African Journal of Biotechnology Vol. 11(104), pp. 16852-16862, 27 December, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB12.2273
ISSN 1684–5315 ©2012 Academic Journals

Full Length Research Paper

Arsenic levels in groundwater aquifer of the Neoplanta source area

Dragica Stojiljković[1], Gordana Šekularac[2]*, Miodrag Jelić[3], Milena Djurić[4], Snežana Komatina-Petrović[5] and Srećko Trifunović[6]

[1]Department of Water Management, Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia.
[2]Department of Soil and Land Reclamation, Faculty of Agronomy, University of Kragujevac, Čačak, Serbia.
[3]Department of Agrochemistry, Faculty of Agriculture, University of Priština-Kosovska Mitrovica, Lešak, Serbia.
[4]Department of Organic Chemistry and Plant Physiology, Faculty of Agronomy, University of Kragujevac, Čačak, Serbia.
[5]Faculty of Ecology and Environmental Sciences, Union-Nikola Tesla University, Belgrade, Serbia.
[6]Department of Chemistry, Faculty of Science, University of Kragujevac, Kragujevac, Serbia.

Accepted 31 December, 2012

As part of a survey on the groundwater aquifer at the Neoplanta source site, standard laboratory analysis of water quality and an electromagnetic geophysical method were used for long-term quantitative and qualitative monitoring of arsenic levels. This study presents only the results of research conducted in the Neoplanta-Koteksprodukt zone for 2005 and 2008 for the purpose of comparison of water quality at the aquifer. Varying levels of arsenic in both industrial and sanitary waters were determined, indicating water pollution with arsenic compounds. The horizontal electromagnetic prospecting method was used to define the extent of the arsenic-polluted zone and pollution direction. Vertical prospecting in the polluted zone helped identify the depth and interval of arsenic infiltration into both soil and water.

Key words: Water source area, arsenic content, electromagnetic method, RADIJAN 2001.

INTRODUCTION

The present research was conducted in the wider area of the City of Novi Sad, the second largest city in the Republic of Serbia. The city is located in the northern Serbian province of Vojvodina about 80 km from the capital city, Belgrade. In geomorphological terms, Novi Sad lies along the southern edge of the Pannonian Basin on the left bank of the Danube. The terrain belongs to the South Bačka (Varoš) loess terrace at the confluence of the Danube-Tisa-Danube (DTD) canal and the Danube, as well as to the Danube alluvial plain. Alluvial plain, alluvial terrace and loess terrace elevations range from 75 to 78, 78 to 81.5 and 81.5 to 82.5 m a.s.l., respectively. In the unprotected area along the Danube, there is an inundation plain flooded during high river levels.

All research sites where electromagnetic detection of groundwater pollutants was performed are located in the industrial zone of the city; along the left bank of the DTD canal, at potential pollution sites throughout the city and in Petrovaradin. This study presents only the results of research conducted within the Neoplanta-Koteksprodukt zone for 2005 and 2008 for the purpose of comparison of water quality at the source.

MATERIALS AND METHODS

Geoelectricity is one of the oldest branches of applied geophysics. It makes one of the most numerous traditional groups of geophysical methods. Geoelectrical methods are based on application of natural and artificial electrical and electromagnetic fields (Komatina,

---

Corresponding author. E-mail: gordasek@tfc.kg.ac.rs. Tel: +381 32 303 400. Fax: +381 32 303 401.

2005). The application of geoelectrical methods is based on differences between electrical properties of geology formations. Major characteristics being determined by geoelectrical methods are: electrical conductivity (σ), or its reversed quantity: specific electrical resistance (ρ); dielectric constant (ε); magnetic permeability (η); electrochemical activity (capability of rocks to create their own electrical potentials); polarization under the influence of external fields (Aranđelović, 1969).

Zvonimir Janković's method

One of the electromagnetic geophysical methods as auxiliary methods in field prospecting is Zvonimir Janković's method which is still in progress. Every element in the Mendeleev's periodic table has a different frequency, from the lightest (according to atomic weight) hydrogen with the highest frequency, to the heaviest nobelium, that is, elements with the lowest frequencies. Mendeleev had distributed the elements in the periodic table according to their atomic weight; by Zvonimir Janković's invention of elements' oscillation frequencies, their distribution was done according to the numerical value of oscillation frequencies being the same as the Mendeleev's distribution.

Oscillation frequencies of periodic table elements are defined by the following formula:

$$F_r(n) = F_r(H) - A_t(n) \times C$$

Where, Fr(n) is the frequency of the element; Fr(H) is the frequency of hydrogen; At(n) is the atomic weight of the element and C is the coefficient.

The frequencies of periodic table elements resonant with the frequencies of brain waves were discovered later according to the formula:

$$RF_r = \frac{F_r(ePS)}{300}$$

By thorough analyses and experiments, he proved them to be the oscillations ranging from 2 to 20 kHz with frequency span between elements from 100 to 300 Hz. The discovered frequencies were implemented in EPROM device RADIJAN-2001 SF used for verification of horizontal and vertical prospecting methods and interferential methods for determining the chemical composition of ores, minerals and chemical compounds.

Technical characteristics of RADIJAN-2001 SF

RADIJAN-2001 SF belongs to the group of equipment in the electromagnetic prospecting field having the following technical characteristics:

i) Frequency span from 2 to 20 kHz, that is, 64 channels; ii) Output antenna power from 0.1 to 5W; iii) A number of transmitting antennas can be connected to the base unit; iv) emission beam width from 60 to 120 cm; v. checked range in horizontal and vertical prospecting to 3000 m (theoretically 21 km for elements of I and II period, and 150 km for elements of VII period); vi) the mass of the device with sensor arrows 6.5 kg; vii) working temperature range from -10°C to +50°C; viii) power supply from chargeable cell battery 12 V; ix) tt discovers ores, minerals and explosives with probability of 93%.

The device RADIJAN-2001 SF contains (Figure 1):

i. Specific transmitting antenna; ii) Emission beam regulators; iii) base unit electronics (transmitter), iv. sensor arrows (receiver); v) stand with rotating platform; vi) chargeable cell battery of 12 v; vii) a bag for kit and manual packing and carrying.

