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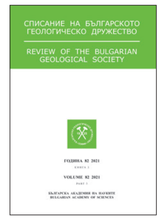

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Analysis of the hydrogeological conditions in Bulgaria in connection with the radon potential

Анализ на хидрогеложките условия в България във връзка с изследване на радоновия потенциал

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Abstract. Natural radon (^{222}Rn) is a radioactive noble gas that occurs in every rock or soil due to the content of radium (^{226}Ra), part of the ^{238}U family, in the lithosphere. Different types of rocks and soils possess different ^{226}Ra content and different permeability. Radon has high mobility and is driven by diffusion and convection with the soil gas throughout connected and water-unsaturated pores and/or cracks in permeable rocks and soils. Therefore, the radon potential of the area could depend on hydrogeology and its particular settings. The study deals with the general characteristics of the groundwater depths in Bulgaria based on the published since 1960’s sources. After analysis of the collected data several distinct regions have been elaborated based on different depth of the groundwater table regarding lithological, tectonic and geomorphological conditions. In addition, zones for screening assessment of groundwater table influence of radon potential have been precised.

Keywords: radon, groundwater, water table, regional hydrogeology.

Introduction

Natural radon (^{222}Rn) is a radioactive noble gas that occurs in every rock or soil due to the content of radium (^{226}Ra), part of the ^{238}U family, in the geological environment (lithosphere). The gas is a product of the decay of natural uranium, found to varying degrees in a wide range of rocks and soils and in building materials. Different types of rocks and soils possess different ^{226}Ra content and different permeability. Radon has high mobility and is driven by diffusion and convection with the soil gas throughout connected and water-unsaturated pores and/or cracks in permeable rocks and soils. Therefore, the radon potential of the area could depend on not only geology but and from hydrogeology and other factors.

In respect of the radon potential and moisture content of the medium, there are established relationships (e.g. Pinault, Baubron, 1996; Hassan et al., 2011, etc.). In accordance with the large area relationships two tendencies have been reported (Sakoda et al., 2011). The first one represented results, which concern the increase of radon potential with increasing of the moisture content of the media (Arvela et al., 2016; Hellmuth et al., 2017). In this case, the geological medium is represented by granites and similar magmatic rocks. The second tendency is an opposite one – the increase of the water content leads to decrease of the radon potential or so-called “screening effect” (Jönsson, 2001; Sakoda et al., 2011). The latter case concerns sediment type of rocks and soils. In Bulgaria, there is national survey study representing the general regional geology settings and the radon potential (Ivanova et al., 2019) but there is absence of detailed investigation of the hydrogeology and the radon potential tendencies. This study is the first attempt to represent a

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methodology and to assess the regional hydrogeological conditions with an emphasis on the shallow groundwater in connection with radon potential fate and evaluation.

Methodology of research

Although the area of Bulgaria is small, the assessment of the regional hydrogeological conditions in connection with an estimation of the radon potential is a sophisticated task as the geological settings are complex. Rocks of various ages, origin, mineral, and chemical composition are present. Their special distribution and position are complicated as a result of the complex tectonic structure of the Balkan Peninsula (Dabovski et al., 2002). Therefore the main issue is to distinguish zones which differ one another in respect to the radon potential increase or decrease due to the saturation level of the host rocks and soils. For that reason, a complex investigation was performed based on the published monographs and hydrogeological reports with subject hydrogeological conditions connected with particular geological and geomorphological settings of the Bulgarian territory. As the emphasis of the study is shallow groundwater aquifers for the first step of the methodology an appropriate geomorphological zonation has to be chosen. It should be based "on territorial combination of forms of the Earth's surface with similar morphogenetic and morphographic features, and supplies a synthetic idea about the morphological evolution of the modern relief and the regularities in its territorial differentiation." (Yordanova, Donchev, 1997). Then, as a second step, the data from the published monographs and hydrogeological reports were related to the geomorphological zones and finally a potential regions or localities with shallow groundwater aquifers were outlined.

Regional geological and geomorphological settings

In order to evaluate the possibilities of water type appearance with the particular rock types on the whole territory of Bulgaria, a condense but overall analysis of the geomorphology, geological settings and tectonic structures is performed. As a base, the comprehensive review made by Zagorchev (2009) was used. As a first geomorphological zonation, which is also one of the most popular, was considered that one proposed by J. Galabov being published with some evolved amendments in Kopralev (2002). In it, four morphological regions are distinguished: I, Danubian hilly plain; II, Stara Planina zone with IIa, foothills of Stara Planina (Forebalkan, Prebalkan), and IIb, main Stara Planina chain; III, transitional strip (zone) with IIIa, Sredna Gora with the Cis-Balkan basins, IIIb, the Kraishte (IIIc) and the Thracian plain (IIId); IV, Rila-Rhodope massif with the Rhodopes (IVa), Rila (IVb), Pirin (IVc), Osogovo-Maleshevo Mountains (IVe) and the Sakar-Strandzha Mountains (IVf) (Kopralev, 2002).

