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GROUND WATER QUALITY OF DOMESTIC WELLS IN CAJVANA TOWN

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Abstract: *The purpose of this paper is to analyze the water quality in some wells of Cajvana town, uniformly distributed in the built area. The water quality is analysed for the following parameters:* NH_4^+*-N,* NO_2^-*-N,* NO_3^-*-N, P-* PO_4^{3-} *and* S^{2-}*. A Hach–Lange spectrofotometer was used in order to analyze the chosen parameters of the water samples collected in August 28th, 2015 (the chosen time is random, for expeditionary measurements purposes). The measured values were converted into interpolation maps of the quality classes of each monitored parameter. Consistent above average (of the built area) concentrations of ammonium and nitrite near the main graveyard of the settlement caused by the decaying organic matter were measured. Nitrite pollution is stronger along Cajvana valley. Nitrate pollution has values above average in the western half of the town. Orthophosphate pollution, caused by domestic wastewaters, has high values in the central part of Cajvana. The water pollution by sulfides is almost absent. The worst quality class recorded for each parameter is: very good for ammonium, average for nitrite and mediocre for nitrate and orthophosphate. The increasing standard of living and human pressure on the environment will most probably cause increased groundwater pollution in the near future if a proper sewerage will not be implemented.*

Keywords: *nitrites, sulfide, wastewater, graveyard, interpolation.*

1. Introduction

Water quality for drinking purposes is a management issue that requires continuous or, at least, repeated measurements of water parameters. In rural areas of Romania, water quality in domestic wells is often not suitable for human consumption. Septic tanks continue to be a source of groundwater pollution in the developed world [1]. Phosphorus and nitrogen based pollutants are a persistent pollution issue of surface waters and groundwaters in both rural and urban environments, from point and diffuse sources and from agricultural to domestic sources [1-4]. The Romanian landscape is not an exception [5]. Even if Cajvana is officially classified in the urban category of settlements, it is, in fact, a larger village due to the lack of public infrastructure meant to improve the life quality, as its landscape proves. Numerous villages in Suceava Plateau were previously investigated concerning the groundwater quality and they have persistent and consistent water pollution with nutrients [6-8]. The aim of this paper is to measure the concentration of some nutrients and sulfides in domestic wells of the studied area and to classify the analysed waters into quality classes. This study was undertaken because there is a lack of case studies that especially analyse the water quality in the built areas of various environments. The various studies concerning the water quality in areas that incidentally include our study area do not contain data that specifically refers to the built area. The Romanian legislation concerning the water quality follows the EU directives. However, the new European Water Framework Directive insists on eliminating any anthropogenic contamination of the ground waters, no matter the national chemical quality standards.

2. Study area

Cajvana is a small town located in Suceava County (Fig. 1). The administrative area covers 24.83 km^2 populated with 6901 inhabitants, according to the 2011 census. According to this data, the population density was of 277.9 inhabitants/km^2, but the official built area covers only 7.52 km^2, implying a much greater human footprint, of 917.7 inhabitants/km^2 in the area occupied by local people on a daily basis.

