

Assessment of Groundwater Quality in Areas Affected by Industrial Activities in Gorj County

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The study aims to assess groundwater quality considering its importance for the development of human communities. The water samples used in the study were collected from wells located in two areas of the Gorj County affected by industrial activities, namely: Ticleni area affected by oil extraction and Turceni area situated under the influence of the energy sector activities. For these samples were monitored a series of physico-chemical parameters of drinking water: pH, water conductivity, fixed residue, chlorides content and sulfur content. It was found that water from the monitoring wells shown exceedances of the maximum allowed concentration of chlorides and sulphates due to industrial activities carried out in the analyzed areas.

Keywords: monitoring, drinking water, quality parameters

Since the groundwater reservoir is the sole source of unpolluted water maintaining of this reserve is a vital condition for humanity. Groundwater is a good source of drinking due to the purification properties of the soil. Pollution phenomenon sometimes occurs in groundwater although it is more protected than surface waters. Groundwater pollution is associated with many unpleasant aspects such as taste, odor, color, hardness and the existence of pathogenic organisms or toxic, explosive or flammable substances [1-3]. Groundwater pollution leads to inability to use the aquifer for long periods of time, on the order of decades or even centuries. This is due to extremely low speeds of groundwater. Groundwater pollution may be continuous or accidental and may be due to industrial, agricultural or health pollutants [4-6].

Much of pollutants that are on the ground or transported by water can contaminate aquifers that are in most cases the source of drinking water in many localities. To study the process of these sources of water pollution should be pursued following aspects: the type and characteristics of pollutants, how to run them into the ground, the transfer of pollutants through soil to groundwater surface, the evolution of pollutants in terms of chemical, biological and physical during transfer period and evolution of pollutants in groundwater called the saturated zone or aquifer. Mainly groundwater pollution occurs as a result of disposal of solid or liquid waste on permeability lands and that are placed near or over water-bearing zones [7-10]. Currently the most important ways groundwater pollution are: vertical infiltration for liquid pollutants through rainwater, snowmelt, water irrigation, infiltration of surface water pollution, rising from sewers damaged, the ponds, storage tanks of petroleum products, mines flooded. The phenomenon of propagation of pollutants in groundwater is accompanied by a complex and intense mitigate contamination due to a self-cleaning process determined by the influence of physico-chemical, geochemical and biochemical phenomena that occur in porous media [11-15]. The processes that occur in self-cleaning are hydrodynamic dispersion, mechanical filtration, the rise of

gas adsorption and precipitation of compounds that are insoluble in water, the action of microorganisms.

Experimental part

In the study conducted during 2012-2014, to assess the quality of groundwater in areas affected by industrial activities in Gorj County, twelve wells were monitored in private households used as individual sources of drinking water. The first area under study was the Ticleni village where were quarterly taken water samples from wells of five families situated in the vicinity of Ticleni oil extraction. Oil exploitation in this area increases the chloride content in groundwater and requires monitoring quality. The selected wells are representative for groundwater quality assessment because they are located in the oil Ticleni area being at risk of contamination by salt water produced as a result of accidental pollution in the area or due to malfunctioning of drilling rigs.

The second study area was the Turceni village where were quarterly taken water samples from wells of seven families, located in the area of influence of ash and slag Ceplea Valley deposit from Turceni power plant. In this area, as a result of seepages from the tailings slag and ash deposit belonging to Turceni power plant, ground waters are strongly influenced by discharged wastewater substantially altering the chemistry of groundwater from wells. Monitoring wells were chosen as representative for the study conducted as they are positioned in the vicinity of Turceni Treatment Station, in an area where groundwater seepage causes sulfate anion concentrations that exceed the natural background.

Sampling and analysis of water quality parameters were made according to standard methods. The following physico-chemical parameters of drinking water: pH, conductivity of the water, fixed residue content of chlorides (Ticleni area) and sulphate content (for the Turceni area) were monitored. The methods and equipments used for monitoring quality parameters are standardized. The results were reported at the maximum value allowed by Law number 458/2002 on drinking water quality.

