Groundwater and Human Pressure In The Ogosta River Basin

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Abstract

Human activities may have serious impact on groundwater. Shallow aquifers suffer mostly from pollutants. The most widespread non-point source pollutant of groundwater in Bulgaria are nitrates

The study refers to the Ogosta River basin in NW Bulgaria. Different kinds of human pressure are presented and assessed. The results show that human pressure on groundwater results mainly in worsened groundwater quality and is closely related to the land use. Locally there are indications of declining groundwater levels, most likely as a result of groundwater abstraction.

Despite of variety of groundwater reservoirs in the study area (porous, fissured and karstic), the groundwater system works as a whole. This inference is made based on hydrodynamic map. This map has been prepared using numerous data on groundwater levels from different reports. It presents an important tool for groundwater management.

Keywords: *groundwater, Bulgaria, Ogosta river, pollution, nitrate*

Introduction

Groundwater in Bulgaria shows warning signs of contamination. The Water Framework Directive (2000/60/EC) and Bulgarian legislation require protection of groundwater from pollution. For effective groundwater management, real and updated information on the groundwater system as well as on human pressures is necessary. Nowadays, quantification of groundwater resources and its vulnerability to pollution are topical questions in Bulgaria. Such work requires much information on the structure and functionality of the groundwater system.

The groundwater resources in the Ogosta river basin are described and human pressure assessed.

Study area

The study area of Ogosta river basin (Fig. 1) is located in the NW Bulgaria with territory about 4200 km^2. The climate in the NW part of Bulgaria is temperate. The annual precipitation sums vary from ~500 mm in the low part of the watershed up to ~1200 mm in the mountain (Koleva and Peneva, 1990). The watershed of Ogosta river covers 3157 km^2, and this of its tributary Skat – 1074 km^2. Ogosta River takes its source in Chiprovska mountain at the altitude of 1660 m a.s.l., and Skat river– at 399 m. Ogosta river outflows to the Danube River at the altitude of about 24 m.

According to territorial subdivision of the country, the Ogosta watershed belongs to Northwest Region including Vidin, Vratsa and Montana Districts. The two last districts belong to the study area. Forests cover 37% and 6% of the watersheds of Ogosta and Skat respectively.

Groundwater resource

Detailed description of groundwater in the Ogosta river basin is given by General Master Plans of water utilization in Bulgaria (2000). Ogosta river basin coincides with Lomski hydrogeological sub-region in the most parts, and its upper section belongs to West-Balkan hydrogeological region. In the study area, groundwater bodies (GWBs) have been identified in porous and karstic media (Table 1). Some of them have been found as being at risk in terms of groundwater quality (National Report, 2007).