Horizontal prospecting

The wanted programme (frequency) is set up by using a key button on the control board based on the frequencies of periodic table elements. When switching on the device, transmitting antenna emits the beam in the wanted direction 1m in width ranging 3000 m. The emitted frequency of the searched element or the compound is reflected from the ore, minerals, water, hidden object or explosive on or under the ground so it creates the searching beam. The searching beam is detected by the sensor arrows. The sensor arrows receive strong signals from the objects lying under the ground for many years and weak signals from the objects lying under the ground for only several years. The quantity of ore, minerals, water and explosive, as well as the size of the hidden object, soil type and adjusted parameters on the device are also significant. The transmitting antenna emits the beam 1m in width at 70° angle (35° above and 35° under the ground) (Figure 1).

In order to find the object at a certain depth it is necessary to handle the device at the distance defined according to the following formula:

$$D_u = \frac{\alpha \times D_n}{C}$$

D_u is the depth in metres; A is the emission angle (35°); D_n is the beam length in metres and
C is the coefficient (50).

Depending on the size of the ore body or the object and its structure, as well as on the adjusted device parameters (output power and impuls duration), it is possible to perform the remote detection even to 3000 m. The remote detection is performed by directing the front antenna emission beam in the wanted direction and the device is gradually moved until the sensor arrow is not turned in the direction of the ore body or the object. When the searched object is affected by the emission beam, the beam is reflected from it, as the return information, which moves the sensor arrow in the direction of the searched ore body or the object.

Vertical prospecting

In order to determine the depth of the searched ore, water, minerals or the hidden object, the device is set up precisely above the detected object in the horizontal prospecting. It is obligatory for the device to be leveled. In vertical prospecting the emission beam is reflected from the searched ore, water, minerals or the object at 45° angle. The reflected beam is detected by using the sensor arrows (Figure 2). The distance from the device to the reflected beam matches the depth of the object underground (l=-h). A new electromagnetic method employing geochemical prospecting, the so-called RADIJAN-2001 SF (later GEOSOLAR), invented by Zvonimir Janković, was used in the industrial area of Novi Sad. The apparatus named ”a low-frequency electromagnetic wave emitter equipped

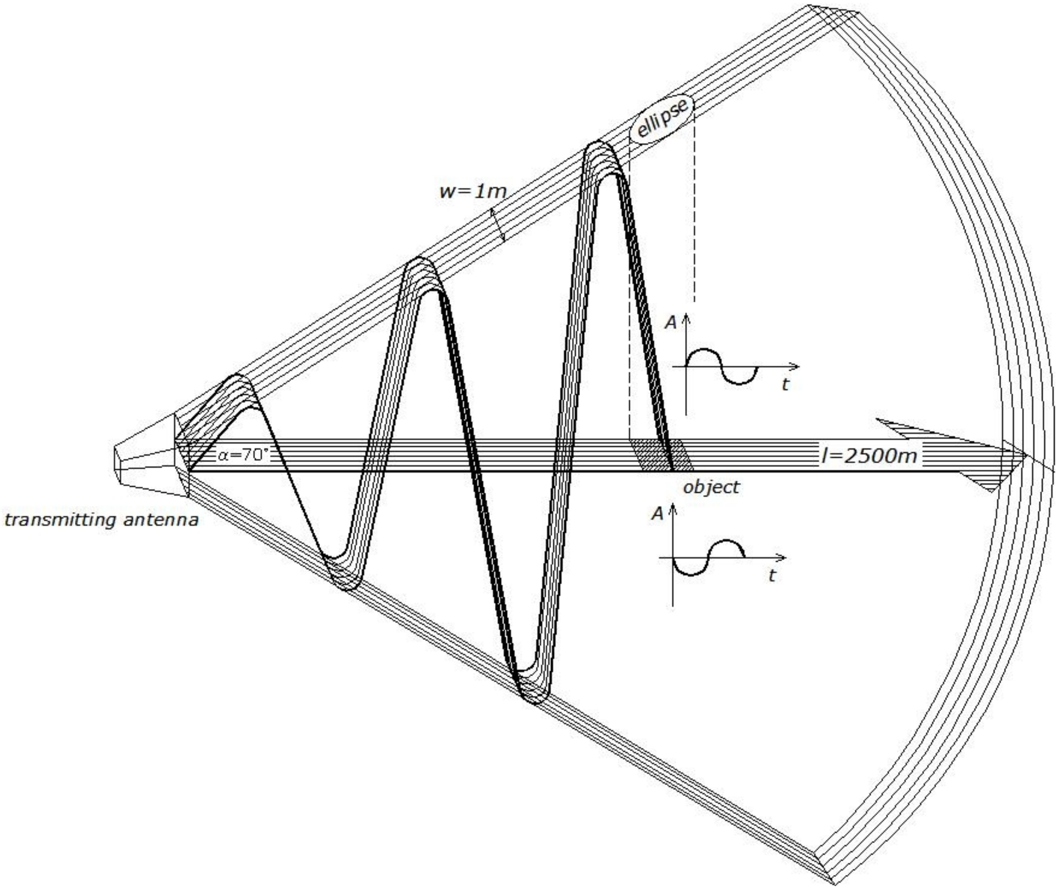

Figure 1. The characteristics of the emission beam in the horizontal prospecting.

with an emission beam regulator" was patented in 1997 upon Decision No. 77 MP and entered into the Minor Patent Register (Janković, 1997).

In the urban region of Novi Sad, this method has been used to identify underground settling tanks and wastewater drainage pipes, both intact and damaged ones to determine the depth-wise and spatial distribution of some pollutants in the infrastructure zone, and identify pollution direction, lithological composition and the occurrence of groundwater that is, of the zone having a predominating infiltration rate. The research herewith presented was conducted during 2005 to 2008 year. The electromagnetic detection of pollution sources was followed by water sampling at the Neoplanta source site for the purpose of evaluation of the content of arsenic and other pollutants in water. The results of chemical analyses of water samples expressed in mg/l were compared with those obtained by the electromagnetic method and expressed in electromagnetic wave strength units recorded by the apparatus. Water samples were collected for chemical analysis during electromagnettic measurements at the following measurement points: 9 (well W-3), 10 (well W-1) and 11 (well at the Salaš site), as presented in Figure 3. The results of the long-term analysis of the chemical composition of groundwater at the Neoplanta source are also presented.

