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REGIONAL ANALYSIS OF THE OCCURRENCE AND SPREAD OF ENGINEERING-GEOLOGICAL PROCESSES IN THE REPUBLIC OF BELARUS

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The relevance. *The issues of studying the scale of distribution and causes of engineering-geological processes in the Republic of Belarus are positioned as one of the priority issues among the wide range of geoecological problems. Obtaining such information allows identifying and analyzing the factors of human economic activity that impact the geological environmental state, identifying the emergence and presence of threats in urbanized territories, leading to decrease in the safety and living conditions of humans.*
The aim *of the research is to analyze the causes and degrees of manifestation of the most noticeable in the regional plan engineering-geological processes occurring in Belarus.*
Objects: *urbanized territories, mineral extraction and processing facilities, reclaimed land, phenomena and processes resulting from engineering and geological human activity.*
Methods: *research and classification engineering-geological processes developing on the territory of Belarus; expert and comparative methods were used to systematize and analyze the main factors of their occurrence and development on the territory of the country, based on the results of earlier published works and present time field investigations carried out by the authors.*
Results. *The author's expert evaluation and field methods of research have established that the most common factors of occurrence and activation of engineering-geological processes in the Republic of Belarus include: land reclamation, open-pit mining and subsurface mining, groundwater overexploitation, static and dynamic loads from structures and transport, engineering and human economic activities in urbanized areas, natural climatic conditions, and the genesis and composition of rocks. Engineering-geological processes and the phenomena such as groundwater table drawdown, gravitational processes, local earthquakes, suffusion, frost heaving, flooding, and waterlogging are identified and characterized. The spread of engineering-geological processes and phenomena has both a local character within settlements and covers vast areas of dozens of square kilometers. As a result of the study, the mapping of sources of technogenic impact on the geological environment and the manifestations of engineering-geological processes in the territory of Belarus were compiled.*

Key words:
Engineering-geological processes, drainage reclamation, groundwater, quarries, mines, dumps, urbanized territories, deformations of buildings.

Introduction

The study of processes occurring in the upper horizons of the lithosphere in relation to human engineering activities can ensure the safe functioning of engineering structures and human economic activities. In this case the subjects of research are most often earthquake and flood which account for 50–90 % of the total number of geological disasters each year, and, to a lesser extent, landslides [1–3]. Most often such geological phenomena are associated with tectonics, the nature of the relief, the impact of water, climatic conditions, and are characterized by a certain geography of occurrence. For example, flooding results from grade lowering and it is a serious problem in coastal cities. Flood incidence also increases in interior basins where stream gradients are affected by subsidence. Earthquake occurrence predominates in three major belts: island chains and land masses forming the Pacific Ocean; the mid-Atlantic ridge; and an east-west zone extending from China through northern India, Turkey, Greece, Italy, and western North Africa to Portugal [4]. The research on such processes mainly focuses on the establishment of disaster prediction models [1–3].

At the same time, various types of human economic activity (industrial, civil, road and hydraulic engineering, land reclamation, development of mineral deposits, etc.) often cause not only the activation of natural, but also the development of engineering-geological processes that create certain dangers and cause losses to human life and property, as well as damage to the environment [1, 5]. The latter are essentially the analogs of natural geological processes; however, they are distinguished by a faster rate of development, a smaller area of distribution, and in some cases by a greater intensity and, of course, a lesser degree of knowledge.

The manifestation of these processes is due to a number of technogenic factors, such as the transformation of the

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conditions of surface runoff, the earth's surface, changes in the hydraulic gradient, temperature regime, pressure from the weight of structures, shaking, etc. Every engineering-geological process has a major or determinant factor. It should be bear in mind that the same technogenic impact under different engineering-geological conditions of the object can cause different engineering-geological phenomena.

Among the engineering-geological processes in the territory of Belarus, the most noticeable manifestation and development have the processes: a) due to land reclamation; b) arising during the creation of quarries and construction excavations; c) arising during subsurface (mines, wells) development of useful fossils; d) arising during the construction of earth structures; e) arising in urbanized areas (Fig. 1).

