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Geological and geomorphological conditions of Archar-Orsoya lowland as a factor for the formation of groundwater chemical composition and in risk of its contamination

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Геоложки и геоморфоложки условия в Арчар-Орсойската низина като фактор при формирането на химичния състав на подземните води и при риска от замърсяването им

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Abstract. The Archar-Orsoya lowland is situated in the Danube floodplain west of the town of Lom, NW Bulgaria. It is aligned in a west-east direction along the Danube River and to the south it is bounded by a high landslide slope, built of Pliocene clays and sands. Parallel to the shore, sand dunes are formed with lowered sections between them, in which there are conditions for swamping. The lowland is made up of the alluvial sediments of the Danube, represented by a lower gravelly-sandy layer and an upper sandy-clayey layer. In the gravelly-sandy layer unconfined groundwater is accumulated, with shallow water table – from 0.5 to 7 m beneath the surface. Groundwater is recharged by infiltration of precipitation, surface water and groundwater, which laterally flows into the alluvium from adjacent aquifers. At high waters, the Danube River suppresses the formed groundwater flow and temporarily feeds it. Due to the described formation conditions in the lowland, the chemical composition of groundwater is formed under the influence of intense dynamics and has a low TDS (total dissolved solids). The shallow groundwater table and the corresponding thin unsaturated zone are a prerequisite for easy groundwater contamination with components entering from the surface. Therefore, a map of depth to groundwater table is drawn to identify the most vulnerable areas.

Keywords: groundwater, chemical composition, contamination, geomorphology, Archar-Orsoya lowland.

Резюме. Арчар-Орсойската низина е разположена в заливната тераса на река Дунав, западно от град Лом, Северозападна България. Тя е изтеглена в запад-източна посока покрай Дунав, като на юг е ограничена от висок свлачищен склон, изграден от плиоценски глини и пясъци.

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Успоредно на брега са се образували пясъчни гредове с понижени участъци между тях, в които има условия за заблатяване. Низината е изградена от алувиалните отложения на река Дунав, представени от долен чакълесто-песъчлив и горен песъчливо-глинест пласт. В чакълесто-песъчливия пласт са акумулирани подземни води с ненапорен характер и плиткозалягащо водно ниво – от 0,5 до 7 m под земната повърхност. Подземните води се подхранват чрез инфилтрация на валежи, повърхностни води и подземни води, които странично се вливат в алувиалните отложения от съседни водоносни хоризонти. При високи води р. Дунав „подпира“ формиралия се подземен поток и временно го подхранва. Поради описаните условия химичният състав на подземните води в низината се формира под въздействието на интензивна динамика и те имат ниска минерализация. Малката дълбочина на залягане на нивото на подземните води и съответната малка дебелина на зоната на аерация са предпоставка за лесно замърсяване на подземните води с навлизащи от повърхността компоненти. Поради това е изготвена карта на дълбочината на залягане на подземните води, за да се идентифицират най-уязвимите зони.

Ключови думи: подземни води, химичен състав, замърсяване, геоморфология, Арчар-Орсойска низина.

Introduction

The Danube lowlands are essential for the sustainable development of Northern Bulgaria. The physico-geographical, geological and hydrogeological conditions in these lowlands contribute to the presence of significant groundwater resources that guarantee both normal living conditions of the population and economic development of the region as a prerequisite for the development of agriculture and industry (Benderev et al., 2014). Therefore guaranteeing the quantity and quality of groundwater is extremely important and in recent years a number of studies have been conducted aimed at clarifying the conditions and processes influencing the formation, regime and vulnerability of groundwater (Benderev et al., 2013; Krastanov, Benderev, 2013; Gerginov, 2015, 2017).