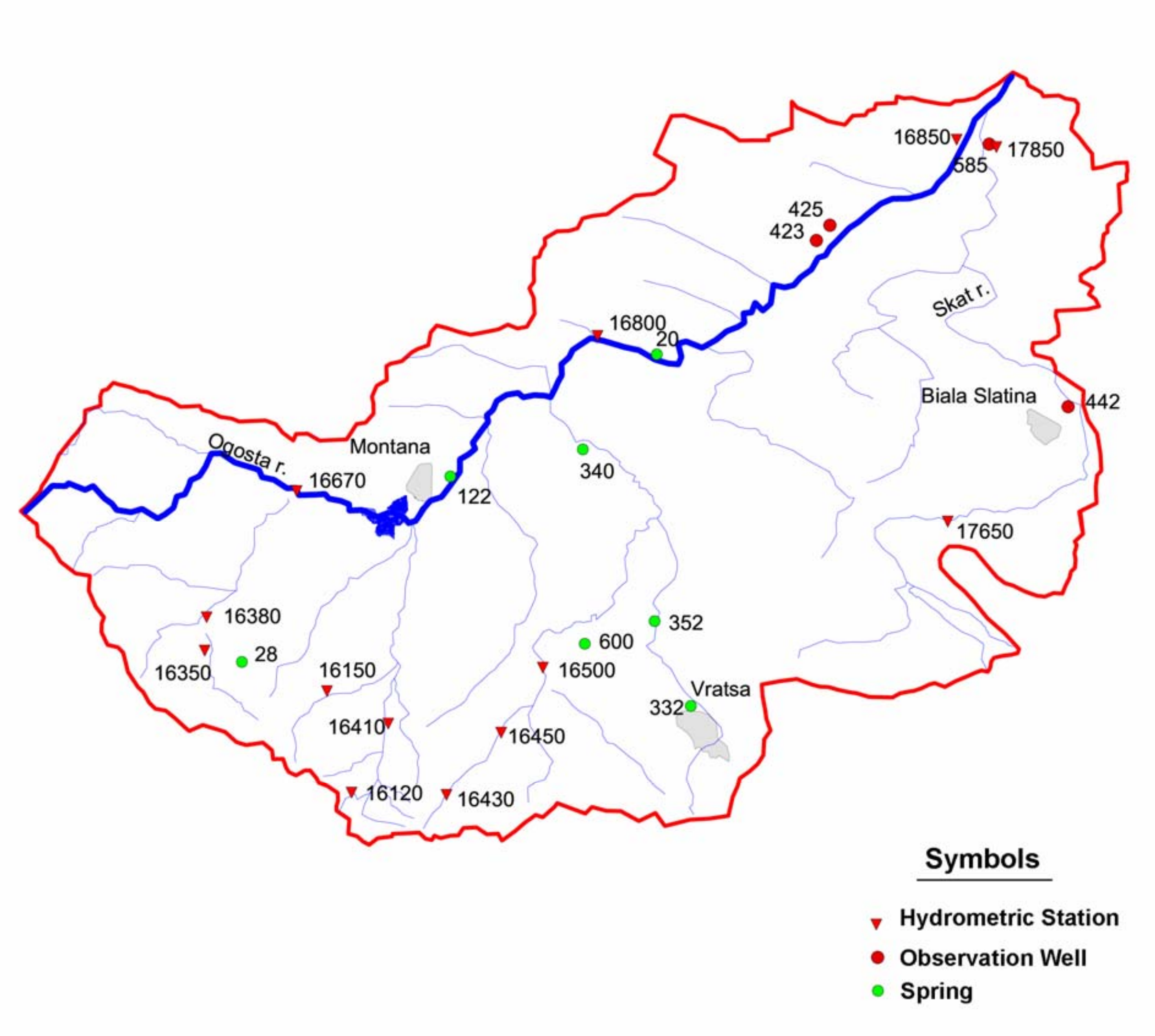

Figure 1. Map of the Ogosta river basin.

Table 1. Groundwater bodies within the Ogosta river basin

Index of GWB	Name of the groundwater body	Area, km^2	Risk assessment
BG1G0000Qal015	Porous groundwater in Quaternary - Ogosta river	250	Risk
BG1G0000Qal016	Porous groundwater in Quaternary - Skat river	110	Risk
BG1G0000Qpl023	Porous groundwater in Quaternary - between the rivers of Lom and Iskar		No risk
BG1G00000Qp027	Porous groundwater in Quaternary - Vratsa proluvial fan	70	Risk
BG1G00000N2034	Porous groundwater in Neogene - Lom-Pleven depression		No risk
BG1G000N1bp036	Karst groundwater - Lom-Pleven depression		No risk
BG1G0000K2s037	Karst groundwater - Fore-Balkan		No risk
BG1G000K1ap043	Karst groundwater - Mramoren massif	71	No risk
BG1G00000TJK044	Karst groundwater - West Balkan		No risk

In the Ogosta watershed porous, karstic and fissured waters are presented. Karstic water is an important source of water in the (rural) mountainous areas in the NW Bulgaria. Porous waters are widespread in the lower part of the region and are rich in groundwater resource (Fig. 2).