Arsenic compounds are soluble in water and enter the human body through food and drinking water. The International Agency for Research on Cancer (IARC) has classified arsenic in Group 1 as carcinogenic to humans (Dreisbach and Robertson, 1989). In 1958, the World Health Organisation (WHO) recommended a maximum allowable concentration (MAC) of 0.2 mg/L for arsenic in drinking water, based on health considerations. In the 1963 International Standards, this value was reduced to 0.05 mg/L, which was retained and adopted in 1984 by the WHO. The WHO set the maximum allowable concentration for arsenic in drinking water at 10 µg/L (WHO, 2003). Arsenic occurs in groundwater as toxic As (III) compounds, relatively non-toxic As (V) compounds and methyl derivatives (Murko et al., 2010; Simonič, 2009). A relatively high arsenic content has been detected in groundwater underlying agricultural soils treated with arsenic-based herbicides. Arsenic pollution of the environment can result from gases and wastewaters from the metal, oil, electronics, ceramic and glass industries as well as from coal combustion and waste mining material containing arsenic (Nikolić et al., 2011).

The presence of arsenic compounds in groundwater has been studied by a large number of authors (Ravenscroft et al., 2005; McArthur et al., 2001; Welch et al., 2003; Smedley et al., 1996; Thu and Quang Toan, 2001; Vasiljev et al., 2000). Concentrations of arsenic in groundwater in Serbia are regulated by Regulations on the Hygienic Safety of Drinking Water (1998). Given the substantial use of arsenic compounds in medicine, fur and textile industries, in agriculture for the production of plant protection agents, as well as in the manufacture of alloys used for the production of transistors, lasers and semi-conductors, the presence of arsenic compounds in

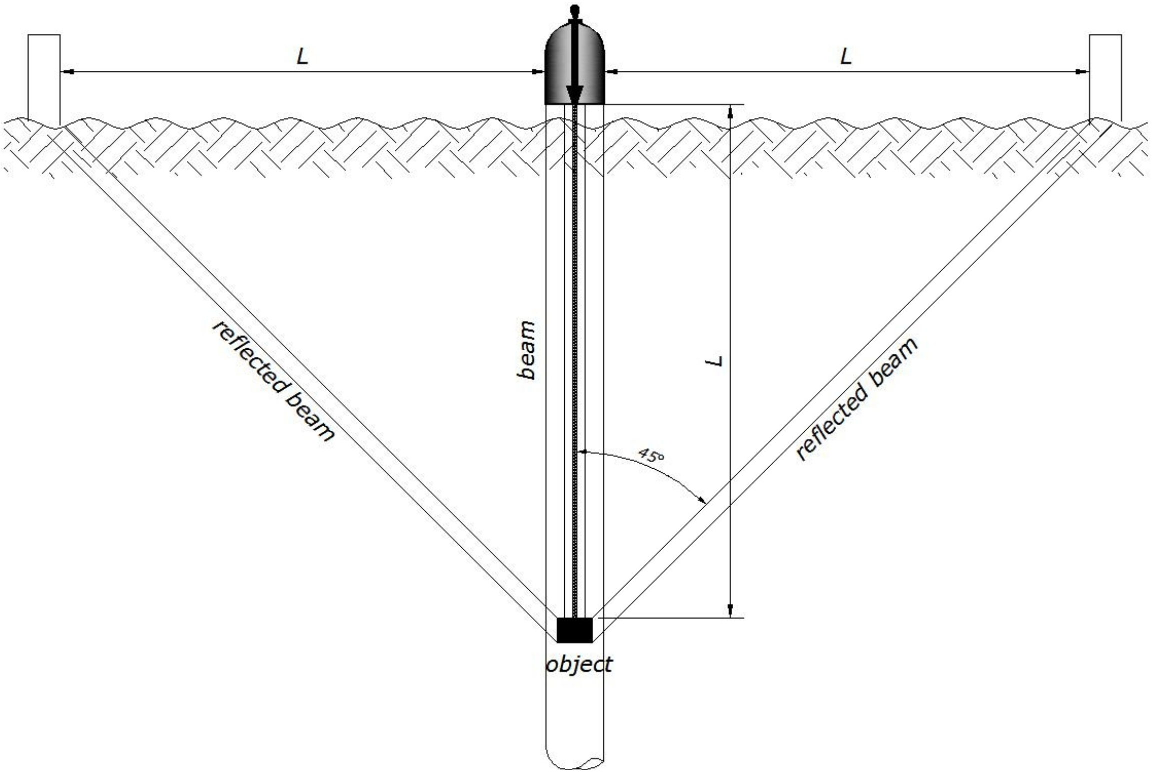

Figure 2. The characteristics of the emission beam in the vertical prospecting.

the environment is quite to be expected (Gomidželović et al., 2010). The aim of this work was to detect the water pollution with arsenic and other pollutants by the electromagnetic detection of pollution sources using an auxiliary electromagnetic method employing geochemical prospecting, the so-called RADIJAN-2001 SF, now GEOSOLAR. The results of chemical analyses of water samples were compared with those obtained by the electromagnetic method.

RESULTS AND DISCUSSION

Electromagnetic research during 2005

Groundwater pollutants were detected by horizontal prospecting at measurement points distributed along two profiles (vertical and parallel to the DTD canal), as presented in Figure 4. The electromagnetic geophysical method was used to determine the extent of the arsenic-polluted zone in the immediate vicinity of the Koteksprodukt wastewater discharge site. Vertical geochemical prospecting was performed at these measurement points along with the determination of the lithological profile down to the first impermeable underlying stratum and identification of water occurrence, pollutant direction, pollution depth and quantitative pollutant content. An increase in detection depth from the projected 25 to 50 m was achieved at each measurement point, with the infiltration of arsenic in both shallow and deep aquifers being monitored. The profile microlocations intended for vertical geochemical prospecting were set up outside the Industrial area, near an exposed wastewater drainage pipe or a settling tank. Based on vertical prospecting, the electromagnetic non-invasive method gave a detailed presentation of sandy/gravelly and clayey intervals at all measurement points at the source as well as in the broa-der region between Neoplanta and Koteksprodukt loca-tions (Table 1).

