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The Assessment of the Influence of the Hydrogeological Regime of Rivers on the Conditions of the Decentralized Water Supply in Karst Areas

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The Assessment of the Influence of the Hydrogeological Regime of Rivers on the Conditions of the Decentralized Water Supply in Karst Areas

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Abstract. The article shows that the level of river flow has a significant impact on the development of destructive karst-suffusion processes. Karst water exchange systems have a high natural and anthropogenic vulnerability of groundwater resources and low ability to self-purify. The water quality of decentralized water supply sources largely depends on the presence of active karst processes. The studies were conducted in the territory of the village of Chud Navashinsky district of the Nizhny Novgorod region, subject to karst-suffusion processes. The hydrogeological characteristic of the study area is determined; the generalized characteristics of the seasonal fluctuations of the river flow are calculated. The development of karst processes in the study area is assessed. It has been determined that during the year, the period of spring flood on the Oka River has the greatest impact on landfall formation. It has been established that unauthorized dumps of municipal solid waste located in the karst zones of the Chud village affect the chemical composition and increase the total salinity of groundwater used for decentralized water supply. The results can be used to improve the regional model for assessing the resources of vulnerability and protection of groundwater and predicting the activation of destructive karst processes in the karst zone of the Oka River basin, Nizhny Novgorod Region.

1. Introduction

The intensity of manifestation and the activity of karst processes is determined by the territorial features and hydrology of the movement of karst water [1,2]. The most sensitive indicator of karst activity in a controlled area is the behavior of rivers feeding on groundwater in the summer, summer and autumn low water. Therefore, the low-flow discharge of the river is the total discharge of groundwater drained by the river [3]. The most sensitive characteristic of the hydrogeological regime of rivers is the minimum river flow. The river flow is formed due to surface and underground flow. In this case, the surface waters flowing in the depression are absorbed by the ponors and feed the rivers. Karst processes violate the zonal nature of the distribution of underground flow, and lead to the redistribution of underground flow in rivers [4-6]. During the spring flood, the value of underground river feeding decreases due to the hydrostatic pressure of the river wave on the fractured-karst aquifer. During this period, rivers serve as a source of groundwater for floodplains and banks. [7]. Accordingly, the level of river flow has a significant impact on the development of destructive karst-



suffusion processes, both on a local and regional scale. Karst water exchange systems, unlike similar systems in insoluble rocks, have high natural and anthropogenic vulnerability of groundwater resources, extremely low ability to self-purify and disperse pollutants [8]. In this case, control over the water quality of sources of decentralized water supply is an urgent and rather difficult task, especially in the presence of active karst processes and in difficult hydrogeological conditions in the territory of settlements. Taking into account the influence of river flow on the intensity of karst processes in areas with decentralized water supply makes it possible to organize geocological monitoring of water use at local and regional levels [9].

The aim of the work is to assess the influence of the hydrogeological regime of rivers on the conditions of vulnerability and protection of groundwater and to forecast the activation of destructive karst processes in the right-bank Oka karst zone of the Oka River basin, Nizhny Novgorod Region. The Chud village located on the right bank of the Oka River in the northwestern part of the Navashinsky district of the Nizhny Novgorod Region, where decentralized water supply is used, was selected as the territory under study.

2. The study area and the assessment of runoff parameters

The territory of the village of Chud belongs to the Pozdnyakovsky village settlement located in the western part of the Volga Upland and is a hilly-plain relief in the interfluvium of the Oka and Tesha figure 1.

