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Impact of anthropogenic environmental changes on geological and engineering conditions for the setting of buildings

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The article presents the key elements of the anthropogenic impact on the environment. Two of them have been discussed in greater detail as they have so far received little consideration while having a major influence on geological and engineering conditions for buildings. These are contamination and chemical degradation of soils and grounds as well as anthropogenic grounds occurring in the substrate.

Based on the data gathered in the testing field, the need for geochemical analyses has been demonstrated in areas of even a slight possibility of contamination, specifying the methods of analysis, evaluation criteria, and examples of recultivation.

The part dealing with anthropogenic grounds presents their characteristic features, classification (including the one applied by the author), possibilities for foundation making in areas where such grounds occur and using them as building substrates.

Key words: anthropogenic grounds, chemical degradation of soils and grounds, setting of buildings

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INTRODUCTION

The ongoing development of civilization and the growth of human population have resulted in more intensive anthropogenic changes in the environment. In our climatic conditions, the key factor in shaping the environment was the clearing of forests, followed by the industrial revolution which began in England at the turn of the 18th and 19th centuries. Nowadays, anthropogenic changes of the environment are of global nature.

Anthropogenic transformations and the degradation of environment due to man's social and economic activities are first of all related to:

- transformations in the land surface due to under ground mining, open pit mining or borehole mining activities,
- changes in the landscape due to the construction of line facilities, including roads and railways,
- ground settlement due to draining,
- changes in land development due to the construction of artificial water reservoirs,
- the impact of dumping grounds and landfills,
- chemical and bacterial contamination of soils and groundwater,
- initiation or stimulation of geodynamic processes such as landslides, infiltering dislocations.

Apart from the well-researched impact of land surface transformations on the geological and engineering conditions, the issues of chemically degraded areas and areas of anthropogenic grounds require a more thorough discussion with regard to the complexity of building setting.

According to S. Kozłowski (1998), one of the main tasks in the lithosphere protection is the protection of its surface against chemical and radioactive contamination. The problems of soil degradation were of particular consideration to J. Siuta (2000) in his speech to the State Council for Environmental Protection. It is very common that even with a very good load-bearing capacity of the substrate, building construction may not be possible due to the chemical degradation of the environment unless recultivating activities are undertaken.

Setting of buildings in areas of anthropogenic grounds faces difficulties related to the very identification of qualities of such grounds as well as the use of appropriate techniques and technology for the setting.

CHEMICAL DEGRADATION OF SOILS AND GROUNDS

Chemical contamination is a very common type of degradation of grounds. Contaminated areas are those where pollutants (solid, liquid, or gaseous) have been introduced into the ground in quantities which disturb the balance of ecosystems or produce hazards to human health.

According to the Ordinance of the Minister of Environment of September 9, 2002 on quality standards for soil and quality standards for grounds, soil or ground are considered to be polluted if the concentration of even one element exceeds the permissible levels.

Permissible levels depend on the actual and planned function of the land. There are three types of areas:

A – land property and areas under protection pursuant to the regulations on nature preservation and the Water Law.

B – agricultural land, forests, and wasteland as well as built-up and urbanized grounds.

C – industrial areas, mining land, and communication land.

The highest quality requirements for grounds are set for group A, and they are relatively lower for groups B and C.

According to the above-mentioned Ordinance, the evaluations should take into account contamination with metals, inorganic pollutants – cyanides, hydrocarbon pollutants (petrol, mineral oil, aromatic hydrocarbons, polynuclear aromatic hydrocarbons); chlorinated hydrocarbons, pesticides; others, including phenols and phthalates.

