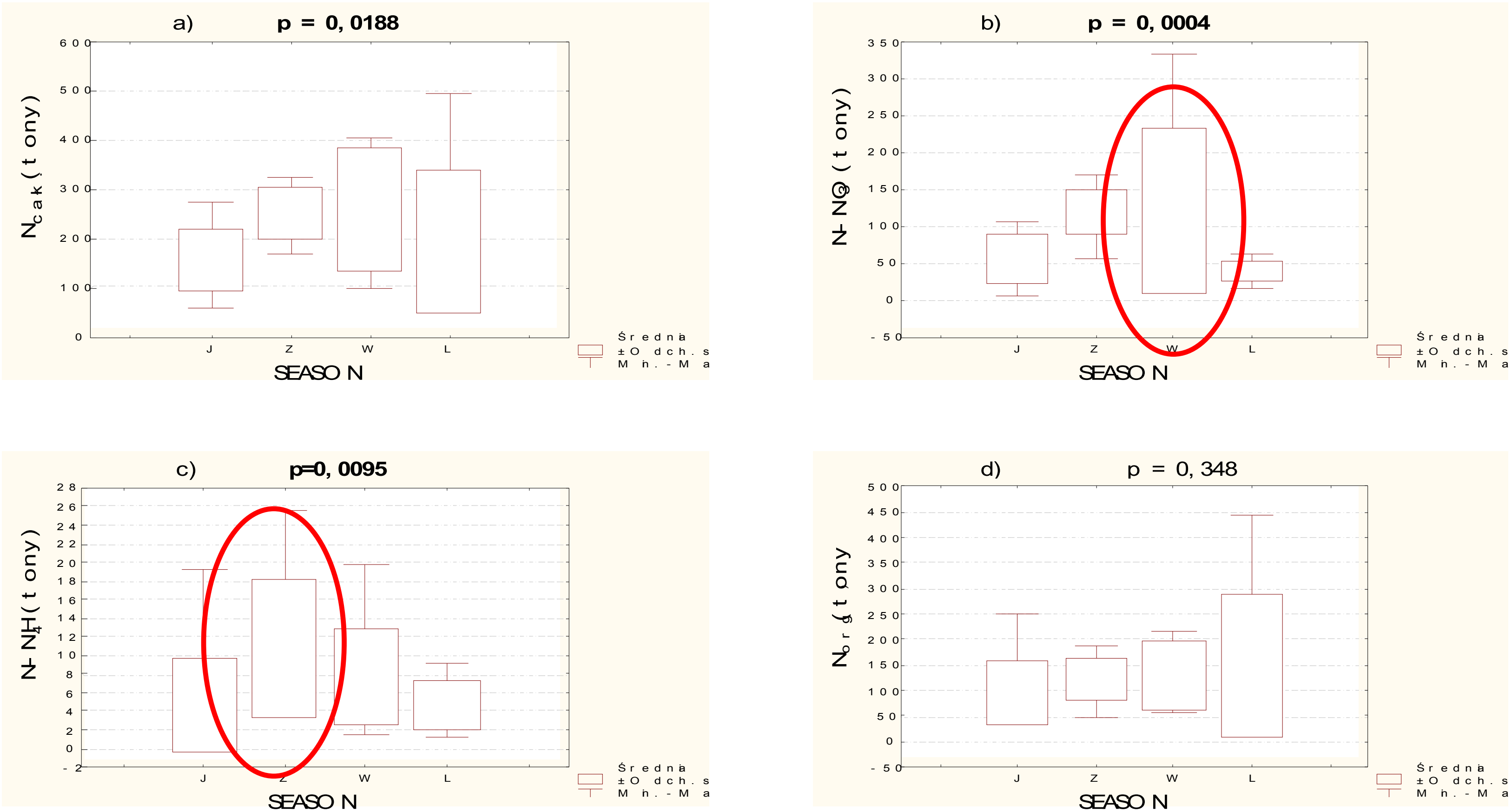
External nitrogen load of the Sulejow Reservoir in years 1998-2001