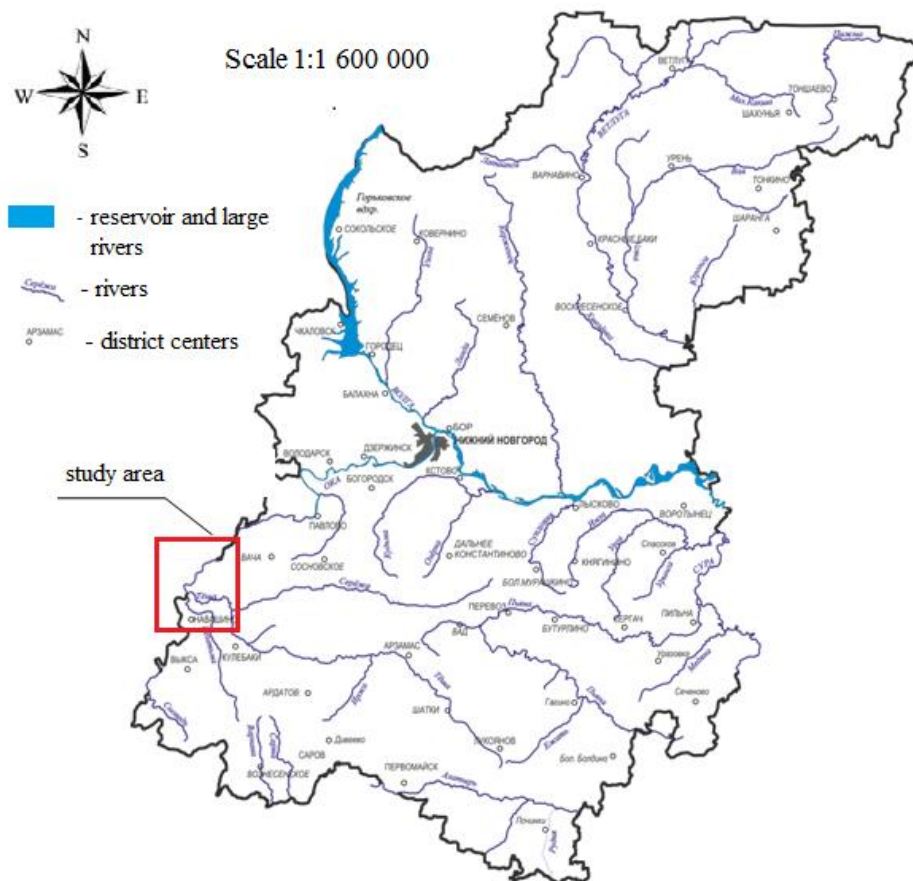


Figure 1. Study area.

Geologically, the settlement territory belongs to the upper part of the Perm system, the lower sub-tier of the Kazan tier. Deposits are represented by dolomites, limestones, marls and clays. In the North-Western part of the settlement in the valley of the Oka river two right-bank terraces are well

expressed. In the southwestern part of the settlement, rivers flow along flat-bottom valleys and have wide floodplains. The relief of the territory as a whole is flat with alternating low-lying plains and hills with fluctuations in absolute elevations of 100-300 m.

A significant part of the settlement is subject to karst formations, which is manifested by the presence of craters, hollows and lakes of karst origin [10-13].

Table 1 presents the average values of precipitation at meteorological stations in Murom, Pavlovo and Vyksa.

Table 1. Average rainfall, mm (1961-2018).

Station	Months												Year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Murom	37	35	27	37	39	70	69	71	63	65	49	46	608
Pavlovo	36	32	27	35	44	64	70	64	55	56	51	47	581
Vyksa	31	29	23	31	42	68	71	66	55	55	46	40	557

The territory is in the zone of sufficient moisture. On average, 550 mm of precipitation falls annually, of which the rainfall of the warm season in the form of rain is 64%, approximately 380 mm. Solid precipitation accounts for 22% of the total, 14% - mixed.

For the study area, generalized characteristics of seasonal variations in river flow were calculated (Table 2). In particular, these include the parameters of the distribution of river flow by months (coefficient of variation C_v and ratio of asymmetry coefficients to coefficient of variation C_s/C_v).

Table 2. Distribution parameters of average monthly river water discharge for the study area.

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
C_v	0,27	0,32	0,35	0,50	0,51	0,23	0,24	0,18	0,21	0,21	0,26	0,28
C_s/C_v	-1,89	-0,98	1,15	2,93	1,84	2,52	3,64	2,33	3,12	0,34	1,58	-0,02

The information base was the data of long-term observations of Roshydromet over river flows at hydrological posts in the vicinity of the village of Chud: the Oka river (Murom, Gorbatov), the Tessa river (Natalino village), Serezha river (Lesunovo village), the Bolshaya Kutra river (Pertovo village). As a result of the initial processing, an array of data was obtained for these hydrological posts containing files with monthly average water discharges and the coordinates of the observation centers.

The analysis of the dynamics of the annual river flow shows that on the rivers of the studied territory the low-water periods in recent decades have become much more [14]. This is due to an increase in temperature in the cold season and, accordingly, more frequent winter thaws, contributing to an increase in winter flow. The same pronounced growth trend is also observed for the time series of the minimum annual average monthly water flow.

3. The influence of river flow on karst processes

As an assessment of the development of karst processes in the study area, the generally accepted methodology for the presence and prediction of surface karst manifestations was used [15,16]. The karstological monitoring data provided by ltd "Stroykarst" for the territory of Dzerzhinsk, Nizhny Novgorod Region, which is an analogue of the study area, is used. Most of the craters, which are not more than 50 years old, are located in the zone of influence of the Oka river on groundwater, as well as on the state of karst rocks and sediments.