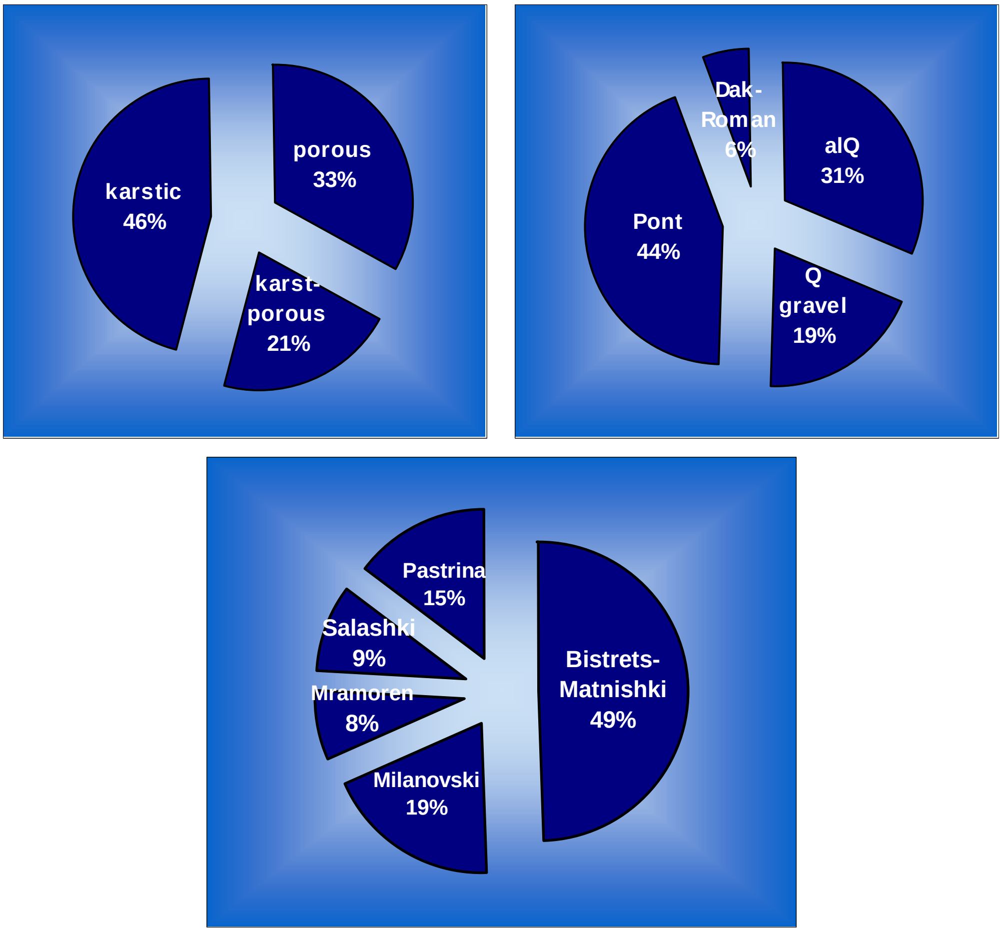

Figure 2. Share of natural groundwater resources in different kinds of reservoirs (a), in porous reservoirs (b), and in karstic reservoirs (c).

Table 2. Groundwater resources in the Ogosta watershed in l/s (General Master Plans, 2000)

Natural resources, l/s	Additional resource from rivers, l/s	Exploitable resource, l/s	Used resource, l/s	Remaining resource, l/s
4380 – 4850	800	2440	1052-1192	1100

Natural resources of groundwater in the Northern Bulgaria had been estimated by V. Spassov (1966) and lately – reassessed and presented in General Master Plans (2000). The total resources in the Ogosta river basin are given in Table 2, and the share of natural groundwater resources in different kinds of reservoirs is presented on Figure 2 based on data from the General Master Plans of water utilization in Bulgaria (2000).

To evaluate the state of the groundwater system, different indicators are used. One of the groundwater sustainability indicators is defined as ratio between two values: “Total groundwater abstraction” and “Groundwater recharge”, expressed in percent. Other presents the ratio between “Total groundwater abstraction” and “Exploitable groundwater resources” (in %). The first indicator gives 24%, and the second – 46%, based on data on groundwater resources for the Ogosta watershed (Table 1). The received values of the indicators show that the use of groundwater in general is sustainable. Yet, this inference refers to mean average values.

Groundwater regime

The groundwater regime in the Ogosta watershed is described based on springs and wells from the National Hydrogeological Network. Time-series of spring discharge and groundwater levels for wells are more than 40 years long. This allows to study long-term variability of the respective time-series, and to quantify the impact of climate variability on the groundwater regime.

An example of seasonal distribution of spring flow (Fig. 3**)** shows maximal discharge values in spring and a well expressed low flow period from July to October. For some years the karst spring discharge decreases considerably as a result of winter and/or summer droughts. Droughts during cold period (mild winters) have strong negative influence on groundwater recharge (Andreeva et al., 2001). The reference period for average monthly data is 1961-1990. A rapid response to the reduction if recharge is observed for the springs from mountainous in the NW Bulgaria.