	Average load of individual form of nitrogen to Sulejow Reservoir tone\ year $^{-1}$ (%)			
	Direct catchment - small rivers	Indirect catment - Pilica and Luciąża Rivers	Precipitation	Total external load
$N\text{-}NO_{2/3}$	17,1 (1,3)	**1313,3 (98,1)**	8,3 (0,6)	1339,0 (100)
$N\text{-}NH_4$	2,5 (2,3)	**100,6 (90,3)**	8,7 (7,5)	111,5 (100)
N_{tot}	29,5 (1,0)	**2794,3 (98,2)**	22,4 (0,8)	2846,2 (100)
N_{org}	11,2 (0,8)	**1380,0 (98,8)**	5,4 (0,4)	1397,0 (100)

Seasonal changes of load N_{tot} (a), $N\text{-}NO_3$ (b), $N\text{-}NH_4$ (c) i N_{org} (d) inflowing with Pilica i Luciąża Rivers in years 1998-2000.



(J – autumn, Z - winter, W – spring, L - summer).

Location of sampling points for denitrification assessment

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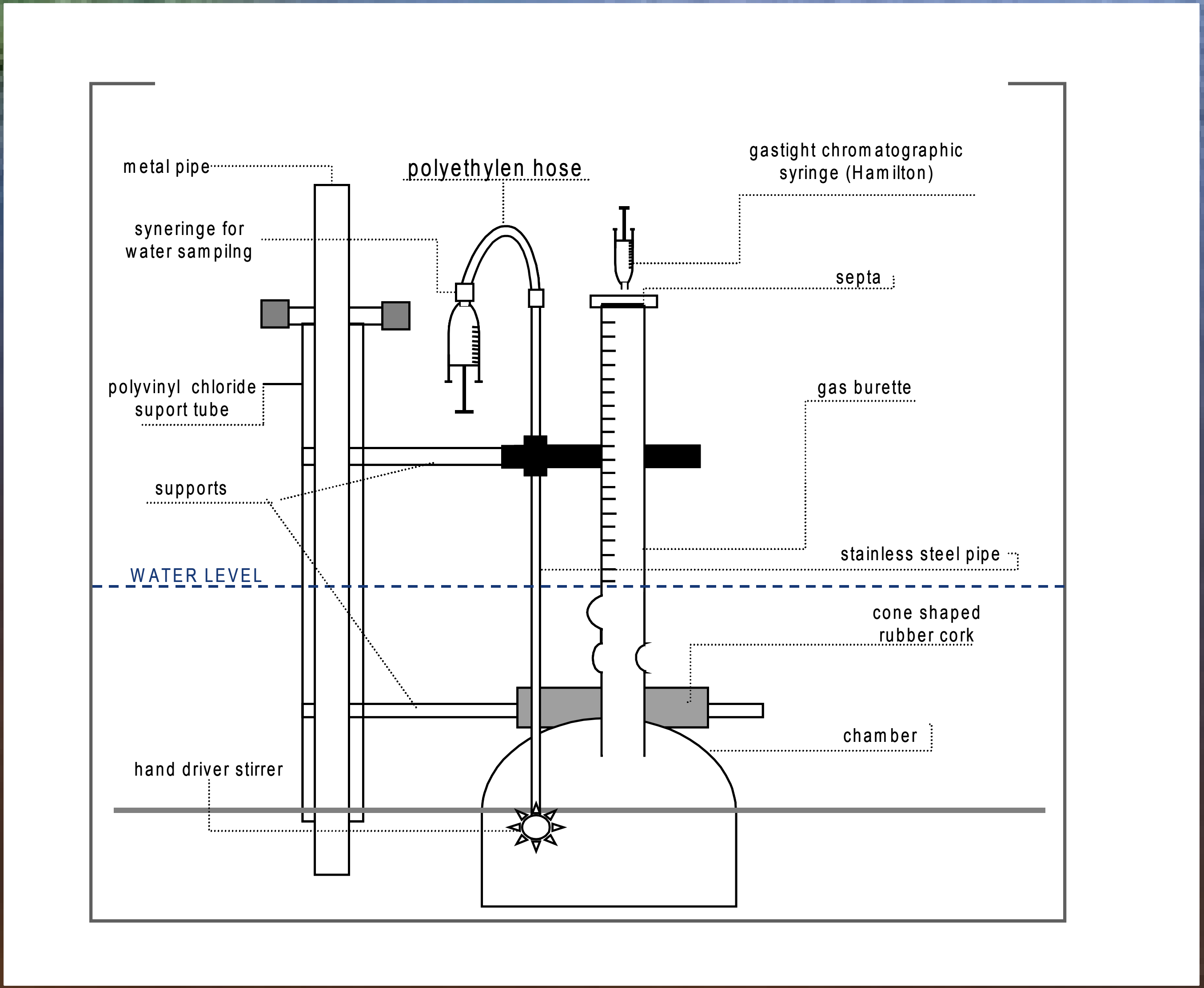
The schematic diagram of the chamber for direct measurement of denitrification (*Tomaszek 1991, changed*)