In this regard, it can be considered that during the year the greatest impact on the sinkhole has a period of spring floods on the Oka river. In the Western part of the village on the observation wells clearly visible seasonal fluctuations in groundwater levels. The rise of the groundwater level in the spring is due to snowmelt and the influence of the backwater from the flood waters on the river Oka. Between the time series of the annual number of karst sinkholes and the average annual water level in the Oka river (the level in the Oka river above the level of 67.2 m BS) recorded at the post in the city of Murom there is a clear almost one hundred percent negative correlation figure 2.

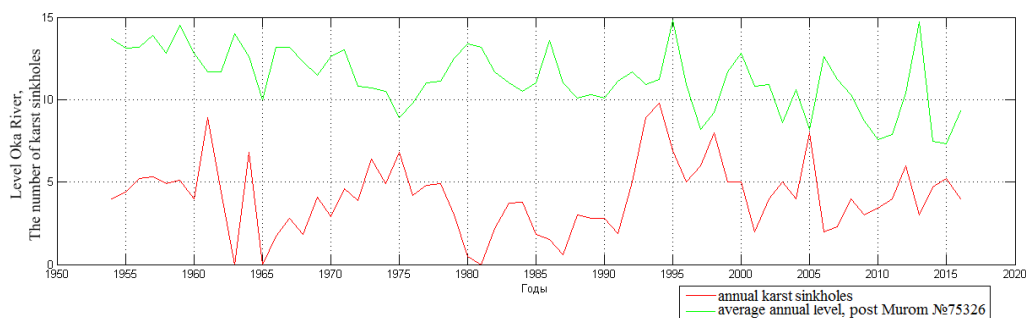


Figure 2. Graphs of changes in water level in the Oka River and the formation of karst sinkholes.

4. The influence of the hydrogeological regime of the Oka river on the conditions of decentralized water supply during the activation of karst processes

At the selected site, preliminary hydrogeological work was carried out to determine the conditions for the movement of karst waters associated with the lithological heterogeneity of the massif. The zones of location of the main sources of decentralized water supply in the village of Chud are determined. The key points of hydrogeological control of the territory, the area of underground flow and the area of discharge of fractured-karst waters in the Oka river are determined. As a result, eight observation wells were also used, which are also used to supply water to users in the village of Chud. At selected wells, seasonal trends in the level of river flow, infiltration of precipitation and surface water, and unloading of groundwater in the karst massif are well manifested [17,18].

Regime observations were carried out from February to September 2018. According to chemical analysis, the waters of the first horizon are sulphate-calcium-sodium. During the spring flood period in the zones of karst formation surface and groundwater accumulate from the flood waters on the Oka river. Pollutants infiltrate with surface water and precipitation and end up in groundwater used for decentralized water supply, changing their chemical composition and increasing overall mineralization and aggressiveness to karst rocks [19,20]. With the development of karst processes in this territory, the use of wells for drinking water supply during the spring and autumn low water periods is unsafe for the population. This period is quite short and is approximately 15-30 days a year. This is confirmed by regime observation data table 3.

Table 3. Experimental data on mineralization.

Months	Mineralization, mg/dm ³ ; observation well numbers							
	1	2	3	4	5	6	7	8
March	189	296	400	297	1203	486	1030	443
April	195	304	559	300	1570	650	1500	590
May	200	317	700	316	1510	781	1662	722
June	177	209	626	266	1375	720	1549	662
July	163	192	570	257	1210	670	1451	620
August	167	280	600	260	1340	688	1480	652
September	184	294	653	285	1310	689	1509	703

5. Conclusion

The minimum river flow is the most sensitive characteristic of the hydrogeological regime of rivers during karst-suffusion processes. Analysis of the dynamics of the annual flow of the Oka, Tesha, Bolshaya Kutra, Serezha rivers shows that on the rivers of the territory under study the low-water periods in recent decades have become much more watery. This is due to an increase in temperature in the winter months of the year and frequent thaws that contribute to an increase in winter flow. The greatest influence on the sinkhole has a period of spring flood on the Oka river. In the western part of the village, seasonal fluctuations in the groundwater level are clearly visible through observation

wells. The rise in groundwater level in spring is due to snowmelt and the influence of backwater from flood waters on the Oka river.

The feedback of the annual number of dips with the maximum water level in the flood on the Oka river is visible. High water years are characterized by the absence or small number of karst sinkholes. In dry years, as a rule, more active dip formation is observed, which is confirmed by a clear negative correlation with $K = 0.875$. During the spring flood period in the karst zones of the village of Chud, there is an increase in the mineralization of sources of decentralized water supply complicated by unauthorized dumps of municipal solid waste in karst sinkholes. At the same time, pollutants infiltrate with surface water and precipitation and fall into groundwater used for decentralized water supply, changing their chemical composition and changing the overall mineralization.

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