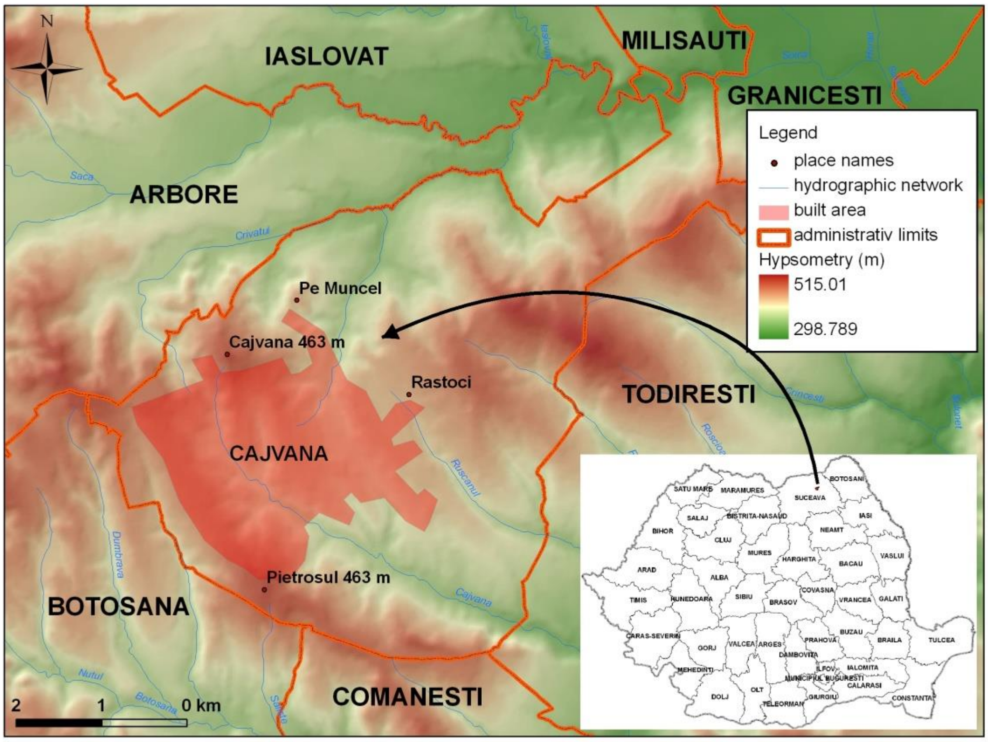

Fig. 1. Geographic location of the studied town

The local surface geology is represented by Volhynian deposits partially covered by Quaternary strata. The alternation of clays, marls, sands and sandstones represents the main lithology. There are some fluvial deposits composed of gravel, sands and clays in Beldean Hill (S). Loessic elluvial deposits can be found in the upper area of the local hills. Holocene deposits lie along the small rivers that spring in the built area. These rivers belong to 2 catchments: Solca catchment in the north, containing Crivăţ and Berbec rivers, and Soloneţ catchment, which covers the main part of the studied territory and contains Cajvana (the main local river) and Ruşcanul rivers. The homoclinal geological strata were modelled by the hydrographic network into cuestas. The town was built on the dip slope of the cuesta between Solca and Solonеț and a small part extended on the escarpment facing north of the same cuesta. The hillsides with high slopes are covered by landslide bodies. These bodies generate springs from small aquifers. The depth to groundwater level is higher on the hills (>5 m) and smaller in the valleys.

The main road crossing the city is DJ 178D, which links some communal roads. The impervious surfaces constituted by roads, roofs and other constructed areas are highly dispersed, as can be seen in any aerial/satellite imagery; therefore, no strong surface water drainage is expected, together with its implications in pollutant movement [9]. The climate is continental temperate, roughly similar to that of the nearby Suceava city [10, 11]; however, an increase in the annual precipitation amount and in the number and intensity of the torrential rains is expected [12], possibly leading to increased land erosion and pollutant movement.

3. Materials and methods

The main objective of this survey is to identify the degree of groundwater contamination in the built area of Cajvana; the measured parameters are ammonium, nitrites, nitrates, orthophosphates and sulfides. In order to fulfill the objective, 15 water samples were collected (no replicates) from Cajvana on August 28th, 2015.

