

Annals of Warsaw University of Life Sciences – SGGW  
 Land Reclamation No 40, 2008: 3–13  
 (Ann. Warsaw Univ. of Life Sci. – SGGW, Land Reclam. 40, 2008)

## Action reducing the outflow of nitrates from agricultural sources to waters on the nitrate vulnerable zone in the catchment of the Samica Sęszewska river

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**Abstract:** *Action reducing the outflow of nitrates from agricultural sources to waters on the nitrate vulnerable zones in the catchment of the Samica Sęszewska river.* The aim of the performed investigations was to assess the scope and effectiveness of actions undertaken on the Nitrate Vulnerable Zone (NVZ) in a catchment area with waters sensitive to agricultural pollution. The investigations on the catchment of the Samica Sęszewska river were conducted in 2005–2007. They included, among others: the estimation of the quality of surface waters, directions and the intensity of agricultural activity, applied agricultural practices, plans and balances of fertilization. The investigations showed that arable lands predominate the examined catchment area of the Samica Sęszewska river and agricultural activity contributed significantly to water pollution. Many farms lacked buildings and the devices for proper storage of manures. The majority of farms realize intensive agricultural production, many of them specialise in swine breeding. High fertilization is complied on farms often and high livestock density. It is the reason of introducing the large quantities of nutrients to agro-ecosystems and causes the nutrient surpluses in balance. Farmers were well-acquainted with principles of good agricultural practice and declared the will of realization of actions introduced on vulnerable zones aiming at reducing nitrates from agricultural sources. The majority of farmers complied with recommendations of the Code of Good Agricultural Practice. No farm exceeded the quantity of  $170 \text{ kg N}\cdot\text{ha}^{-1}$  in manures recommended in the Nitrates Directive, yet the level of fertilization on the catchment area was high.

*Key words:* nitrate directive, nitrate vulnerable zones, water pollution, action programme, good agricultural practice.

## INTRODUCTION

The prolonged impact of agriculture on the environment, including the quality of waters in some regions, led to the considerable intensity of degradation of both surface and underground waters and that, in turn, also contributed to the pollution and degradation of the Baltic Sea. The main receivers of the pollution from agricultural sources are rivers which transport it to lakes and seas.

After becoming the EU member in May 2004, Poland was obliged to introduce the resolutions of the European Union Nitrate Directive (91/676/EEG) and to incorporate this directive into the domestic law. According to the guidelines of the Nitrate Directive, waters sensitive to the pollution with nitrogen compounds from agricultural sources ( $> 50 \text{ mg NO}_3 \text{ dm}^{-3}$  and  $40\text{--}50 \text{ mg NO}_3 \text{ dm}^{-3}$ ) and Nitrate Vulnerable Zones (NVZs) from which the outflow of nitrates from the agricultural sources should be reduced were outlined in Poland. In the first stage, 21 zones were marked out which, in total,

occupy 2% of the country area. Most of these areas are in the water region of the Warta river, where the total length of the rivers regarded as waters sensitive to the pollution with nitrogen compounds from agricultural sources equals 359 km and the total area of Nitrate Vulnerable Zones (NVZs) is 2488.9 km<sup>2</sup>. One of these zones is the Samica Stęszewska river and the Mogilnica river NVZs which cover 162.5 km<sup>2</sup>. It is typical agricultural area with a high share of arable land (76.4% in the Samica Stęszewska and 72.6% in the Mogilnica river catchment areas). Progress in the improvement in the quality of waters in Polish NVZs has been slight and in many areas constantly exceeds concentrations of nitrates and phosphates are being taken down. What results from it is that achieving the Directive purpose is very slow and difficult.

The aim of the performed investigations was to assess the scope and effectiveness of actions undertaken on the Nitrate Vulnerable Zone (NVZ) in a catchment area with waters sensitive to agricultural pollution.

