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GROUNDWATER QUALITY AND ITS SUITABILITY FOR DRINKING AND AGRICULTURAL USE IN A RURAL AREA FROM CLUJ COUNTY (FLORESTI VILLAGE)

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Abstract

In the present study, a hydrochemical investigation was conducted in a rural area from Cluj County, Romania, in order to determine the chemical composition of groundwater and to evaluate if the investigated water sources can be used for drinking or agriculture purposes. Several groundwater samples were collected from fifteen wells in order to analyze the major dissolved ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-}). The analyzed waters proved to have a low level of sodium (0.27 - 41.87 mg/l), magnesium (0.11 – 25.17 mg/l), calcium (0.59 – 117.30 mg/l), chloride (3.33 – 97.68 mg/l) and sulphate (4.42 – 132.80 mg/l), and a high level of potassium (0.22 – 22.59 mg/l), nitrites (detected only in one sample - 1.36 mg/l), nitrate (6.58 – 92.96 mg/l), fluoride (0.24 – 1.40 mg/l) and phosphate (12.44 –18.26 mg/l). The possibility of using these waters for agricultural purposes has been assessed by calculating the sodium adsorption ratio (SAR). The results of the present study indicate that the use for agricultural purposes of some of the analyzed groundwater represent no threat for vegetation, as the SAR level was lower than 3.0.

Key words: *Cluj County, Floresti village, groundwater, major ions, sodium adsorption ratio*

INTRODUCTION

In the rural areas, the groundwater is the major source of drinking and irrigation water. Due to human activity, groundwater composition and quality is changed, directly or indirectly, so much that it can be no longer safe for drinking or agriculture purposes.

In the present study, a hydrochemical investigation was conducted in a rural area (Floresti village) from Cluj County, Romania, in order to determine the chemical composition of groundwater and to evaluate if the investigated water sources can be used for drinking or agriculture purposes. Several groundwater samples were collected from fifteen wells in order to analyze the phisyco-chemical parameters (temperature, pH, redox potential – ORP, electrical conductivity – EC, total dissolved solids – TDS, salinity, dissolved oxygen – DO and turbidity) and the major dissolved ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-}). The phisyco-chemical parameters were measured in situ using a portable multi parameter (WTW inolab 350i) and a portable turbidimeter (WTW pHotoFlex Turb), while the major ions were analysed by an ion chromatograph (IC1500 Dionex). The possibility of using these waters for agricultural purposes has been assessed by calculating the sodium adsorption ratio (SAR). Sodium is a unique cation because of its effect on soil as it causes adverse physico-chemical changes in the soil, particularly to the soil structure. SAR is calculated based on the sodium, calcium and magnesium concentrations. SAR is a simple method to evaluate the danger of high-sodium irrigation water use. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium which can destroy the soil structure leading to dispersion of clay particles [1,2]. Usually, when SAR is lower than 3.0 there is no threat to vegetation, while a SAR level greater than 12.0 is considered a real threat for the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability [1,3,4].

The study area is located in Floresti village, which is situated at 5 km from Cluj Napoca town and it is part of the Cluj-Napoca metropolitan area (Fig. 1). The European road E60 is passing through Floresti village. The village is located on the right bank of the Somesul Mic River at the junction of the Apuseni Mountains and Transylvania Plateau. The total area of the Floresti village is 6300 hectares and almost 2000 hectares is arable land [5]. The population of Floresti increased considerably since 2003, when it was approximately 2% of the population of Cluj, reaching almost 8% of Cluj population in 2011 (Fig. 2). Now the stable population of Floresti represents 22,818 of inhabitants. The Floresti village has a relief of depression; surrounded by hills with an average elevation of about 400-500 m. Floresti village has a continental climate, characterized by warm dry summers and cold winters.