The first longitudinal profile for horizontal electromagnetic prospecting purposes was set up along the Neoplanta fence at a length of 250 m, parallel to the DTD canal. Horizontal prospecting resulted in the detection of arsenic at measurement points MT- 3/5, 4/5, 5/5 and 6/5, as presented in Figures 4 and 5. The separation of the polluted undergound stream into two directions is induced by the depth and inclination of the underlying stratum along which the pollutant moves (Figure 4). The underlying stratum composed of grey impermeable clays is located high between the two directions of the underground stream. In morphological terms, it is a river lake that separates the Danube branch from the riverbed. The pollutant occurrence in the second aquifer (Figure 5) suggests the association of the first and second strata

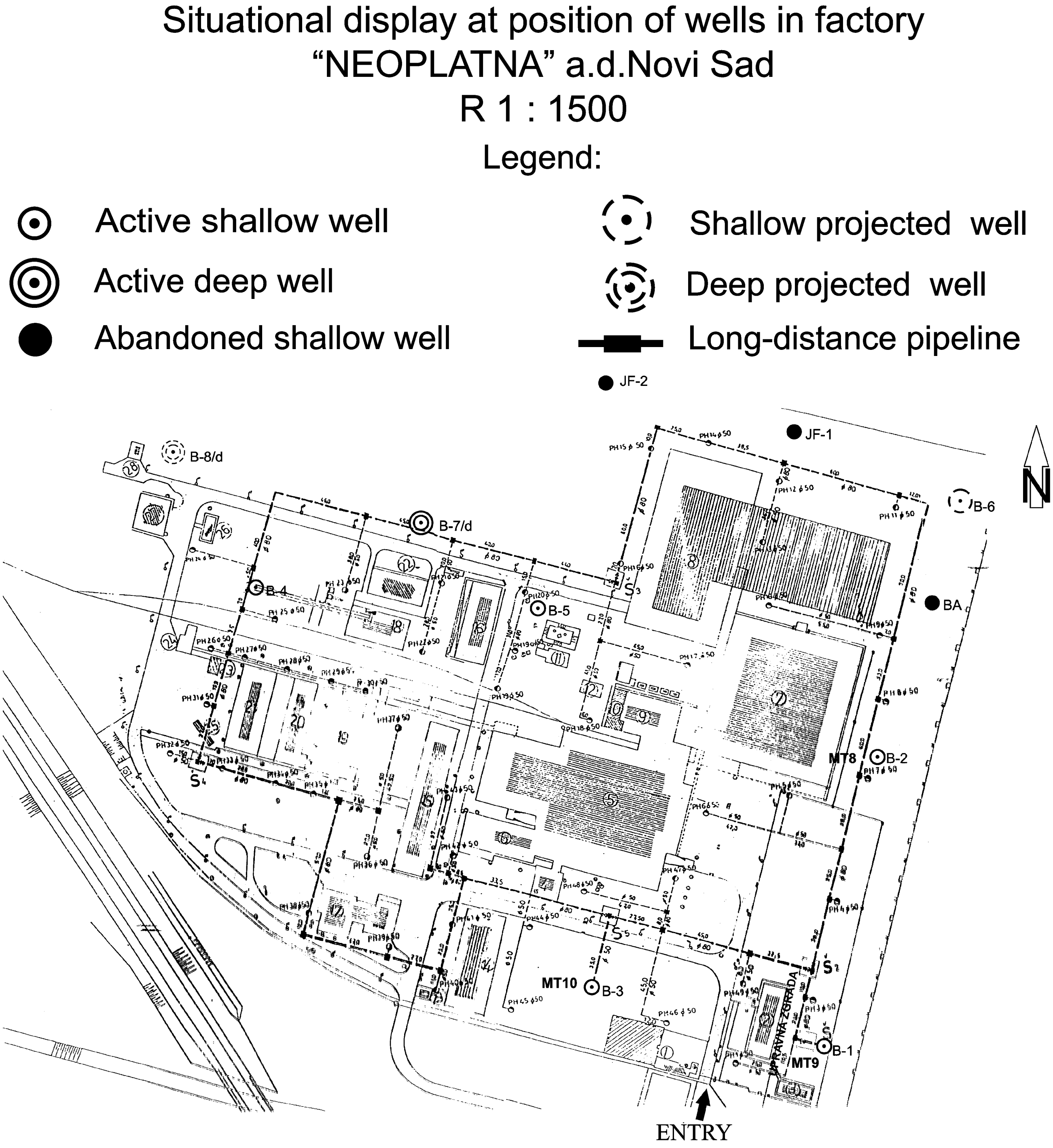

Figure 3. Location of wells, measurement points and water sampling sites at the NEOPLANTA source area site.

through a deeper intake structure in the area of Neoplanta or the Koteksprodukt, which should be checked by employing a higher density of profile lines. There is also another reason for the separation of the polluted underground stream. The direction of pollution is parallel to the series of water supply wells at the source area site (W-1, 3 and 6a wells) (Figure 3). Increasing water consumption led to a more rapid flow of groundwater towards the wells

Table 1. Extent of vertical geochemical prospecting research during 2005 year .

Measurement points	Depth (m)	Sand Interval (m)	Gravel interval (m)	Pollution Interval (m)
Neoplanta				
1/5	35.0	7.90 - 9.60	26.50 -32.50	3.00 - 3.90
2/5	50.0	6.50 - 9.00	25.50 - 31.50	7.30 - 9.00
3 /5	40.0	3.50 - 9.40	25.00 - 31.00	9.00 - 9.30
4/5	35.0	7.00 - 10.80	25.00 - 32.00	10.00 - 10.70
5/5	35.0	0.00 - 5.00	-	4.50 - 5.00
6/5 arsene	12.0	6.50 - 9.30	-	9.30 - 10.70
Koteksprodukt				
13/5	23.0	7.80 - 9.50	15.00 -19.00	8.20 - 9.40
14/5	15.0	8.00 -10.00	-	8.00 - 10.00
15/5	25.0	9.00 -11.50	17.00 - 19.00	10.00 - 11.50 13.50 - 15.40 18.00 - 19.00
16/5	22.0	7.30 - 9.00	-	7.50 - 9.00
18/5	21.0	5.80 - 7.00	15.00 - 17.50	5.60 - 7.00
19/5	25.0	5.00 - 8.20	16.80 - 20.00	no pollution
20/5	31.0	5.40 - 7.20	25.00 - 28.00	5.90 - 7.20 26.00 - 28.00
21/5	14.0	6.00 - 7.50	-	7.00 - 750
22/5	35.0	6.00 - 8.00	11.20 - 12.50 27.00 - 29.00	6.50 - 8.00 28.00 - 29.00
23/5	18.0	-	12.00 - 13.80	3.40 - 4.30

at the Neoplanta source site, as well as to a change in the flow direction of one part of the arsenic-polluted stream.