## MATERIAL AND METHODS

The investigations were carried out on one part of the Samica Stęszewska river and the Mogilnica river NVZ in the Samica Stęszewska river catchment. The survey was conducted in 2005–2007 within the framework of the research project 2 PO6S 026 28 funded by the Ministry of Science and Informatisation. The investigations carried out in 2007 comprised 29 farms (28 of them are individual ones and one is a large-area farm) located in the upper

part of the Samica Stęszewska river catchment, to the cross-section on the outlet from the Niepruszewskie Lake. Investigated farms comprised 75% of all controlled farms in that region. This area was classified as a Nitrate Vulnerable Zone (NVZ) from which the nitrates outflow from agricultural sources should be reduced in accordance with the Decree issued by the Director of the Regional Water Management Board in Poznań on 2nd December 2003 (Jo of O. of Wlkp. Voiv. No 192, pos. 3568). In surface waters on the analysed catchment, very high nutrient concentrations were observed. Following three years of measures undertaken to reduce nitrogen pollutions from agriculture sources, nitrate concentrations in the water were still very high (Ławniczak et al. 2008).

The characteristics of farms and the assessment of nutrient management were prepared on the basis of the data assembled by means of questionnaire surveys and documentation kept for the farms covered by the action programme within the NVZ in the Samica Stęszewska river catchment. The balance of compounds was estimated 'on the field surface balance method', according to guidelines described in the Decree by the Minister of Environment on the 23rd December 2002 in the matter of detailed requirements that the action programme of reducing the outflow of nitrogen from agricultural sources should meet (Jo. of laws from 2003, No 4, pos. 44), taking into consideration:

- 1) Input: the use of organic and animal manures, fertilizers, biological by-products ploughed under, ploughed under remains of papilionaceous plants, nitrogen deposits from

atmospheric depositions (according to the data from chemical monitoring of precipitation);

- 2) Output: taking components out with crops (main and marginal) from farmland, taking out components from grasslands.

The information concerning the degree of the acquaintance with the action programme and the farmers' awareness of the extent of the agricultural influence on the environment, especially the threat to waters, as well as the assessment of their knowledge of good agricultural practice principles and the effectiveness of its popularization was compiled on the basis of questionnaire surveys, interviews and the participation in consultative meetings with farmers and advisers, as well as of farm documentary files kept by the Wielkopolska Agricultural Advisory Centre in Poznań. The following elements were taken into consideration: storage of manures and silages on farms, capacity of storing devices, compliance with the principles of manure application by farmers, the assessment of practical use of documentation.

## RESULTS AND DISCUSSION

The investigated farms run typical and representative for the Wielkopolska region agricultural production, both with reference to the direction as well as the level of production. Investigations were not carried out on small, extensive farms, which are not covered by the action programme according to the Nitrate Directive and do not keep documentation.

The total area of farms was 991.91 ha, including 206.4 ha occupied by the large-area farms. The average area of privately-owned farms amounted to 35.01 ha ranging from 11.47 ha up to 95.0 ha. In the land use structure, arable lands were dominant constituting over 94% of agricultural land (AL), and on 16 farms the arable land constituted 100% of the area. Green fields on the arable land occupied the area of 520.69 ha in total and constituted almost 53% of all arable land. Permanent grasslands appeared scarcely on 11 farms and they constituted circa 1.8% of all arable lands and their average area on farms amounted to 0.54 ha. Durable plantations in the form of an orchard (0.19 ha) occurred only in one farm and had the smallest participation.

A distinct specialization in the pig breeding was a characteristic feature of the majority of farms in the examined region. Only seven farms did not have animals and they were geared exclusively towards crop production. One farm, apart from pigs, specialized also in poultry production (goose and duck breeding). Horses and ponies were kept on one farm only. On average, the livestock density on the investigated farms was  $0.5 \text{ LSU} \cdot \text{ha}^{-1}$  and on the individual farms ranged from 0 do  $1.95 \text{ LSU} \cdot \text{ha}^{-1}$  (Tab. 1). On one farm, the livestock exceeded the value of  $1.5 \text{ LSU} \cdot \text{ha}^{-1}$  of the farmland, determined in the Code of the Good Agricultural Practice (Kodeks... 2002), and on two, it was similar to this value. Majority of the crop production was used for the needs of the animal production. Fodder mixtures were made out of the produced grains buying only some concentrates with substantial contents of protein and phosphorus.

