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GROUNDWATER QUALITY ANALYSIS OF DEEP AQUIFER IN KIKINDA, SERBIA

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ABSTRACT

Municipality of Kikinda spatially belongs to the northern part of Banat, Autonomous Province of Vojvodina and covers an area of 782 km^2. The water supply system uses groundwater wells which capture water from deep aquifer at a depth of about 200 meters and consists of central city water source and water sources from surrounding local communities.

City's central water supply system contains 14 wells, divided in several water sources which are: "Šumice", "Toza Marković", "Jezero" and "Masarikova". The total projected yield of all 14 wells is 260 l/s.

Regarding the chemical composition, water from all observed wells in the whole area is hygienically unfit or does not correspond to the Regulation on hygienic quality of drinking water. For example, it should be noted here that there is a significant increase of organic matter and increase of ammonia, while the occurrence of iron, nitrate and nitrite is contained within the reasonable standard considering the period of 1989-1990 and for the period 1997-1998.

Having in mind the whole issue of the given municipality, this paper will present the groundwater chemistry analysis and distribution of pollutants of the central water source "Šumice", using a software package for modeling groundwater chemistry.

Key words: ground water quality, pollution, modeling

INTRODUCTION

Municipality of Kikinda, with an area of 782 km^2, and 10 local communities, is located in Autonomous Province of Vojvodina and represents the administrative center of North Banat district. In the prewar period (till 1990) Kikinda was one of the most developed municipalities of Autonomous Province of Vojvodina regarding mining, industry and agriculture [1]. In the last 20 years some of the industrial activities have been shut down; however their environmental consequences can still be felt [2]. Among others, one of the endangered resources is also groundwater of the unconfined and confined aquifer [2]. The whole aquifer has a dynamic hydraulic mechanism which is the reason why the connection between hydrogeological complexes that are made of several water-bearing beds is complicated and not completely clear. This certainly points to migration of pollutants from deep aquifer (confined) to first aquifer (unconfined) which is certainly connected with surface water flows that are also polluted [2]. Potential pollution sources of water resources are: irrational exploitation of ground water, inadequate realization and closure of wells, impact of oil and gas exploitation, above and below surface transport of oil and gas, drilling mud usage, unsupervised exploitation of clay, sand and gravel, waste waters from industry and agriculture, inadequate waste management, agricultural activities – large areas are under intensive agriculture and are also used for animal husbandry [1, 2, 3].

The water supply system in municipality of Kikinda is organized in the following way [1, 2, 3]: Central water supply source in the city of Kikinda is made of 14 wells with total projected yield of 260 l/s and water sources from surrounding local communities of 20 wells with total projected yield of 313 l/s. The wells from central water supply source are grouped in several water sources which are "Šumice" (which will be analyzed in this paper), "Toza Marković 1 and 2", "Jezero" and "Ulica Masarikova". All wells capture water-bearing bed of confined aquifer at the depth between 150 and 240 meters.

This paper will present the groundwater chemistry analysis and distribution of pollutants of the central water source "Šumice" for a period between 1989 and 1990. This water source was extensively analyzed during the mentioned period which enabled acquiring data necessary for the modeling software. "Šumice" is a particularly important water source since it is the main source of city's drinking and technical water.

METHODS AND MATERIALS

For the analysis of the central water source "Šumice" modeling software EnviroInsite was used. This software gives a review of spatial distribution of chemical species in ground water. Data input for the modeling was based on samples from 7 wells which are located in the city's center and are a part of water source "Šumice". These wells are B1, B2, B3, B13, B14, B15 and B16 with coordinates given in table 1 [4]. This table also gives the number of samples taken during the analyzed period for NH_3, NO_3, NO_2, and total Fe [5].