Electromagnetic research during 2008

Measurement points at the Neoplanta site in 2008 were set up at the water supply wells W_1, W_2 and W_3 (Figure 3 and Table 2). At measurement point 8/8 set up as the first measurement point next to the W-2 well (Table 2), the aquifer located at 12.0 to 24.5 and 33.0 to 50.0 m comprises grey sands of different particle size distribution and interstratified clayey sediments. Arsenic and other pollutants were detected only in the first stratum down to 12.0 m depth (their readings being 15 units), whereas the presence of ammonia and nitrates was detected at 25 to 30 and 30 units, respectively. The second measurement point 9/8 was set up next to the water supply well W to W_3. The related aquifer was made up of grey sands of different particle size distribution at 5.5 to 11.0 and 20.0 to 35.0 m. An arsenic reading of 10 units was recorded at the 28.0 to 35.0 m stratum within the so-called capture stratum marked by the highest groundwater flow rate. The other pollutants detected along the lithological profile included ammonia and nitrates, their respective readings ranging from 3 to 40 and 3 to 40 units.

The third measurement point 10/8 is located at the well W_1 site. The aquifer at this point comprises grey sands of different particle size distribution, at a depth of 1.0 to 21.0 and 38.5 to 45.0 m (Table 2). Different pollutant readings were recorded along the lithological profile, with the arsenic reading of up to 15 units at a depth of 17.0 to 21.0 m being the most striking example. Apart from arsenic, readings of ammonia and nitrates of 20 units were also detected. Measurements at this point also

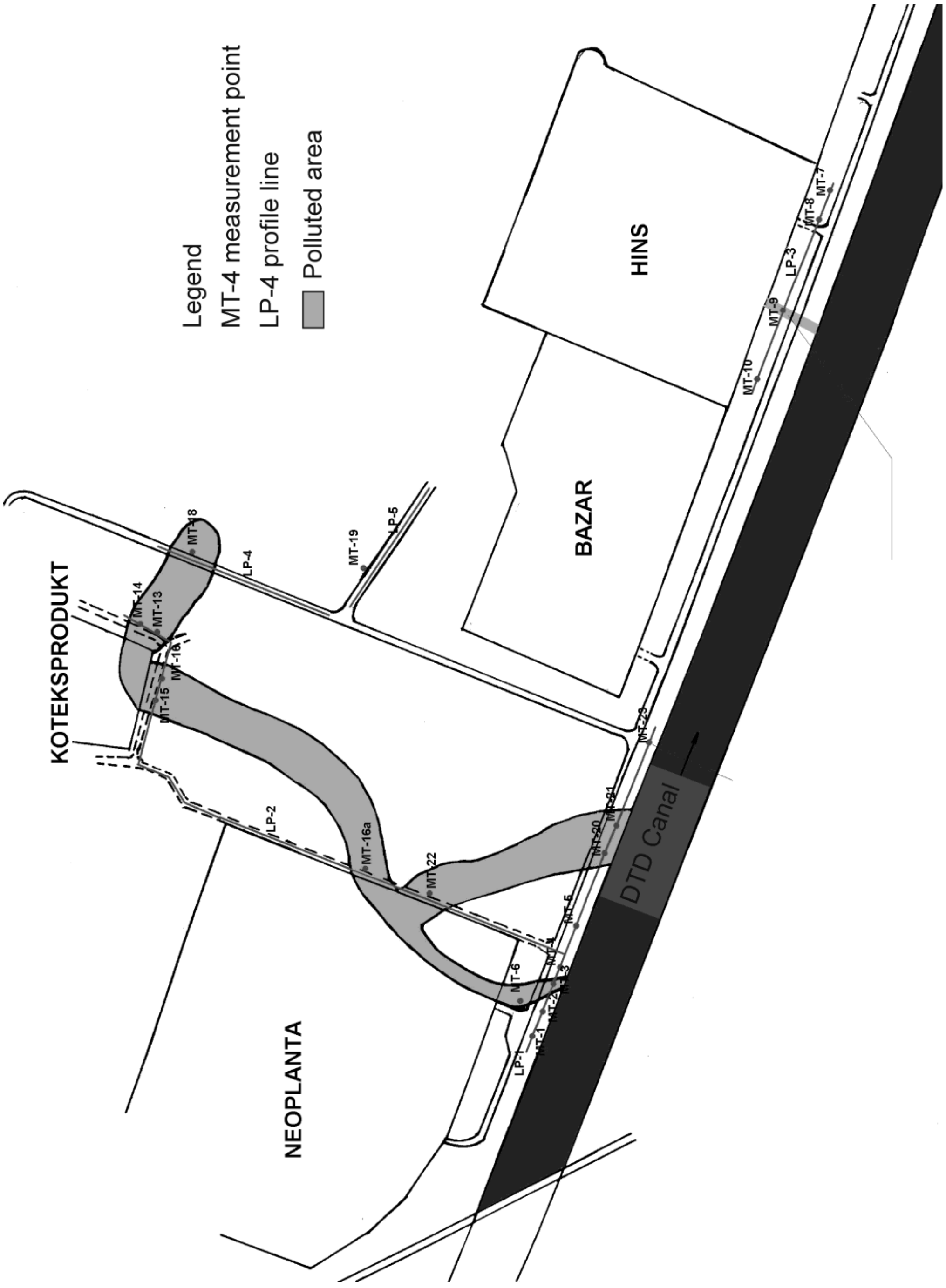

Figure 4. The industrial zone of Novi Sad with the locations of profile lines and horizontal pollutant prospecting. Legend: “Neoplanta” Meat Industry, “Koteksprodukt” Fur Processing; “Bazar” Warehouses, “HINS” Chemical Industry, MT-1/23 measurement point, LP- 1/4 profiles.

involved chemical analysis of raw water in the presence of arsenic and ammonia. The measured concentration of arsenic was 0.023 mg/L, being equivalent to the reading of 15 units, and that of ammonia was 1.35 mg/L that is, the reading equivalent of 20 units.