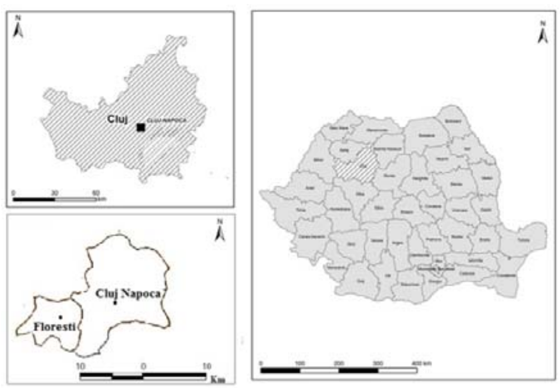

Fig.1. Location of the study area

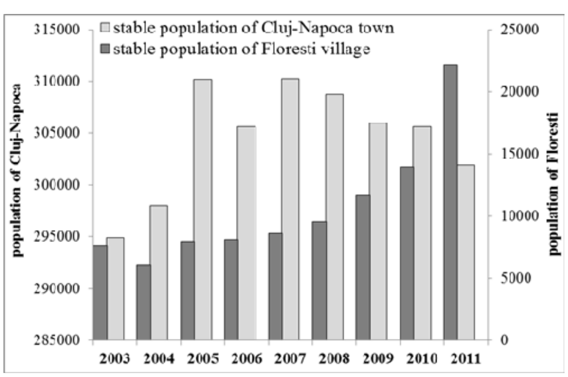

Fig.2. The stable population of the Cluj-Napoca town and Floresti village, during 2003-2011 [6]

MATERIALS AND METHODS

Groundwater samples were collected from fifteen wells located in a rural area (Floresti village) from Cluj County, Romania, in November 2013 (Fig. 3). The water from wells is used for drinking, cooking, bathing and for agricultural purpose. In order to compare the quality of the groundwater from the investigated wells and the quality of water distributed to the public network from the village, a tap water sample was also collected.

Fig.3. Study area with sampling points

The unstable phisyco-chemical parameters (temperature, pH, redox potential – ORP, electrical conductivity – EC, total dissolved solids – TDS, salinity, dissolved oxygen – DO and turbidity) were measured in situ using a portable multiparameter (WTW inolab 350i) and a portable turbidimeter (WTW pHotoFlex Turb). The water samples used for major dissolved ions analysis were collected in polyethylene bottles; the water samples were filtered in situ using 0.45 µm syringe filters. The samples were then shipped to the laboratory, stored at dark and 4ºC, and analyzed within 48 hours from sampling. The major dissolved ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-}) were analyzed in the Environmental Laboratory from the Faculty of Environmental Science and Engineering, by ion chromatography (IC1500 Dionex).

RESULTS AND DISCUSSIONS

The physico-chemical and chemical parameters of the analyzed water samples are presented in Table 1 and Table 2. The analyzed waters proved to be slightly acidic to neutral, having the pH between 6.32 and 7.41. Two of the investigated wells (W1 and W2) have the pH lower than 6.5, the limit imposed for drinking waters. With the exception of W1 and W2, the water from the other wells had a negative redox potential, between -52.3 and -1.2 mV. Water samples with a lower (more negative) redox potential have a tendency to lose electrons and to be oxidized by reducing processes. As a consequence the majority (75%) of the analyzed water samples had the dissolved oxygen level lower than 5 mg/l, the limit imposed for the drinking water. The water turbidity had a low level (0.04 – 1.76 NTU) with the exception of well W3 were a very high turbidity was registered (65.1 NTU). The levels of EC and TDS were within the permissible limits for all the analysed water samples (Table 1).