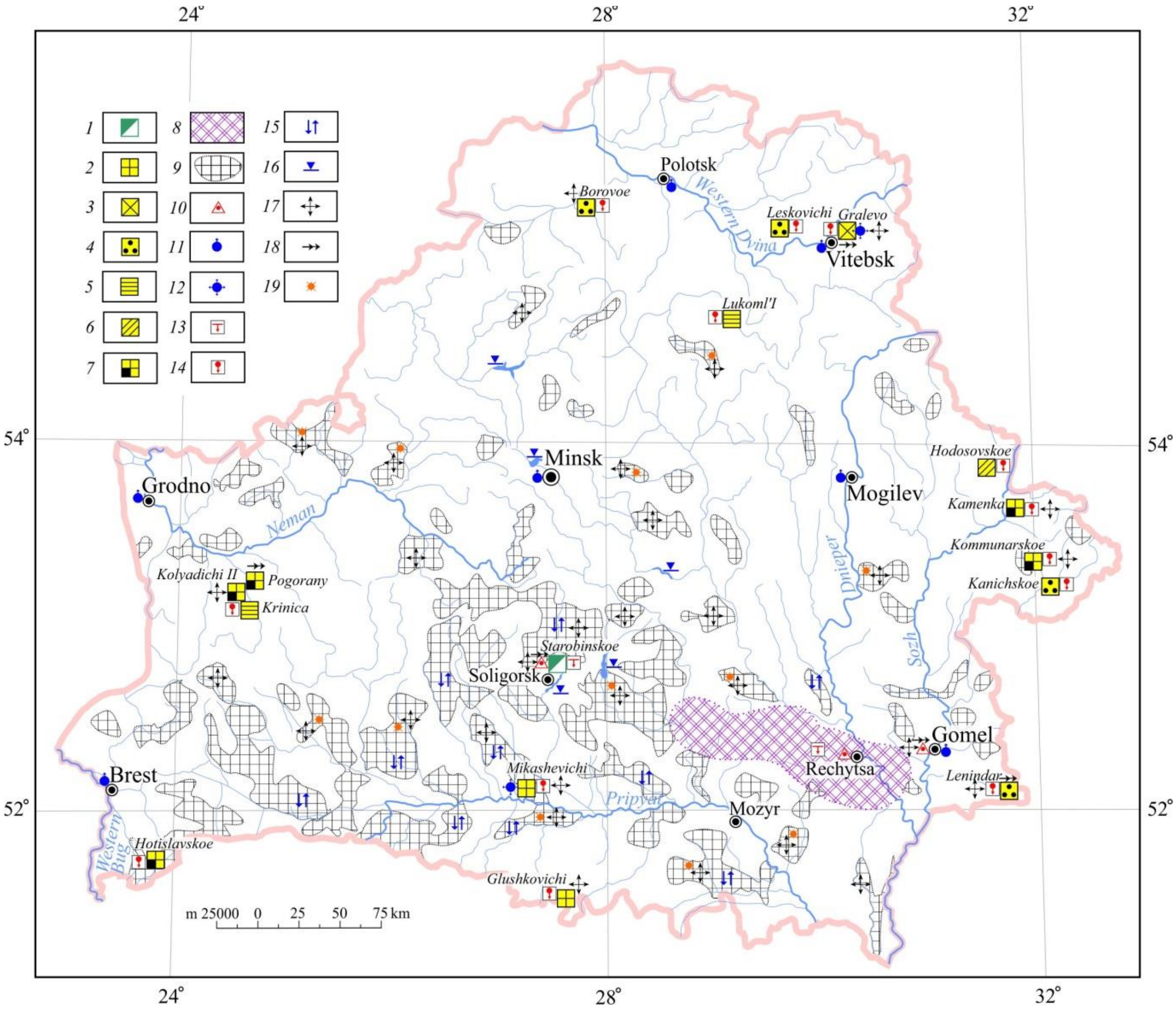

Fig. 1. *Schematic map of the sources of technogenic impact on the geological environment and distribution of engineering-geological processes on the territory of Belarus: 1–8 – mining operations:1 – subsurface mining of potassium salt; 2–7 open-pit mining: 2 – granite; 3 – dolomite; 4 – sand; 5 – clay; 6 – sand loam; 7 – chalk; 8 – oil field development territories; 9 – areas of intensive land reclamation; 10 – large industrial dumps; 11 – groundwater intakes in large cities; 12 – drainage from quarries; 13 – surface subsidence; 14 – gravitational processes; 15 – increase/decrease groundwater level due to land reclamation; 16 – flooding within water reservoirs; 17 – deflation (on reclaimed land, in mine workings, industrial dumps); 18 – suffusion (in areas of mine workings, industrial dumps, urbanized areas); 19 – decomposition of organic matter (on reclaimed land)*

Рис. 1. *Схематическая карта источников техногенного воздействия на геологическую среду и распространения инженерно-геологических процессов на территории Беларуси: 1–8 – горнодобывающая деятельность: 1 – разработка калийных солей подземным (шахтным) способом; 2–7 разработка полезных ископаемых открытым способом: 2 – граниты; 3 – доломиты; 4 – пески; 5 – глины; 6 – супеси; 7 – мел; 8 – территории разработки нефтяных месторождений; 9 – районы интенсивной мелиорации земель; 10 – крупные промышленные шламоотвалы; 11 – водозаборы подземных вод в больших городах; 12 – водоотлив из карьеров; 13 – оседание поверхности земли; 14 – гравитационные процессы; 15 – повышение/снижение уровня подземных вод в результате мелиорации земель; 16 – подтопление в пределах водохранилищ; 17 – дефляция (на мелиорированных землях, в горных выработках, промышленных отвалах); 18 – суффозия (на участках горных выработок, промышленных отвалах, урбанизированных территориях); 19 – разложение органического вещества (на мелиорированных землях)*

