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DISTRIBUTION OF NITRATE POLLUTION IN THE NIRAJ (NYÁRÁD) RIVER BASIN

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Abstract. The goal of our research was to conduct a systematic study of ground water nitrate pollution in the Niraj (Nyárád) River Basin, to evaluate this contamination, and it's causes. Samples of water were obtained from individual water sources (wells) from villages and from surface water sources. In the individual water sources the concentration of nitrate has increased significantly over time, exceeding in many cases the maximum contaminant level, indicating a potential health risk to nearby residents.

The relationship between the potential pollution sources and groundwater nitrate pollution was analyzed in function of the agricultural practices, the nature of the pollution sources (punctual and diffuse pollution sources), the geographical conditions, hydrological conditions, and rainfall regime. During our research we linked the diffuse and punctual pollution sources with the spatial distribution of nitrate pollution of groundwater.

According to our research the main cause of pollution of the groundwater with nitrate is the type of agricultural practices employed, especially small scale farming with animals and bad management of the manure/waste and the untreated household's wastewater. In the Niraj catchment area, in 43% of the sampled wells, the nitrate pollution exceeds 50 mg/l. The results differ in different parts of the catchment area, in the upper part (over 350 m a.s.l.) the proportion of the sampled wells (where the concentration of the nitrate is higher than 50 mg/l) is 26%, and in the lower part (under 350 m a.s.l.) the percentage of the sampled wells where the concentration of the nitrate is higher than 50 mg/l is 64%. These differences are probably caused by the soil properties and topography. According to our results, on the terraces and downstream the localities, there exists a concentration of nitrate pollution. The nitrate pollution of the groundwater depends also on the rainfall regime.

Key-words: nitrate pollution; nitrate leaching; Nitrate Directive, Niraj (Nyárád) River cachement area, pollution sources, water sampling.

1. INTRODUCTION

The nitrate pollution of groundwater is widely studied, especially pollution of groundwater from agricultural sources. Nitrate leach downward into the soil profile, out of the crops rooting zone, and eventually into the groundwater is a complex process. With some soils it may take only a few years (or less) for nitrate to leach into the groundwater, whereas with other soils the chance of nitrate leaching into groundwater is remote. A large number of experiments have been conducted to observe the correlation between NO_3-leaching and the environmental or management factors. Recent researches were conducted to merge the several models to improve the modeling reliability. It was also studied the nitrate leaching and runoff into rivers and estuarine ecosystems causing algal blooms and eutrophication. A special case is the nitrate pollution of the individual water sources that pose public health risk. For example, 9% of U.S. domestic wells sampled during 1993–2000 had nitrate concentrations exceeding the U.S. Environmental Protection Agency's (EPA) maximum contaminant level of 10 mg/1 as N. In the Yakima River Basin of Washington State, 13% of the samples taken from small-watershed sites exceeded the EPA's maximum contaminant level, indicating a potential health risk to nearby residents with shallow wells.

Our research was made in the Niraj River catchment area. The objective of the research was to study the nitrate pollution of water in individual wells in function of the topography, farm management practices used, agricultural practices, rainfall regime, and situation of the buffer zones in the Niraj River catchment area.

2. METHODS, TECHNIQUES, MATERIAL STUDIED AND AREA DESCRIPTION

2.1. Methods, techniques

2.1.1. *Selection of the area designated to evaluation.*

The area designated for evaluation was selected according to the relevant criteria (above) for the Niraj river catchments area. Evaluation of individual water sources from localities from the upper, middle and lower part of the river basin was made in order to evaluate the situation of the ground water pollution from the catchments area. Other criterion of selection included the situation of the localities in relation to the Niraj River and tributaries. Localities along the Niraj River and along the tributaries were selected.

2.1.2. Selection of the individual water sources (wells) designated for monitoring

The individual water sources for monitoring were selected according to their distribution in the locality and according to their distance from potential pollution sources. During our research we intended to identify the relation between the potential pollution sources and the nitrate pollution of the groundwater. The sampled wells were domestic wells of every day use and all of shallow wells. The samples from surface water were obtained from the tributaries, where it was possible at two sampling points: before and after the locality.

2.1.3. Piezometric level measurements

In order to evaluate the tendencies of distribution of the nitrate in the groundwater, which was very important in obtaining our research data, the piezometric level was measured with a GPS (Garmin E-trex).

2.1.4. Analyses of the water samples

The nitrate concentration of the water samples was analyzed in the laboratory of the Szent István University from Gödöllő, using a distillation method. During the pre-evaluation of the nitrate concentration in the studied area other methods were also used (Merck nitrate test and spectrophotometric method, using 2, 4 dimetilphenol).