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Sample symbol	Analyzed parameters							
	pH (pH units)		Conductivity ($\mu\text{S}/\text{cm}$)		Fixed residue (mg/L)		Cl ⁻ (mg/L)	
	Average value	Max. value	Average value	Max. value	Average value	Max. value	Average value	Max. value
F1	7.73	7.84	841	864	546.6	587.4	93.59	98.69
F2	7.23	7.27	1036.5	1100	673.72	715	207.39	216.26
F3	7.42	7.48	889.66	961	578.28	624.65	154.24	194.99
F4	7.14	7.34	770.33	1073	557.21	697.45	127.84	177.21
F5	7.26	7.33	875.33	895	573.05	594	134	159.53
F6	7.41	7.82	906	943	588.9	598.2	134.72	142.51
F7	7.38	7.4	878.5	936	569.72	605.8	223.35	230.44

Table 1
PHYSICO - CHEMICAL
PARAMETERS OF TICLENI
DRINKING WATER (2012)

As a method of analysis for determination of sulphate ions was applied spectrophotometric method by measuring the absorbance of the resulting solution by barium precipitation. The measurement was performed at a wavelength of 450 nm using a UV-VIS spectrometer, Cintra 101 model. Determination of chloride ions was achieved by volumetric method by titrated with silver nitrate in the presence of potassium chromate (Mohr method). Determination of pH was done by potentiometric method using a portable pH-meter Hanna model. Electrical conductivity of water samples given by all dissolved salts was measured by standardized electrochemical methods using a Consort multiparameter. The fixed residue indicator analysis was performed by standard in force gravimetric method.

Results and discussions

The parameters values monitored for Ticleni area in 2012 are shown in table 1. For this area the interesting parameters were: pH, electrical conductivity, fixed residue and the chloride content of water samples, since dominant industrial activity in the area is the extraction of crude oil. The water reservoir is a source of salts pollution for groundwater, especially chlorides which have an impact on its quality and its utilities as a source of drinking water. From the data presented in table 1 is observed that the average and maximum values of pH are between 6.5 to 9.5 pH limits established by Law number 458/2002 on drinking water quality. Electrical conductivity of analyzed samples is below the maximum admissible value of 2500 $\mu\text{S}/\text{cm}$ and the chloride content has values under law permissible values namely below 250 mg/L. Fixed residue has average and maximum values within the limits

regulated for drinking water (100-800 mg/L).

Data recorded for 2013 year (table 2) show normal average values for pH and electrical conductivity, but appear breaches of the maximum permitted chloride, in four of the seven wells that were monitored as follows: 1.28 VMA for F2 well, 1.04 VMA for F3 well, 1.46 VMA for F4 well and 1.02 VMA for F5 well.

Average and maximum values measured for water quality parameters from monitored wells, in 2014 year, are shown in table 3. The results of measurements indicate a variation in average chloride content which exceeds the maximum allowed value (VAM) in all monitored wells, recorded average values ranging between 1.02 and 1.56 VMA. The maximum values for this indicator show an excess between 1.27 and 1.74 VMA to those regulated by Law number 458/2002 content regarding the drinking water quality.

In figure 1 it is shown the variation of electrical conductivity and fixed residue in 2012-2014 monitoring