Taking into account the geometry of contamination occurrence in space, we can distinguish areas of linear source pollution, areas of surface pollution, and areas of in-depth pollution. The issues regarding the degree of an area degradation, carrying out regular geochemical analyses and the recultivating means are very important in defining solutions for land development. A good example of a solution of area contamination problems in relation to its land development scheme is the central part of Łomianki near Warsaw. It has the area of ca. 2 hectares and is planned for residential buildings in the spatial development plan. The surface layers of the construction site turned out to be heavily contaminated with arsenic and chromium. The data contained in "Atlas geochemiczny Polski" (the Geochemical Atlas of Poland) at a scale 1 : 2 500 000, edited by J. Lis and A. Pasieczna, do not indicate any arsenic or chromium contamination in this area. "Atlas geochemiczny Warszawy i okolic w skali 1 : 100 000" (The Geochemical Atlas of Warsaw and its Surroundings at a scale 1 : 100 000) (Lis, 1992) registers the content of arsenic and indicates its occurrence in the area in question at a higher concentration (over 200 ppm), yet not so high as indicated by the research (Lis, Juskowiak, 1993; Lis, Irminski, 1994) conducted for a water intake and focusing mainly on soil contamination as well as a research (Drągowski, Cabalski, Radzikowski, 1996) on geochemical conditions of land development for a housing estate. Those researches, apart from identifying and evaluating the geological and engineering conditions of the substrate (which turned out to be positive as the substrate is composed of alluvial, moderately compacted sand formations covered by anthropogenic grounds from the surface), demonstrated an exceptionally high concentration of arsenic and chromium in most parts of the site. Contrary to the previous researches, they also allowed for a spatial, including the in-depth one, mapping of contamination. The contamination results from wastes from the local tannery (1920–1950), which were used as a fertilizer.

The way of executing the investment scheme will depend on a detailed identification of the degree of the substrate degradation as well as its spatial extent in relation to the lithologic formation of layers, engineering-geological and hydrogeological conditions and the resulting concept of recultivation.

The geochemical analysis was conducted by stages, gradually increasing the number of boreholes from which samples were collected. In total, there were about 300 samples.

All determinations of arsenic and chromium as well as of co-existing elements and those having a substantial impact on the element migration, such as calcium, cadmium, iron, magnesium, manganese, were made by atomic absorption. It resulted in distinguishing three zones within the site of the planned investment, which specified the extent of contamination and the changeable contamination level in soils and grounds (Fig. 1).

Zone I covers the area where the performed determinations did not show any ground contamination, both on the surface and in-depth. The discovered level of arsenic contamination of soils and grounds does not exceed 20 ppm, and that of chromium does not exceed 150 ppm, which are permissible values for group B according to Environmental Minister's Regulation (Journal of Laws No. 165, item 1359).

Zone II covers the area where contamination of the surface layer only of soil and grounds, down to 1 m deep, was discovered, whereas grounds below are not contaminated with arsenic or chromium. The average arsenic concentration in the contaminated substrate is approx. 33 ppm, and the chromium concentration level is approx. 43 ppm.

Zone III covers the area where the extent of contamination is deeper (more than 1 m deep) and the average arsenic and chromium concentrations in soils and grounds are approx. 1000 ppm.

The in-depth extent of contamination is presented in the geological and geochemical cross-sections. The selected cross-section is shown in Fig. 2.

Regarding the distinguished zones, the land development concept for the housing estate has been presented together with specific directions for recultivation and land development for construction purposes. The research shows that despite confirming the advantageous conditions of the substrate and the site location in the city centre, the construction of a housing estate will be impossible without special technical solutions and measures because of the confirmed degradation of soils and grounds by arsenic and chromium in Zones II and III (Fig. 1).

Recently, the area recultivation concept has been presented, which proposes creating a protective layer made of natural soil coming from excavations for the estate buildings located in Zone I. Before the protective layer is formed, the area must be covered with a betonite mat on which synthetic drain is laid down. On the top of that, a humus layer should be laid and biological recultivation should be carried out. The recultivation scheme is presented in Fig. 3.