2.1.5. Elaboration of the nitrate distribution maps of the groundwater in the research area, evaluation of the results

The distribution of the nitrate in the groundwater was represented in GIS maps.

2.2. The studied material

The nitrate pollution of groundwater is widely studied, especially the pollution of groundwater from agricultural sources. Nitrate leaching downward into the soil profile out of the crops rooting zone and eventually into the groundwater is a complex process. With some soils, it may take only a few years (or less) for nitrate to leach into the groundwater, whereas with other soils the chance of nitrate leaching into groundwater is remote.

Prominent among factors that affect the nitrate-leaching process are soil properties, topography, climate, kind of crops grown, and farm management practices used (Smith & Cassel, 1991). Classification of soils by their susceptibility to leaching represents an effective management aid. Four aids in estimating nitrate-leaching potentials are: (1) permeability (Cassel & Vasey, 1974), (2) available water holding capacity (Cassel & Nielsen, 1986), (3) hydrologic group (Musgrave, 1955), and leaching class (Kissel et al., 1982). It was demonstrated by research in a pilot area (Füleky, 2004) that in the case of increasing artificial fertiliser use, nitrate leaching it is significant. This research demonstrated that nitrate can be found at soil depths of 3 m, the plants are using the nitrate from the artificial fertiliser above and the nitrate below resulted from the mineralization of the organic material which leached into the soil. Research in different catchment field systems (Pierre, 1983) demonstrated that (i) the increase of nitrate concentration in water is directly related to the rainfall regime and to the degree of intensification of agriculture, (ii) there is a relation between agricultural practices and the quality of water (average nitrate concentration over the period for forestry, mix agriculture and intensive agriculture is 9, 22 and 53 mg/l respectively); the geographic structure of land influences nitrogen dynamics, as well as buffer zones which reduce nitrogen leaching. According to other research (Dugast, 1999) in Aurade catchment (France) the measurement of soil nitrogen solution confirmed the efficiency of a grass-strip along the river, a 8-10 m width was considered sufficient.

A large number of experiments have been conducted to observe the correlation between NO_3^- leaching and the environmental or management factors. However, with limited time and funding for field experiments, estimation of $NO3^-$ leaching, especially at a regional scale, has had to rely on mathematical models. Some of the models, such as MIKE SHE (DHI, 1999) and MODFLOW (Harbaugh et al., 2000) are hydrology-oriented with less details about N biogeochemical processes; and some, such as CENTURY and SOILN (Liu et al., 2000; Johnsson et al., 1987), have N turnover functions but with marginal hydrological features.

Recent research was conducted to merge the two kinds of models for improving the modeling reliability. As a result of this research a biogeochemical model was adopted with limited modifications to serve as a NO_3^- leaching prediction tool that can be used for farm management planning (Li et al., 2006). In comparison with several existing biogeochemical models, such as CASA, CENTURY, or Roth-C (Potter et al., 1993; Johnsson et al., 1987; Jenkinson, 1990), DNDC possesses a relatively complete suite of N transformation processes under both aerobic and anaerobic conditions.

In addition, a one-dimension water flow module has been developed in DNDC (Li et al., 1992; Zhang et al., 2002a,b). The existing models provided a basis for further developing the newer model with new features such as N leaching.

Nitrate leaching and runoff into rivers and estuarine ecosystems are responsible for algal blooms and eutrophication and also pose a public health risk (Beman, Arrigo, & Matson,. 2005, Wolfe, & Patz, 2002). For example, 9% of U.S.domestic wells sampled during 1993–2000 had nitrate concentrations exceeding the U.S. Environmental Protection Agency’s (EPA) maximum contaminant level of 10 mg/l as N (Nolan, B. et al., 2002). In the Yakima River Basin of Washington State, 13% of the samples taken from small-watershed sites exceeded the EPA’s maximum contaminant level, indicating a potential health risk to nearby residents with shallow wells (Führer et al., 2004).

2.3. Description of the studied area

2.3.1. Climatic data

The Niraj River catchment basin is divided in two different parts: mountainous and hilly with an annual average temperature of 8.5 °C. The climate is continental. The annual average rainfall is situated between 700-1200 mm having a difference between the mountain zone and the lower part, and the evapo-transpiration is situated between aprox. 600 mm at the low altitude and 450 mm in the mountainous zone.

2.3.2. Morphology

The Niraj River is a left tributary of the Mures River. The source of the Niraj River is in the Gurghiu Mountains of volcanic origin (1776 m high) at 1300 m asl. The river is 79 km long and the river mouth it is situated at Ungheni at 300 m. asl The difference in height between the source and the river mouth is about 1000 m. The catchment basin is 625 km^2 large and in this area there are situated 63 communities.