In order to determine the source of groundwater pollution, the Salaš site and the related measurement point 11/8 were also installed. Vertical prospecting down to

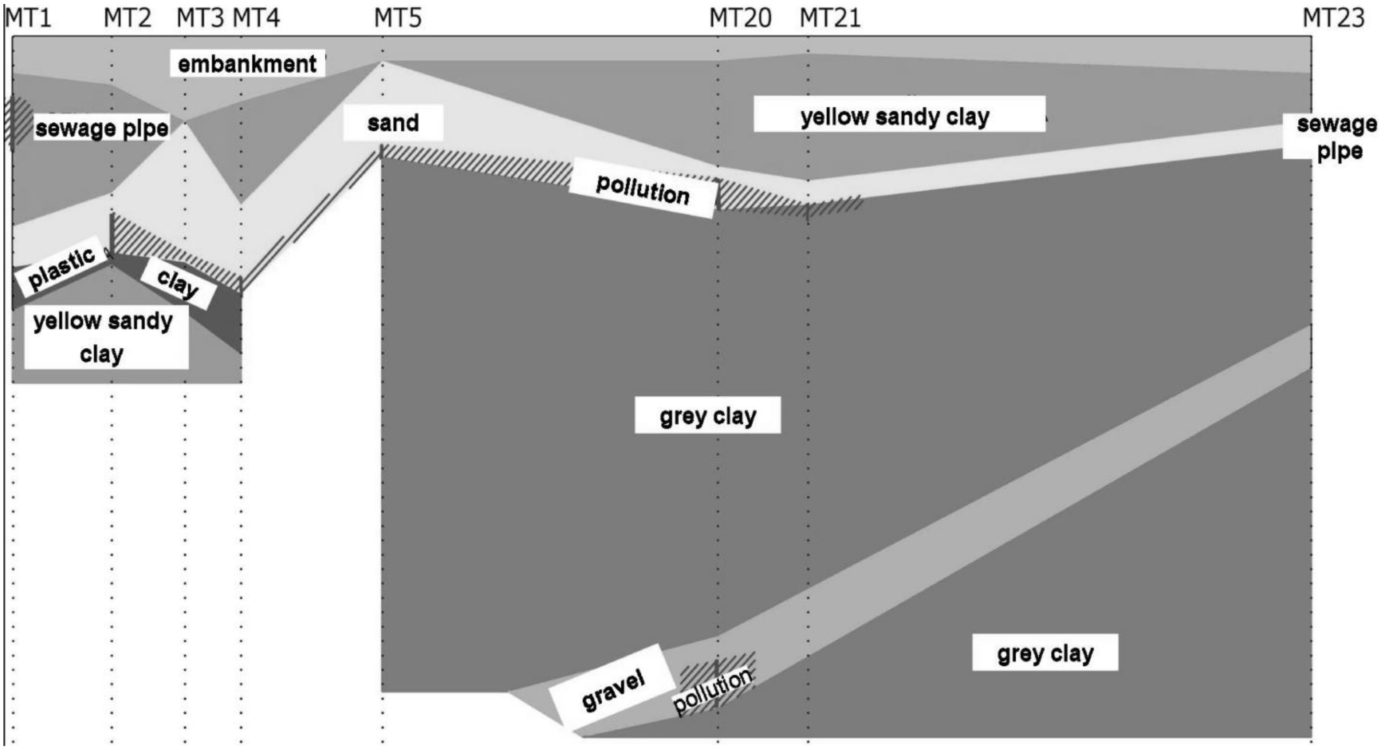

Figure 5. Industrial zone (North), Novi Sad- vertical prospecting for pollutants. MT, 1/23 measurement points with a detailed description (embankment; yellow sandy clay; sand; gravel; grey clay; sewage pipe).

30.0 m depth resulted in the detection of arsenic at 1.5 to 14.5 m depth and intensive infiltration of 20 units. Apart (reading range of 5 to 25 units), nitrates (20 to 25 units), iron (10 to 30 units) and manganese (5 to 25 units). Moreover, the reading value of 10 units for lead was recorded at 18.0 to 22.0 m depth. The chemical analysis of raw water revealed the following pollutant concentrations: 0.02 mg/L for arsenic, 0.62 mg/L for ammonia, 1.02 mg/L for iron, 0.192 mg/L for manganese and below 0.01 mg/L for lead.

In 2008, at the Koteksprodukt site, vertical prospecting for the analysis of pollutants down to 30.0 m depth was carried out at three measurement points. At measurement point 12/8, 45 units of arsenic were detected down to 2.0 m depth. At a depth of 13.0 m, 35 to 40 units of ammonia and 20 to 30 units of sulphates were identified. The sandy stratum at 13.0 to 18.5 m depth was found to be polluted with 25 units of arsenic, 20 units of manganese and 30 units of sulphates. The sandy strata marked with intensive water infiltration at a depth of 18.5 to 23.5 m contained detectable arsenic and sulphate readings of 20 and 5 units, respectively, with the two pollutants being most likely infiltrated from wastewaters. Vertical prospecting at a depth of 2.0 to 12.5 m at the second measurement point 13/8 at the Koteksprodukt site detected the from arsenic, the following pollutants were also detected in the groundwater at this measurement point: ammonia presence of arsenic at 40 units, sulphates at 25 units and nitrates at 45 to 50 units. In the sandy stratum at 12.5 to 19.5 m depth having a higher rate of infiltration, the following pollutants were detected: arsenic (50 units), ammonia and nitrates (20 units), sulphates (10 units). The underlying stratum at 19.5 m to 30.0 m depth was found to be polluted with ammonia (10 units), sulphates (20 units) and arsenic (30 units).

