The Comparison of the Russian and Foreign Mining Wastes Classification Systems

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Abstract. The important part of doing a research about artificial soils is their classification. Nowadays there is no generally accepted classification system of artificial soils. Moreover, the principles of classification in Russia and over European Union significantly differ from each other. Then, in present paper, different classification systems have been analysed and the attempt to classify two types of studied artificial soils have been made. The paper explain the authors’ position about the question from which side is more appropriate to classify artificial soils for purposes of engineering geology.

1. Introduction
Nowadays the rates of solid mining wastes accumulation, which in present paper regarded as artificial soils, is the crucial issues for the mining industry. Artificial soils are the soils, which were formed, altered or displaced due to anthropogenic activity. According to the Government report, in 2018 more about 6,8 billion tons of mining wastes were formed in Russia, accounting for 94,2% of total produces wastes [1]. Solid mining wastes occupy large territories, which leads to degradation of the landscapes, devastation of the ecosystems. On the Figure 1 the ratio of produced to utilized wastes for 2010-2018 is presented. So, the permanent growth of mining wastes accumulation is observed, despite the growth of the rates of waste utilization. Moreover, authors have shown that stored wastes, coal wastes in particular, have a significant impact on a stress-strain state of the ground and may cause land surface deformation [2].

![Figure 1. The dynamics of mining wastes accumulation and their utilization in Russia in 2010-2018 (according to Government report "About environmental data and environment protection in Russian Federation over 2018", 2019).](image-url)
Above-mentioned points confirm the relevance of artificial soils studying. In addition, there is still lack of studies in this field. The important part of artificial soils research is their classification. Nowadays there is no certain generally accepted classification system of artificial soils, despite the number of Russian specialists attempts to develop the conventional one. Moreover, Russian authors base on other classification principles than foreign authors. Then, in present paper, different classification systems have been analyzed and the attempt to classify studied artificial soils according to European standards have been made. The paper explain the authors’ position about the question from which side it is more appropriate to classify artificial soils for purposes of engineering geology.

2. State-of-the-art
The different classification systems, made by Russian authors have been reviewed. The analysis shows their shortcomings, as some of them are too detailed, when other do not have quantitative characteristics for typification. For example, Pashkevich M.P. [3] presented the classification, which characterized mining wastes according to hazard mode, so author suggest to classify artificial soil according to their chemical and toxicological properties. Such principle cannot be considered as efficient for engineering geology purposes.

Afonin et al [4], provided one of the most sufficient classification systems. The classification characterized the artificial soils according to their genesis and structural features. Nevertheless, the position of some types of artificial soils, for example, soils stored as heap leach pads has not determined.

Nowadays in Russia, the national standard named GOST 25100-2011 [5] had been enacted. According to it, artificial soils as a class had been excluded from this classification system, which means that principles of classification for the artificial soils are the same as for natural ones. So, specific properties of the artificial soils cannot be examined [6]. Summing up, it may be concluded that no one from the existing Russian classification systems may be assumed as efficient system for engineering geology.

In case of European Union classification approaches, one of the most detailed review was provided by DHI [7]. Generally, artificial soils in the European Union are regarded as a type of wastes [8]. The classification of the mine wastes is built on their genesis and based on Directive 2006/21/EO [9] and Resolution 2000/532/EO [8].

Based on Directive 2006/21/EC [9], the main criteria for mining waste classification is their hazardous properties. If one of the above-mentioned issues relevant for the mining wastes, it is characterized as Category A – potentially hazardous or non Category A. Classification of the soils as Category A requires implementation the following administrative and organizational measures: “notification without undue delay in case of an incident” and “transboundary information”, “monitoring and maintenance after closure”, “reporting and economical responsibility for closed facility”, “minimized cyanide concentration in facility” and “financial security for closure and post-closure”. So, principle of ensuring human and environmental safety is the main classification principle according to Directive 2006/21/EC [9].