2.3.3. Hydrology

The Niraj River from Ghiurghiu to Eremitu is a rapid river and its alluvium consists of coarse gravel. In this part of the Niraj River there is a high gradient. Between Eremitu and Miercurea Nirajului the high slope is maintained enough that the alluvia still consist of coarse gravel and sand. This part of the river is called Nirajul Mare and at Miercurea Nirajului the Niraj River joins the Nirajul Mic. The main characteristics of the run-off in the Niraj catchment basin is the concentration of the flow in the mountainous and hilly area at the Nirajul Mare until Miercurea Nirajlui as well as the concentration of the outflow downstream to the confluence with Nirajul Mic. After Miercurea Nirajului (in the middle and lower part of the basin) the bottom of the valley becomes 1.6 km wide and from here the river has meanders. This broad valley persists (in some sectors it is 2 km large) which is unusually large for a river with such a small water output (average 3,6 m^3/s). It is characteristic that in the case of floods the water output it is much higher than the annual average (the maximum water output was 330 m^3/s in May 14, 1970). Thanks to the fine lime particles carried by the tributaries, the water of the river has a yellow color. Due to this color the Niraj River received the popular epithet “blond”. The valley has an asymmetric character, several tributaries flow into the valley on its left side. The tributaries from both sides are almost perpendicular to the main watercourse. Most of the tributaries are coming from the left side of the valley. These tributaries bring large quantity of lime which at all times pushes the minor riverbed to the right side of the valley and contributes the choking of the riverbed. To collect the water from these tributaries on the left side of the Niraj valley flood plain more than 300 years ago a channel was created by the local inhabitants. The channel is named Vecka and is approx. 22 km long. Currently this channel begins in Nirajul Mic (at Miercurea Nirajului) and flows to meet the Niraj River at Cinta village. At the commune Gheorghe Doja the valley enlarges like a fan towards the Mures River valley where its gradient decreases even more. There are bigger meanders until the river mouth, which is situated at the village Vidrasău, approx. 17 km downstream to Tg. Mures. Alongside the entire inferior part of the river the flow is quiet (now the situation is changed a little bit due to gravel quarrying) due to the reduced slope.

2.3.4. Pedology

In the Niraj River catchment basin the soil diversity is high. In the upper part there are mainly lithomorphic soils (andosol, vertisol), on the floodplain there are mainly hidromorphic soils. In the catchments area most frequently there are argillic soils, but there are also mollic soils and cambic soils.

2.3.5. Population and land use

The Niraj River basin traditionally has been one of the most populated areas of Transylvania. The Niraj River catchement basin is entirely situated in Mures County.

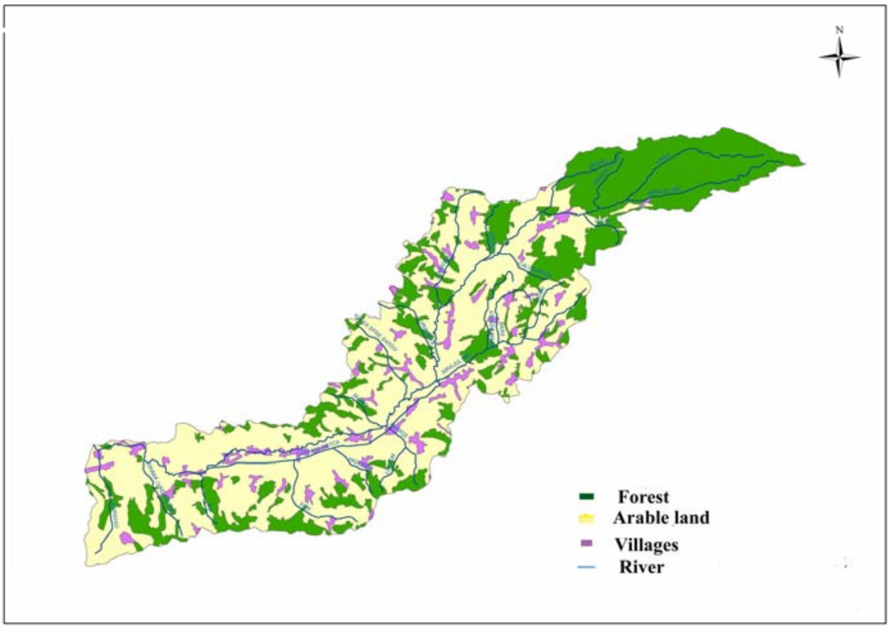

Fig..1 Land cover map of the Niraj River catchment basin conform Corine Land Cover