Processes due to land reclamation

Land reclamation is one of the significant factors affecting the engineering-geological situation of the territory and, as experts admit today, is not always positive. In the conditions of Belarus, reclamation transformations cover more than a century and are mainly associated with the drainage of swamps and wetlands. At present, 34,2 thousand km^2 have been drained, which is about 16,5 % of the country's territory [6]. However, together with the lands adjacent to the hydrotechnical facilities, the reclamation impact extends to about 1/3 of the country's area.

Drainage reclamation is a powerful means of impact, mainly on groundwater and overburden. It changes the balance of groundwater, the recharge of which can increase or decrease depending on the hydraulic connection of aquifers. In addition, within the reclaimed lands, mainly created with peat soils, deflation processes are observed [7].

To a greater extent, the environmental problems associated with land reclamation were manifested in Belarusian Polesie (Fig. 2). As a result of drainage reclamation, both the micro-component and macro-component composition of groundwater are changing. M.F. Kozlov et al. [8] conducted research on one of the drained bog massifs of the Belarusian Polesie and discovered that the total mineralization of groundwater increased by 1,5–2,5 times in the post-reclamation period, owing primarily to bicarbonate, calcium, magnesium, and, at later stages of drying, sulfate. This is caused, firstly, by the increase in the inflow of pressurized bicarbonate calcium water. Secondly, the decrease in the absorption capacity of peat soils and Ca^{2+} and Mg^{2+} removal. Third, oxidation of peat organic matter and iron sulfide minerals, which are present in small quantities in peat. Particular close attention should be paid to the presence of high iron concentrations in groundwater. It leads to a decrease in the efficiency of drainage systems due to their clogging. There is ironification of near-surface strata of drained peatlands due to capillary pulling of groundwater, etc.

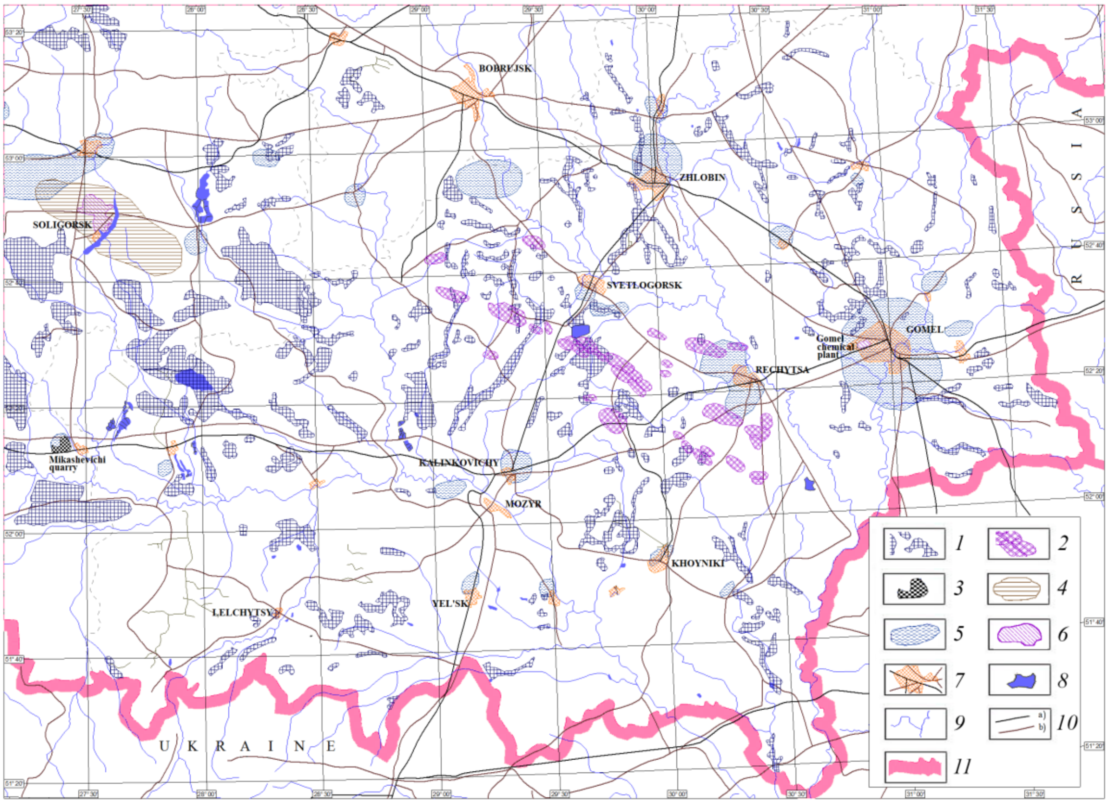

Fig. 2. Sites and facilities of engineering-geological processes in the south-east of Belarus. Sites of manifestation of the processes caused by: 1 – land reclamation; 2 – oil field development; 3 – quarrying of non-metallic raw materials; 4 – mining of potassium salts; 5 – water intakes; 6 – waste dumps; 7 – urbanized territories; 8 – lakes and reservoirs; 9 – rivers; 10 – roads: a) railways, b) highways; 11 – state border