Vertical prospecting down to 5.5 m depth at the third measurement point 14/8, at the Koteksprodukt source site, resulted in an arsenic reading of 25 units. Down do 16.5 m depth, the following pollutants were detected: oil (10 to 40 units), nitrates (20 units), ammonia (50 units), boron (30 units), pyralene (10 to 30 units) and lead (30 units). The sandy stratum at 16.5 to 22.0 m depth was found to contain arsenic (10 units), ammonia (40 units), nitrates and nitrites (35 units), manganese (10 units), phenols (10units) and boron (15units).

Groundwater chemical composition

Long-term chemical analyses of the groundwater of the

Table 2. Extent of vertical geochemical prospecting research, measurement point locations, aquifer intervals and pollution depth values for 2008 year.

Measurement point	Depth (m)	Sand interval (m)	Gravel interval (m)	Pollution interval (m)
Neoplanta				
8/8	50.0	5.0 - 8.0	8.0 - 12.0 24.5- 33.0	1.0 - 5.5 8.0- 12.0
9/8	50.0	5.5 - 11.0	11.0- 15.0 28.0- 35.0	5.0 - 35.0
10/8	45.0	1.0 - 5.5	17.0 - 21.0 38.5- 45.0	1.0 - 21.0
11/8	30.0	3.5 - 14.5	18.0 - 22.0	1.5 - 12.5 12.5-22.0
Koteksprodukt				
12/8	30.0	7.5 - 23.5	-	2.0-23.5
13/8	30.0	-	12.5 - 19.5	2.0 - 30.0
14/8	30.0	-	16.5 - 22.0	0.0 - 22.0

Danube alluvial plain conducted during 1986 to 2005 at different stages of the survey of the left and right banks of the Danube suggest that the waters were classified as bicarbonate-type, according to the predominating cation, as well as calcium/magnesium type waters, according to the predominating anion. Maximum allowable concentrations indicate that the content of the following elements determined by groundwater analysis exceeds the permissible values: 1.78 to 2.52 mg/L for iron (MAC 0.3 mg/L), 0.19 to 0.23 mg/L for phosphates (MAC 0.15 mg/L), 0.26 to 0.39 mg/L for manganese (MAC 0.05 mg/L), and 0.51 to 0.66 mg/L for ammonia (MAC 0.10 mg/L). The results of the above chemical analyses were processed by the Chemical Laboratory, Water Supply Services, Novi Sad. They are reported in this study in order to present the actual chemical composition of groundwater in the Danube alluvial sediment deposits. However, the chemi-cal analysis of groundwater samples collected from piezometres in 1988 and 1989 at the Ratno Ostrvo during the hydrogeological survey suggests excessive concentrations (above MAC) of the following pollutants: hydrogen sulphide, iron, manganese, ammonia, arsenic, phenols and mineral oils.

The chemical composition of water samples collected from the Neoplanta source site and the catch basin, as well as that of the raw water obtained from the wells W-1, W-3 and W-6a until 2007 did not show substantial deviation from MAC values set forth by the Regulations (FRY 42/98 and 44/99). Following this period, the increased exploitation at the Neoplanta source site induced groundwater quality deterioration. The results are given in Table 3. The results of electromagnetic apparatus readings and those obtained by the chemical analysis of water samples show the following: the raw water sample collected from the W-1 well in 2008 contained 1.35 mg/L ammonia that is, the equivalent reading value of 20 units. The 0.023 mg/L arsenic as determined by chemical analysis is equivalent to the reading value of 15 units. The Salaš well water was found to contain 0.62 mg/L or 5 to 25 units of ammonia, 0.025 mg/L or 20 units of arsenic, 1.02 mg/L or 10 to 30 units of iron, 0.192 mg/L = 5 to 25 units of manganese and below 0.01 mg/L = 10 units of lead. However, the correlation between the water concentrations of the above elements obtained by chemical analyses and the reading values recorded by the apparatus is so difficult to find, due to fact that the sandy / gravelly stratum at 17 to 37 m was captured in the wells, whereas the water sample for chemical analysis combined waters from a single well or all wells when collected from the catch basin at the source area. Then, the apparatus was used to conduct thorough electromag-netic measurement of each centimetre inside the vertical profile of the well, regardless of arsenic presence in soil or water. This monitoring of the presence of arsenic in water will continue at the two source areas Neoplanta and Koteksprodukt.

Conclusion

The electromagnetic method employing horizontal and vertical prospecting was used to identify groundwater pollutants, most notably arsenic, at the Neoplanta and Koteksprodukt sites. Horizontal prospecting was used to define the extent of the polluted zone, pollution direction and pollution source. Vertical prospecting helped identify the depth and interval of the polluted zone. The polluted underground stream was separated into two directions due to the depth and inclination of the underlying stratum

Table 3. Physical and chemical properties of groundwater (mean concentration ± SD, n=5) in free-level aquifers (captured interval 17-37 m) at the NEOPLANTA source site.