3. Materials and methods
In the present paper, the following two types of soils were studied:

- The coal sludge from the waste dump of the Pechora coal processing plant, Russia
- The soils from the heap leach pads, Kuranakh gold mine site, Russia

Studied artificial soils should be classified as Category A or not Category A in relation to:

a) Failure - due to loss of structural integrity or incorrect operation – that could give rise to a major accident

b) The presence of waste classified as hazardous waste above a certain threshold

c) The presence of substances or preparations classified as dangerous above a certain threshold

When classifying a mining waste facility, all three issues must be considered. If a facility is classified under Category A according to some of the above listed issues, and it is not necessary to
consider the other two issues further. Directive 2006/21/EC [9] includes the list of properties of the mining wastes which characterized them as hazardous, which was used for examination of the studied soils.

4. Results

4.1. The coal sludge from the waste dump of the Pechora coal processing plant, Russia

The dump of a waste-rock is located is located in the Extreme North of European Russia, about 20 km from the city of Vorkuta. The dump area is 5 km² and the height is 40 m. This is a fine grained material, which corresponds with natural clays according to the grain size (<0.002 mm). Nevertheless, mineralogical composition of the sludge consists mostly of coal particles. Therefore, the angle of repose for studied wastes is 44°, which is the same as angle of repose of initial coal material before the processing. Moisture content in the sludge is 24.2%. Excess moisture often creates problems due to freezing of coal in winter. This mine site has been under exploration beginning with 1975 till nowadays.

4.1.1. Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation.

The area where the wastes are located is flat and afforested. The consequences of limited rock-mass movements are presently small and they would only be local and not dangerous for human life nor would they cause any significant environmental impact. Therefore the heap is classified as “not Category A” with respect to failure due to the loss of structural integrity. No environmental protection measures are applied to the coal processing wastes heap so far. Although the mining activity on this site has a negative effect on the environment [10], the facility of coal sludge is classified as “not Category A” with respect to failure due to incorrect operation.

4.1.2. Classification based on the content of hazardous waste

According to the European Waste Catalogue [8], the coal sludge is not dangerous. The washery refuse was classified as “01 04 12 tailing and other wastes from washing and cleaning of minerals”. The dump does not contain “flammable substances” at concentration leading to self-ignition. Mineralogical content is shown in Figure 2. Therefore, according to this criterion the dump is “not Category A”.

4.1.3. Classification based on the content of dangerous substances and preparations

The waste deposited on heap does not contain any substances or preparation classified as dangerous under Directive 1999/45/EC (As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, V and Zn), which leads to the classification of the heap as “not Category A” with respect to Dangerous substances.

Figure 2. The percentage of the mineralogical content in the sample of coal sludge, Pechora coal processing plant.
According to Resolution 2000/532/ EO [8] the overall classification of the studied soils is “not Category A”.

4.2. The soils from the heap leach pads, Kuranakh gold mine site

The Kuranakh ore field is located in North-East Siberia, in the southern part of the Republic of Yakutia. This mine site has been under exploration from 1956. Currently, part of the waste ore is located in waste dumps, where the heap leaching process has been managed. Gold concentration in the ore is less than 1 gram per ton. Approximately 1,500 thousand tons of ore have been stored on the heap leaching site each year.

The technological scheme heap leaching on the mine site includes crushing of ore, pelletizing with Portland cement, stacking of ore, irrigation with cyanide solutions, detoxification and conservation of ore stack by cyanide solutions, then collection of the productive solution of sodium cyanide and subsequent transfer of the solution to the refinery.

4.2.1. Classification based on the consequences of a failure due to loss of structural integrity or incorrect operation

The heap leach pads are located on an even site at an angle of 3°. Based on the mechanical properties or the ore and the external conditions, the conclusion about probability of failure has been made. The risks of this unfavorable event are related to inaccurate geotechnical calculations, and the lack of monitoring. Thus, the soils of heap leach pads are classified as "Category A" in terms of failure due to loss of structural integrity.

4.2.2. Classification based on the content of hazardous waste

The waste from the heap leach facility is processed water and the ore stack itself. At the end of the heap leach facility exploitation, process water is neutralised and treated. Cyanide destruction results in residual cyanide concentrations below the limit value of 0.1% or 1 g/l. The neutralization and treatment of the water and solid wastes, in strict compliance with technological regulations, does not pose any environmental hazard and these types of waste can be classified as "not Category A" waste.