Рис. 2. Участки и объекты проявления инженерно-геологических процессов на территории юго-востока Беларуси. Участки проявления процессов, обусловленных: 1 – мелиорацией земель; 2 – разработкой нефтяных месторождений; 3 – карьерной добычей нерудного сырья; 4 – шахтной добычей калийных солей; 5 – водозаборами; 6 – отвалами; 7 – урбанизированными территориями; 8 – озера и водохранилища; 9 – реки; 10 – дороги: а) железные, b) автомобильные; 11 – государственная граница

According to the study [9], fluctuations in the concentration of iron (II, III) in groundwater are primarily determined by the level regime in the bog massifs of various genetic types of the Belarusian Polesie. The highest groundwater levels corresponded to iron concentrations of 0,1–0,5 mg/dm^3. Iron concentrations increased to 8–10 mg/dm^3 and higher during low-water periods. As a result of the deterioration of the connection with the atmosphere, the oxygen concentration in the upper zone of groundwater decreases from 3,0–5,0 to 0,5–1,0 mg/dm^3. This contributed to the formation of a more restorative environment, favorable for the accumulation of iron (II) in the waters. Bog drainage causes a decrease in groundwater levels. When levels drop to 1,0–1,5 m, this leads to a significant increase in iron concentration of 10–18 mg/dm^3 and more. Oxygen concentrations in water reach a minimum and are 0,5–0,8 mg/dm^3. The greatest increase in iron concentrations is characteristic for lowland floodplain peatlands, which accumulate large reserves of total iron in various forms.

The abundance of organic matter in them has a great influence on iron migration in bog waters. The organ-mineral form of migration is of the greatest importance for iron (III). In the waters of undrained bogs, the share of these forms averaged 72 %, and in the surface waters of bogs – 54 %. Such waters are capable of maintaining significant supersaturation with respect to $Fe(OH)_3$ for a long time. After draining, a sharp decrease in the concentration of organic substances in groundwater was observed, accompanied by a decrease in the proportion of organically bound iron (III) to 39 % and an increase in the content of the form $Fe(OH)_3$. The degree of supersaturation of groundwater in terms of iron hydroxide has aged 60–300 times, which created favorable conditions for its precipitation at the oxygen barrier when these waters enter the drainage pipes [9].

Processes arising from the creation of quarries and construction excavations

During open-pit mining and transport construction, a large number of excavations appear, which causes significant changes in the relief, surface and underground runoff, the stress state of soil massifs, conditions of heat and mass transfer in the upper layers of the soil, etc.

A striking example of the activation of landslide processes is the Gralevo dolomite quarry. It is located on the left bank of the Western Dvina in the Vitebsk district and occupies an area of 0,39 km^2. The thickness of overburden reaches 20 m or more. They are mainly represented by moraine sandy loamy, loamy soils, and alluvial sands. The confinement to overburden soils of the underground aquifer, the weatheredness of moraine deposits, and a significant steepness of slopes (up to 50°) caused widespread development of landslides (Fig. 3). In dolomite rocks on the slopes there are lateral fissures, the density and strength of the rocky mass decrease, which leads to the formation of scree and rockfall. Drilling and blasting operations, which are often carried out in the quarry, also contribute to their development [10].

Fig. 3. *Southern wall of the Gralevo open pit for dolomite mining with numerous rockfall-landslide areas (May 2010). Photo by A.N. Galkin*

Рис. 3. *Южный борт карьера «Гралево» по добыче доломитов с многочисленными обвально-оползневыми участками (май 2010 г.). Фото А.Н. Галкина*

In Belarus, gravity processes are widespread in almost all mining excavations, but they differ in type, shape, and volume of displaced masses of rocks (Fig. 4) [10].

Concentrated water withdrawal is part of the technological process often used in open-pit mining. Drainage from quarries leads to the formation of depression funnels, the area of which can reach dozens of square kilometers. As a result, groundwater levels drop and small rivers and reservoirs dry up. For example, in the Mikashevichi open-pit, the permanent drainage often exceeded 60 thousand m^3/day, and the maximum value reached 430 thousand m^3/day and more. This led to a lowering of the groundwater table by 3,5–11,0 m, and the zone of influence extended to a distance of up to 3 km. The natural chemical composition of groundwater has changed, and two small rivers in the zone of influence of the quarry have dried up [11].