The analyzed waters proved to have a low level of sodium (0.27 - 41.87 mg/l), magnesium (0.11 – 25.17 mg/l), calcium (0.59 – 117.30 mg/l), chloride (3.33 - 97.68 mg/l) and sulphate (4.42 – 132.80 mg/l), lower than the maximum contaminant level set by the Romanian legislation (Low 458 from 08.07.2002) (Fig. 4 and 5). On the other hand there were recorded exceeding of the maximum contaminant level for the fallowing dissolved ions: potassium (for 25% of the samples), nitrites (only for one sample – the tap water), nitrate (for 56% of the samples) and fluoride (for 19% of the samples). The phosphate was detected in three of the investigated wells (W3, W5 and W6), and the level ranged between 12.44 and 18.26 mg/l. The level of phosphate is very high, considering that the maximum contaminant level for phosphate is 0.1 mg/l for 1st class of water quality (which is used for drinking water – Order 161 from 16.02.2006), respectively >0.9 mg/l for 5th class of waters quality (very bad ecological status). The phosphate is not toxic, but has negative effects on the aquatic environment like the water eutrophication. The presence of high levels of nitrates, nitrites and phosphates in the analyzed waters is a consequence of agricultural activities in the area. Some of the lands located close to these wells are cultivated with vegetables and are treated with fertilizers based on nitrogen and phosphorus. Another important source for nitrates, nitrites and phosphates in the analyzed waters is the presence in the close vicinity of chicken farms. The residual waters generated by these farms and an inadequate management of manure can lead to high contamination of groundwater with nitrates, nitrites and phosphates.

Table 1.Physico-chemical parameters of the analyzed water samples

Sample	T (° C)	pH	ORP (mV)	EC (µS/cm)	TDS (mg/L)	OD (mg/L	Turbidity (NTU*)
W1	17.3	**6.48**	2.5	493	318	5.96	0.74
W2	17.1	**6.32**	10.2	470	301	**4.96**	1.47
W3	17.4	7.41	-52.3	423	272	**4.95**	**65.1**
W4	17.2	7.26	-40.8	286	182	**4.82**	0.05
W5	16.3	6.88	-22.1	625	401	**4.42**	0.5
W6	15.8	6.66	-9.5	565	356	**4.37**	0.04
W7	15.1	6.56	-3.8	575	368	**4.57**	0.61
W8	15.2	6.67	-9.9	654	422	**4.31**	0.38
W9	15.8	6.7	-11.9	578	371	**4.8**	0.56
W10	15.2	6.51	-1.4	546	349	**4.3**	0.7
W11	15.9	6.84	-19.3	135	87	**4.47**	0.08
W12	15.4	6.74	-13.1	218	140	5.05	1.76
W13	15.9	6.67	-9.7	448	287	**4.81**	0.23
W14	16.8	6.58	-4.9	439	281	**4.73**	0.38
W15	17.2	6.51	-1.2	486	312	5.12	0.21
TAP	17.1	7.36	-48.6	54	35	5.61	0.81
MCL	-	**6.5-9.5****	-	**2500****	**500*****	**>5****	**≤5****

*NTU-nephelometric turbidity units; **MCL-Maximum Contaminant Level according to Romanian legislation for drinking water (Low 458 from 08.07.2002); ***MCL-Maximum Contaminant Level according to BC Health Act Safe Drinking Water Regulation–Canada [8] and World Health Organization [9]

Table 2.Chemical parameters of the analyzed water samples

Sample	Na^+	Mg^{2+}	K^+	Ca^{2+}	Cl^-	NO_3^-	F^-	SO_4^{2-}
	(mg/l)							
W1	0.27	0.13	nd*	0.84	59.16	47.42	1.10	65.92
W2	0.37	0.12	0.22	0.70	52.99	**55.15**	1.14	56.31
W3	0.28	0.11	nd	0.59	49.98	**76.19**	0.96	43.29
W4	19.38	12.23	5.72	53.80	21.63	44.07	0.93	33.44
W5	40.75	21.00	**14.51**	111.30	89.06	**61.39**	nd	110.61
W6	41.87	19.43	**21.71**	85.90	86.35	**55.06**	nd	65.16
W7	39.52	21.25	**22.59**	88.00	86.79	**69.19**	**1.32**	70.07
W8	40.84	22.41	**10.51**	117.30	97.68	**92.96**	nd	132.80
W9	33.50	25.17	9.87	108.40	65.30	**54.57**	**1.40**	97.29
W10	31.20	22.74	8.17	102.50	47.54	**64.37**	**1.29**	68.16
W11	4.37	4.96	1.85	28.95	50.10	**60.1**	1.11	79.30
W12	8.76	7.35	3.11	45.12	11.13	17.43	0.48	33.17
W13	37.22	17.19	2.74	66.20	82.11	31.9	1.10	46.72
W14	38.77	16.57	3.21	66.10	84.01	30.74	0.93	44.39
W15	40.14	18.28	7.22	71.80	88.59	33.45	1.11	51.72
TAP	1.75	2.25	0.64	11.27	3.33	6.58	0.24	4.42
MCL	**200****	**50*****	**10*****	**200*****	**250****	**50****	**1.2****	**250****