Table 1. Well coordinates and number of samples for analyzed chemical species

Wells	Coordinates	Number of samples for the period between 1989 and 1990			
		NH_3	NO_3	NO_2	Fe
B1	E7457233 N5075166	11	10	8	9
B2	E7457040 N5074972	13	12	10	11
B3	E7456835 N5074939	14	13	11	11
B13	E7457344 N5075206	12	12	10	10
B14	E7457152 N5075220	13	13	12	12
B15	E7456959 N5075183	9	10	10	11
B16	E7456758 N5075145	12	12	10	10

The necessary parameters used for modeling the chemistry of the water source "Šumice" include [4,5]:

1. Concentrations of the measured NH_3, NO_3, NO_2 and total Fe values
2. Lithological description of wells based on strata types at different depths
3. Deep confined aquifer capture zone's depth and with which was used for sampling

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4. Depth and with of first (unconfined) and second (confined) aquifer
5. Ground water level of confined aquifer
6. Wells' elevation
7. Wells' spatial relation

In EnviroInsite modeling software spatial distribution of NH_3, NO_3, NO_2 and total Fe was calculated in plan and in cross-section between points with following coordinates: A – N456298 E5073961; A` - N456963 E5074255. This calculation was based on observed concentrations at 7 wells and inverse distance interpolation.

ANALYSIS OF RESULTS – DISTRIBUTION OF CHEMICAL SPECIES

For the analyzed chemical species in the period between 1989 and 1990 only ammonia exceeds the permitted concentration which is 0.1 mg/l based on the Regulation on hygienic quality of drinking water [6]. Nitrites and nitrates concentrations are in accepted range (50 mg/l for NO_3 and 0.03 mg/l for NO_2), however their distribution is not in coincidence with ammonium distribution, figure 1, 2 and 3. The highest concentrations of ammonia were observed in wells B3, B16 and B13, and the lowest was in well B15.

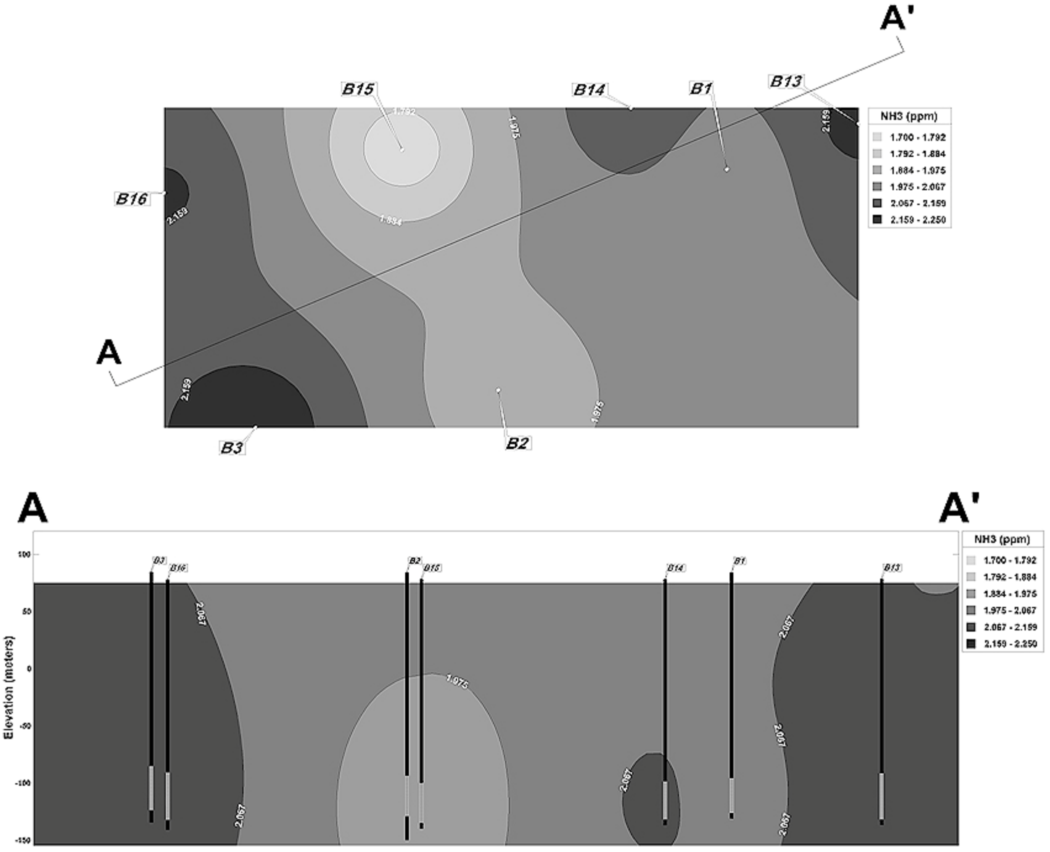

Figure 1. Ammonia spatial distribution at the water source "Šumice"