TABLE 1. General profile of farms

Specification	Average	Range	
		from	to
Area [ha]			
Total	35.01	11.5	206.4
Agricultural land	34.05	11.7	206.4
Arable land	33.14	0	206.4
Grasslands	0.64	0	5.66
Durable plantation	0.01	0	0.19
Green fields	18.71	0	39.06
Field with ploughed straw	0	0	0
Livestock [unit]			
Goose	214.3	0	6000
Ducks	214.3	0	6000
Ponies	0.4	0	10
Horses	1.1	0	31
Cattle	1.2	0	14
Pigs	1391.4	0	36000
Livestock density [LSU·ha <sup>-1</sup> ]	0.4	0	1.95

The selection of plants for cultivation and the cropping pattern were subordinated to the dominating kind of production, i.e. pigs. On the researched farms, crops constituted the majority, which was, on average, close 70%. Two farms were geared exclusively towards the production of maize for grain, and a small area was occupied by mustard. On three farms, the cultivation of cereal crops covered the entire area of the arable land (100%). Triticale dominated in the group of cereal crops and covered over 46% of the area of the cultivated cereal crops; barley, wheat and rye constituted the smaller part. Cereal mixtures and oat occupied the smallest part of the area; together they constituted 13.5% of the surface sown with cereal crops. They were mainly used for the production of feeds for livestock. On some farms

rapeseed was also cultivated, on average on 3.5% of the surface of arable land. From fodder plants, apart from maize, fodder beets were quite common taking up 2.6% of the surface, and potatoes – 1.2% of the surface. The remaining crop plants such as: lupine, lucerne, pea, ostopest blotchy and mustard did not constitute any significant part in the area and their sowing surface did not exceed 1%. Limited areas were sown with after-crops, the surface of which on average did not exceed even two hectares per farm. In total, after-crop area constituted only 5% of all farmlands.

The crop production on most of the investigated farms was quite intensive. Yields of cereals were between 3.5–4.5 t·ha<sup>-1</sup>; on average, they amounted to 4,0 t·ha<sup>-1</sup> and they were bigger than the average in the country. Farmers also got

good root crop yields, including potatoes – 21 t·ha<sup>-1</sup> and beets – 38.4 t·ha<sup>-1</sup>, as well as the rapeseed – 3.4 t·ha<sup>-1</sup>.

The level of fertilization on farms was high and in 2007 amounted to 260.5 kg NPK·ha<sup>-1</sup> AL, of which: 175 kg NPK·ha<sup>-1</sup> AL in mineral fertilizers and 85.5 kg NPK·ha<sup>-1</sup> AL in manures. Diversification of the level of mineral fertilization fluctuated from 59 up to 410 kg NPK·ha<sup>-1</sup> AL (Tab. 2). The highest levels of fertilizers were applied by a farmer who planted only maize and did not have any animals, while the smallest quantities of fertilizers were used by a farmer on a farm with a diversified structure of sown area, without any animals and using rather small amounts of manures.

The nutrient balance and the proportion of the input and output are a measure of the rationality of nutrient management (Kopiński 2005, Oenema 1999, Sapek 1996, Zbierska et al. 2002). It is assumed that, because of the quality of waters, the balance of nitrogen should not exceed 30 kg N·ha<sup>-1</sup> (Kodeks... 2002). In the case of the examined farms, the average surplus of nitrogen calculated ‘on the field surface method’ used as obligatory in Poland, amounted to 30 kg N·ha<sup>-1</sup> and, so it was within the recommended value (Tab. 2). On three farms, the balance was much bigger, achieving 99 kg N·ha<sup>-1</sup> in one of them. These farmers did not have animals and the total inflow of nutrients to the farms came from mineral fertilizers. The