Due to the lime rich nutrients the soil of flood plain is very suitable for the production of vegetables, this part of the Niraj River valley being named the "Carrot Country". Due to the Vecke channel a very specific way of production in the Niraj valley was employed, water management was linked with the production structure of vegetables in the fertile lime. From documents we know, that the Vecke channel was part of a production system, which reflected a remarkable conception for that time, and the Vecke was not as simple of a water channel as it is now. This production system used the nutrient rich sediment carried by the river during the floods on the right side of the valley for the production of vegetables and to also reduce/stop potential damages caused by large water outputs. Villages are situated on the right side of the valley and in the relatively long valleys of the tributaries on the left side, there are also villages (e.g.. Lucson creak, Dorman creak). The structure of the villages show that in the past the central part of the valley (the 1-2 km large part situated between the Niraj River and Vecke channel) was considered a flood plain and the production structure was adapted to this situation. This farming system, beside the mentioned vegetable production, included fruit and animal farming. This specific form of production made it possible for the Niraj valley to have, as it has historically, one of the highest population densities in Transylvania, which increased the pressure on the ecological system and increased the nitrate pollution of ground water. Unfortunately with the increasing cereal production (mainly during the socialist period) the former agricultural practices where no longer employed. Part of the Niraj river (79 km long) was "regularized": for example, the segment between Miercurea Nirajului and Cinta was shorted by 35%. The dams created to prevent the floods were situated near the river (100 m) and do not follow the existing meanders, reducing the flooded area to 7% of the original size.

Watermills existed along the Niraj river in each village (some villages had more than one). To ensure access to water for the mills, small dams which prevented the erosion process and maintained the water of the river at a permanent level were constructed. Due to this fact, the ground water and the living river were in permanent contact with one another, ensuring good water quality for the population of the villages. The small natural dams improved the water quality of the water quality of the springs and wells, allowing the farmers to reap the benefits.

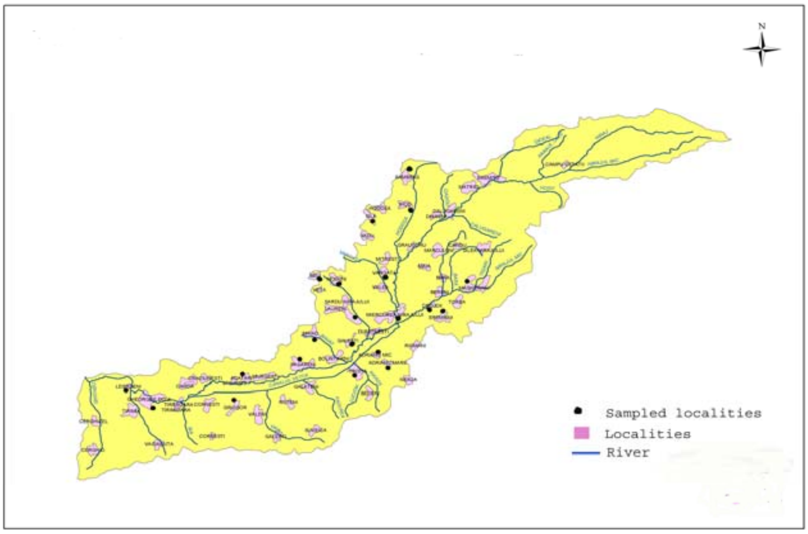

Fig.2. Sampled localities in the Niraj River catchment area

Due to recent water regulation work, the gravel from the bottom of the river has been moved and now we can find only sand and lime in the river bed. This newer composition has caused serious changes in the hydrological characteristics of the river and has caused severe erosion. The consequences of the erosion process are visible in Vargata village (10 km upstream from the regularized segment) where the houses built on the once "safe" side of the river are now in danger. These changes have made it less possible to maintain the landscape of the Niraj valley, where the flood area was characteristically the site of growing vegetables, orchards and pastures and the upper part was occupied by forests.

3. RESULTS

During our research in the period 2003-2006 in the Niraj River catchments area 17 localities were evaluated, from the upper, the middle, and from the lower part. (fig. 2)

Table 1. Nitrate concentration in localities situated under 350 m a.s.l.