Another suitable geomorphological zonation is the one based on fluvial and fluviolacustrine systems that drained the Balkan area and produced at different stages planation surfaces, river terraces, gorges and other land forms (Zagorchev, 2009). In it, four groups of fluvial systems are distinguished: Northern Aegean (peri-Aegean) drainage basin: rivers systems Aliakmonas (in Greece), Vardar/Axios (in Macedonia and Greece), Struma/Strymon (in Bulgaria and Greece), Mesta/Nestos (in Bulgaria and Greece), Maritsa/Evros/Merich (in Bulgaria, Greece and Turkey); Marmara Sea drainage basin; Danube-Euxinian drainage basin that consists of Morava river system (in Serbia and Bulgaria), western Southdanubian river systems (between the Morava and Iskar river system), Iskar river system, eastern Southdanubian river systems; Euxinian (Black Sea) drainage basin (Zagorchev, 2009).

Hydrogeological localities

Based on both the geomorphological zonation and archive book and monograph sources of hydrogeological characteristics of the shallow ground soils and rocks in the territory of Bulgaria (Kamenov et al., 1963), the following hydrogeological localities were distinguished.

Western Thracian lowlands. The most extensive region in our country with shallow ground waters (0–4 m) is located in the South Central Bulgaria. There, these waters occupy an area of about 1700 km^2 from the vast terrace of the Maritsa River and its tributaries, and in many places (Plovdiv, Pazardzhik and elsewhere) cause swamping of large areas. They create serious difficulties for the construction of deep construction foundations, as well as the sewerage network. Significant areas with shallow water are also in the Sofia field (about 400 km^2 – mainly in the terraces of the rivers Iskar and Lesnovska), in the Stara Zagora field (about 420 km^2 – between the rivers Sazliyka and Blatnitsa), and also in the Radomir region, Kyustendil, Ihtiman and some other fields in Southwestern Bulgaria. In Northern Bulgaria, the largest areas with shallow groundwater are those in the Danube lowlands between Vidin and Silistra, which cover a total of about 700 km^2. The water level in them, especially near the river, shows significant fluctuations – up to 3–4 meters and more.

Depth of groundwater observed by the irrigation of construction excavations and foundations. The issue of flooding of excavations and foundations is especially relevant in the range of river valleys, where the widespread spatial distribution of shallow ground water exists. In the rock complexes of the pre-Quaternary formations, which are rich in fissure and karst waters, the water level is at a considerable depth. Almost everywhere they lie more than 10 m below the surface and therefore the danger of hydration of the excavations is practically non-existent. In the Pliocene basins, the groundwater level is at different depths and is related to both the relief and the position of the sand lenses in the general complex. For example, in the East Thracian Pliocene basin in some places the water level is less than 2–3 m from the surface, and elsewhere it exceeds 15–20 m depth level of deep pressure horizons. In proluvial torrential cones, the groundwater level is most often 4 to 10 m below the surface, but somewhere it is deeper (15–20 m). As a rule, to the periphery of the cones, the waters become entangled and swamps often occur, especially when the contoured alluvial deposits have lower filtration properties.

Swamps. In Bulgaria they are observed mainly in the lowlands and valleys. There are larger swampy areas in the Danube lowlands, Thracian plain, Sofia, Burgas and part of the Trans-Balkan valleys and in the terraces of some rivers, such as Rositsa and Yantra, Kamchia, Struma. The reasons for the swamps are most often the shallow groundwater level and the support of the rivers or the scattered groundwater outlet of the surface between the flooded and non-flooded terrace. In the Burgas region and in the valley of the Kamchia River the swamps are due to surface waters.

Loess and loess-like sediments. They are usually attached to the lowest horizons and does not pose a risk of flooding construction excavations. The depth of their level from the surface is most often from 10 to 30 m. Only in the southernmost parts of the loess formation, in the range of loess and loess-like clays, groundwater is sometimes attached to higher stratigraphic horizons and can meet at a depth of up to 4–5 m from the surface.

Conclusion

Perspective regional and local hydrogeological studies have been started to characterize groundwater and its shallowness as a factor for the level of radon potential, including further elaboration of a map of the shallow ground water localities (0 to 3 m). These studies will serve to establish a connection between the radon potential and the geogenic features on the territory of Bulgaria.

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