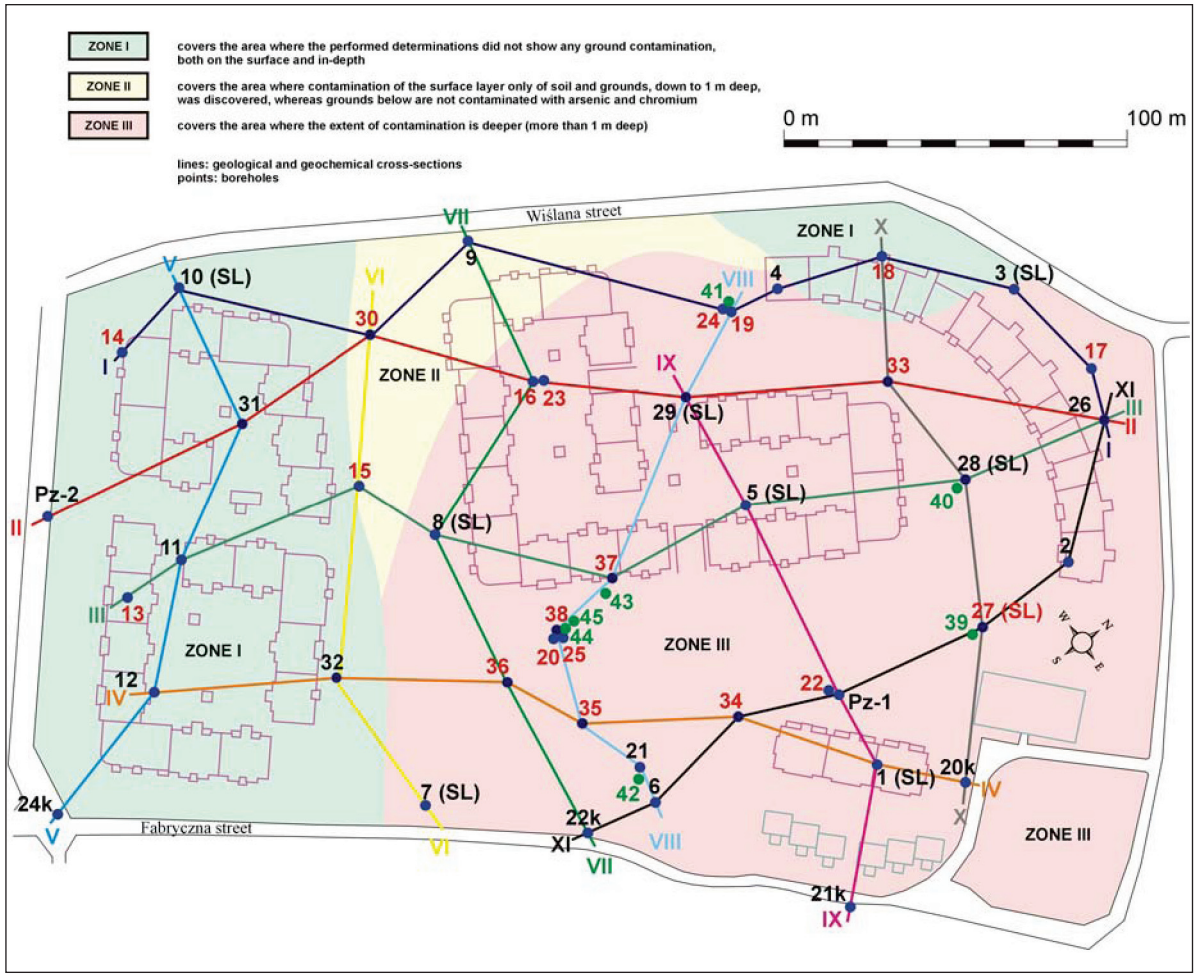

Fig. 1. Map of geochemical zones

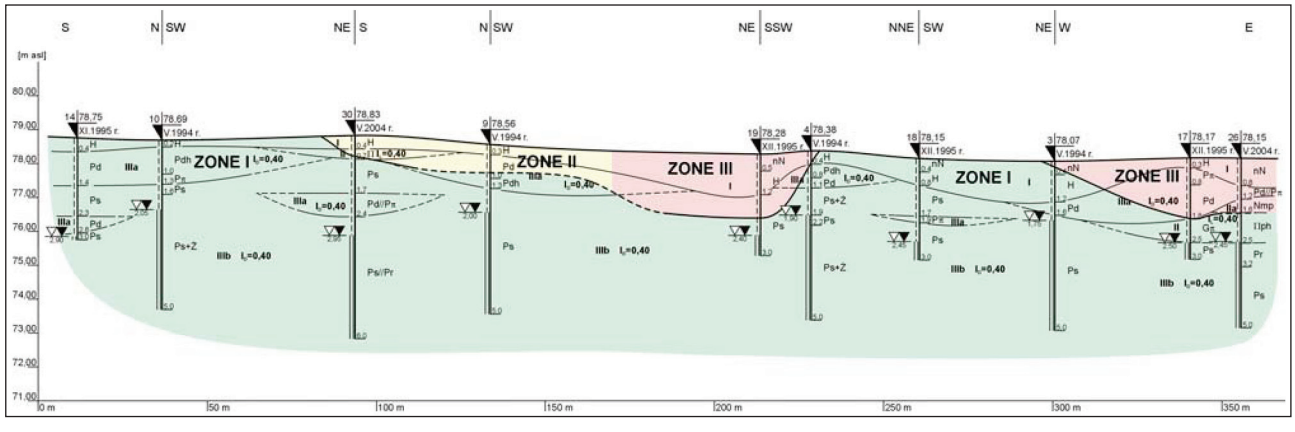

Fig. 2. Geological and geochemical cross-section I–I

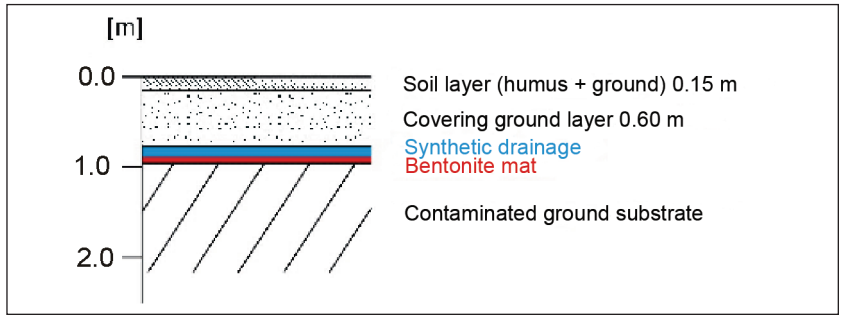

Fig. 3. Scheme for recultivating solutions

ANTHROPOGENIC GROUNDS

The term "anthropogenic grounds" was first introduced into professional literature in Poland in seminar materials "Building on low-bearing soils, made grounds and anthropogenic grounds in the Warsaw area" ("Budownictwo na gruntach słabych, nasypowych i antropogenicznych rejonu Warszawy") in 1979. According to the author's definition (Drągowski, 1979), anthropogenic grounds are the grounds that have been created as a result of human activity. There are therefore natural soils, man-made grounds, removed and re-deposited soils as well as waste soil deriving from human social and economic activities. The classification of anthropogenic soils, currently modified by the author (Drągowski 1979, 1998) is presented in Fig. 4.

The need to distinguish this group of soils arose from a more and more common occurrence of such soils and their importance in designing solutions of specific problems of land development and construction. The crucial role of such soils was appreciated only in 1986. The Polish Standard (PN86/B-02480) for soil classification in construction introduces the term "anthropogenic ground" and divides grounds into natural and anthropogenic, yet leaving made grounds within the group of natural grounds, contrary to the author's intention.