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	1	2	3	4	5	6	7	8	9	10
Sântana	139.0	16.0	74.7	198.4	11.6	2.4	93.4	118.0	36.9	195.0
Găleşti	139.0	76.7	159.0	106.0	141.8	4.4	139.0	141.0	375.0	107.0
Păsăreni	18.8	4.9	58.3	3.2	44.5	53.4	25.7	2.3	56.5	45.0
Satul Nou	59.2	68.0	103.0	59.8	71.5	280.0	271.0	189.0	62.5	215.0
Leordeni	54.6	31.1	114.0	18.4	101.5	73.1	79.6	74.3	221.0	98.0

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	11	12	13	14	15	16	17	18	19	20
Sântana	25.8	110.3	150.4	195.0	6.9	1.9	0.6	nd	nd	nd
Găleşti	93.5	20.4	31.4	60.7	68.4	67.3	45.2	15.2	120.0	19.0
Păsăreni	46.3	4.7	60.9	28.9	19.3	18.5	43.7	16.6	23.3	204.0
Satul Nou	207.0	99.2	26.2	340.0	120.0	63.8	214.0	297.0	257.0	173.0
Leordeni	71.4	462.0	406.0	133.0	233.0	311.0	347.0	75.3	354.0	254.0

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	21	22	23	24	25	26	27	28	29	30
Găleşti	nd	nd	nd	nd	nd	nd	26.3	89.4	66.9	93.5
Păsăreni	82.8	104.0	113.0	114.0	68.1	52.5	96.4	68.6	174.0	nd
Leordeni	5.3	22.5	222.0	195.0	280.0	14.2	120.0	112.0	70.4	449.0
Satul Nou	156.0	nd	nd	nd	nd	nd	nd	nd	nd	nd
Leordeni	170.0	96.8	121.0	24.9	86.1	309.0	nd	nd	nd	nd

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	31	32	33	34	35	36	37	38	39
Găleşti	62.0	51.7	8.0	41.6	60.5	40.7	70.4	233.0	140.0
Leordeni	440.0	nd	nd	nd	nd	nd	nd	nd	nd

Out of 355 wells sampled, 152 wells(43 %) exceeded the nitrate concentration standards of the EU (50 mg/l), (table nr.1 and 2) which is much higher than in the Yakima River Basin of Washington State, where 13% of the samples taken from small-watershed sites exceeded the EPA's maximum contaminant level in shallow wells (Führer et al., 2004).

The different nitrate levels throughout the valley are geographically important considering the agricultural practices are similar in the different villages. The varying nitrate levels are caused by the soil properties and the topography of the landscape

(Smith & Cassel, 1991). There are significant differences between the sampling points in the higher part of the catchment area, over 350 m, and those sampling points situated in the lower part of the catchment area, under 350 m. In the lower part of the catchment area the nitrate concentration exceeds in 66 % the 50 mg/l (Table 1) and in the upper part, the nitrate concentration exceeds the 50 mg/l in 26 % of the sampled wells (Table 2).

Table 2. Nitrate concentration in localities situated over 350 m a.s.l.

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	1	2	3	4	5	6	7	8	9	10	11
Măgherani	4,3	66,4	90,7	41,1	45,9	24,0	15,3	34,7	12,7	27,0	145,0
Mărculeni	13,7	64,4	116,0	36,3	49,5	148,0	87,1	53,0	53,9	82,0	94,2
Adrianu Mare	2,7	4,5	1,3	1,7	4,3	3,5	1,9	5,8	51,2	2,7	1,9
Adrianu Mic	9,4	23,1	2,7	10,1	4,7	1,6	110,0	45,8	113,0	5,6	3,6
Beu	4,4	3,1	29,6	0,7	32,7	1,3	3,2	1,0	1,3	0,7	12,3
Măiad	3,9	46,1	120,0	59,4	51,7	76,4	12,7	26,5	92,8	47,0	58,4
Isla	7,2	2,7	46,0	34,0	17,9	34,2	50,7	13,3	154,0	112,0	17,7
Sâmbriaş	20,2	14,2	83,7	37,4	50,6	20,0	49,5	34,0	17,8	5,0	10,6
Hodoşa	2,3	31,6	3,5	nd	nd	nd	nd	nd	nd	nd	nd
Gruişor	6,0	74,1	16,4	5,2	17,9	41,4	36,7	17,8	153,0	nd	nd
Drojdie	7,4	34,1	10,2	42,0	10,7	10,9	nd	nd	nd	nd	nd
Eremieni	6,1	40,1	17,0	143,0	8,0	0,2	nd	nd	nd	nd	nd

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	12	13	14	15	16	17	18	19	20	21	22
Măgherani	27,7	13,1	45,3	91,5	102,9	13,2	59,8	8,6	144,0	19,0	14,1
Mărculeni	138,0	76,0	41,0	102,0	88,7	1,0	60,1	23,6	63,5	114,0	50,3
Adrianu Mare	4,0	119,0	220,0	3,1	52,8	1,4	46,8	1,4	1,7	9,7	2,3
Adrianu Mic	9,7	14,3	20,6	3,1	5,3	13,4	4,0	63,0	46,7	2,7	3,4
Beu	45,9	28,5	1,3	77,1	79,1	129,0	35,4	17,9	10,0	nd	nd
Măiad	39,3	4,8	172,0	5,7	119,7	10,4	nd	nd	nd	nd	nd
Isla	84,3	84,3	12,5	nd	nd	nd	nd	nd	nd	nd	nd
Sâmbriaş	103,0	9,4	21,1	74,6	4,8	nd	nd	nd	nd	nd	nd