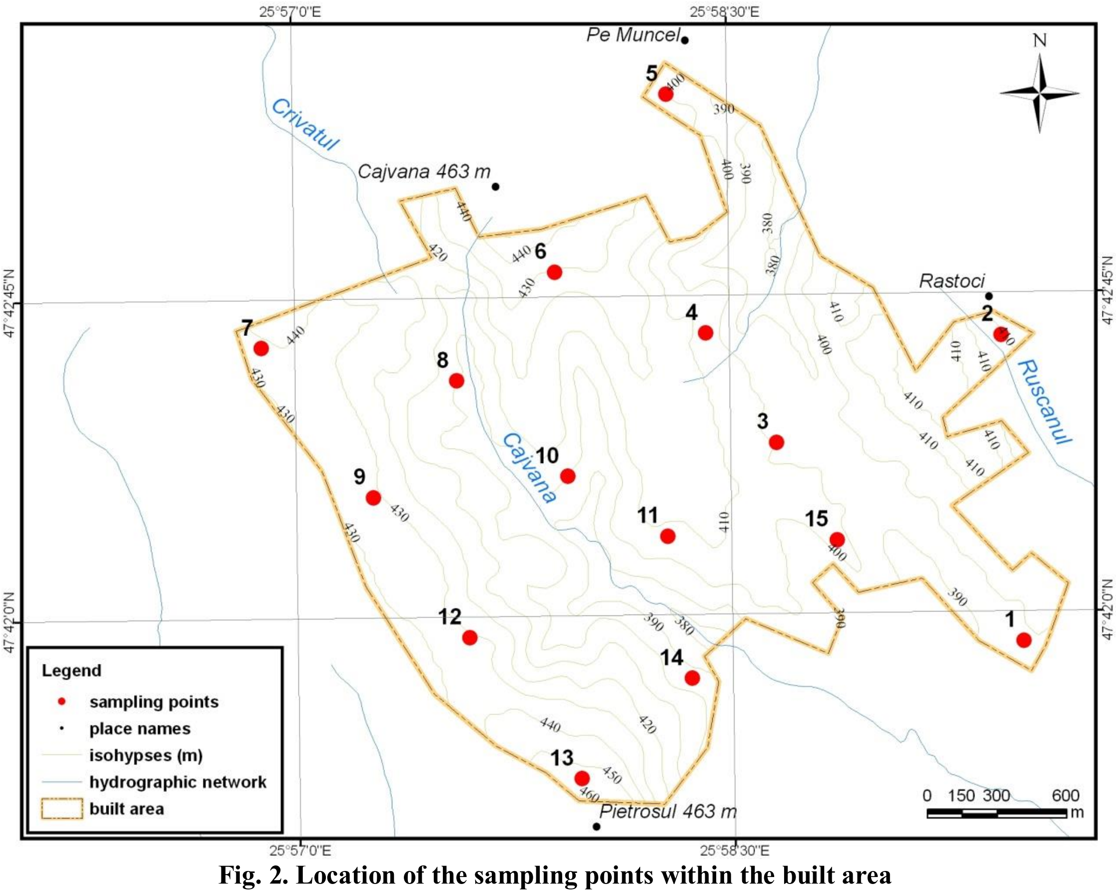

Fig. 2. Location of the sampling points within the built area

The sampling points are represented by wells drilled in geologic strata containing phreatic waters. Their territorial distribution is homogenous and almost ideal for obtaining interpolation maps of the studied parameters (Fig. 2).

The water samples were collected with polyethylene bottles and analysed within 24h from sampling. A Hach-Lange DR2800 spectrophotometer was used with reagents that have the following detection ranges: 0.015-2 mg/l NH_4^+-N, 0.002-0.3 mg/l NO_2^--N, 0.1-10 mg/l NO_3^--N, 0.02-2.5 mg/l PO_4^{3-} and 5-800 µg/l S^{2-}. The chemical analysis methods are specific to the Hach-Lange DR2800 spectrofotometer [13] and are based on Standard Methods for the Examination of Water and Wastewater [14]. The described methodology was also previously used by other authors for analyzing the groundwater quality in Suceava Plateau [6-8].

The maps showing the spatial distribution of the values of analysed parameters were done by using the methodology described by Briciu and Oprea-Gancevici [8], which is mainly a simple interpolation based on the "natural neighbors" function in the ArcGIS software. The interpolated values are those of the quality classes corresponding to each sampling point per studied parameter, according to the official water quality classification described in Order 161/2006, issued by the Romanian government.

4. Results and discussion

The ammonium concentration in wells is very low (Fig. 3) and all sampling points have a very good water quality for this parameter.