TABLE 2. Utilization of fertilizers and the balance of nutrients in farm

Specification	Average	Range	
		from	to
Fertilization [kg·ha <sup>-1</sup> ]			
Nitrogen (N)	78	25	190
Phosphorus (P <sub>2</sub> O <sub>5</sub> )	39	0	88
Potassium (K <sub>2</sub> O)	58	0	132
Total NPK [kg·ha <sup>-1</sup> ]	175	59	410
Balance of nutrients [kg·ha <sup>-1</sup> ]			
Nitrogen (N)	30	-23	99
Phosphorus (P <sub>2</sub> O <sub>5</sub> )	16	-16	39
Potassium (K <sub>2</sub> O)	32	-38	95
Input/Output			
Nitrogen (N)	1.2	0.7	1.7
Phosphorus (P <sub>2</sub> O <sub>5</sub> )	1.3	0.6	1.7
Potassium (K <sub>2</sub> O)	1.3	0.6	1.8
Utilization of nutrients [%]			
Nitrogen (N)	83	62	145
Phosphorus (P <sub>2</sub> O <sub>5</sub> )	83	58	160
Potassium (K <sub>2</sub> O)	81	57	118

deficit of nitrogen amounted to  $-23 \text{ kg N}\cdot\text{ha}^{-1}$ , in farm without livestock. There low fertilizing was being practiced. The ratio of nitrogen input to output was, on average, 1.2 (it was balanced) and ranged from 0.7 to 1.7. The average use of nitrogen was 83% and fluctuated from 62 up to 145%.

The balance of phosphorus calculated using the 'on-the-field-surface method' fluctuated from  $-16$  up to  $39 \text{ kg P}_2\text{O}_5\cdot\text{ha}^{-1}$ , on average it was  $16 \text{ kg P}_2\text{O}_5\cdot\text{ha}^{-1}$ . The proportion of phosphorus input to output was about 1.3 on all farms (was close to balanced) and, on the individual farms, it fluctuated from 0.6 to 1.7. The utilization of this component was correct (on average 83%); however on farms with the largest surplus, it amounted only to 58%.

The average balance of potassium calculated with 'on-the-field-surface method' was similar to the balance of nitrogen and amounted to  $32 \text{ kg K}_2\text{O}\cdot\text{ha}^{-1}$ , ranging from  $-38$  up to  $95 \text{ kg K}_2\text{O}\cdot\text{ha}^{-1}$ . The highest ratio of input to output (1.75) was noted on the farm with the largest number of animals ( $1.95 \text{ LSU ha}^{-1}$ ), at a relatively small use of fertilizers ( $59.3 \text{ kg NPK}\cdot\text{ha}^{-1} \text{ AL}$ ). It results from the fact that the factor deciding about the level of the balance of potassium is animal production, with which the purchase of fodders is connected. The results of the component balance in the investigated farms were more beneficial than in 2000-2002 in this area (Zbierska et al. 2002) and comparable with the findings of other tests for similar farms in Poland (Kopiński 2005; Sapek 1996; Szponar et al. 1996). They are also more favourable than those in different nitrate vulnerable zones in

the aqueous region of the Warta River, which were checked by Kupiec (2007); larger nutrient surpluses were found. Differences between balance results in this paper and those reported by other researchers could result from the great diversification of farms in the examined area, differences in production levels, much more deliberate management of nutrients by farmers on the investigated farms, and choice of methodology used by scientists in Poland (Kupiec 2008).

The action programme implemented on the Nitrate Vulnerable Zones (NVZs) in order to protect waters requires, for example, appropriate conditions of manures and silage storage on farms, appropriate capacity of facilities for manure storage, compliance with the principles of application and the practical use of documentation, including nutrient management plans.