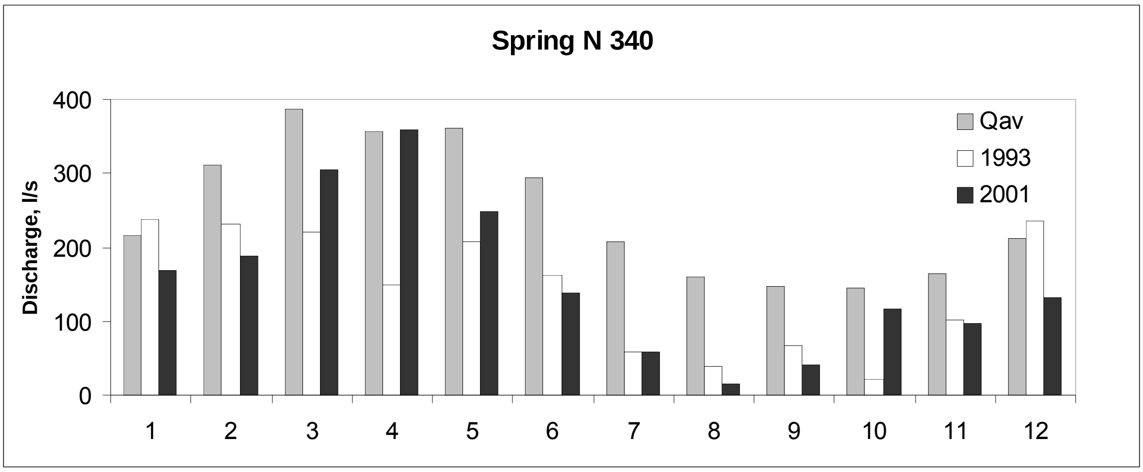

Figure 3. Monthly distribution of discharge for spring N 340 for dry years (1993 and 2001) compared with long-term characteristics.

Droughts influence both over surface water and groundwater. Our previous study (Orehova et al., 2001) showed negative impact of the 1982-1994 drought period in Bulgaria on shallow porous and karstic aquifers. For the observation well N 423, the groundwater levels during this drought period were lower in average with 30 cm compared to the reference period 1961-1990, and for N 442 – lower with 20 cm. Evidently, variations in meteorological conditions have a pronounced effect on the natural recharge. Besides this effect, for some observation wells an evident water level decline after the year 2000 has been registered (Fig. 4 and 5). Most likely, the cause of this substantial drop in groundwater levels is groundwater exploitation in the vicinity.

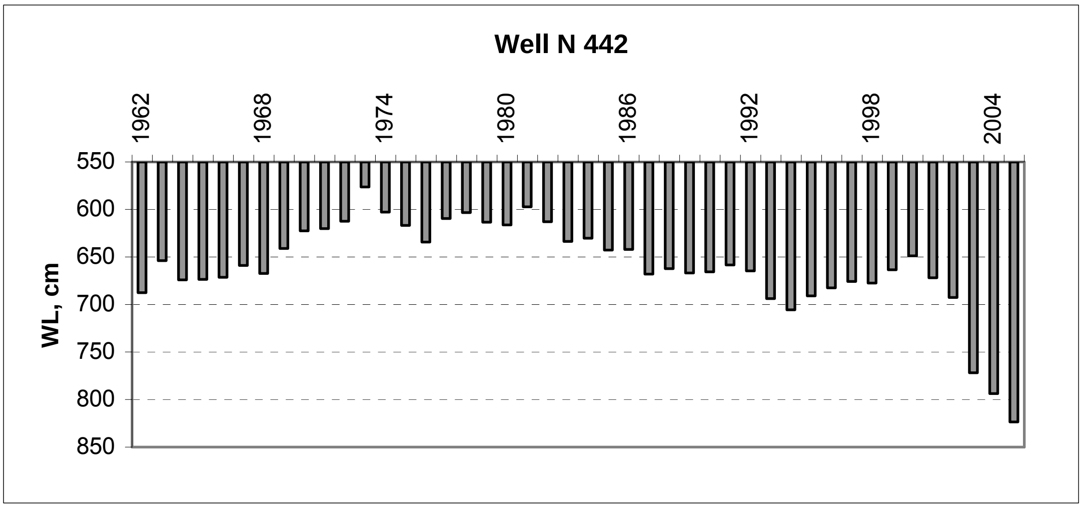

Figure 4. Variation of groundwater levels for well N 442 for the period 1962-2005.