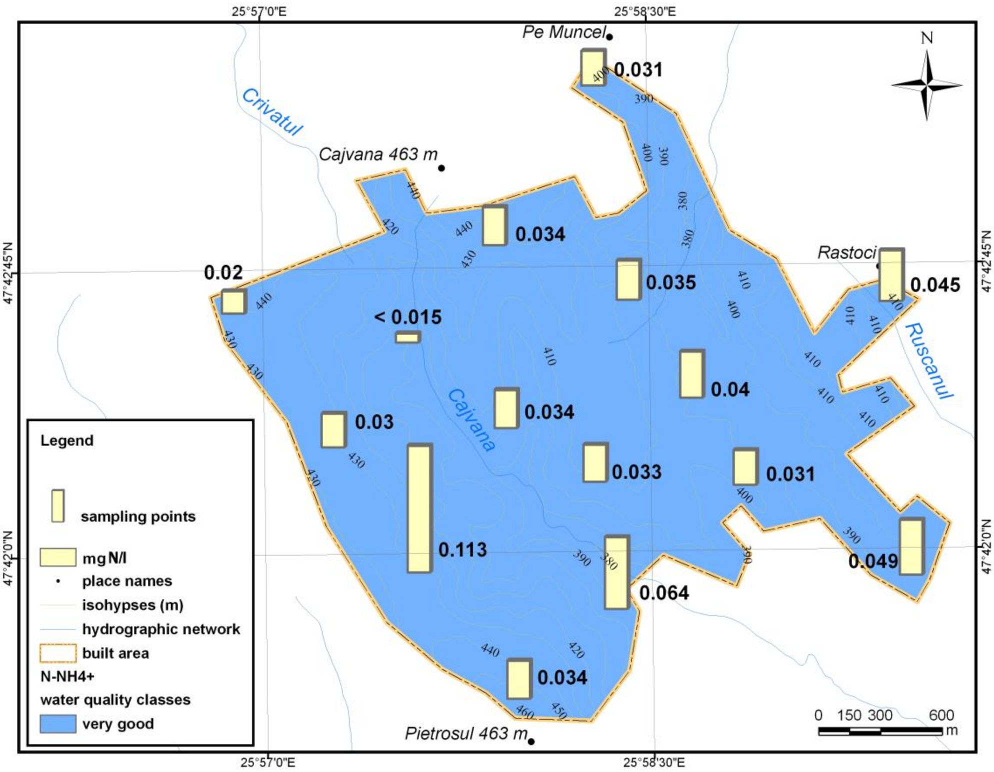

Fig. 3. Territorial distribution of the ammonium concentration and quality classes

No value is higher than the Maximum Admissible Concentration (MAC) of 0.5 mg/l for potable water. Nitrite water pollution is higher in Cajvana valley, where average groundwater quality can be found (Fig. 4). However, the MAC threshold of 0.5 mg/l is far from being reached.

One can observe that the highest nitrite contamination corresponds to the highest ammonium contaminantion, meaning that at least a part of the actual nitrite pollution results from ammonium pollution via biological oxidation of ammonium into nitrite. The Orthodox graveyard is within 200 m from the sampling point number 12 (recording the maximum ammonium and nitrite concentrations) and this can explain the higher ammonium concentration, possibly generated by the decaying corpses in the graves. On the other side, there is another graveyard in the town, belonging to the Pentecostals, located within 100 m from the sampling point no. 13, where low ammonium and nitrite concentration were recorded. The different size of the two graveyards is the key point, the Orthodox graveyard being ~5 times higher than the other one (the graveyards surface ratio is approximately similar to the percentage of the people belonging to the implied confessions: 71.48% Orthodox, 26.71% Pentecostals – according to the 2011 census). The bigger graveyard seems to have reached the critical mass and density to become an environmental hazard.