Zone of influence of concentrated water withdrawal in the amount of 370 thousand m^3/day from the quarry Gralevo spread over a distance of 10–12 km. Within its boundaries, there was a decrease in groundwater levels, which led to a change in the low-water runoff of the river Vitba and the failure of water wells near located rural settlements [10].

a

b

c

Fig. 4. *Gravitational processes in the sides of the quarries: a) talus in the Leskovichi quarry for sand extraction (Shumilinsky district, 2008); b) talus in the Mikashevichi quarry for the extraction of granite (Luninetsky district, 2010); c) landslide in the open pit «Khmelevskie ponds» for sand extraction (Minsk district, 2015) [10]*

Рис. 4. *Гравитационные процессы в бортах карьеров: a) осыпи в карьере по добыче строительного песка «Лесковичи» (Шумилинский район, 2008); b) осыпи в карьере по добыче гранита «Микашевичи» (Лунинецкий район, 2010); c) оползень в песчаном карьере «Хмелевские пруды» (Минский район, 2015) [10]*

Processes caused by subsurface mining and water withdrawal

Regional changes in engineering-geological conditions can also be observed during subsurface mining or during the withdrawal of water for water supply to large settlements [12–15]. There are a number of artificial and natural causes for ground subsidence. Short- and long-term conversion of underground burning coals to clinker results in a significant volume loss that can lead to subsidence. In other mining areas, trimming of mine pillars can cause their failure, inducing subsidence of overlying geologic materials. Withdrawal of petroleum in many sedimentary basin units results in surface subsidence when proper reservoir pressure management (e.g., secondary water-flood or tertiary fluid pressure support) is not applied [16]. Thus, during the development of minerals by the subsurface method, large cavities are formed, which often leads to deformations on the earth's surface. These are the so-called deflection troughs or sinkholes. They began to form on the territory of the republic relatively recently and began to appear in the areas of subsurface development of potash salts of the Starobinsky deposit (Soligorsk region), oil deposits (Rechitsa region) and large water intakes (Fig. 2).

The most noticeable sinkholes are found near Soligorsk. The total area covered by the deflection troughs is more than 200 км2 with a depth of 4,0–4,5 m. The steepness of the slopes is close to 3–4°. The combination of factors including surface subsidence, shallow groundwater table (from 0 to 2,0–4,0 m), well-developed engineering and reclamation system, numerous shallow reservoirs (lakes, ponds) with water surface area up to 0,01–0,03 $км^2$, large Soligorsk reservoir, led to the processes of waterlogging and swamping [17–19] (Fig. 5).

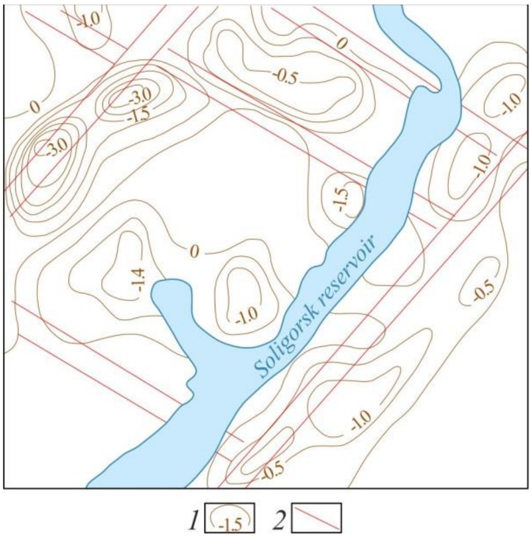

Fig. 5. *Scheme of subsidence of the earth's surface in the territory of the Soligorsk industrial region: 1 – isolines of actual subsidence of the earth's surface; 2 – tectonic faults. Adapted from [20]*

Рис. 5. *Фрагмент картосхемы оседания земной поверхности на территории Солигорского промышленного района: 1 – изолинии фактического оседания земной поверхности; 2 – тектонические разломы. Адаптировано по [20]*

Surface subsidence from fluid extraction is a common phenomenon and probably occurs to some degree in any location where large quantities of water, oil, or gas are removed. Short-term detection is difficult because surface movements are usually small, are distributed over large areas in the shape of a dish, and increase gradually over a span of many years [4].

The amplitude of subsidence over the exploited oil fields of Belarus is no more than 1 m. It was found that within such areas in the Pripyat Trough, ground surface subsidence can reach up to 10 mm/year [19].

Ground subsidence due to groundwater withdrawal occurs when groundwater is withdrawn from an aquifer faster than it can be replenished [16]. Lowering the groundwater level reduces the buoyant effect of water, thereby increasing the effective weight of the soil within the depth through which the groundwater has been lowered [4].