Poor situation in the area of manure storage facilities was confirmed by the fact that 41% of farmers declared lack of such devices, 24% of farms had such facilities but they were old and in bad or insufficient condition; only 7% of farms had new devices in a very good condition (Tab. 3). The manure concrete should provide possibilities of collecting and storing manure in periods, when it is not used agriculturally. In most of the checked farms (52%), the concrete was insufficient; only 17% had the concrete which met the necessary requirements. It was somewhat better in the case of liquid manure storage in containers, the capacity of which, in 28% of farms, was sufficient; however, in 48% – it was still insufficient and the available facilities were, in most cases, in satisfactory conditions.

TABLE 3. Percentage of farms in the evaluation of manures and silage storing and the rules of application

The visual assessment of storing manures and silages	Devices for storing [% of farms]						
	not apply	no	old and in bad condition	old and in sufficient condition	old and in good condition	old and in very good condition	new, very good condition
Manure storing	24	41	3	21	4	0	7
Liquid manure storing	28	10	7	45	3	0	7
Silage preservation	86	7	0	7	0	0	0
Assessment of the capacity of storing devices	Capacity of devices [% of farms]						
	N/A		insufficient			sufficient	
Plate capacity	31		52			17	
Tank capacity	28		44			28	
Assessment of obeying the principles of applying manures	Obeying the rules of application [% of farms]						
	not apply	do not obey	obey very rarely	try to obey – always	always obey		
Manures are used in permissible periods	21	0	0	0	79		
Manures are mainly used on grasslands	21	0	0	3	76		
Manures are covered not later than next day	14	0	0	0	86		
Manures are used minimum 20 m from waters	14	0	0	0	86		

Actions connected with obeying the principles of fertilization by farmers concern manure application:

- in liquid and solid forms in the allowed periods,
- in a solid form only on grasslands and long-term crops,
- on the arable lands and their coverings or mixing with the soil not later than the next day after using them,
- in the distance of at least 20 m from the water zone.

They also involve bans on the application of:

- manures on soils that are flooded with water, covered with snow or frozen to the depth of 30 cm;
- manures in a liquid form and nitrogen fertilizers on soils without plant cover, located on 10% slopes;
- manures in a liquid form during the vegetation of plants intended for direct human consumption;
- organic and organic-mineral manures obtained from animal by-products or containing such products on pastures.

A vast majority of farmers declared that they obeyed principles of application (Tab. 4). Almost all farmers knew recommendations and documentation connected with the actions programme and they always obeyed them (34–48%) or tried to obey (45–66%) them. Only two farmers did not apply the determined rates of doses of manures for the year and one of them also did not obey the nitrogen balance made out with ‘on the field surface balance’ method.

About the 60% of farmers positively evaluated actions taken for the purpose of water protection and expressed a belief that they would bring expected results in the form of the improvement of water quality. About 20% of farmers expressed negative opinions in this respect. The remaining persons did not have any opinion in this matter or they did not give any answer.

A lack of program of support for farmers on NVZs and limited (too small) funds for investments on farms, on the one hand and, at the same time, their obligation to carry out some tasks connected with the action programme, puts the farmers on NVZs in an adverse economic situation. The situation is even worse because of the fact that farmers in these areas have small possibilities of using the financial support within the agro-environmental programs. The actions written down in the program became compulsory in these areas and farmers could not declare them as agro-environmental actions. It is the result of the lack of agreement between the departments of agriculture and environment and the inconsistency of the executive provisions. These matters should be better solved and agreed upon

in the next 4-year period of the application of the Nitrate Directive and the realization of the new action programme in the Nitrate Vulnerable Zones in order to create a greater possibility of achieving the expected effect of the improvement in the quality of waters.