The object of the present study is the Archar-Orsoya lowland, which is situated in the Danube floodplain, west of town of Lom (Northwestern Bulgaria). It is aligned in a west-east direction along the Danube River and morphologically is divided into two parts – Archar lowland and Orsoya lowland, between which a higher part of the coast protrudes between the villages of Dobri Dol and Archar (Fig. 1). Its greatest width is between the village of Dobri Dol and the village of Slivata (between 2.5 and 3.0 km). To the south the lowland is bounded by a high landslide slope, built of Pliocene clays and sands. Parallel to the shore, sand dunes are formed with lowered sections between them, in which there are conditions for swamping, mostly in the spring – associated with the high level of the Danube at that time.

From a geological point of view the lowland represents an imposed form on an old erosion depression (Antonov, Danchev, 1980) and is made up of the alluvial sediments of the Danube, which are underlain by the Pliocene sands and clays. The alluvial sediments are represented by a lower gravelly-sandy layer and an upper sandy-clayey layer. The upper layer is composed of fine-grained sands, sandy loams and clays and

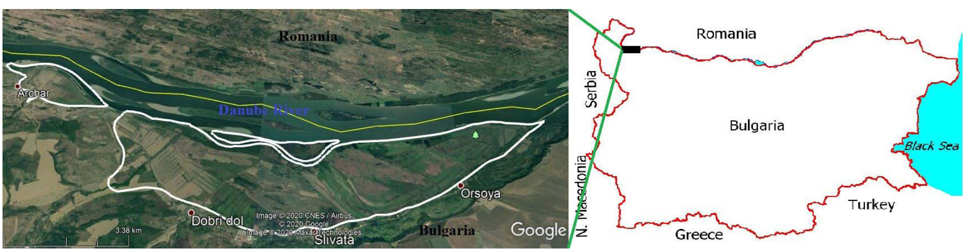

Fig. 1. Location and borders of studied area – The Archar-Orsoya lowland (data source: Google Earth).
Фиг. 1. Местоположение и граници на изследваната територия – Арчар-Орсойската низина (по Google Earth).

its thickness is between 1 and 12 m. The thickness of the lower gravelly-sandy layer varies in the range from 4 to 25 m, and there unconfined groundwater is accumulated with shallow water table – from 0.5 to 7 m beneath the surface. For the gravels a hydraulic conductivity of up to 100–150 m/d was established and for the cover – 0.4 m/d (Antonov et al., 1962). Groundwater is recharged by infiltration of precipitation, surface water (mostly Skomlya River) and groundwater, which laterally flows into the alluvium from the adjacent Upper-Pontian aquifer (Benderev et al., 2010; Túri et al., 2019). At high waters, the Danube River suppresses the formed groundwater flow and temporarily feeds it. Groundwater discharge is provided exclusively by the Danube River and drainage channels.

The present study considers the described geological and geomorphological conditions of the lowland as a factor for the formation of the groundwater chemical composition and in risk of its contamination as the shallow groundwater table and the corresponding thin unsaturated zone are a prerequisite for easy groundwater contamination with components entering from the surface.

Methods and materials

Assessment of conditions and factors for the formation of chemical composition of groundwater in the Archar-Orsoya lowland is carried out on the basis of collection of published and archival materials and their processing through GIS. The result is compilation of various maps (groundwater flow map and a map of depth of groundwater table) and graphs which can serve as a basis to clarify the processes of recharge, flow, level regime and discharge of groundwater and to identify the areas where groundwater is most vulnerable.

Results and discussion

The drawn hydraulic head map (Fig. 2) shows the general direction of groundwater flow – from south to north, respectively from the zone of most significant recharge