This idea is compatible with the proposed classification of soil for construction, developed by the International Organization for Standardization PN-EN ISO 14688-1.2 (2006), based on proposals from the European Committee for Standards in 2001 (Fig. 5). The author's classification goes much further as it takes into account both the genesis and types of storage (dumps – meaning mechanically deposited materials, deposits – meaning sediments washed in and settled in the water environment) as well as the provisions of the Law on waste materials of April 27, 2001 according to which he divides them into neutral, hazardous and other than neutral or hazardous, depending on their impact on environment and human health. Anthropogenic grounds are exceptionally diverse due to their material, settling or dumping conditions, self-compaction, or especially selected compacting methods, chemical and biochemical changes. They can occur as cultural layers in cities, dumps or deposits, construction material for road embankments, railway embankments, earth walls or deposits from the micro-levelling process.

The methodology of testing anthropogenic grounds must be properly selected, considering their formation as well as the research goals. Apart from the common standard methods, specialised tests similar to those for natural virgin soil must be introduced, taking into account changes of the physical, mechanical,

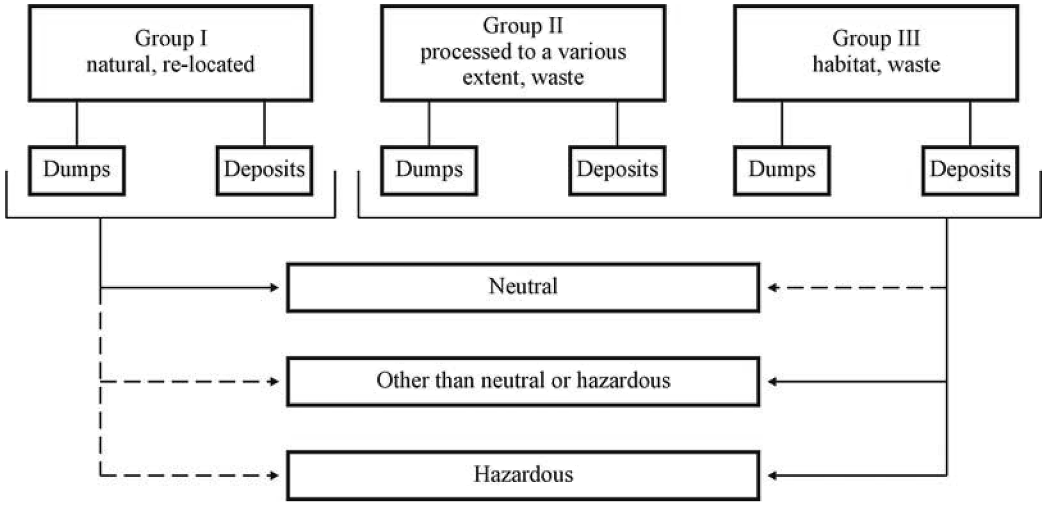

Fig. 4. The modified classification of anthropogenic grounds according to the author