Localities	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l	NO_3^- mg/l
Well Nr.	23	24	25	26	27	28	29	30	31	32	33
Măgherani	4,9	10,6	5,2	118,9	9,6	10,2	nd	nd	nd	nd	nd
Mărculeni	29,3	24,0	nd	nd	nd	nd	nd	nd	nd	nd	nd
Adrianu Mare	1,7	1,3	3,1	3,5	2,7	10,3	4,4	5,1	13,4	4,0	5,0
Beu	46,7	38,9	16,7	2,6	3,1	11,2	3,9	nd	nd	nd	nd

However, in the upper part of the catchment area in the case of the villages situated on the terraces of hillsides, the percent of heavily contaminated wells is much higher. For example, in the case of the village Mărculeni, (Table 2) 64 % of the sampled wells had nitrate concentrations exceeding 50 mg/l. In the case of other villages situated on steep slopes, the percent of sampled wells where the nitrate concentration exceeded 50 mg/l is much lower, as in the case of Adrianu Mare(Nagyadorján) (see Table 2) where only 12% of wells exceeded 50 mg/l.

Table 3. Altitude of the water table and nitrate concentration of the sampled wells in Adrianu Mare

Altiutude (m)	388	380.5	384	387	374	376	387	383
Nitrate concentration (mg/l)	2.7	4.5	1.3	1.7	4.3	3.5	1.9	5.8
Altiutude (m)	377.5	362.5	364.5	364.5	361	365	365	367
Nitrate concentration (mg/l)	4	119	220	3.1	52.8	138	46.8	1.4
Altiutude (m)	368.5	369	367.5	368	369.5	366	364.5	362.5
Nitrate concentration (mg/l)	2.7	3.4	1.7	1.3	3.1	3.5	2.7	10.3
Altiutude (m)	367	368.5	370	387	383	382	368	367
Nitrate concentration (mg/l)	4	5	3.4	4.8	4.3	16.9	5	7.3

For the villages situated on upper part of the catchment area the percent of wells exceeding 50 mg/l of nitrate was similar to that of Adrianu Mare (about 12%). In this case the nitrate pollution is concentrated under the central part of the village, as it is in other research sites (Kerényi et. al, 1995).

As we can see in fig. 3, the village of Adrianu Mare is situated in the bottom of a valley of a tributary (Dorman creek). The distribution of the sampled wells covers the whole territory of the village. The nitrate concentration is low in areas of the village where there is a steep slope and is higher on the terraces. In this case we have two terraces, where we have higher nitrate concentration (see Table 3).

The centre of the village is situated on the main terrace, thus having the highest concentration of nitrate in the groundwater. The nitrate is concentrating at this point from pollution of diffuse and punctual sources from the village. On the lower part of the village where the slope again becomes steep, the nitrate concentration is reduced.

For the villages situated in lower part of the catchment area, under 350 m a typical village is Leordeni (Lőrincfalva). In this village 31 wells were sampled (fig. 4).