Water intakes of large cities in Belarus have a serious and growing impact on the subsidence of the earth's surface [21]. This influence is most noticeable in the Minsk region, which is characterized by the maximum water withdrawal in the republic. So, for example, at the Novinki water intake, the long-term operation of groundwater led to the subsidence of the earth's surface by more than 0,5–0,6 m. As in the case of water withdrawal in mining by quarrying, the exploitation of groundwater at water intakes leads to a change in the hydrogeological situation. Basically, the chemical composition and groundwater recharge change, and depression funnels are formed. At water intakes in river valleys with a hydraulic connection between groundwater and surface water, 50 to 90 % of the water received at the water intake is provided by the river. The impact of the water intake leads to reduction in the river flow and a decrease in the groundwater table towards the watershed at a distance of 1–2 km. In shallow aquifers, a groundwater regime is formed due to overflow, and the zone of influence extends to 2–6 km [21, 22].

For deep-lying layers, a transient filtration regime is characteristic during operation. Here, the resulting production rates are provided by the resources of the reservoir itself. In this case, the radius of depression of the piezometric surface of the horizon reaches 10–15 km. As the difference in the heads of the exploited and adjacent horizons increases, overflows form from the latter, which serve as additional sources of power for the exploitable reserves, which often leads to a change in the chemical composition of groundwater [21, 22].

Processes arising during the construction of earthworks

The creation of embankments, dams, dumps leads to a violation of the existing natural balance due to high pressures transmitted over a large area. This entails inhomogeneous deformations with the formation of alternating depressions and shafts, landslides, rockfalls, changes in the relief of the territory, the manifestation of seismic phenomena, violation of the surface runoff regime, waterlogging, etc.

So, for example, in the overburden dumps of the Gralevo dolomite quarry, there are often landslides. Most of them are relatively small in size. But sometimes landslides cover large areas. So, in November 1998, due to frequent rains in the direction of the bridge over the river Western Dvina slipped a vast mass of land, which had a diameter of about 70 m with a displacement height of up to 10 m. This landslide displaced about 20 thousand m^3 of soil. As a result, private buildings located near the dumps were destroyed [7].

Long-term operation of the Gomel Chemical Plant led to the creation of phosphogypsum dumps on an area of 0,9 km^2, a height of 60–70 m and a weight of over 21,3 million tons [6]. Dumps are comb-shaped and plateau-shaped. The dumps significantly change the surface topography, transforming its natural state and morphometry (Fig. 2; Fig. 6, *a*). The storage of wastes from the production of phosphorus fertilizers caused a significant rise in the level of groundwater and, as a consequence, swamping of areas adjacent to the chemical plant at a distance of up to 1 km.

In the Soligorsk mining region, the storage in dumps of large volumes of potash production wastes (over 1 billion tons of halite waste on an area of more than 5 km^2) over underworked mine fields due to a violation of the isostatic equilibrium in the earth's interior has caused man-made earthquakes (Fig. 2; Fig. 6, *b*). Such earthquakes in the Soligorsk region are recorded up to a hundred per year, and some of them reach 4–5 points [23, 24].

Processes occurring in urbanized areas

The existence of any city in itself presupposes changes in the geotechnical environment of the territory where it is located. Currently, on the territory of Belarusian cities, a whole complex of engineering-geological processes is sufficiently developed, among which there are the processes caused by static and dynamic loads from structures (industrial and residential) and transport, suffusion, frost heaving, flooding, etc.

The development of multistorey buildings in the cities of Belarus leads to a significant increase in static loads on the rocks, the value of which can be anywhere from 0,5 to 2,0 MPa. Soil compaction and a decrease in its moisture content occur in the zone of active compression at a depth of up to 30 m or more, which can lead to the settlement of engineering structures.

a

b

Fig. 6. *Transforming of the natural surface topography: a) phosphogypsum dumps of the Gomel chemical plant (October 2020); b) salt dumps of the JSC «Belaruskali» (October 2020). Photo by O.V. Shershnev*

Рис. 6. *Трансформация естественного рельефа: a) отвалы фосфогипса Гомельского химического завода (октябрь 2020); b) солеотвалы ОАО «Беларуськалий» (октябрь 2020). Фото О.В. Шершнёва*

Soils of different composition, genesis, and state react differently to stress. For example, the deformations of the foundations of structures, represented by lacustrine-glacial clay deposits, are distinguished by significant unevenness. This is evidenced by the experience of construction in Vitebsk, Polotsk, etc. Thus, in the residential building under construction on Moskovsky Avenue in Vitebsk, after two years of conservation, deformation of the foundation wall blocks occurred, expressed in the formation of cracks with an opening width of up to 50 mm. This occurred as a result of the destructuring of the foundation soil caused by uneven watering and the various physical and mechanical properties of the sandy loam underlying the foundation.