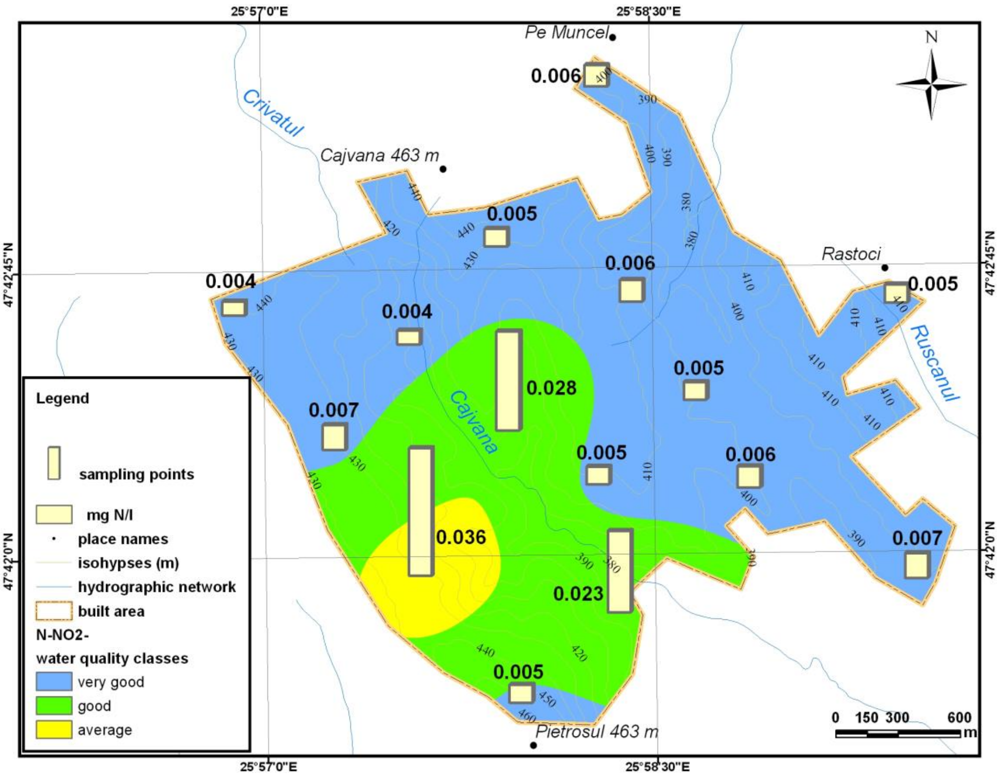

Fig. 4. Territorial distribution of the nitrite concentration and quality classes

The area of high nitrite concentration (from human and animal manure) in Cajvana valley could be explained by the terrain slope, permeable soils and geologic strata which favour the nutrient concentration from the surrounding hills into the valley. Also, this is partly an explanation for the spatial distribution of the nitrates in groundwater (Fig. 5). The MAC value of 50 mg/l nitrate for potable water is not reached in any point, but the groundwater quality is not in a good state when nitrate is concerned; 86.6% of the sampling points have water quality oscillating from average to mediocre quality. At least in Cajvana valley, some nitrates originate from the chemical oxidation of the locally abundant nitrites. In the entire town, the main source of nitrates could be the N-based fertilizers used by people in their own gardens. According to the 2011 census, from 3341 people engaged in economic activities in Cajvana, 2549 (76.3%) were involved in agriculture, silviculture and fishing.

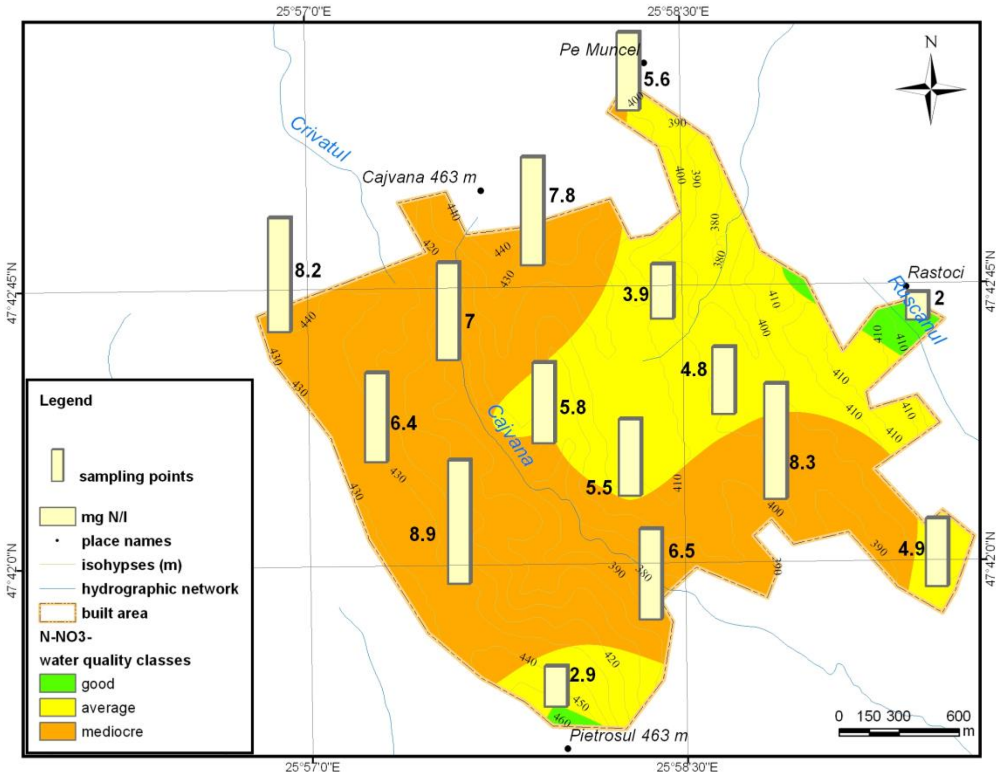

Fig. 5. Territorial distribution of the nitrate concentration and quality classes