Based on figures 2 and 3 we can observe that the distribution of nitrites and nitrates is relatively in coincidence. Maximal concentrations of nitrites and nitrates that are in range of allowed values, were measured in well B3, and minimal concentrations for nitrite were observed in wells B13 and B16, while the concentrations of nitrate for all other wells are almost equal.

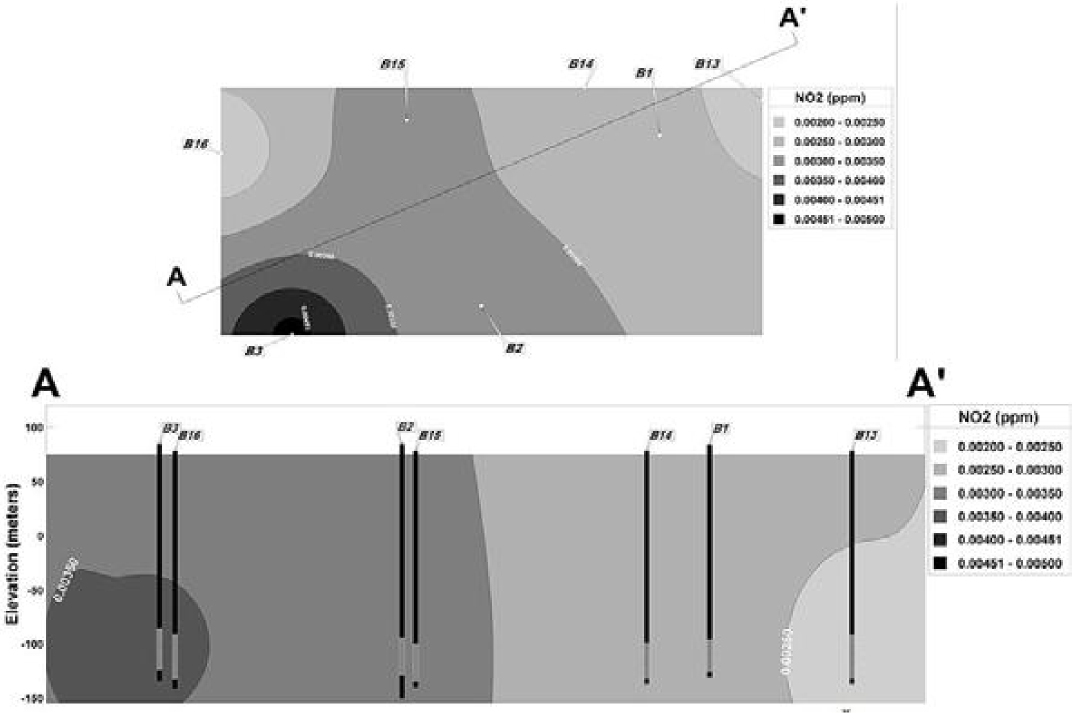

Figure 2. Nitrite spatial distribution at the water source "Šumice"