Dynamic loads affect soils in different ways, depending on the peculiarities of their composition and structure, as a result of which loose underconsolidated soils are compacted (with a density of less than 0,6) and the structure of thixotropic soils is disturbed. Dynamic loads on the ground are transmitted as a result of vibration during vehicle movement, the action of construction and other shock-vibration mechanisms. Deformations of foundations and wall structures in Vitebsk quite often occur in buildings and structures located along streets with heavy traffic. These deformations are especially intense in buildings built on the soils of the cultural layer, which are characterized by low strength and increased compressibility (Fig. 7).

Fig. 7. *Building of the first power station in Vitebsk (1897–1898) along Frunze Avenue in the historic part of the city and cracks in wall structures resulting from vibrations during the movement of urban transport (2016) [25]*

Рис. 7. *Здание первой в Витебске электростанции (1897–1898 гг.) на проспекте Фрунзе в исторической части города и трещины в стеновых конструкциях, образовавшиеся в результате вибрации при движении городского транспорта (2016 г.) [25]*

One can observe suffusion on the territory of many settlements of Belarus due to technogenically disturbed hydrodynamic regime. Quite often, it manifests itself along the routes of underground utilities in soils that are not uniform in grain size distribution, causing the formation of craters on the surface of the earth (Fig. 8). This process can also begin in filled up large ravines as they continue to serve as natural drains.

Construction on relatively steep slopes (creation of pits, long-term zero cycle work) can contribute to the activation of suffusion both in terms of creating conditions for unloading and in terms of the formation of large pressure gradients of the filtration flow due to the unhindered entry of atmospheric precipitation into the strata.

Frost heaving is quite widespread. Especially in the northern regions of the country. It occurs due to volumetric deformations of clay, silty and fine sandy soils during their freezing (the volume of soil increases by 10–20 %) and manifests itself mainly in the form of deformations of the asphalt pavement, as well as buildings and structures. This process is especially dangerous for the foundations of structures and engineering communications, laid above the base of the active layer (Fig. 9).

Their composition has a great influence on the depth of freezing of soils. So, inclusions of organic matter with low thermal conductivity significantly reduce the depth of freezing. Lowering the level of groundwater, removing snow cover and other processes increase the depth of freezing. However, the shallow occurrence of groundwater contributes to the inflow of moisture to the freezing front, which activates the heaving process.

The process of raising the level of groundwater is typical for many cities in Belarus, up to the flooding of residential buildings and industrial facilities. The reasons for flooding are varied. This is also a change in the existing surface topography, which determines the surface runoff (construction of embankments, dams); destruction of the existing hydrographic network (elimination of small rivers and streams, canalization of rivers, backfilling of ravines, etc.); silting and littering of natural drains; reservoir construction; shielding the earth's surface by buildings and asphalt; loitering with buried structures and structures of the underground stream; leaks from water-carrying communications and dumping of technogenic soils with poorly water-permeable and impermeable layers, etc.

Flooding processes are widespread in many settlements in Belarus. For example, the area of flooding in Gomel reaches 30 km^2, including up to 50 % of residential buildings. Settlements in the country can be grouped into several categories depending on their proneness to flooding. The first category includes such settlements as Minsk, Bobruisk, Svetlogorsk and Stolbtsy. They are in the zone of local flooding and require preventive measures. The second category includes settlements that are in the zone of probable flooding area and require certain technical measures for protection. Such settlements include the cities of Gomel, Brest, David-Gorodok, Turov, Mogilev, Bykhov and Zhlobin. The cities of Vitebsk, Polotsk, Verkhnedvinsk, Soligorsk and Pinsk are in the zone of active flooding and are referred to the third group of cities requiring engineering protection [7].

Fig. 8. *Deformations of sidewalks and highways caused by suffosion: a) in Vitebsk near the Summer Amphitheater (2012); b) in Minsk along Mogilevskaya street (2014); c) in Gomel near the Ice Palace (2013); d) in Zhlobin near gymnasium no. 1 (2014) [10]*

Рис. 8. *Деформации тротуаров и автомобильных дорог, вызванные суффозией: a) в Витебске вблизи Летнего амфитеатра (2012); b) в Минске по улице Могилевской (2014); c) вблизи Ледового дворца в Гомеле (2013); d) в Жлобине вблизи гимназии № 1 (2014) [10]*

Fig. 9. *Cracking in a residential building on the Lenin street, 101 in Liozno (Vitebsk region) as a result of heaving of moraine soils (2005) [10]*

Рис. 9. *Трещинообразование на здании жилого дома по ул. Ленина, 101 в г. Лиозно Витебской области в результате пучения моренных грунтов (2005 г.) [10]*