The western half of the town is also more polluted when analyzing the groundwater pollution with orthophosphates (Fig. 6). The water pollution with phosphorus is caused by P-based fertilizers and by wastewaters rich in detergents. The P-based water pollution has certainly aggravated in time because of the increasing standard of living that was not, unfortunately, accompanied by the construction of a centralized wastewater collection system. Therefore, the local people are pumping pheatic water, use it and, then, send it back into background with all types of domestic water pollutants. The increased standard of living over time is proven by the increased number of buildings in the built area: 1569 (1992 census), 1878 (2002 census) and 2201 buildings (on December 31st, 2013 [15]). The inhabitable surface has risen from 57371 m^2 (1992) to 91038 m^2 (2002) and 128004 m^2 (on December 31st, 2013 [15]).
The higher density of constructed spaces implies a higher wastewater volume, even if the population number is in a slight decline (7069 inhabitants in 1992, 7263 inhabitants in 2002 and 6901 inhabitants in 2011). The total number of residents on July 1st, 2014, was 9279 [15].
Public water distribution and wastewater collection networks are planned in the near future for Cajvana town. It is likely that, due to the lack of funds, the potable water system will be realized first, leading to an increased groundwater pollution with orthofosphates, nitrites and nitrates until

the wastewater collection network will be finished.

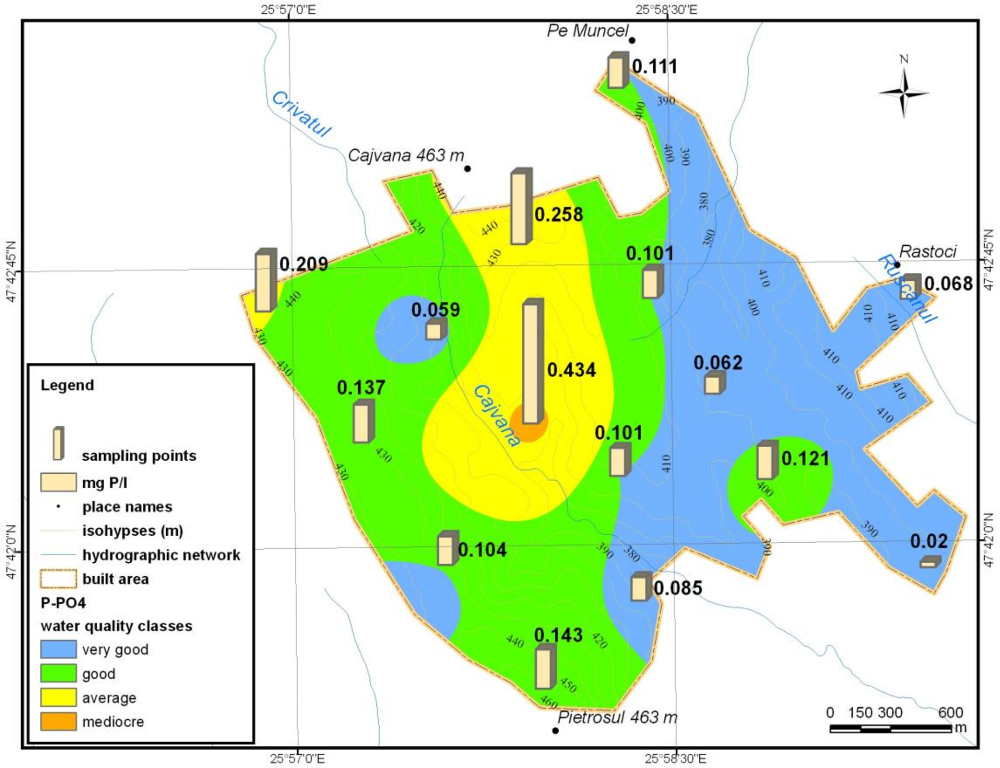

Fig. 6. Territorial distribution of the orthophosphate concentration and quality classes

Only one sampling point (no. 1) showed sulfide concentration inside the detection limits of the used method (Fig. 7). No groundwater contamination with anthropogenic sulfides is to be suspected and the water quality is very good.