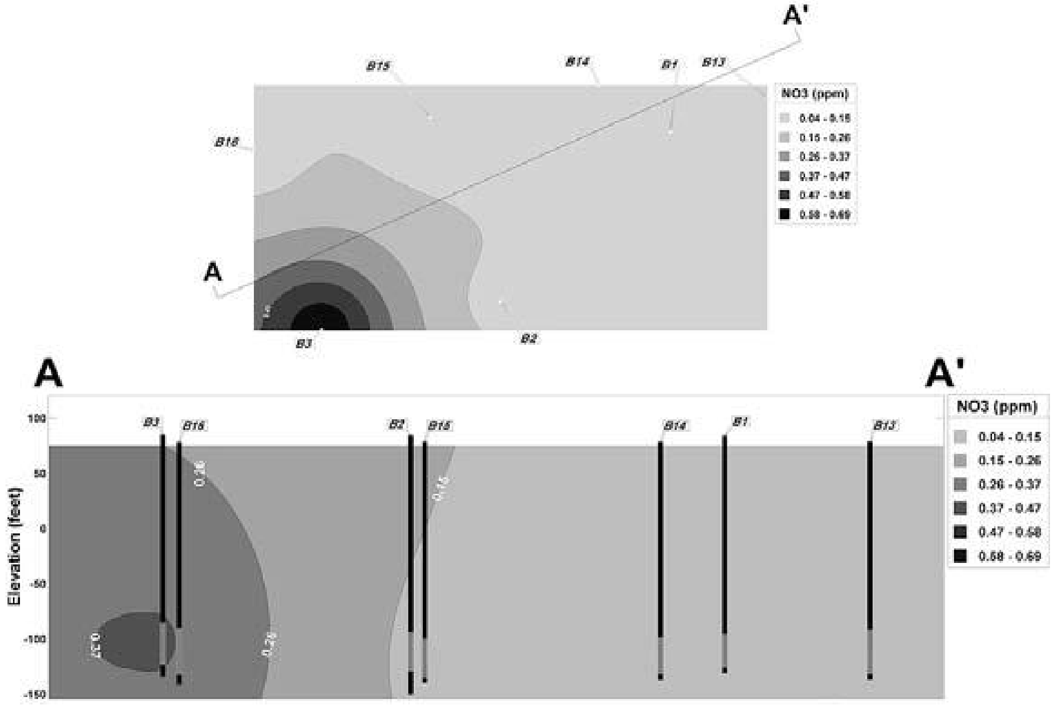

Figure 3. Nitrate spatial distribution at the water source "Šumice"

For the same analyzed period most of the measured Fe concentrations do not exceed the allowed concentrations of 0.3 mg/l (based on the Regulation on hygienic quality of drinking water), except for a very few samples [5]. The spatial distribution of Fe is also not in coincidence with ammonia. Highest concentrations of total Fe were observed in well B2 and lowest in wells B1 and B16, figure 4.

Since ammonia concentrations exceed the permitted levels it is important to consider its sources and degradation processes. It can be assumed that the appearance of ammonia is connected to the increased concentrations of organic matters. Chemical analysis for the ground water from these wells for various periods reveals that the concentrations of organic matter is constantly above the permitted level, which is based on the $KMnO_4$ usage [4,5,7].