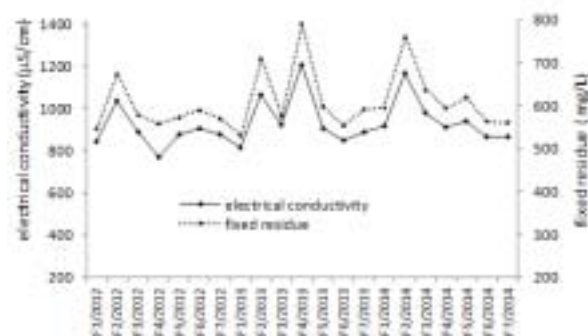


Fig.1. Variation of electrical conductivity and fixed residue for Ticleni wells

Symbol sample	Analyzed parameters							
	pH (pH units)		Conductivity ($\mu\text{S}/\text{cm}$)		Fixed residue (mg/L)		Cl ⁻ (mg/L)	
	Average values	Max. values	Average values	Max. values	Average values	Max. values	Average values	Max. values
F1	7.2	7.3	815	824	529.75	532.5	180.81	189.92
F2	7.28	7.33	1064.5	1239	710	841.5	319.07	368.71
F3	7.24	7.37	923.66	1055	575.56	594.3	261.15	319.07
F4	7.21	7.31	1205	1690	789.73	1098.5	363.98	382.89
F5	7.19	7.36	905.33	975	597.25	633.75	256.43	326.16
F6	7.48	7.58	850	862	552.5	562.8	230.44	236.54
F7	7.25	7.36	890	950	590.6	617.5	212.71	354.53

Table 2
PHYSICO - CHEMICAL
PARAMETERS OF TICLENI
DRINKING WATER (2013)

Sample symbol	Analyzed parameters							
	pH (pH units)		Conductivity ($\mu\text{S}/\text{cm}$)		Fixed residue (mg/L)		Cl ⁻ (mg/L)	
	Average value	Max. value	Average value	Max. value	Average value	Max. value	Average value	Max. value
F1	7.27	7.32	915	924	594.7	598.87	310.46	316.53
F2	7.35	7.38	1169.5	1239	760.17	805.35	388.60	397.07
F3	7.24	7.29	981	1132	637.65	735.8	318.94	436.25
F4	7.27	7.36	912.66	1318	593.06	856.7	386	412.81
F5	7.22	7.36	939	1066	618.63	692.9	257.35	304.89
F6	7.15	7.25	866	874.5	562.8	564.6	382.41	389.32
F7	7.29	7.42	862.5	880	560.62	572	316.96	354.53

Table 3
PHYSICO-CHEMICAL PARAMETERS
OF TURCENI DRINKING WATER
(2014)

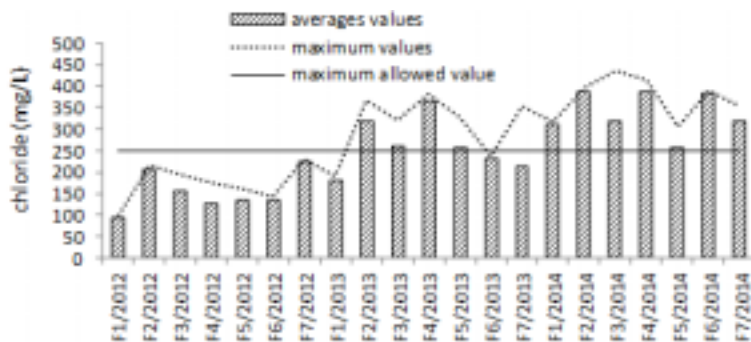


Fig.2. Variation of chloride content for Ticleni wells

Sample symbol	Analyzed parameters							
	pH (pH unit)		Conductivity ($\mu\text{S}/\text{cm}$)		Fixed residue (mg/L)		SO_4^{2-} (mg/L)	
	Average value	Max. value	Average value	Max. value	Average value	Max. value	Average value	Max. value
F1	7.6	7.77	1419.75	1481	922.84	962.65	680.75	902
F2	7.62	7.74	1545.5	1621	1004.57	1053.65	626.25	851
F3	7.58	7.83	1665.5	2010	1082.57	1306.5	339.5	596
F4	7.53	7.72	1996.5	2375	1297.71	1543.75	302.5	612
F5	7.58	7.82	1637.75	1990	1064.53	1293.5	213	349

Table 4
PHYSICO-CHEMICAL
PARAMETERS OF TURCENI
DRINKING WATER (2012)

period of time, in Ticleni area, for seven analyzed wells and framing these values in the maximum permissible limits.

Regarding the evolution of chlorides content during the monitoring period (2012-2014), the data represented in figure 2 show that from 21 measurements 11 averages of them exceed the maximum permissible value, meanly a percentage of 52.38%, which indicates a high advanced pollution rate for water intended for consumption. The maximum values recorded in 2013 and 2014 exceeded the maximum allowed value (VMA = 250 mg/L).