The gases produced in the sediment form bubbles that rise through the sediments, and can be collected in a burette placed at the top of the incubation chamber.

In situ denitrification measurements

This method is useful for shallow and nutrient rich reservoirs.

These gas samples were collected with 1 or 5 ml glass Hamilton's gas tight syringes and in the laboratory they were injected into the column of gas chromatograph (model PU-4410/19).

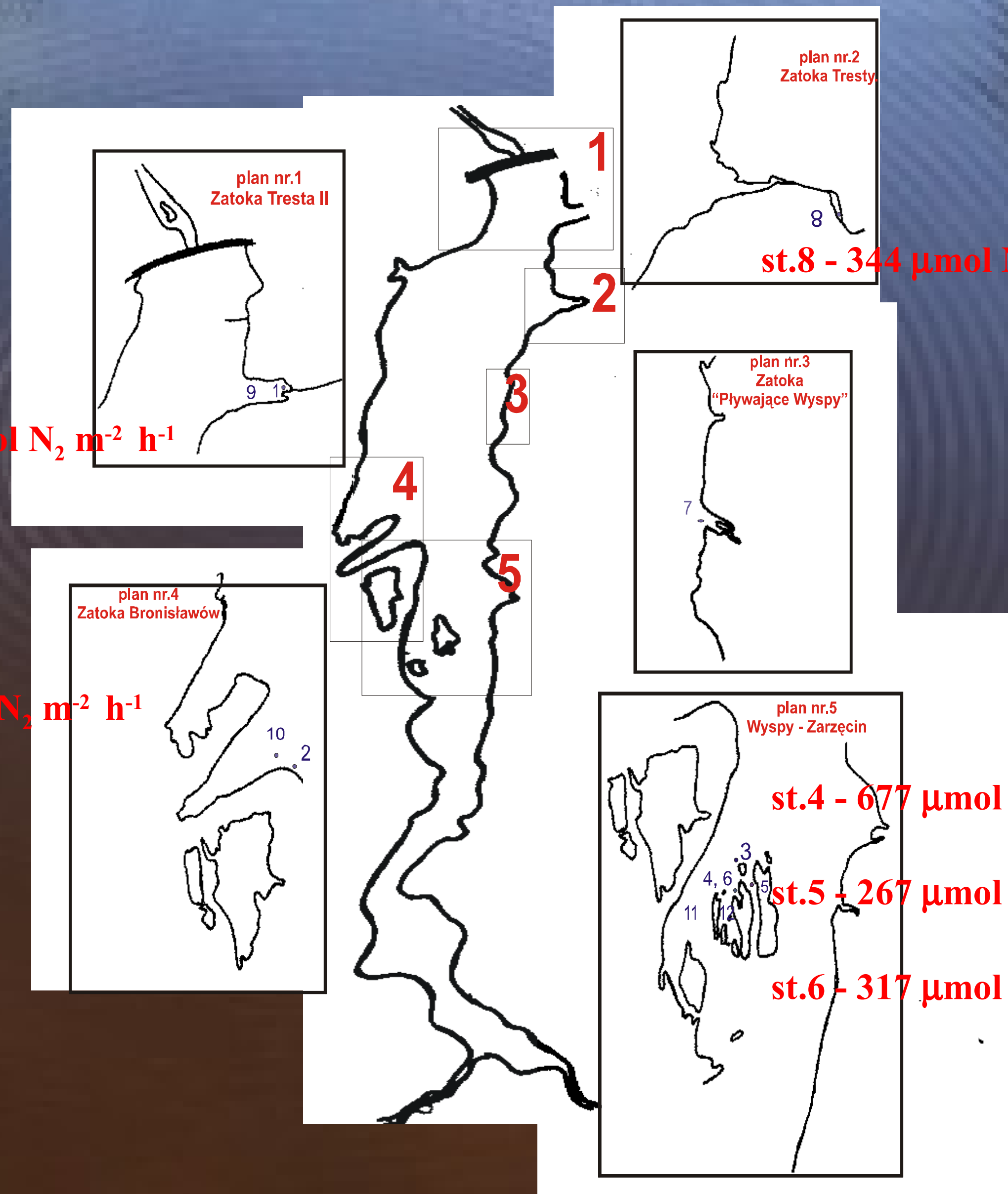
The *in situ* denitrification rate was calculated from the total N_2 flux out of the sediment, and presented in $\mu mol\ N_2\ m^{-2}\ h^{-1}$.