*nd-not detected; **MCL-Maximum Contaminant Level according to Romanian legislation for drinking water (Low 458 from 08.07.2002); ***MCL-Maximum Contaminant Level according to BC Health Act Safe Drinking Water Regulation–Canada [8] and World Health Organization [9]

The present study showed that the pollution with nitrate, nitrite, phosphate, fluoride and potassium of the drinking water in the area may pose high potential health risks to local residents.

The possibility of using these waters for agricultural purposes has been assessed by calculating the sodium adsorption ratio (SAR). Sodium is a unique cation because of its effect on soil as it causes adverse physico-chemical changes in the soil, particularly to the soil structure.

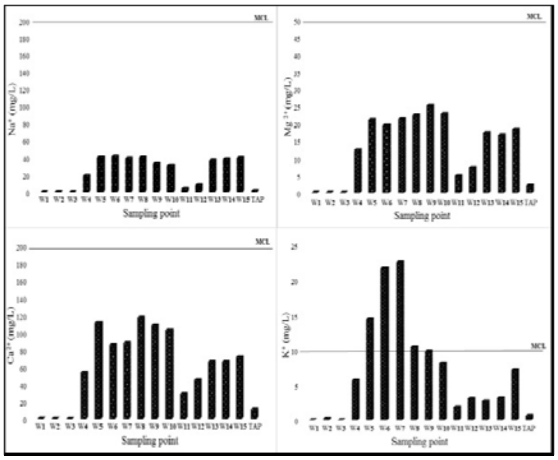

Fig.4. The level of major dissolved cations

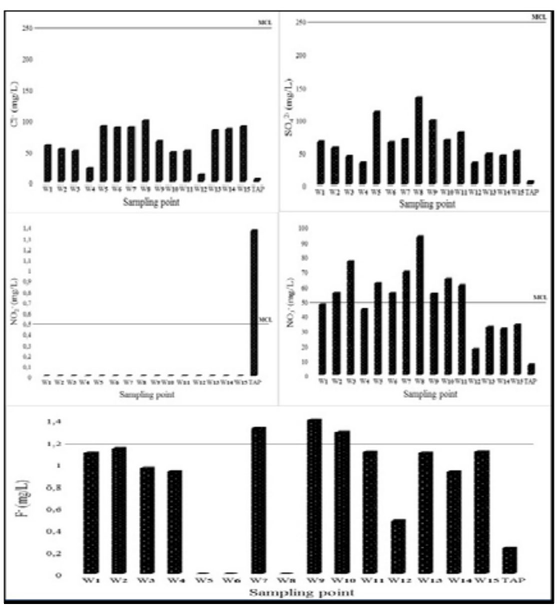

Fig.5. The level of major dissolved anions

SAR was calculated based on the sodium, calcium and magnesium concentrations, according to the fallowing formula [1,3,4]:

$$\text{SAR} = \frac{Na^{+}}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}}$$

where, all ionic concentrations are expressed in milliequivalent per liter.

The level of SAR for each of the investigated water source is presented in Fig. 6. The SAR values ranged from 0.06 to 1.10. According to the Richards (1954) classification based on SAR values (Table 3), all the water samples belong to the excellent category.