In table 4 are presented the experimental data corresponding to quality parameters determined for water samples collected in Turceni in 2012 year. For this area were monitored the following parameters: pH, electrical conductivity, fixed residue and sulphate content of water samples in order to assess the influence of the energy sector activities on groundwater quality. The evolution of pH and electrical conductivity values were within the limits laid down in Law number 458/2002 on drinking water quality. Fixed residue had similar values for all five monitored wells. Regarding the sulphate content in the analyzed samples, the data presented in table 4, it is observed that: the average values are in the range from 213 to 680.75 (mg/L); average values exceed the maximum allowable values for F1, F2, F3 and F4 wells; the maximum value is between 349- 902 (mg/L); maximum value is 3.6 VLA for F1 well and 3.6 VLA for F5 well.

In figure 1 it is shown the variation of electrical conductivity and fixed residue in 2012-2014 monitoring period of time, in Ticleni area, for seven analyzed wells and framing these values in the maximum permissible limits.

Regarding the evolution of chlorides content during the monitoring period (2012-2014), the data represented in figure 2 show that from 21 measurements 11 averages of them exceed the maximum permissible value, meanly a percentage of 52.38%, which indicates a high advanced pollution rate for water intended for consumption. The maximum values recorded in 2013 and 2014 exceeded the maximum allowed value (VMA = 250 mg/L).

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Data recorded in 2013 year for samples of Turceni area shown in Table 5. It shows a mean sulfate ion content over the allowed limit for four of the wells monitored in the range exceeding the 1164 VMA - 2.23 VMA. The maximum values recorded are well above the allowed value, so the risk of contamination with sulfates is increased. If F4 source, the maximum sulfur content is 3.24 times higher than the allowed value and other sources of drinking water have exceeded between 2124 VMA - 2.44 VMA. The electrical conductivity also shows increased value for F4, the highest value recorded in 2013 is close to the maximum allowed by regulations on drinking water quality (VMA = 2500 $\mu\text{S}/\text{cm}$ at 20°C).

The measured values in 2014 year are shown in table 6. They show the variation of pH around the neutral value, the limits of variation being between 7.22 to 7.31 pH units. The electrical conductivity measured during 2014 year shows the increased values for F4 well both for the average and maximum value. The sulfur content is an indicator of water pollution in monitored wells by values that exceed the allowed value accepted by law. For F1 well was recorded the highest average value namely 2.78 VMA, and a maximum value of 3.2 VMA. Average values for F1, F2 and F3 wells are included in the spread values of 1.23 VMA to 2.78 VMA.

Evolution of electrical conductivity indicator in 2012-2014 period of time, for wells of the Turceni area is shown in figure 3. There is an evolution of this indicator below the maximum value allowed by law on drinking water quality. Variation of fixed residue for monitoring drinking water

Sample Symbol	Analyzed parameters							
	pH (pH units)		Conductivity ($\mu\text{S}/\text{cm}$)		Fixed residue (mg/L)		SO_4^{2-} (mg/L)	
	Average value	Max. value	Average value	Max. value	Average value	Max. value	Average value	Max. value
F1	7.17	7.29	1458.75	1602	962.42	1041.3	557.5	610
F2	7.28	7.41	1235.75	1549	819.83	1006.85	476	539
F3	7.20	7.26	1565.5	1646	1057.35	1118	246.75	531
F4	7.41	7.53	2092.75	2214	1391.31	1503	351.25	810
F5	7.26	7.39	1284.5	1410	853.35	957.7	291	486

Table 5
PHYSICO-CHEMICAL PARAMETERS
OF TURCENI DRINKING WATER
(2013)

Sample symbol	Analyzed parameters							
	pH (pH units)		Conductivity ($\mu\text{S}/\text{cm}$)		Fixed residue (mg/L)		SO_4^{2-} (mg/L)	
	Average value	Max. value	Average value	Max. value	Average value	Max. value	Average value	Max. value
F1	7.31	7.56	1430.33	1480	942.9	962	697.33	800
F2	7.25	7.32	1452	1750	955.4	1137.5	490.66	534
F3	7.22	7.24	1598.33	1715	1069.46	1115.4	311	549
F4	7.32	7.39	1998.33	2105	1317.91	1368.25	307.66	416
F5	7.29	7.58	1452	1610	959.3	1093	229	301