Chemical composition of the bottom sediments combined with average denitrification rate.

Stations	Composition of sediments (% dry mass of sediment)			Temperature (^{o}C)	Denitrification rate ($\mu mol\ N_2\ m^{-2}\ h^{-1}$)
	Organic matter	Organic carbon	Total nitrogen	average	average
1	0,89	0,94	0,58	21,3	56
2	0,41	0,60	0,06	20,6	0
3	0,61	0,54	0,18	20,7	15
4	**20,30**	**10,32**	**9,29**	22,5	**677**
5	**21,77**	**9,33**	**8,25**	18,3	**267**
6	**17,72**	**8,51**	**7,66**	19,2	**317**
7	4,23	2,49	0,43	16,9	278
8	**10,09**	**5,35**	**3,15**	15	**344**
9	**9,09**	**5,15**	**3,25**	20	**814**
10	**17,41**	**8,60**	**7,06**	20,6	**833**
11	2,61	1,54	1,18	19,7	162
12	2,30	1,82	2,29	20,5	130

The highest denitrification rate (*in situ* chambers)

Sandy and hard bottom sediments restrict migration of nitrogen compounds between sediments and hyporeic water.



Availability of carbon compounds stimulates the process.

Results:

- Denitrification rate in bottom sediments of the Sulejów Reservoir differs from **0 to 833 µmol N_2 m^{-2} h^{-1}** - characteristic value for eutroficated reservoirs.

- Spatial distirbution of denitrification rate depends mainly on the type and structure of bottom sediments ($r^2 = 0,84$).

- Assuming that the mean denitrification rate is 376,6 µmol N_2 m^{-2} h^{-1} and the bottom **sediments with high carbon content occupy 5% to 10%** of the reservoir area - therefore from **6,2 do 12,4 %** of the annual nitrogen load is removed from the reservoir by denitrification.

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Microbiological analyses

For comparison of denitrification rate using the *in situ* chamber method also bacteriological characteristic has been done at the same sampling station.

Occurrence of denitrifying bacteria was determined by means of the most probable number (MPN) and plate counting (PC) methods.

Identification of denitrifying bacteria was performed according to:

the colouring Grama's method,

production of fluorescent pigment on King's A and B,

starch hydrolysis,

presence of cytochromium oxidases ,

the API 20 NE (bioMerieux), a standardised micro-method combining 8 conventional tests and 12 assimilation tests.

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Amount of denitrification bacteria in sediments of selected environmental stations

Estimated with the :

MPN method

up to 15.8%

PC method

up to 26%

of the total microflora

Percentage of genus of denitrifying bacteria in sediments of Sulejow Reservoir

	Genus			
Stations	Pseudomonas	Alcaligenes	Bacillus	Not identified
1	68,6	31,4	0	0
2	92,8	0	7,2	0
3	75,0	0	12,5	12,5
4	100	0	0	0
5	66,7	26,7	6,6	0
6	46,2	0	53,8	0
7	-	-	-	-
8	100	0	0	0
9	33	67	0	0
10	14,3	71,4	14,3	0
11	75	16,7	8,3	0
12	59,1	13,6	27,3	0

Percentage of denitrifying bacteria species in sediments of Sulejow Reservoir determined on the basis the API 20 NE (bioMerieux) - a standardised micro-method, combining 8 conventional tests and 12 assimilation tests,