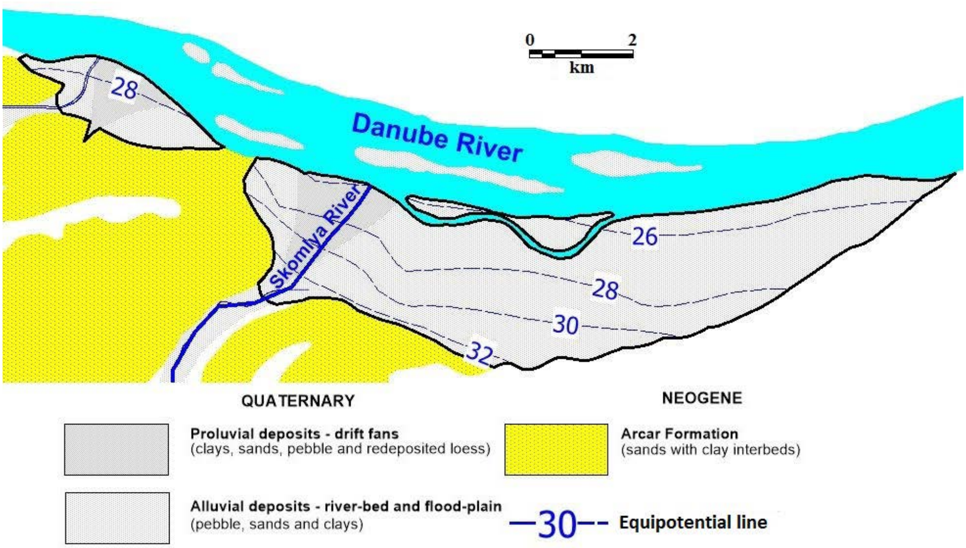

Fig. 2. Hydraulic head map (groundwater table elevation, m ASL) and contact of the alluvial deposits with the Upper-Pontian aquifer (Archar Formation).

Фиг. 2. Хидродинамична карта на подземните води (кота на подземните води, m) и контакт на алувиалните отложения с Горнопонтийския водоносен хоризонт (Арчарска свита).

(from the adjacent Upper-Pontian aquifer – Archar Formation) to the zone of drainage in the Danube River. In the western part of the Orsoya lowland there is a deformation in the groundwater flow lines, which is probably due to additional recharge coming from the surface waters of Skomlya River.

A map of the depth of groundwater table has been also prepared (Fig. 3), thanks to which two zones with a smaller thickness of the unsaturated zone (< 3 m) have been separated, which are also the most vulnerable to contamination from surface (Fig. 4). The eastern shallow groundwater zone is attached to an area where swamps are still observed nowadays and the western one is connected with the zone of additional recharge from the Skomlya River. Although between these two zones there were extensive swamps in the past (Fig. 4b), at present they are drained by channels. Therefore the conditions for groundwater recharge had significantly changed and in this area significantly deeper groundwater table is observed. The zone with the most significant thickness of the unsaturated zone (> 6 m), respectively the most protected groundwater, is beneath the dunes near the Danube River, which have a higher altitude and stand out above the surrounding area.

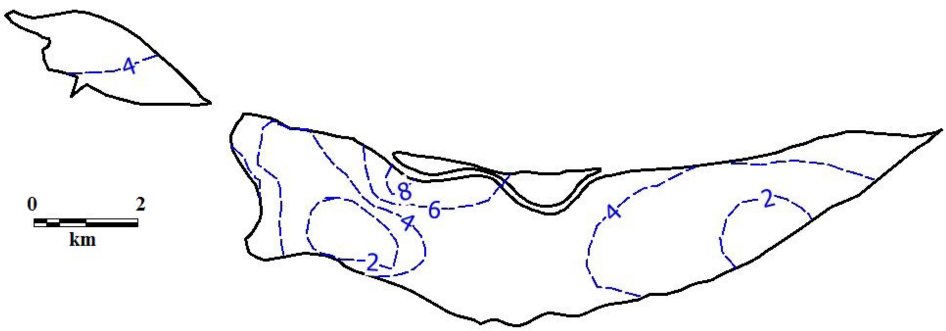

Figure 3. Map of the depth of groundwater table from the surface, m.
Фигура 3. Карта на дълбочината на подземните води от повърхността, m.