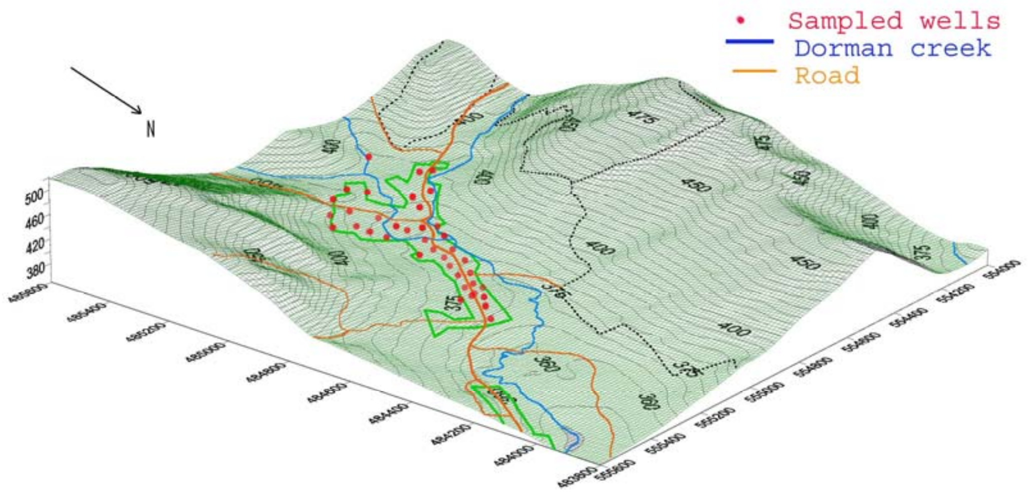

Fig. 3. Sampled wells in Adrianu Mare

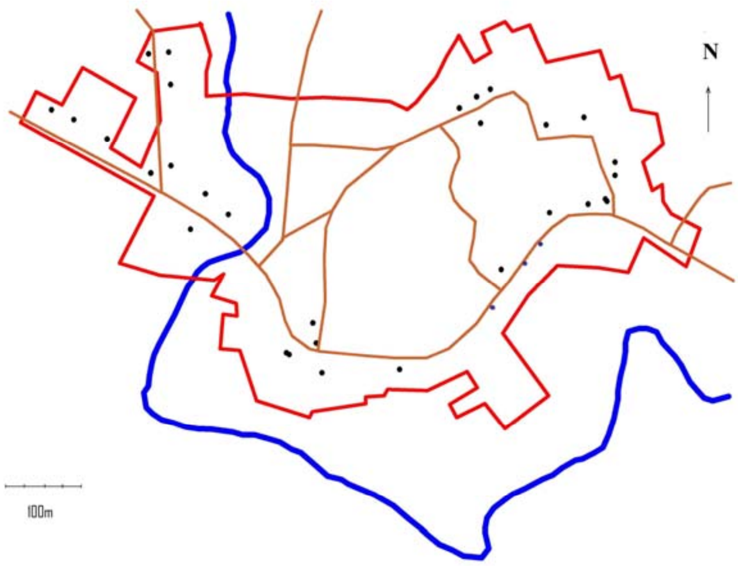

Fig.4. Sampled wells in Leordeni

In this case there are high values of the nitrate concentration of the sampled wells (90% exceeding 50 mg/l), so it can be said that the groundwater is severely polluted with nitrate. There are lower values only on higher parts of the village and near the river where the groundwater is in direct contact with water from the river (see Table 4).

Table 4. Altitude of the water table and nitrate concentration of the sampled wells in Leordeni

Altitude (m)	297	296	297	296	295	295	294	294	294	293
Nitrate concentration (mg/l)	54.6	31.1	114	18.4	101.5	73.1	79.6	74.3	221	68

Altitude (m)	299	297	295	296	298	300	297	294	295	297
Nitrate concentration (mg/l)	462	406	133	233	311	347	75.4	354	254	170

Altitude (m)	298	301	305	305	308	314	314	314	310
Nitrate concentration (mg/l)	121	24.9	86.1	309	120.8	112	70.4	449	440

The village of Leordeni is situated partly on the floodplain of the Niraj River and partly on the terrace. In the village 31 wells were sampled, the difference between the highest water table (314 m) and the lowest water table (293 m) being 21 m (see Table 4). In this case we have two concentrations of nitrate pollution. We have a concentration point on the terrace situated on the higher part of the village (314 m) and another concentration point on the terrace situated on the lower part of the village (293 m). In both cases the groundwater pollution is caused by diffuse pollution sources and punctual diffusion sources.

According to the results of our research in Leordeni (Lőrincfalva), the modeling of water flow confirms the observation of previous authors that the nitrate pollution of groundwater is dependent on the groundwater flow (Zhang et al., 2002a,b) and the efficiency of grass-strip/vegetation along the river (Dugast, 1999). We can observe reduced nitrate concentrations of groundwater in the vicinity of the river, where water from the river is in direct contact with the groundwater, causing dilution.

During our research we created the nitrate spatial distribution maps and the groundwater flow maps for all 17 selected villages similarly to the presented cases. According to our research, the nitrate pollution of the groundwater is linked to the agricultural practices so we can confirm that there is a relation between agricultural practices and the quality of water (Pierre, 1983). Most of the inhabitants, having small farms and a small number of animals (2-15 cattle, 2-5 pigs, poultry), are not managing the animal waste properly. Manure heaps are not insulated causing the nitrate to leach into the groundwater. These manure heaps are individual pollution sources and the main cause of the high concentration of nitrate under the localities is represented by individual pollution sources.