The values of groundwater pollution with ammonium, nitrite, nitrate, orthophosphate and sulfide is similar to those often found in other rural settlements in Suceava Plateau, meaning that waters are not of better quality than in Fratautii Noi and not as bad as in Veresti [8] (Table 1). Considering the worst quality class identified for all parameters per each sampling point, one can observe that the dominant water quality is the mediocre one and that covers ~75% of the built area (Fig. 8).

If we try to mediate the values of quality classes in each monitoring point (1 is the best quality, 5 is the worst), instead of choosing the worst identified quality class at each sampling point, the average water quality class is dominant. Moreover, it is useful to analyze the average concentration of the analysed parameters for the entire town: 0.04 mg/l NH_4^+-N, 0.013 mg/l NO_2^--N, 6.23 mg/l NO_3^--N, 0.134 mg/l PO_4^{3-}P and 0.6 µg/l S^{2-} (if we take into account all values, including those that did not fit in the high precision detection range). According to these values, within the built area, there are very good waters for the ammonium criterion, good waters for the nitrite and orthophosphate criteria, average waters for the nitrate criterion; the sulfides in groundwater are almost absent.

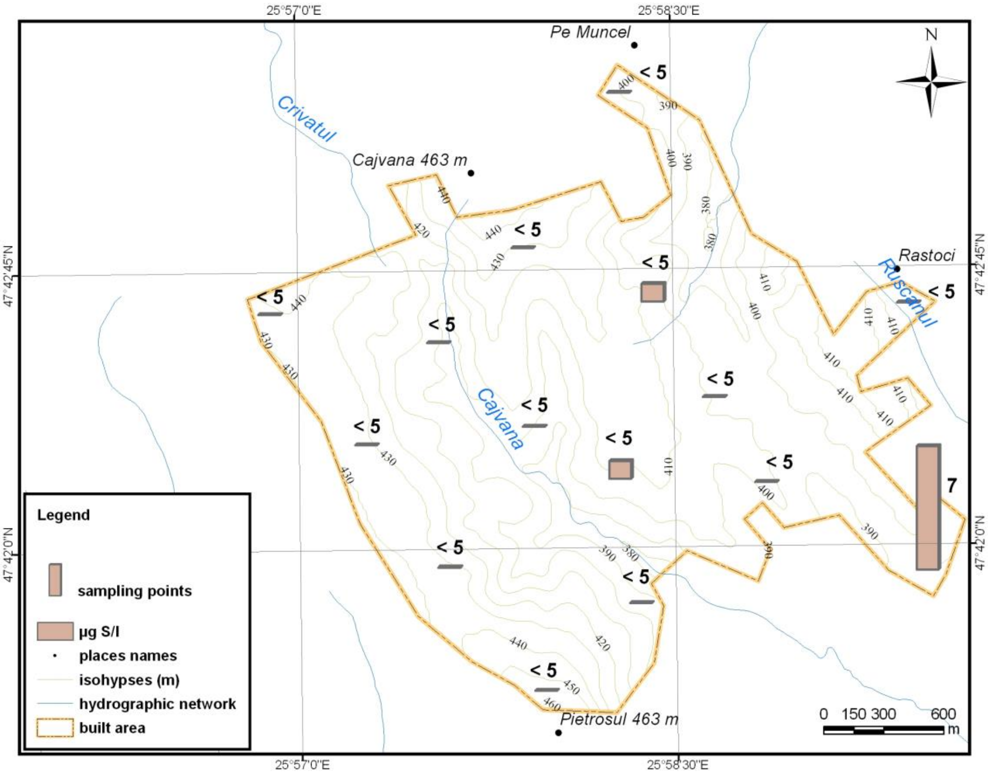

Fig. 7. Territorial distribution of the sulfide concentration

Table 1.
Comparative water quality analysis of some settlements in Suceava Plateau (according to this study and other sources [7, 8])

	Frătăuții Noi	Cajvana	Verești
parameter	average quality in all sampling points		
Ammonium-N	very good	very good	very good
Nitrite-N	good	good	deteriorated
Nitrate-N	good	deteriorated	average
Orthophosphate-P	good	good	good
	worst quality in all sampling points		
Ammonium-N	very good	very good	very good
Nitrite-N	mediocre	average	deteriorated
Nitrate-N	mediocre	deteriorated	mediocre
Orthophosphate-P	deteriorated	mediocre	deteriorated

Concerning the real spatial distribution of the different quality classes, it should be noted that it slightly differs from the mapped one because of the heterogenous distribution of the geologic strata and because of the variable lithology. The various slopes of the topographic surface contribute to the complexity of the real spatial distribution of groundwater pollutants. Predictive and empiric numeric models (such as MNP [16]) applied to groundwater quality issues are necessary in order to perfectate the maps of the territorial distribution of the quality classes.