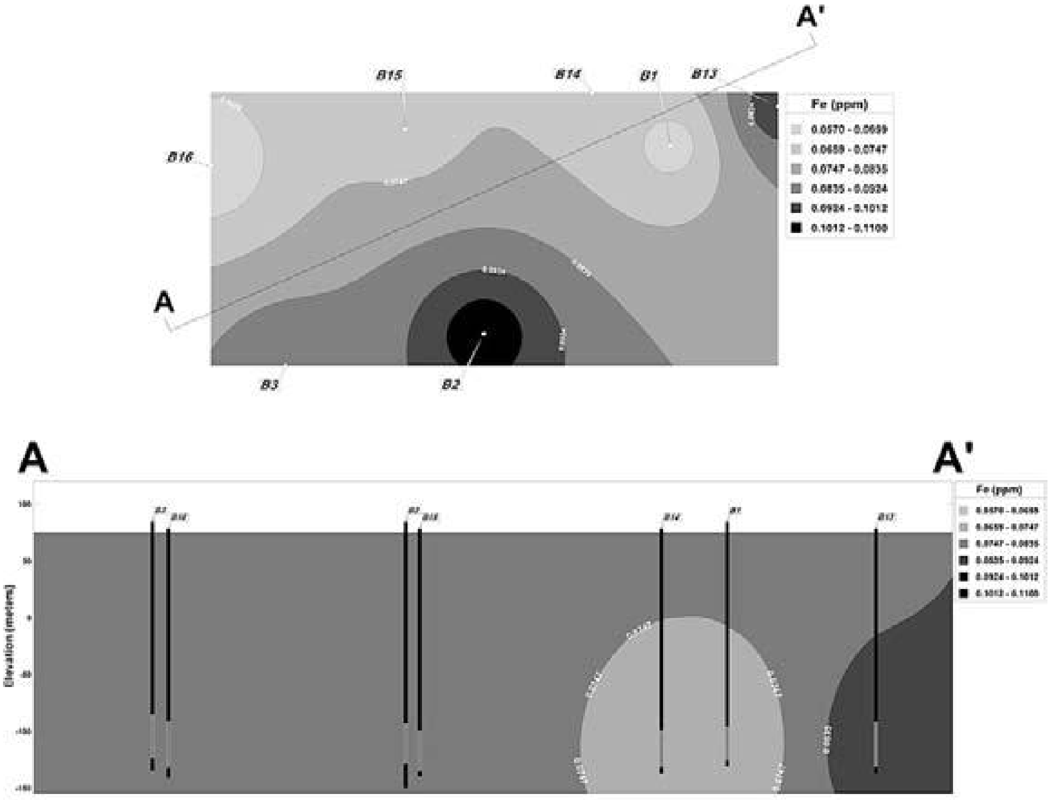

Figure 4. Total Fe spatial distribution at the water source "Šumice"

Regarding the whole situation, it should be mentioned that based on previous research a biological process of ammonium oxidation in anaerobic conditions (which are characteristic for ground water) was already observed. This process includes the connection between ferry iron as a terminal electron acceptor during the microbial oxidation of ammonia to nitrite [8]. This process could partially explain the present distribution of analyzed concentrations of NH_3, NO_3, NO_2 and total Fe. However, if this would be the main biogeochemical process of nitrogen species in water source "Šumice" their spatial distribution would different from the one that was obtained by modeling software. The presence of a complex hydraulic mechanism (complicated litho-stratigraphy) is probably one of the reasons which influence the chemical equilibrium of nitrogen species.

Total Fe which is present in ground water of water source “Šumice” confined aquifer can influence the process of nitrification in another way. Formation of Fe colloids which most often happens at pH values greater than 7 and with some oxygen present, can increase the microbiological nitrification of ammonium ion [9]. In the water source “Šumice” measured pH values for the analyzed period are over 7, more precisely around 9 in the western part of water source “Šumice”[10]. In anaerobic conditions ammonia can also be degraded by anammox reactions which are done by bacteria from the phylum *Planctomycetes.* In this process nitrite is used as a terminal electron acceptor and the final product is N_2.

For the period between 1997 and 1998 ammonia concentrations are somewhat lower, but are still above the permitted level, while nitrite and nitrate concentrations are still in acceptable ranges [5].

Most recent sampling which was done between 2007 and 2010 show that all concentrations of analyzed chemical species change very little, ammonia and organic matter being the only parameters that cross the permitted levels [7].

CONCLUSION

For the water source “Šumice” analyzed parameters have not change considerably during many years. This probably points to a constant inflow of ammonia (through organic matter) and to an unestablished chemical balance in degradation of organic matter and ammonia. Based on the present chemical analysis potential methods for remediation of groundwater could include aerobic remediation with oxygen, adding nitrite which would be used as terminal electron acceptor and adding appropriate microorganisms. To better understand the whole situation and to apply most adequate remediation treatment it is necessary to discover the main sources of ground water (both confined and unconfined aquifer) pollution, but also surface water pollution because of the certain hydraulic connection between them. According to that detail hydro-geological survey should include:

- Identification of pollution sources with an established database – Integral cadastre of pollution sources in GIS
- Establish a piezometer monitoring system at water source “Šumice” for regular sampling of ground water
- Establish a piezometer monitoring system near the surface flows to monitor the hydraulic connection between ground and surface water
- Detail analysis of litho-stratigraphy with a special emphasis on connection between unconfined and confined aquifer
- Detail analysis of biogeochemical processes

Future research should also consider the impact of oil and gas exploitation in this area. Oil and gas wells penetrate to a depth between 1500 and 2000 meters, which means they pass through the water bearing beds of confined aquifer at the location of water source “Šumice” [4].

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