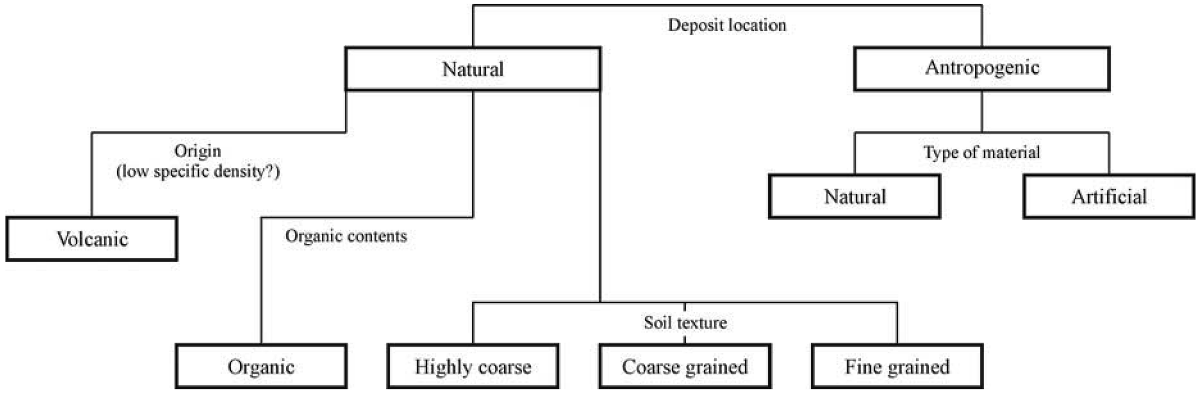

Fig. 5. Classification of soils according to PN-EN ISO 14688-1.2

chemical, and mineral properties of soils (Drągowski, Bażyński and others, 1999). The occurrence of anthropogenic soils is first of all related to areas of urban agglomerations, industrial areas, communication routes, storage of waste and dumping. In Warsaw, for example, such grounds are characterized by a varied thicknes – from one to several metres. They occur as organic soil in Stare Miasto (Old Town), in the so-called Góra Gnojna, and in Nowe Miasto.

The construction rubble derived from the city destruction during the war is deposited as dumps in different locations of Warsaw: Szczęśliwice, Moczydło, in Bartycka Str. and also as the ground cover (up to 2 m) in the area of the former Jewish ghetto in Muranów as well as the substrate of the northern part of Wisłostrada. The municipal waste dumps (big, over-surface) are in Radiowo, and the dumps of ashes and slag are in power plants: EC Żerań, EC Siekierki, EC Kawęczyn.

Due to the non-homogeneous structure of anthropogenic grounds, changes of their propeties, susceptibility to geodynamic factors, it is suggested to upgrade the level of the substrate complexity by one, e. g., from basic to compound, when determining the geotechnical category (Instruction 1998). Direct setting of buildings is possible, to a limited extent, only after detailed tests of the substrate have been conducted and foundations properly supported (with slabs, framework). In case of a substantial thickness of anthropogenic grounds, indirect setting is used on piles of various structures.

CONCLUSIONS

1. When documenting the setting conditions in areas where chemical degradation of soils is suspected, geochemical tests should be carried out alongside the geological and engineering or geotechnical research.

2. In case of discovering chemical contamination, the scope of geochemical tests should be broadened to a more complex one.

3. The future use of the land will depend on the results of these tests, either for construction after performing proper recultivation activities or excluding it from building.

4. The research on the area degradation should determine the extent of contaminated land and the concentration of contaminants both horizontally and in vertical profiles.

5. Apart from the alteration of concentrations, the tests should also determine the mobility of contaminations, which will allow for specifying their relocation dynamics.

6. The hydrologic conditions will require a detailed analysis, including parameters of the water-bearing layer, water dynamics (directions of flow, periodic changes).