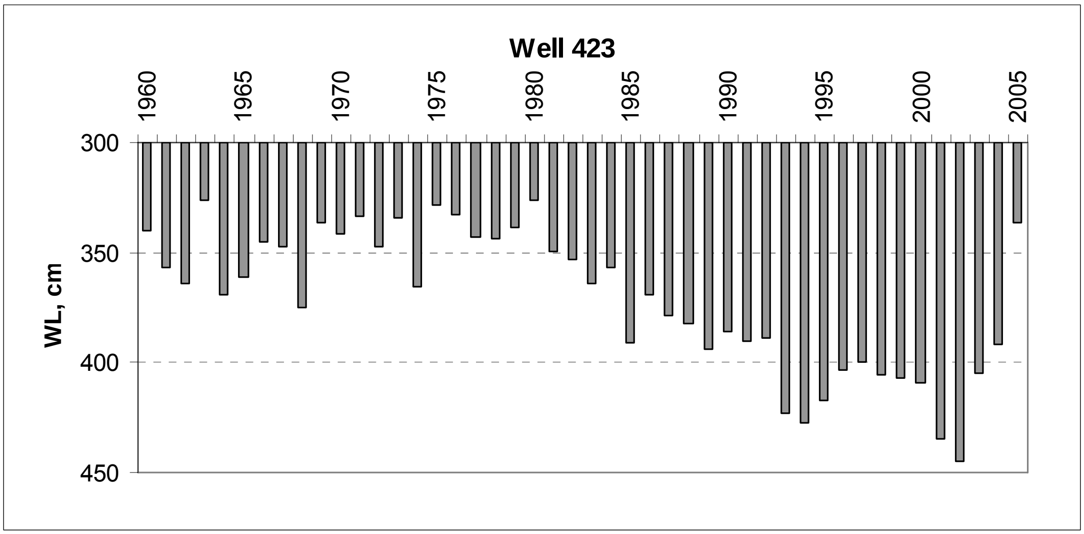

Figure 5. Variation of groundwater levels for well N 423 for the period 1960-2005.

The yearly maximal, average and minimal groundwater level for observational well N 423 (Fig. 6) reflect decreased amplitude of groundwater fluctuation during the 1982-1994 drought period. It implies that substantial reduction of recharge occurred. High values of groundwater level in 2005 are related to intensive rainfall events that have led to inundations in many regions of the country.

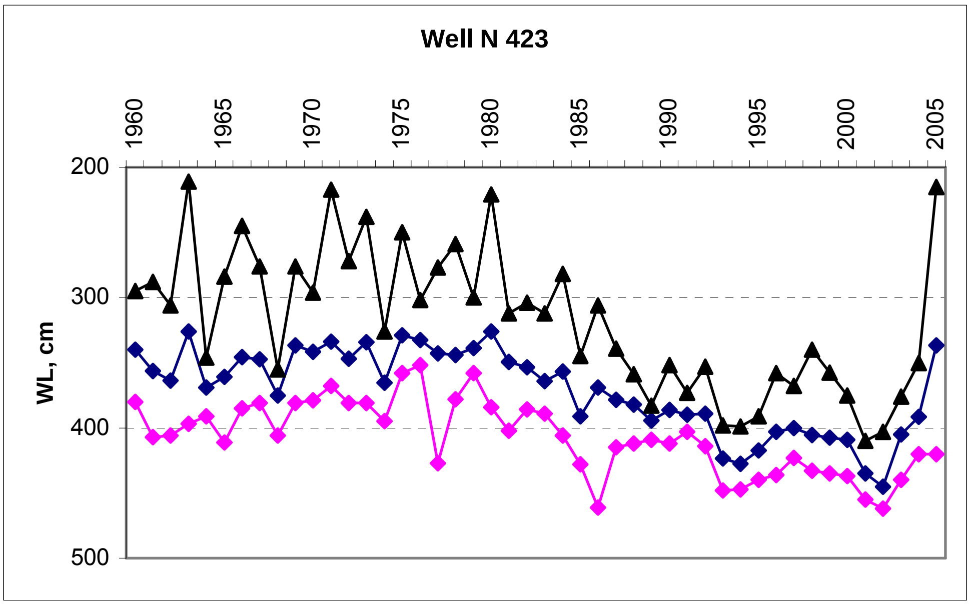

Figure 6. Annually maximal, average and minimal groundwater level for observational well N 423.

Groundwater quality

The groundwater quality is characterized based on General Master Plans of water utilization in Bulgaria (2000) and data from groundwater monitoring network from EEA (Executive Environmental Agency at the Ministry of Environment and Water) for 2000-2005. The network of groundwater quality stations from EEA is rather sparse, and thus unable to reflect all important features and spatial variability in chemical composition of groundwater in details.

The pollution of groundwater is assessed based on values of environmental and pollution thresholds (ET and PT) for the corresponding components included in the Appendix N 3 from the Regulation № 1 for research, utilization and protection of groundwater. The threshold values for the main components - pollutants from agricultural sources are presented in Table 3 according to different regulations. Bulgarian Regulation N 9 for drinking waters is harmonized with the European Drinking Water

Directive (Council Directive 98/83/EC on the quality of water intended for human consumption). Based on results of groundwater analyses, the status of groundwater is determined according to the article 86 from the Regulation № 1. The emphasis is made on groundwater pollution from agricultural activities (phosphate, nitrate, ammonium, nitrite).