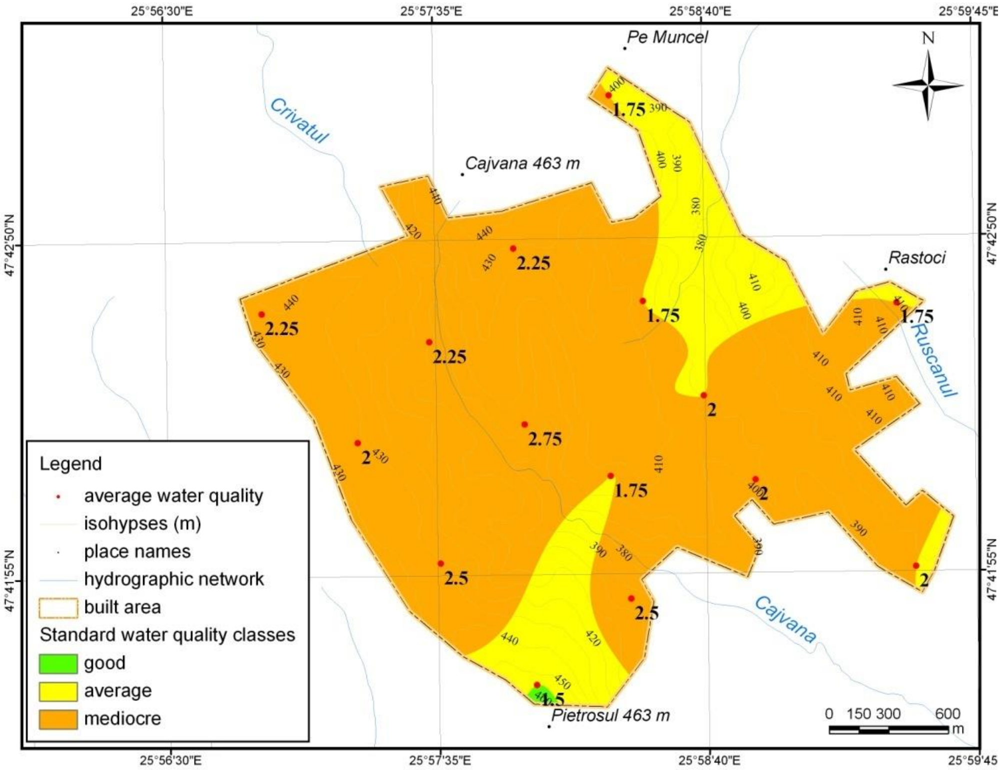

Fig. 8. The worst water quality classes (colour palette for: 1 – very good… 5 – deteriorated) and the arithmetic average (displayed numeric values on map) of all recorded water quality classes per each sampling point

The groundwater generates the small rivers withn the built area and the groundwater pollution is transferred into them. When these rivers have high levels due to surface runoff at torrential rains (which can wash some pollutants from the topographic surface), the rivers can feed the groundwater and new amounts of pollutants will be inserted into the ground, complicating the process of identifying their source and their spatial distribution. Also, the diurnal thermal regime of the rivers [17] is influencing the same groundwater regime along the rivers and the chemical reactions in the underground.

4. Conclusion

In conclusion, we can remark that the most important water pollution in wells is caused by nitrates. There is a distinct groundwater pollution with ammonium and nitrite in the extreme west built area caused by the main graveyard of the town. The lack of a public sewerage is causing water pollution with orthophosphate, which will most probably worsen in the near future due to the increasing standard of living.

The average water quality of the domestic wells in Cajvana town is different depending on the analysed parameter: very good – ammonium, good – nitrite, deteriorated – nitrate and good – orthophosphate. Very small concentration of sulfides was detected.

It is necessary for the future studies to map in detail the various sources of water pollution in order to identify the best local water management strategy.

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