As a result of technogenic waterlogging of soils, their strength and deformation characteristics change. For example, the decrease in the angle of internal friction may reach 10–15 %. There is a 2,0–2,5 times decrease in the cohesion intercept of the soil, and the modulus of deformation may decrease by 2,0–3,5 times. Several examples can be cited as accidents that happened for this reason. Thus, in the building of the joint-stock company Technopark Mogilev in Mogilev, due to uneven deformations of the base because of flooding, inclined and vertical cracks formed along the load-bearing walls, the basement of the building was filled with groundwater. Reinforcement of the outer walls with strained steel straps was carried out, systematic control of the behavior of underground and aboveground structures of the building was established [10]. In the town of Bykhov in the Mogilev region, in the building of the Belagroprombank branch, due to soaking of the base soils and uneven settlements, vertical cracks exceeding 20 mm appeared on the inner bearing wall. The repair work did not stop new cracks from appearing [7]. The flooding of urban areas and the often accompanying chemical and bacterial contamination, increasing temperature and aggressiveness of groundwater can lead to the destruction of the body of the foundations, corrosion of reinforcement and concrete, and leaching of lime mortar from rubble foundations. Such processes are observed almost everywhere in the buildings of the old layout.

Conclusions

Engineering-geological processes, which are widespread on the territory of Belarus, are the most active and most powerful factor in the development (or transformation) of engineering-geological conditions at the present stage. They are also a factor that changes the engineering-geological conditions of both large areas and local areas.

Various types of engineering-geological processes caused by human economic activity have been established in the Republic of Belarus: 1) groundwater table depletion as a result of land reclamation and drainage during open-pit mining; 2) landslides, rockfall and talus actively occurring during the creation of quarries and excavations; 3) subsidence of the earth's surface during subsurface mining or during the direct groundwater abstraction for water supply; 4) landslides, seismic phenomena, violation of the surface runoff regime, waterlogging due to creation of man-made landforms (dumps, waste heaps, dams), which are comparable in size with natural ones; 5) suffusion, frost heaving, flooding, waterlogging within settlements and industrial facilities due to technogenically disturbed hydrodynamic regime, the natural features surface topography and rocks, static and dynamic loads from structures (industrial and residential) and transport.

The regional spread of these processes has a negative impact on the components of the geological environment and complicates the living conditions of human.

The results of the study can be used to make design decisions in capital construction and reconstruction of buildings and structures, in creating a monitoring system of the geological environment of cities, mineral extraction and processing facilities, as well as the formation of a set of measures aimed at optimizing spatial planning.

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РЕГИОНАЛЬНЫЙ АНАЛИЗ ВОЗНИКНОВЕНИЯ И РАСПРОСТРАНЕНИЯ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ ПРОЦЕССОВ В РЕСПУБЛИКЕ БЕЛАРУСЬ

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Актуальность. *Вопросы изучения масштабов распространения и причин возникновения инженерно-геологических процессов в Республике Беларусь позиционируются в качестве одних из приоритетных среди широкого спектра геоэкологических проблем. Получение такой информации позволяет выделить и проанализировать факторы влияния хозяйственной деятельности человека на состояние геологической среды, выявить возникновение и наличие угроз на урбанизированных территориях, приводящих к снижению безопасности и качества жизни населения.*

Цель: *анализ причин возникновения и степени проявления наиболее заметных в региональном плане инженерно-геологических процессов, происходящих на территории Беларуси.*

Объекты: *урбанизированные территории, объекты добычи и переработки полезных ископаемых, рекультивированные земли, явления и процессы, возникающие в результате инженерно-геологической деятельности человека.*

Методы: *исследование и классификация инженерно-геологических процессов, развивающихся на территории Беларуси; для систематизации и анализа основных факторов их возникновения и развития на территории страны были использованы экспертный и сравнительный методы, основанные на результатах ранее опубликованных работ и современных полевых исследований, проведенных авторами.*

Результаты. *Авторская экспертная оценка и полевые методы исследования позволили установить, что к наиболее распространенным факторам возникновения и активизации инженерно-геологических процессов в Республике Беларусь относятся: мелиорация земель, разработка полезных ископаемых открытым и шахтным способами, чрезмерный водоотбор, статические и динамические нагрузки от сооружений и транспорта, инженерная и хозяйственная деятельность человека на урбанизированных территориях, природные климатические условия, генезис и состав горных пород. Выявлены и охарактеризованы инженерно-геологические процессы и явления, среди которых: снижение уровня подземных вод, гравитационные процессы и локальные землетрясения, суффозия, морозное пучение, затопление и подтопление. Распространение инженерного-геологических процессов и явлений имеет локальный характер в пределах населенных пунктов, но также охватывает обширные территории в десятки квадратных километров. В результате исследования составлены картосхемы источников техногенного воздействия на геологическую среду и проявления инженерно-геологических процессов на территории Беларуси.*

Ключевые слова:
Инженерно-геологические процессы, осушительная мелиорация, подземные воды, карьеры, шахты, отвалы, урбанизированные территории, деформации зданий.

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