Table 3. Threshold values according to different regulations

Parameters	Symbols	Dimension	Regulation № 1		Regulation № 9	Drinking Water Directive
			ET	PT		
Ammonium	NH_4	mg/l	0.12	1.2	0.50	0.50
Nitrite	NO_2	mg/l	0.025	0.125	0.50	0.50
Nitrate	NO_3	mg/l	10	30	50	50
Phosphate	PO_4	mg/l	0.1	1	0.50	0.50
Sulphate	SO_4	mg/l	50	150	250	250

The groundwater quality assessment for the Ogosta river basin is based on 6 stations from national database for the period from February 2000 up to February 2006.

Groundwater chemistry in Quaternary sediments

The chemical composition of groundwater in Quaternary deposits in the catchments of Ogosta and Skat rivers is HCO3-Ca-Mg, HCO3-Mg-Ca-Na, HCO3-Na-Ca-Mg, or HCO3-Na. The enrichment of groundwater by magnesium occurs from loess. The TDS content is usually 0.7-1.4 g/l. The temperature of groundwater is within the range from 13.8°C to 15.0°C. The pH values show weakly alkaline water; in average, pH = 7.66÷7.86 (General Master Plans, 2000).

The values above pollution threshold (PT) were registered for nitrate concentrations for station in towns Hayredin (N 0215) and Mizia (0135), for sodium and chlorides in Mizia, and rare cases of sulphate, nitrite and dissolved matter – for Mizia. Values between ET and PT were registered for phosphate, sulphate, sodium, dissolved matter, ammonium, and for nitrite – on rare occasions. Nitrates, phosphates and ammonium concentrations are analyzed for the stations in relative values (the concentration ratio is defined as concentration of the respective pollutant divided on the value of its PT).

The most important is increase in nitrate concentrations with average values within 38-60 mg/l for almost half of the groundwater samples. Groundwater is in good status for the station near Montana town. Only several samples have shown values above ET (for nitrate, sulphate, phosphate, nitrite and dissolved matter, rarely for ammonium).

Groundwater chemistry in Neogene sediments

The chemical composition of groundwater in Neogene deposits in the catchments of Ogosta and Skat rivers is of HCO3-Mg-Ca or HCO_3-Mg-Ca-Na type**.** The TDS content is in the range 0.3-1.9 g/l. The temperature of groundwater is from 13.7 to 14.6°C. The groundwater is weakly alkaline (in average, pH = 7.5÷8.5).

The groundwater in Neogene deposits in the study region is vulnerable to pollution. Monitoring station of EEA in Byala Slatina (N 0247) shows enhanced values of nitrate concentration – between 1 and 2 times more than the respective pollution threshold. On rare occasions phosphate is problematic as well. The spring at Septemvrijtsi (N 0044) shows enhanced nitrate concentrations above 50 mg/l and increasing trend for the phosphate content.

Pesticides have been registered in groundwater above the pollution threshold value of 0.1 µg/l in a well (Byala Slatina) and in tapped spring (Kriva Bara).

In the upper part of the watersheds of the Ogosta River and neighbor Iskar River, a region of endemic nephropathy is found. Many macro- and micro- components have been defined in groundwater since 1963 (Boyadjiev et al., 1965). Different hypoteses have been propounded. Yet, the etiology of the Balkan Endemic Nephropathy (BEN, dangerous chronic disease) is unknown up to now. There are different hypotheses of risk factors for this disease, such as environmental pollution in endemic settlements, including groundwater pollution.

Hydrodynamic map of shallow groundwater

In order to present groundwater flow in the Ogosta River basin, we have compiled available data on groundwater levels from different reports. These reports had been prepared based on hydrogeological surveys (Mollov, Spassov et al., 1988; 1990). In the mountainous region with lack of boreholes, we have used springs' issues to mark the groundwater levels (Fig. 7). In spite of numerous groundwater bodies and heterogeneity of its hydraulic characteristic, a uniform groundwater flow is observed in the Ogosta River basin.