## CONCLUSIONS

1. The investigated area has a typically agricultural character with the dominance of arable lands and a small part of forests, meadows and pastures. This phenomenon is adverse and supports the increased washing out of elements and the transport of nutrients to waters. The cropping pattern is simplified with mainly cereal crops in it, mainly wheat, triticale and barley. The majority of farms is involved in intensive agricultural production and applies high levels of manure and fertilizers.
2. Animal production is dominant on the investigated farms. High livestock density causes increased production of manures increasing the risks of nutrients getting into the environment.
3. The balances of compounds on the majority of farms showed surpluses, resulting, above all, from large amounts of purchased mineral fertilizers and feeds. In the case of farms geared towards animal production, the balances were much higher, since large amounts of compounds were brought in feeds, and relatively small amounts taken out in the sold livestock. For this reason, the farms specializing in



TABLE 4. Percentage of farms in the evaluation of the principles of manure application and practical use of documentation

Assessment of obeying the rules of manure application	Obeying the ban on using manures [% farms]				
	not apply	do not obey at all	obey very rarely	tries to obey always	always obey
On flooded, covered with snow and frozen soil	10	0	0	0	90
Not on soil without plant cover, located on > 10% slopes	97	0	0	0	3
Natural in the vegetative period of plants for direct eating	93	0	0	0	7
Organic received Organic adventitious	97	0	0	0	3
Assessment of practical use of documentation	do not obey/do not use	obey/use very rarely	tries to obey/use always	always obey/use	
Annual nutrient management plan for cultivation	0	0	66	34	
Dose of the manures during a year contains < 170 kg N ha <sup>-1</sup> UR	7	0	45	48	
Balance of nitrogen made out with 'on the field surface balance' method	3	0	62	35	

animal breeding, especially pigs, pose a greater threat to the quality of waters and environment.

Farmers showed extensive knowledge of the principles of good agricultural practice and they declared the will of the completion of actions implemented in the chosen vulnerable zones to nitrates from agricultural sources. In most cases, they complied with the recommendations of the Code of Good Agricultural Practice. No farm exceeded the amount of 170 kg N·ha<sup>-1</sup> in manures which is

recommended in the Nitrate Directive; however, the fertilizing level in the river basin area is quite high.

## ACKNOWLEDGMENT

The study described in this paper has been carried out within the research project 2 PO6S 026 28 founded by Ministry of Science and Informatisation. The financial support by this organization is gratefully acknowledged.

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**Streszczenie:** *Działania ograniczające odpływ azotanów ze źródeł rolniczych do wód na obszarze szczególnie narażonym w zlewni rzeki Samicy Stęszewskiej.* Celem przeprowadzonych badań była ocena zakresu i skuteczności działań prowadzonych na obszarze szczególnie narażonym na azotany w zlewni obejmującej wody wrażliwe na zanieczyszczenia rolnicze. Badania w zlewni Samicy Stęszewskiej prowadzono w latach 2005–2007. Obejmowały one m.in. ocenę jakości wód powierzchniowych, kierunków i intensywności działalności rolniczej, stosowanych praktyk rolniczych, planowania i bilansowania nawożenia. Badania wykazały, że na obszarze zlewni rzeki Samicy Stęszewskiej dominują użytki rolne i rolnictwo ma znaczący udział w zanieczyszczeniu do wód. W wielu gospodarstwach brak budowli i urządzeń do właściwego przechowywania nawozów naturalnych. Większość gospodarstw prowadzi intensywną produkcję rolną, wiele specjalizuje się w chowie trzody chlewnej. Często

stosuje się w nich wysokie nawożenie mineralne i występuje wysoka obsada zwierząt. Powoduje to wprowadzanie dużych ilości składników do agro-ekosystemów i dodatnie salda składników nawozowych. Rolnicy wykazali się dobrą znajomością zasad dobrej praktyki rolniczej i deklarowali wolę realizacji działań wprowadzonych na wyznaczonych obszarach szczególnie narażonych na azotany ze źródeł rolniczych. W większości przypadków stosowali się do zaleceń, jakie nakazuje im Kodeks Dobrej Praktyki Rolniczej. Żadne gospodarstwo nie przekroczyło zalecanej w Dyrektywie Azotanowej ilości  $170 \text{ kg N}\cdot\text{ha}^{-1}$  w nawozach naturalnych, jednakże poziom nawożenia na terenie zlewni jest dość wysoki.

*MS. received – November 5, 2008*

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