The comparison of the available monitoring data for the groundwater levels in observation boreholes (Fig. 5) shows that in most of it the changes in groundwater level are strongly dependent on the levels of the Danube River, with which they are hydraulically connected. Table 1 shows that the only borehole in which no correlation is observed (Dobri Dol 2) has a groundwater level that is located higher above the Danube River. The significant fluctuations in groundwater levels (reaching 4 m at borehole Archar 4) due to the relevant fluctuations of the Danube River lead to a significant change in the thickness of the unsaturated zone, respectively the vulnerability of groundwater.

Due to the described formation conditions in the lowland, the chemical composition of groundwater is formed under the influence of intense dynamics. It is hydrocarbonate-calcium-magnesium type (Fig. 6) and has a low TDS (total dissolved solids) (< 1000 mg/L). Although it can be said that the data on the chemical composition of the groundwater in the Archar-Orsoya lowland is insufficient, in the available monitoring observations considerable exceedances of the regulatory limits were detected sporadically only in the contents of nitrates and manganese (Table 2). These incidental contaminatons are local (registered only in 2, respectively 4 out of 30 monitoring points) and temporary and probably are due to some agricultural activities and stagnant waters of the drainage channels.

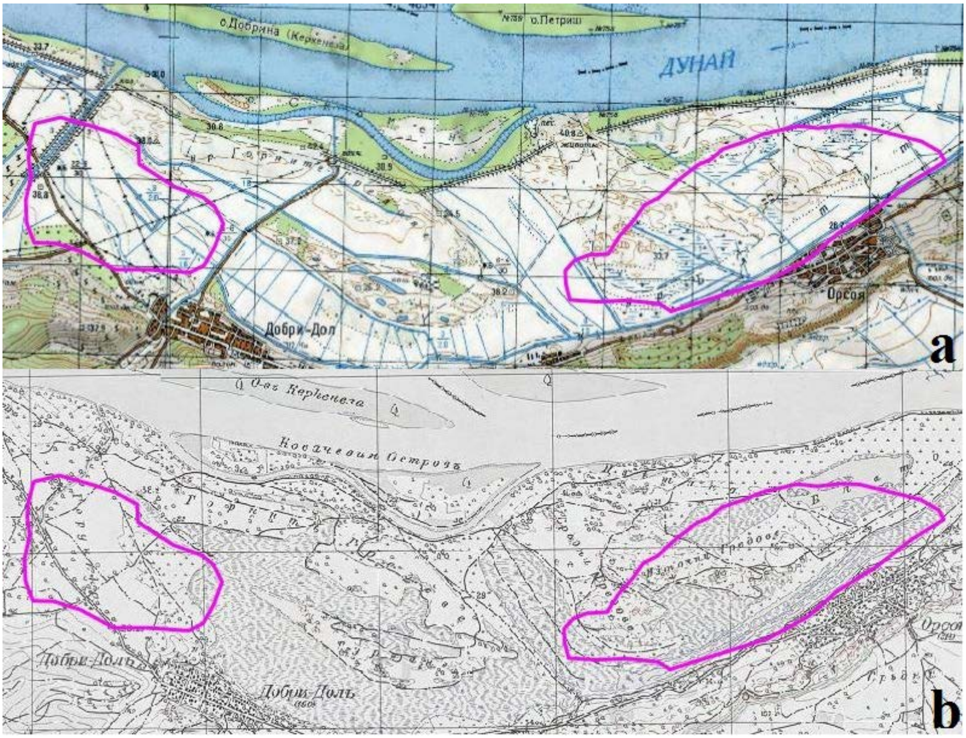

Fig. 4. The two identified zones with a smaller thickness of the unsaturated zone (< 3 m): a) over modern topographic map; b) over topographic map from 1930s.
Фиг. 4. Двете идентифицирани зони с по-малка дебелина на зоната на аерация (< 3 m): а) върху съвременна топографска карта; б) върху топографска карта от 1930-те г.