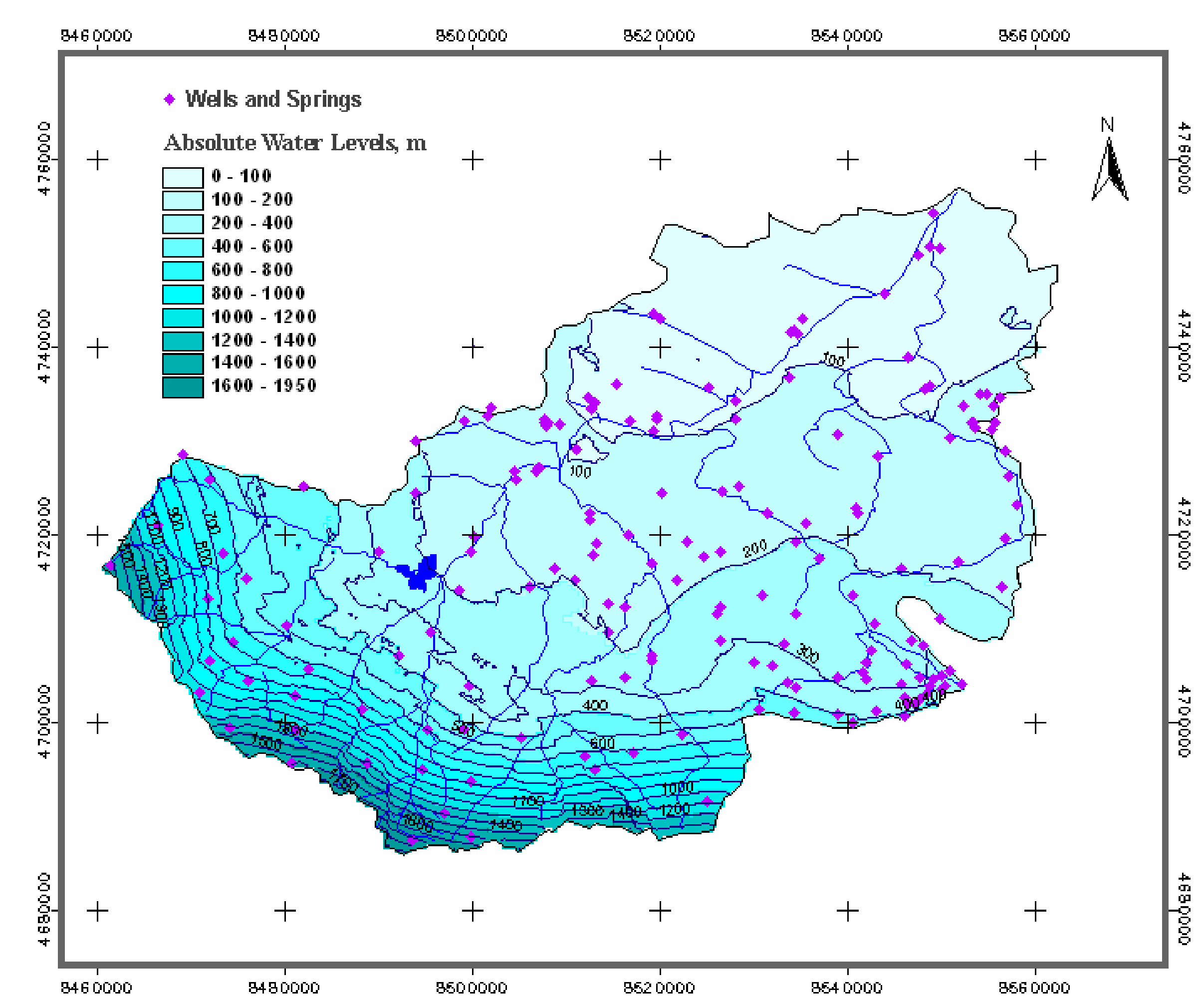

Figure 7. Hydrodynamic map of the shallow groundwater in the Ogosta River basin.

The general features of the groundwater flow are steep slopes in the mountainous part showing low permeability and enhanced recharge values. Considerably lower gradient is observed in the plain that is characterized with high values of transmissivity. The map reflects draining role of the internal rivers, and general direction of the groundwater flow to the Danube River.

The prepared map is a good basis for hydrodynamic analyses including modeling and resource assessment. Close relationships had been found between groundwater resource values and hydraulic gradient, representing the hydraulic properties of water-bearing rocks and determining specific groundwater discharge rates. Meaningful values of correlation coefficients (up to 0.7–0.8) were obtained in 11 out of 15 cases (Zektser and Everett, 2004).

The hydrodynamic map will be used to define depths to the groundwater table and may give important information for vulnerability assessment. It is known that the most vulnerable are aquifers with groundwater levels close to the land surface.

The map is important for groundwater management, as pollution in groundwater is propagated mainly by convective flow.