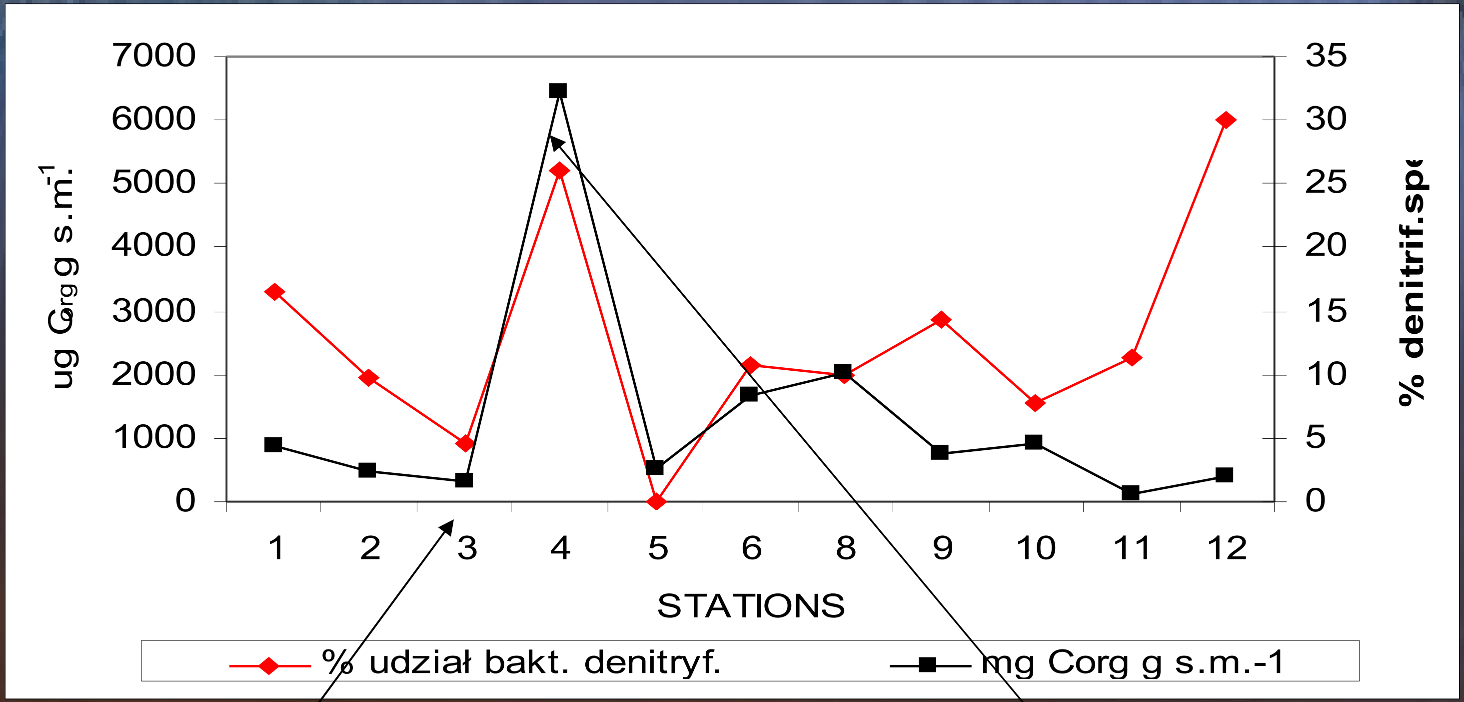
	STATIONS											
SPECIES	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
P. fluorescens	5,7	42,8	25,0	64,5	0,0	0,0	-	71,5	0	0	8,3	36,4
P. stutzeri	25,7	21,4	0,0	3,2	40,0	46,2	-	28,5	33	14,3	16, 7	0
P. aeruginosa	5,5	0,0	0,0	0,0	0,0	0,0	-	0,0	0	0	25	9,1
Pseudomonas sp.	31,4	28,6	50,0	32,	26,7	0,0	-	0,0	0	0	25	13,6
Alcaligenes sp.	31,4	0,0	0,0	0,0	26,7	0,0	-	0,0	67	71,4	16,7	13,6
Bacillus sp.	0,0	7,2	12,5	0,0	6,6	53,8	-	0,0	0	14,3	8,33	27,3
Not identyfied	0,0	0,0	12,5	0,0	0,0	0,0	-	0,0	0,0	0,0	0,0	0,0

Percentage of denitrifying bacteria species by different nitrite accumulation scenario

	Accumulation $N\text{-}NO_2$ due reduction of $N\text{-}NO_3$		
	Without accumulation	Low accumulation **<70 mg $N\text{-}NO_2$**	High accumulation **> 70 mg $N\text{-}NO_2$**
I series: 7 XI 2000; stations: 1-8.	39,6	12,5	47,9
II series: 13 VII 2001; stations: 9-12;	75	8,33	16,67
average	57,3	10,4	32,3

About 30 % – of the bacteria isolated from natural microflora accumulates toxic nitrite in total denitrification activity.