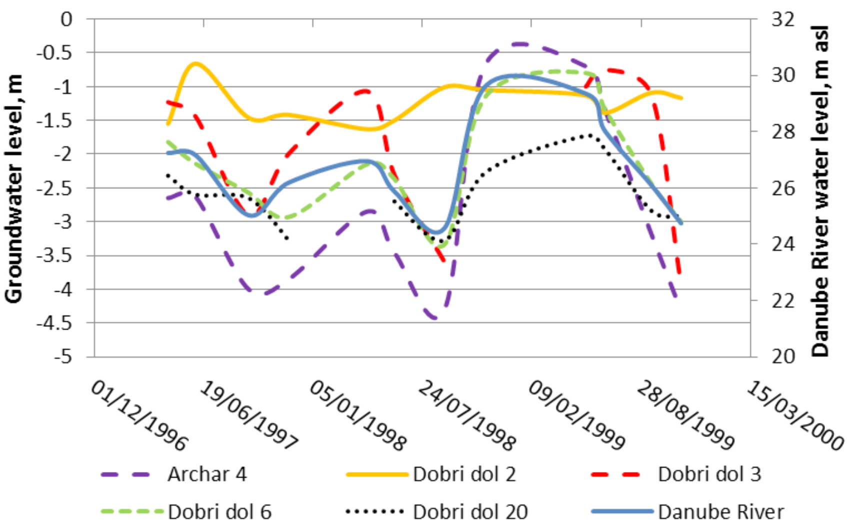

Fig. 5. Groundwater level fluctuations observed in boreholes depending on Danube River water levels.
Фиг. 5. Колебания в нивото на подземните води, наблюдавани в сондажи и зависимост от водните нива на река Дунав.

Table 1. Correlation between groundwater and Danube water level changes.
Таблица 1. Връзка между промените в подземните води и нивата на река Дунав.

Borehole	Correlation	Average groundwater level, m ASL	Danube level, m ASL
Archar – 4	0.96	26.97	28.2
Dobri Dol – 6	0.89	27.44	27.5
Dobri Dol – 3	0.73	25.86	27.3
Dobri Dol – 20	0.66	28.46	27.5
Dobri Dol – 2	0.01	30.08	27.3

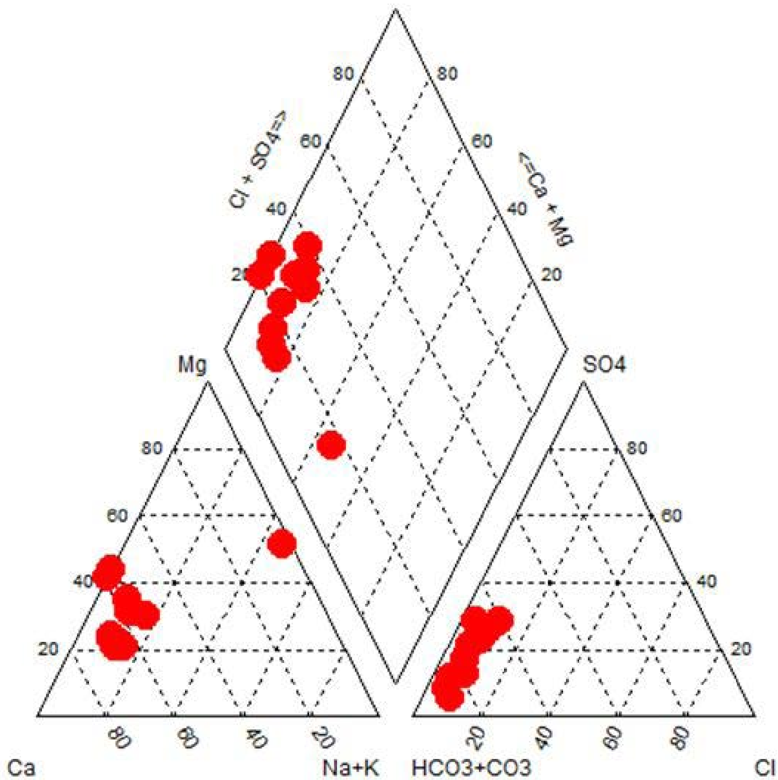

Fig. 6. Piper diagram of groundwater in Archar-Orsoya lowland.
Фиг. 6. Диаграма на Пайпър на подземните води в Арчар-Орсойската низина.