Human activities

In this study, we emphasize on human activities that affect groundwater quantity and quality in the Ogosta watershed. According to territorial subdivision of the country, the Ogosta watershed belongs to Northwest Region, where underdeveloped rural areas predominate. Agricultural activities in rural regions are the main source of revenue for local people.

This is mainly agricultural region, especially in lower part of the watershed. The main cultivated crops are: wheat and other cereals including grain fodder, sunflower, maize, beetroot and vegetables. Meadow and fruit-tree plantations are usual as well. Large areas present uncultivated and fallow lands. Animal (livestock) breeding is usual: pigs, sheep, goats, cattle, buffalos, and poultry. Small holdings prevail in the region.

Towns Montana and Vratsa are centers of regional importance for the territory of the districts with developed industry and high pressure on the environment. The Botunya River (that is a tributary of Ogosta River) is polluted by wastewater from chemical industry and local purification station in Vratsa town. Wastewater from manufacturing plant for paper and cellulose (Harlets), chemical industrial and metal processing works are sources for anthropogenic substances in groundwater. In the region of Chiptovstsi, previous mine activity has led to pollution of soils with heavy metals.

Impact from human pressure

Groundwater abstraction
Groundwater abstraction is the most evident pressure on aquifers. In the upper part of the watershed, where karstic and fissured waters occur that are discharged by springs, the groundwater is used through tapped springs. In the lower part, where porous groundwater is developed, the withdrawal of water occurs from wells and boreholes. Data on groundwater abstraction are registered based on permits.

During dry season (late summer – early autumn), the discharge of springs decreases considerably. As a consequence, water shortage during low flow period is actual. Seasonal scarcity of the groundwater resources is usual in mountainous areas in NW Bulgaria and especially the region of Vratsa. These regions receive much precipitation, but the low flow periods are strongly expressed due to limited regulative capacity of the aquifer.

In general, the groundwater resources in the Ogosta watershed are underdeveloped. The problem of water scarcity is related to low flow periods and prolonged droughts.

Irrigation and dams
Ogosta dam is the largest hydrotechnical object in the study area. Besides it, there are many small dams - 54 in the watershed of the main river and 41 – in the catchment area of its tributary Skat. The impact of the Ogosta dam on the discharge of the neighbor spring had been studied by Benderev et al. (2000). Increased spring discharge had been registered during filling of the dam, which became considerably higher during the exploitation period (as high as 2 - 2.2 m^3/s).

Nowadays, low percent of really irrigated areas is registered both in the study area and in the country. Due to high prices for water supply, many farmers are compelled to refuse water supply services. In this region, groundwater is not used for the purposes of irrigation.

Agriculture and groundwater pollution
It is known that agricultural land use presents a threat for shallow groundwater. In Bulgaria, pollution of groundwater occurs mainly due to over-fertilizing of crops in past time, animal breeding (lagoons, liquid waste) and lack of WWTP (wastewater treatment plants) in many settlements.

A serious problem with contamination of waters goes from livestock manure, which are usually preserved incorrectly. Besides, they are not used enough. In implementation of the Nitrate Directive (Bulgarian Regulation N 2), the Code for good agricultural practices has been developed with the objective of reducing pollution by nitrates. It describes rules for preservation of livestock manure during 6-8 months before its application as natural fertilize, including (way to estimate) the capacity and construction of storage vessels for manures, and land application of fertilizer.

In rural areas, however, the most widely found nonagricultural source of nitrate is probably on-site sanitation systems. There intensive agriculture and unsewered sanitation generally occur together and both contribute to pollution of groundwater.

To reduce nitrate contamination from agriculture, stock density and application of fertilizers and manure should be controlled. It is necessary to reduce pollution load on shallow groundwater from wastewater.

Conclusion

The study summarizes information about human activities affecting groundwater quantity and quality in the Ogosta river basin from NW Bulgaria. Groundwater abstraction, impact from dams, irrigation, agricultural land use and pollution from settlements without WWTP are the main factors that affect groundwater.

Prepared hydrodynamic map presents close relationships between groundwater resource values and hydraulic gradient, representing the hydraulic properties of water-bearing rocks and determining specific groundwater discharge rates. The map may be used for the purposes of groundwater management.

The results show that the groundwater quality is closely related to the land use. From the quantitative point of view, water stress occurs during low flow periods, as well as throughout drought periods. Declining groundwater levels are observed locally.

Nitrates are the most common contaminant. Pollution sources are multiple. Important task for the region is vulnerability assessment and mapping. To improve groundwater quality, it is important to reduce the pollution load in the watershed.

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