During our research we have examined how the influence of pollution sources (diffuse and punctual) from the localities effects the pollution of surface waters with nitrates (see fig. 5.). This examination was possible where a creek was flowing over the locality. In each case a significant increase of nitrate concentration in the creek after running through the village was observed: Drojdie (Seprőd) from 7.44 mg/l to 10.88 mg/l, Maiad (Nyomát) from 3,92 mg/l to 10,94 mg/l and Isla (Iszló) 7,55 mg/l to 12,48 mg/l. In the mentioned cases before, the first sampling point punctual pollution source doesn't exist and the pollution of the water with nitrate is from diffuse pollutions sources. In the localities the pollution of the water with nitrate is from diffuse and punctual pollutions sources.

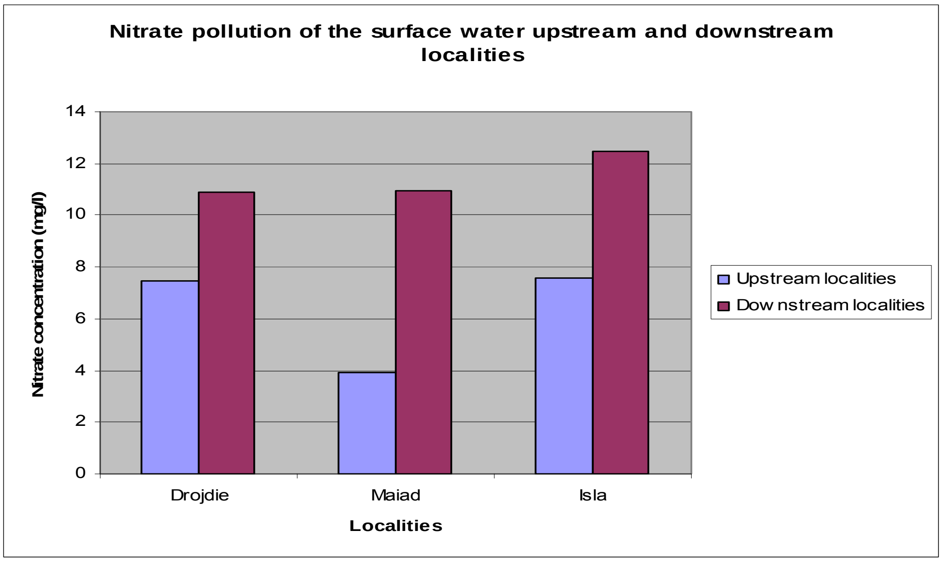

Fig. 5. Pollution of the surface waters with nitrate by the diffuse and punctual pollution sources from the localities

During our research we studied the influence of the rainfall on the pollution of the groundwater and we obtained results which confirm that the increase of nitrate concentration in water is directly related to the amount of rainfall (Pierre, 1983). We sampled 17 wells in the village of Maiad during the snows melting period (March 2006) and during the dry period from autumn (September 2006). In the profile of this village we can observe that it is situated on a terrace along a tributary of the Niraj River and we can observe the accumulation of the nitrate on the terrace. According to our results, on the steep slope the high water table increases the nitrate concentration on the terraces. During dry period, the nitrate concentration is higher but when there is more water/a high water table, the nitrate concentration decreases (Table 5).

Table 5. Variation of the nitrate concentration as the function of rainfall in Maiad(Nyomát)

Altitude (m)	390	389	387	387	386	387	387	382	382.4
Nitrate concentration (mg/l) March 2006	3.92	46.1	120	59.4	51.7	76.4	12.7	26.5	92.82
Nitrate concentration (mg/l) September 2006	0.15	25.4	99.9	53.7	8.77	1.81	42	37.8	57.15

Altitude (m)	384.9	381	370	381	375	375	369.5	370	
Nitrate concentration (mg/l) March 2006	46.64	58.4	39.3	4.8	172	5.68	119.7	10	
Nitrate concentration (mg/l) September 2006	23.66	69	83.1	5.14	164	170	139.3	6	

4. CONCLUSIONS

Nitrate pollution of the groundwater in the Niraj River Basin is a major concern and important issue, in 43 % of the sampled wells nitrate concentrations exceeded EU standards (50 mg/l). In our study, the main cause of groundwater pollution with nitrate was due to agricultural practices and untreated household water. High nitrate concentrations exist under the localities because of the large number of small scale farms where animal waste is not managed properly and the household waste water is not treated. The nitrate leaching depends on topography, and soil proprieties. On the different parts of the catchment there are different nitrate concentrations of the groundwater even though the agricultural practices and the small farms management are not different. On the upper part (over 350 m) 26% of the sampled wells have an average concentration of nitrate higher than 50 mg/l, and in the lower part (under 350 m) 64% of the sampled wells have concentrations of nitrate higher than 50 mg/l. The concentration of nitrate is significant on the terraces and on the floodplain of the river. On the steep slopes the nitrate concentration is lower. The nitrate concentration in the groundwater depends also on the amount of rainfall.

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