Relationship between amount of organic carbon (µg C-org./g d.m) and percentage of denitrifying bacteria ($r^2=0.86$)



4,6% - 302,8 µg C-org./g d.m.

26% - 6425,3 µg C-org./g d.m

Results:

1. A positive correlation between the contents of organic matter in sediments and the amount of denitrifying bacteria ($r^2 = 0.86$; $p<0.05$), and between denitrification rate and the sediment structure ($r^2 = 0.84$; $p<0.05$) was found.

3. To increase the denitrification rate in litoral zone, we have to increase the sedimentation of organic matter, e.g. by increase of plants cover

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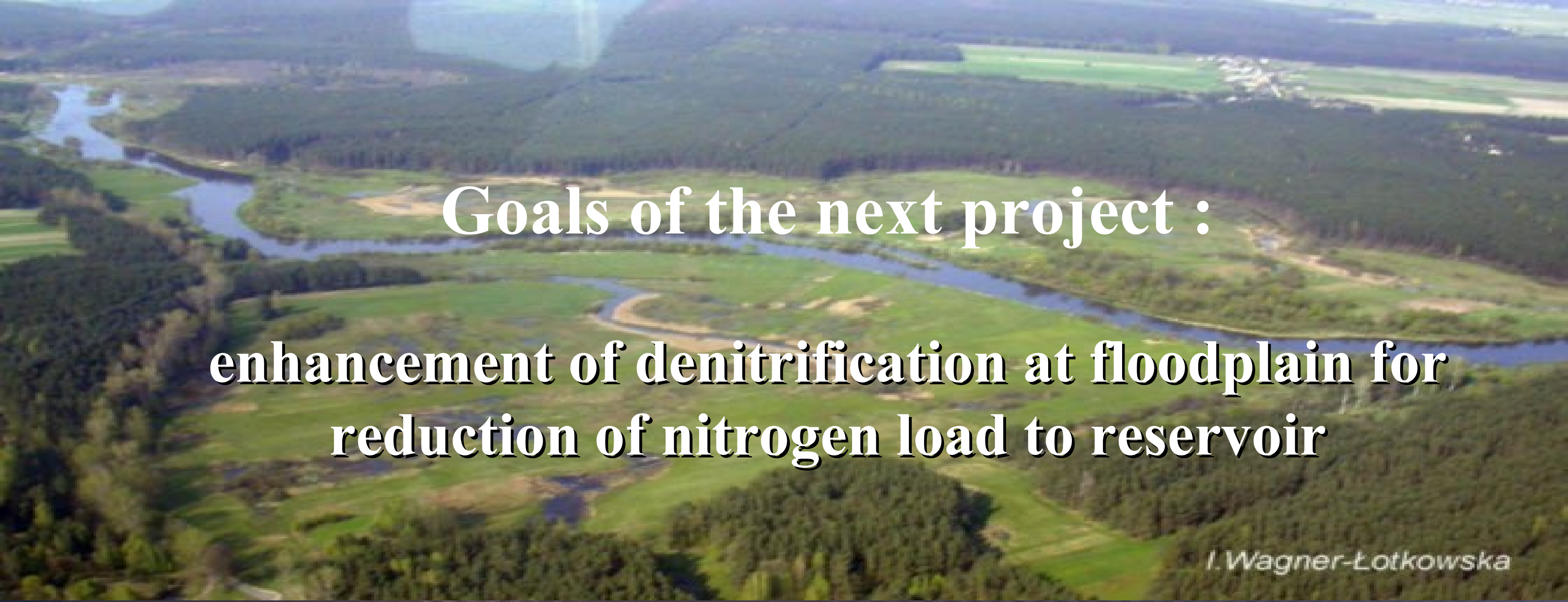