7. All geochemical and environmental elements related to the current standards should be the basis for distinguishing zones of land degradation in the study area.

8. Testing anthropogenic grounds for construction purposes should cover their spatial occurrence and their specific features allowing determining conditions for building setting.

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APLINKOS ANTROPOGENINIŲ POKYČIŲ POVEIKIS INŽINERINĖMS GEOLOGINĖMS SĄLYGOMS

Santrauka

Cheminė gruntų tarša bei antropogeninės kilmės gruntų slūgsojimas statinių pagrinde yra svarbūs veiksniai vertinant užstatomos teritorijos inžinerines geologines sąlygas. Tyrimais nustatyta, kad gruntai buvo užteršti arseno ir chromo junginiais, nustatytos teršalų ribinės vertės priklausomai nuo teritorijos paskirties. Teritorija, užstatyta gyvenamaisiais namais, buvo priskirta B kategorijai. Analizuojamas atvejis, kai inžinerinės geologinės sąlygos statybai palankios, bet dėl per didelio užterštumo teritorijoje būtini rekultivacijos darbai. Cheminė degradacija bei antropogeninės kilmės gruntai turi įtakos įrengiant pamatus. Pateikta antropogeninių gruntų analizė ir įvertinimas, aptarti Varšuvos teritorijoje slūgsantys antropogeninės kilmės gruntai, jų savybių kaita. Siūloma antropogeninių gruntų išplitimo atvejais padidinti geotechninių sąlygų sudėtingumo kategoriją.

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WPŁYW ANTROPOGENICZNYCH PRZEKSZTAŁCEŃ ŚRODOWISKA NA WARUNKI GEOLOGICZNO-INŻYNIERSKIE POSADOWIEŃ OBIEKTÓW BUDOWLANYCH

Streszczenie

W artykule zajęto się problematyką zanieczyszczeń chemicznych, występowaniem gruntów antropogenicznych w podłożu i ich wpływu na warunki geologiczno-inżynierskie posadowienia. Przedstawiono metodykę i sposób interpretacji wyników badań prowadzonych na wybranym poligonie badawczym, gdzie gleby i grunty zostały w dużej mierze skażone i zdegradowane arsenem i chromem. Zakres przeprowadzonych badań pozwolił na określenie zasięgu skażeń przekraczających dopuszczalne standardy uzależnione od przeznaczenia terenu. W tym przypadku jest to grupa B obejmująca tereny zabudowy mieszkaniowej (rys. 1). Pomimo dobrych warunków geologiczno-inżynierskich podłoża, w świetle obowiązujących przepisów, ze względu na zanieczyszczenie, teren nie będzie mógł być zabudowany bez przeprowadzenia prac rekultywacyjnych (rys. 3).

Podobnie jak degradacja chemiczna podłoża tak również występowanie gruntów antropogenicznych wpływa na warunki posadowienia obiektów budowlanych. W artykule dokonano analizy i oceny stosowanych podziałów gruntów antropogenicznych, określono na przykładzie Warszawy ich wykształcenie i formy występowania. W związku z niejednorodnością gruntów antropogenicznych, przemiennością ich właściwości i podatnością na czynniki zewnętrzne, zaproponowano aby przy ustalaniu kategorii geotechnicznej przedsięwzięcia stopień złożoności podłoża podnieść o jeden, np. z prostych na złożone.

Анджей Дранговски

ВЛИЯНИЕ АНТРОПОГЕННЫХ ИЗМЕНЕНИЙ СРЕДЫ НА ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИЕ УСЛОВИЯ

Резюме

Химическое загрязнение и залегание грунтов антропогенного происхождения являются факторами, важными для оценки инженерно-геологических условий. Исследования выполнены на экспериментальной площадке. Проведена интерпретация полученных результатов. Установлено, что грунты загрязнены соединениями арсена и хрома. Определены предельные значения загрязнения в зависимости от назначения территории. Застроенная жилыми домами территория отнесена к категории Б. Анализируется случай, когда инженерно-геологические условия вполне удовлетворительны, но из-за превышения норм загрязнения территория не может быть использована под строительство без рекультивации. Химическая деградация и залегание антропогенных грунтов влияют на устройство фундаментов. Представлена классификация антропогенных грунтов и дана им оценка. Выделены антропогенные грунты, залегающие на территории Варшавы, и отмечена изменчивость их свойств. Предлагается в случаях распространения таких грунтов повысить категорию сложности геотехнических условий.