Table 2. Exceedences of the regulatory limits, according to Regulation №1 (30.10.2007) for exploration, use and conservation of groundwater
Таблица 2. Превишения на регулаторните граници, съгласно Наредба №1 (30.10.2007 г.) за проучване, използване и опазване на подземните води

	pH	TDS, mg/L	Ca, mg/L	Mg, mg/L	Na, mg/L	Fe, mg/L	Mn, mg/L	HCO_3, mg/L	Cl, mg/L	NO_3, mg/L
Min	7.0	327	6	10	12	0.09	0.02	200	7	2
Max	8.3	942	152	83	140	0.23	0.94	540	191	75
Limit	6.5-9.5		150	80	200	0.2	0.05		250	50

The map of TDS (total dissolved solids) concentrations in groundwater (Fig. 7) shows that in the Orsoya lowland there are zones with higher values (> 500 mg/L), spread in the direction of recharge – two of them seems to be connected with the proluvial fans, respectively with the additional recharge coming from the surface waters of Archar and Skomlya Rivers, and the other one probably is associated with the recharge from the adjacent Upper-Pontian aquifer, which is not outcropped on the surface in that zone (Fig. 2) and its groundwater has more stagnant regime, respectively higher TDS content.

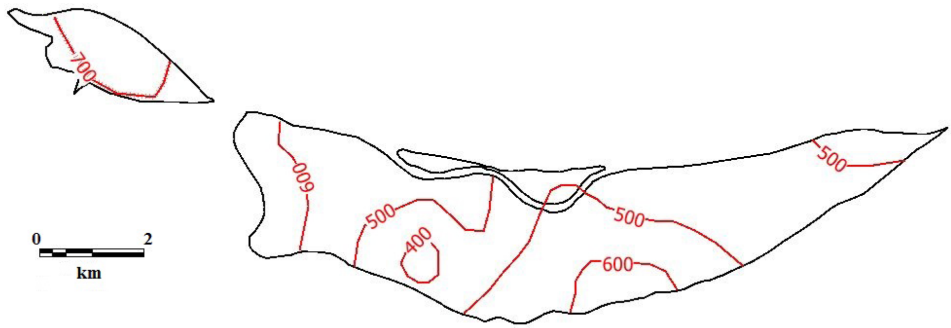

Fig. 7. TDS (total dissolved solids) concentration in groundwater, mg/L
Фиг. 7. Минерализация на подземните води, mg/L

Conclusion

The general direction of groundwater flow in the Archar-Orsoya lowland is from south to north, respectively from the zone of most significant recharge (from the adjacent Upper-Pontian aquifer – Archar Formation) to the zone of drainage in the Danube River. Two zones with a smaller thickness of the unsaturated zone (<3 m) have been separated, which are also the most vulnerable to contamination from surface. The zone with the most significant thickness of the unsaturated zone (> 6 m), respectively the most protected groundwater, is beneath the dunes near the Danube River, which have a higher altitude and stand out above the surrounding area. The changes in groundwater level are strongly dependent on the levels of the Danube River, with which they are hydraulically connected. Due to the described formation conditions in the lowland, the chemical composition of groundwater is formed under the influence of intense dynamics and has a low TDS. Still, in order to better understand the processes of groundwater recharge, further study is necessary on the interaction of surface and groundwater, with longer-term observations, including a wider range of observed components.

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