Goals of the next project :

enhancement of denitrification at floodplain for reduction of nitrogen load to reservoir

by:

water level control

increase of sedimentation of organic matter

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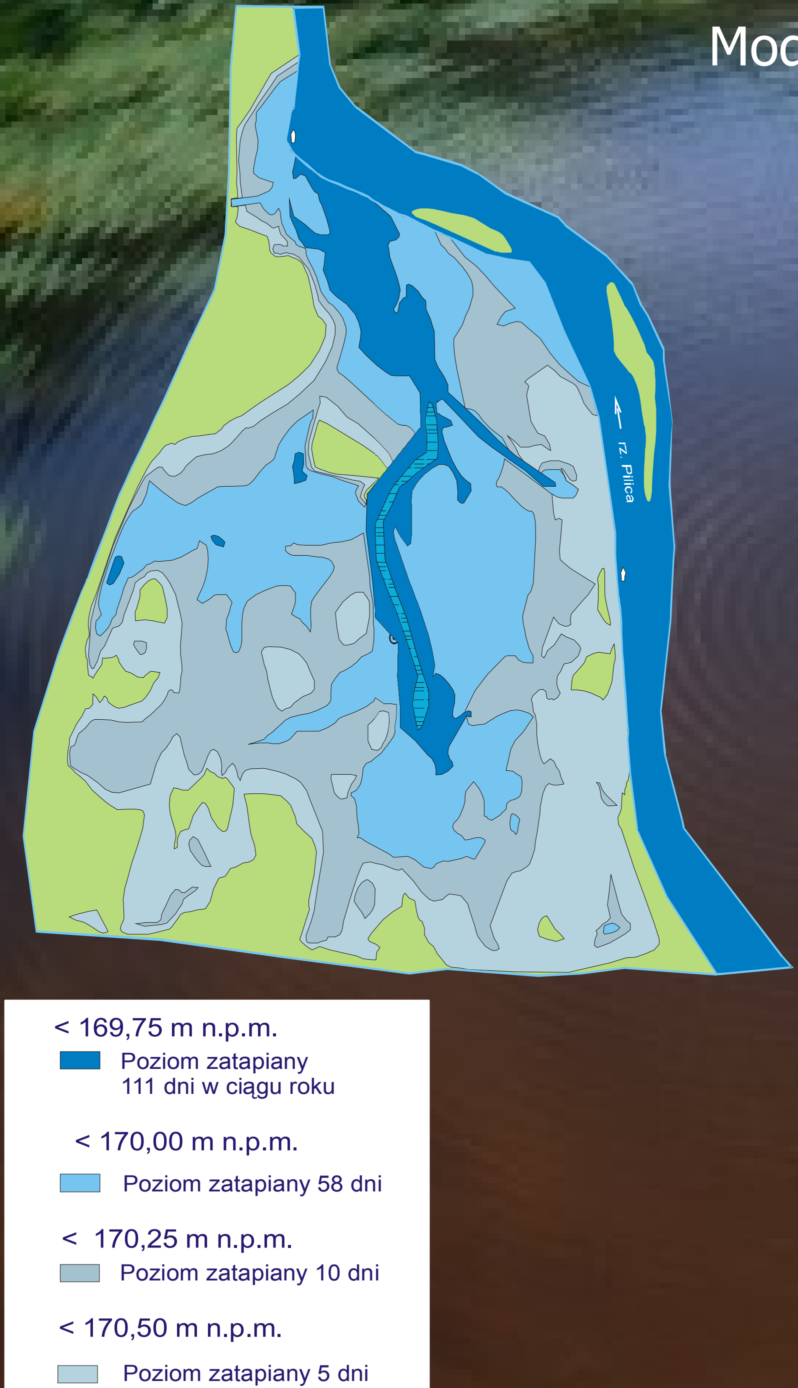
Model of flooding of the Pilica River floodplain

(*Kiedrzyńska i in. 2003*)



Denitrification process is the most efficient in inundated areas and in constructed wetlands.

Sedimentation of organic matter inflowing with tributaries on the floodplain would **accelerate the rate of nitrogen removal** via denitrification and would be one of the methods of the reservoir recultivation.

One of typical denitrifying sites

Caricetum gracilis / Caricetum vesicariae

Salix purpurea

Phragmitetum australis – old river-bed

Thank you for attention!

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