Table 6
PHYSICO-CHEMICAL PARAMETERS
OF TURCENI DRINKING WATER
(2014)

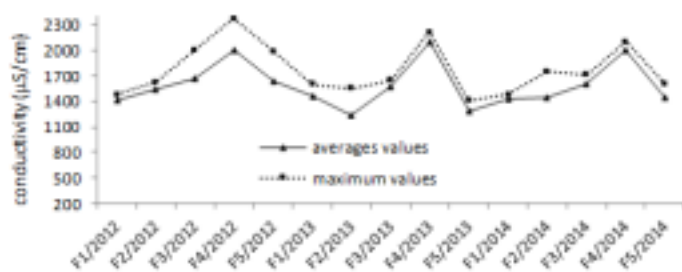


Fig.3. Variation of electrical conductivity for Turceni wells

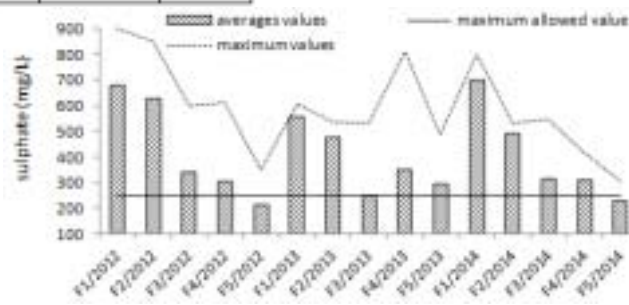


Fig.5. Variation of sulphate content for Turceni wells

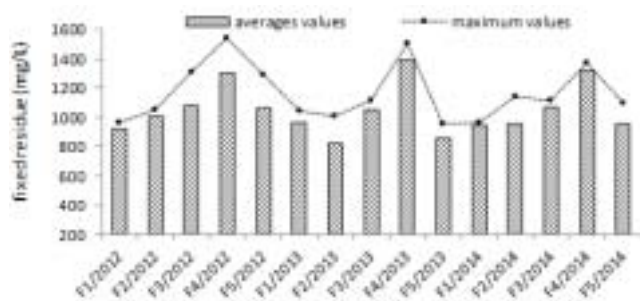


Fig.4. Variation of fixed residue for Turceni wells

wells in Turceni area is shown in figure 4.

The growth of average and maximum content of sulphate ions in drinking water taken from the five wells in the Turceni area is shown in figure 4. Of the 21 values recorded during the monitoring period, 18 of them were above the maximum permissible value of 250 mg/L, which means a rate of 85.71%. The sulphate pollution degree is significant overruns being very large in number and value. The most increased averages values were recorded for F1 and F2 wells for the entire monitored period.

Conclusions

Quality assessment of individual sources of drinking water supply from Turceni and Ticleni area was done by monitoring of quality parameters: pH, conductivity, fixed residue, chloride and sulphate containing, in 2012-2014 period. The measured values were reported in the requirements of legislative regulations on drinking water quality. For monitored wells was highlighted that the pH is close to neutral pH value, electrical conductivity and fixed

residue shows normal values with small average values variations. Regarding the content of chlorides in the Ticleni monitored area, it was found the exceeding of the maximum allowed value with a rate of 52.38% of the measurements, indicating a degree of advanced managed water pollution mainly due to oil extraction activities in the study area. Evolution of sulphate content in the monitored Turceni area shows a significant level of pollution, exceedance of the maximum allowed value by drinking water law is high in both number and value. In this study, there were excesses in the percentage of 85.71% of the measurements and average values exceeded even three times the allowed value. We can say in the Turceni area as a result of seepages from the slag and ash Ceplea Valley deposit belonging to Turceni power plant, groundwater are strongly influenced by discharged wastewater which substantially altering the chemistry of groundwater from wells. SO_4^{2-} ion values determined in monitored wells in the Turceni area far exceed the maximum permissible value of 250 mg/L, so that are affected the Turceni inhabitants because of non-potable water.

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Manuscript received: 13.05.2015