4.2.3. Classification based on the content of dangerous substances and preparations

Concentration of the heavy and trace metals in leaching solution is significantly higher than the allowable level for the environment, which makes the leaching solution extremely dangerous for the environment and human life. In figure 2 the excess of permissible concentration of chemical substances in technological cyanide leaching solution is presented [11].

Moreover, cyanide also tends to react readily with many chemical elements, producing a wide variety of toxic, cyanide-related compounds. Thus, the facility is consequently classified as "Category A" with respect to dangerous substances and preparations.
According to Resolution 2000/532/ЕО [8] the overall classification of the studied soils is “Category A”.

5. Discussion
The two types of mining wastes produced by Russian mining companies have been classified according to European standards. Although both types of wastes, based on their genesis [8] are regarded as non-hazardous “01 04 12 tailing and other wastes from washing and cleaning of minerals”, wastes produced as a result of heap leaching belong to Category A wastes.

Moreover, it may be affirmed, that general principles of Russian and foreign classification are different. Russian authors mostly focus on genetic and morphological characteristics of the mining wastes. In spite of the fact that this approach allows to structure the classification system and determine the qualitative and in some cases quantitative criteria, within the framework of the topical geotechnical challenges namely to ensure the human and environmental safety, method of the risk assessment may be more applicable on practice. In table 1 the names for the studied soils are provided according to some of the abovementioned classification systems.

Table 1. Russian classification systems for artificial wastes and Directive 2006/21/EC [9].

| Classification  | The coal sludge from the waste dump of the Pechora coal processing plant, Russia | The soils from the heap leach pads, Kuranakh gold mine site, Russia |
|-----------------|---------------------------------------------------------------------------------|------------------------------------------------------------------|
| Directive 2006/21/EC | 01 04 12 tailing and other wastes from washing and cleaning of minerals | 01 04 12 tailing and other wastes from washing and cleaning of minerals |
| Afonin et al, 1990 | Man-made soils; hydraulic waste disposal | Man-made soils; hydraulic waste disposal |
| GOST 25100-2011 | Altered due to anthropogenic activity soils in class of unbound disperse soils | Displaced due to anthropogenic activity and altered soils in class of unbound disperse soils |
| F.V.Kotlov, 1978 | Ground-based hydraulic mining waste | Ground-based hydraulic waste from the processing |
| Classification by hazard class | «Class V» (the lowest degree of harmful impact) | «Class V» (the lowest degree of harmful impact) |

As it may be seen, the distinct difference between two studied types of artificial soils emerges only when classifying according to Directive 2006/21/EC [9]. Nevertheless, after classifying the mining wastes according to Directive 2006/21/EC [9], the uncertainties rise up:

1. The waste facility most probable is not homogeneous due to variations in ore properties, prolonged storage process and tailings quality. It means that stratification occurs in vertical and horizontal directions and prediction of the distribution of the properties may cause difficulties. Moreover, hazardous wastes, stored in the upper part of waste facility will be more critical than on the base in the bottom part of the facility. It means that for accurate risk analysis it is not enough to classify the wastes, but the only way to produce the reliable scenario is to combine the data on waste type with quantities and distribution of the waste and assumptions about waste behavior, where as a result the extensive scenario model should be presented. So, quite large amounts data are required for making reliable assumptions.

2. In European system, mining wastes are regarded as wastes. It means the basic physical and mechanical properties, which in some cases may be essential to determine the waste facility behavior, are not taken into account.

6. Conclusion
Summing up, one of the most applicable methods for mining wastes classification is risk assessment. If the proper analysis of the risks was carried out, it may be the key argument for decision making as during forthcoming mining works, as during closing stage. So, even if this approach requires a bulk
information and quite deep analysis of external and internal conditions, the results may be used for ensuring the safe conditions on the mine site.

Considering the Russian classification systems, the general idea in the majority of classifications is to show the genesis of the mining wastes, their state, chemical and mineralogical content. As a rule, such classifications are applied for solving geological and geotechnical issues. Nevertheless, foregoing analysis suggests that in the modern world it is not enough to appeal only such kind of classification as it may be not efficient enough. It is needed to extend such kind of research about typification and classification of the mining wastes for providing both rational and ensuring safety decision making.

7. References

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