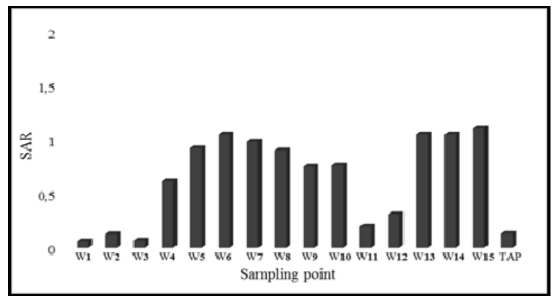

Fig.6. The level of sodium adsorption ratio (SAR) for the investigated water sources

Usually, when SAR is lower than 3.0 there is no threat to vegetation, while a SAR level greater than 12.0 is considered a real threat for the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability [1,3,4].

Table 3. Water classification based on SAR values

Sodium adsorption ratio (SAR)	Status
<10	Excellent
10-18	Good
18-26	Doubtful
>26	Unsuitable

SAR can indicate the degree to which irrigation water tends to enter cation exchange reactions in soil. The replacement of calcium and magnesium by sodium is hazardous because it causes damage to the soil structure by making the soil compact and impervious [2]. The %Na was also calculated, based on sodium, potassium, calcium and magnesium concentrations, using the fallowing formula [1,3,4]:

$$\%\text{Na} = \frac{(Na^{+} + K^{+}) \cdot 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}$$

where, all ionic concentrations are expressed in milliequivalent per liter. The %Na ranged between 16.73 and 61.56 (Fig. 7).

According to the Wilcox (1955) classification, which is based on %Na values, 12.5% of the samples belong to the excellent category, 25% belong to the good category, 50% belong to the permissible category and 12.5% belong to the doubtful category [7].

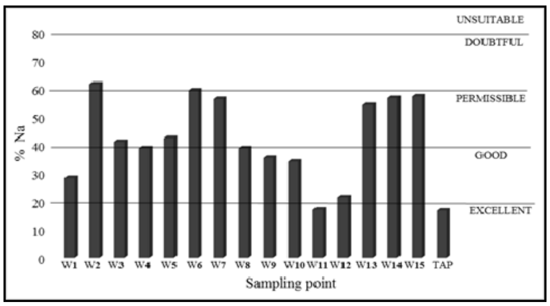

Fig.7. The percent of sodium for the investigated water sources

In conclusion, considering the low level of SAR and %Na, the investigated waters do not pose threat to vegetation and can be safely used in agricultural purposes as irrigation water. A special attention should be paid to the waters taken from wells W2 and W6, considering that according to %Na level these waters belong to the doubtful category.

CONCLUSIONS

The analyzed waters proved to have a low level of sodium (0.27 - 41.87 mg/l), magnesium (0.11 – 25.17 mg/l), calcium (0.59 – 117.30 mg/l), chloride (3.33 - 97.68 mg/l) and sulphate (4.42 – 132.80 mg/l), lower than the maximum contaminant level set by the Romanian legislation (Low 458 from 08.07.2002). On the other hand there were recorded exceeding of the maximum contaminant level for potassium (for 25% of the samples), nitrites (only for one sample – the tap water), nitrate (for 56% of the samples) and fluoride (for 19% of the samples). The phosphate was detected in three of the investigated wells (W3, W5 and W6), and the level ranged between 12.44 and 18.26 mg/l.

The presence of high levels of nitrates, nitrites and phosphates in the investigated water samples is a consequence of agricultural activities in the area (the use of fertilizers based on nitrogen and phosphorus) and the presence in the close vicinity of chicken farms (residual waters, inadequate management of manure). The present study showed that the pollution with nitrate, nitrite, phosphate, fluoride and potassium of the drinking water in the area may pose high potential health risks to local residents.

Considering the low level of SAR (0.06 to 1.10) and %Na (16.73 to 61.56), the investigated waters do not pose threat to vegetation and can be safely used in agricultural purposes as irrigation water.

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