Parameter of measurement	Well symbol and year of chemical analysis					MAC
	Catch basin (2005)	**Catch basin (2007)**	**Well W-3 (July 2008)**	**Well W-1 (March 2009)**	**Well W-6a (January 2009)**	
Odour	No	No	No	No	No	No
Turbidity (NTU)	0.48±0.01	0.43±0.01	4.36±0.38	2.83±0.10	1.62±0.04	1.0
Colour (Pt/Co)	5	5	25	20	10	5
pH	7.90±0.01	7.91±0.01	7.70±0.02	8.39±0.02	7.57±0.02	6.8-8.5
Electrical Conductivity (µS/cm)	805.2±5.8	782.0±3.2	693.4±3.6	768.8±2.6	775.0±3.1	1000
Dry residue at 105^0 (mg/L)	493.2±3.2	486.6±2.3	431.2±4.5	474.8±1.9	482.8±2.2	-
Total hardness (^{o}dH)	-	-	16.0±0.5	-	16.3±0.5	-
Consumption of KMnO4 (mg/ L)	6.78±0.13	6.32±0.19	9.22±0.15	7.42±0.08	6.50±0.16	8.0
Ammonia (as N) (mg/ L)	< 0.07	< 0.07	1.22±0.03	1.85±0.02	0.50±0.02	0.1
Arsenic (As) (mg/ L)	0.01±0.001	0.01±0.001	0.025±0.002	0.014±0.001	0.014±0.001	0.01
Fluorides (F) (mg/ L)	0.16±0.01	0.24±0.01	0.13±0.01	0.12±0.01	0.34±0.02	1.20
Iron-total (Fe) (mg/ L)	0.22±0.01	0.22±0.01	1.39±0.01	1.06±0.02	0.79±0.02	0.30
Chlorides (Cl) (mg/ L)	49.70±0.1	45.60±0.23	29.00±0.70	25.90±0.74	28.60±0.36	200.0
Sodium (Na) (mg/ L	-	-	40.42±0.26	-	56.38±0.35	150.0
Calcium (Ca) (mg/ L)	-	-	67.36±0.27	-	51.26±0.11	200.0
Potassium (K) (mg/ L)	-	-	3.14±0.11	-	2.22±0.15	12.0
Magnesium (Mg) (mg/ L)	-	-	29.76±0.19	-	42.42±0.33	50.0
Manganese (Mn) (mg/ L)	0.03±0.001	0.04±0.001	0.13±0.007	0.11±0.007	0.22±0.004	0.05
Nitrates (as NO_3) (mg/ L)	4.27±0.04	3.62±0.04	0.70±0.02	0.56±0.04	6.16±0.04	50.0
Nitrites (as NO_2) (mg/ L)	0.01±0.001	0.01±0.001	0.01±0.001	0.07±0.006	0.01±0.001	0.03
Sulfates (SO_4) (mg/ L)	-	-	20.18±0.08	-	56.74±0.11	250.0
Hydrocarbons (HCO_3) (mg/ L)	-	-	402.10±1.52	-	438.60±1.14	
Phenols (mg/ L)	< 0.001	< 0.001	< 0.001	< 0.001	0.36±0.02	0.001

along which the pollutant moved. The separation of the underground stream of polluted waters was induced by the presence of the underlying stratum composed of grey impermeable clays high between the two directions, which resulted in the separation of the Danube branch from the riverbed. Given the fact that the pollution direction was parallel both to the Neoplanta fence and the series of exploitation wells at the source, increasing use of water led to a more rapid flow of groundwater towards the wells at the Neoplanta source, and hence to a turn of one part of the arsenic polluted stream into that direction. The increased content of arsenic and the other pollutants detected in sandy intervals immediately above the water tight clayey stratum or interbed proves higher accuracy of the thoroughly defined lithological profile in the wider zone of the water source as compared to the profile obtained by boring.

The electromagnetic method is a rapid reliable field method used to identify groundwater and soil pollutants. The apparatus RADIJAN-2001 SF is portable and easy to use; it does not cause risks to soil and water or environmental pollution. The major advantages of the electromagnetic methods justifying their widespread application, including Zvonimir Janković's method, are: i) Measurement speed and economy; ii) possibility to work in surface layers of high resistance; iii) possibility to detect anomalies even with relatively little level of electric conduction.

The major disadvantages are:

i) Expensive equipment; ii) interpretation methods are still in progress; iii) more efficiency in conductive area research in comparison to high electric resistance areas.

The advantages of these methods are still substantially overcoming their disadvantages so the role of electromagnetic methods cannot be neglected, especially in recognition field phase.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Education and Science (Projects No. OI 172016 and TR 31054) for their financial support.

REFERENCES

Aranđelović D (1969). Geophysics in civil engineering. Serb. J. Vesnik. 10: 135-349.

Dreisbach R, Robertson W (1989). Poisoning – prevention, diagnostics and treatment. Book. Serbia: pp. 266-270.

Gomidželović L, Požega E, Trujić V (2010). The possibilities of the utilization of the polymetallic concentrate Čoka Marin. Serb. J. Chem. Soc. 75: 1733-1741.

Janković Z (1997). Federal Republic of Yugoslavia. Intellectual Property Office. Minor Patent Register. Decision No. 77 MP. pp.1-12

Komatina S (2005). Ecogeophysics-Geophysics and Environmental Protection, book NIS Naftagas, Novi Sad, Srbija. pp.36-39

McArthur JM, Ravenscroft P, Safiullah S, Thirlwall MF (2001). Aresenic in groundwater: testing pollution mechanisms for sedimentary aquifers in Bangladesh.Water Resour. Res. 37: 109-117.

Murko S, Milačić R, Veber M, Ščančar J (2010). Determination of Cd, Pb and As in sediments of the Sava River by electrothermal atomic absorption spectrometry, Serb. J. Chem. Soc. 75: 113–128.

Nikolić Đ, Milošević N, Živković Ž, Mihajlović I, Kovačević R, Petrović N (2011). Multi-criteria analysis of soil pollution by heavy metals in the vicinity of the Copper Smelting Plant in Bor (Serbia). Serb. J. Chem. Soc. 76: 625-641.

Ravenscroft P, Burgess WG, Kazi MA, Burren M, Perrin J (2005). Arsenic in groundwater of the Bengal Basin, Bangladesh: distribution, field relations and hidrogeological setting., Hydrogeol. J. 13: 727-751.

Regulations on the Hygienic Safety of Drinking Water (1998). „Sl. list SRJ“ br. 42/98, Beograd, Srbija.

Simonič M (2009). Arsenic occurs in the oxidation states. Serb. J. Chem. Soc. 74: 85-92.

Smedley PL, Edmunds WM, Pelig-Ba KB (1996). Mobility of arsenic in groundwater in the Obuasi gold-mining area of Ghana: some implications for human health, Environ. Geochem. 113: 163-181.

Thu LT, Quang Toan ET (2001). Country Report of Vietnam. Workshop on Drinking Water Quality Surveillance and Safety, Kuala Lumpur: pp. 42-48.

Vasiljev D, Joksović N, Miloradov VM (2000). The issue of the presence of arsenic in water Subotica region in the light of our recommendations and directives 29. Conference on current problems of water, Protection of Water, Mataruška Banja, pp. 303-313.

Welch AH, Watkins SA, Helsel DR, Focazio MF (2003). National Analysis of Trace Elements. National Water-Quality Assessment, United States Geological Survey- Publisher, United States, pp. 4-78.

WHO (2003). Arsenic in drinking-water, Background document for preparation of WHO Guidelines for drinking-water quality, World Health Organization (WHO/SDE/WSH/03.04/75), Geneva.