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THE PILE STORAGE OF POTASH PLANT TO THE SELECTED RECLAMATION DIRECTIONS

Summary. Storage of mine rocks into the outer piles must be carried out taking into account the direction of the subsequent use of restored areas. On the mine technical stage of the reclamation salt piles are to have an acceptable slope angle for further placement of waterproofing coating and fertile layer. Flattening the angle of the slope with increasing footprint of salt pile is unacceptable as entails an increase in the area of disturbed land. In addition, the flattening of slopes significantly increases the volume of the waterproofing works of salt pile and construction of hydraulic structures for drainage and collection of brines, being formed under the influence of precipitation. To solve this problem, it is offered the option of storing salt pile using berms: transport and technology. By forming berms resulting angle of slope of salt pile is up to 30° with a slight increase in height of salt pile. Berm parameters are selected from condition for transport accessibility and the possibility of future maintenance and monitoring of waterproofing coating and fertile layer. As a waterproofing material used geo-membrane.

Keywords: mine technical reclamation, salt piles, salt waste, halite waste deposit of potassium salts, the salt piles parameters, berm.

SKŁADOWISKO W FORMIE NASYPU POCHODZĄCE Z KOPALNI POTAŻU W KONTEKŚCIE POŻĄDANYCH KIERUNKÓW REKULTYWACJI

Streszczenie. Składowanie odpadów górniczych na nasypach zewnętrznych musi być przeprowadzone z uwzględnieniem kierunku dalszego użytkowania terenów rekultywowanych. W górniczej, technicznej fazie rekultywacji nasypy soli muszą mieć odpowiednie nachylenie zbocza, aby nałożyć na nie wodoodporne podłoże i warstwę nawozu. Złagodzenie nachylenia zbocza wiąże

się z poszerzeniem terenu nasypu soli, co jest nieakceptowalne, gdyż powoduje powiększenie zaburzonego terenu. Dodatkowo złagodzenie zbocza znacząco zwiększa zakres wodoszczelnych zabezpieczeń nasypu soli i wymusza konstruowanie struktur hydraulicznych do odprowadzania i gromadzenia słonej wody, która tworzy się wskutek opadów atmosferycznych. W celu rozwiązania tego problemu zaproponowano opcję składowiska w formie nasypu. Formowanie wałów pozwala na uzyskanie nachylenia zbocza do 30°, z niewielkim podwyższeniem wysokości nasypu soli. Parametry wałów zostały wybrane na podstawie dostępności transportu i możliwości przyszłego konserwowania oraz monitoringu powłoki wodoodpornej i warstwy nawozu. Jako materiał wodo-odporny stosuje się geomembranę. W celu nałożenia warstwy nawozu zaleca się technikę, która powoduje jak najmniejszy nacisk na powierzchnię.

Słowa kluczowe: techniczna rekultywacja górnicza, nasypy soli, odpady zawierające sól, odpady z halitu, zawierające złoża soli potasu, parametry nasypów soli, wały.

1. Introduction

Currently potash plants produce for the world market 40-42 million tonnes of output annualy, which is associated with 100-120 million tonnes of solid halite waste (salt refuse and clay slime) and approximately the same amounts of superfluous salt brines[1].

The technology of potassium waste storage has to be addressed as an integral part of the production process, with due consideration of environmental requirements. Taking into account the fact that salt piles are sources of secondary pollution, measures have to be taken to assure waterproofing in cases of high pressure and salt brine attacks.

Halite waste of potash plants, stocked into piles, has some specific properties, e.g. slumping tendency, water solubility and phytotoxicity. Phytotoxicity of halite waste results from high (up to 80% of total mass) content of NaCl, which complicates reclamation works[2].

Taking into account specific parameters of territory transfer caused by salt waste piling and state standard GOST 17.5.3.05-84, it is feasible to carry out land reclamation in sanitary-hygienic direction. Sanitary-hygienic reclamation of salt piles is aimed at biological or technical preservation of halite waste, having a negative impact on surface and subterranean waters in the waste pile region. Sanitary-hygienic reclamation resolves the issue of rapid erosion-preventive soil stabilization through setting plants on the slopes.

Phytotoxic rock should be safely isolated from overlying soil, i.e. an impermeable membrane should be placed between the salt and the soil. On the one hand, this membrane

[1] Vostretsov S.P., Tagilov M.A., Korobova N.E.: Concept of halite waste storage in salt piles for OAO "Uralkaliy" OAO "Galurgia", Perm 2013, p. 50.
[2] Vostretsov S.P.: Promotion of safety for high-pile salt dumps in the Urals. Development of potash deposits, Perm 1989, p. 174-181.

will prevent salts from getting into the soil layer, on the other - it will leave out the contact between atmospheric precipitation and the waste pile. To protect the material of the membrane from solar radiation and mechanical damage, there is a need for a topsoil cover (potentially fertile). Its minimal thickness should not be less than 50 cm. To create a topsoil cover, potentially fertile soil is stabilized by planting meadow grass and thereby preserving halite waste.

To facilitate rapid growth of ameliorative plants, it is feasible to create plateau (flat) waste piles, having a regular geometric shape most closely resembling a square or a rectangle[3]. This shape of waste piles is most reasonable for reclamation and subsequent use of restored lands[4].

Flattening of salt pile slopes is unadvisable, as it requires additional land transfer and screening; moreover, slumping and recrystallization of salts lead to changes in structural behavior of halite waste - the salts acquire a new aggregate state, a solid man-made material with mechanical properties of a hard rock[5].

2. The pile storage of potash plant to the selected reclamation directions

In order to resolve this issue, an option to create salt piles using berms on the slopes is suggested. Construction of berms on the slopes reduces the resulting angle of the slope, but in order to maintain the volume of rock stocked the height of the pile must be increased[6].

The limiting factors for the height of the salt pile include morphology requirements for the selected reclamation method[7]. When selecting the maximum height, it should be taken into account that the higher the salt pile is, the bigger share of land amounts to the slopes, the reclamation of which is more difficult and expensive than the one of the flat top. The maximum height of the waste pile, satisfying the requirements of economic efficiency, has to be justified.

In simplified form, cross section of a salt pile is a trapezium; its lower base is constant and its upper base decreases depending on the slope angle and height. Let us consider an average value of the cross section area: if lower base equals 500 m, height is 100 m and slope angle is 38^{o}, the cross section area will amount to 37,200 m^2. Relationship between the height of the salt pile and the slope angle at a constant cross section area is presented in Table 1.

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[3] Opryshko D.S.: Modern approaches to mining reclamation works. GIAB No. 10/2011, Moscow 2011, p. 191-194.
[4] Fomin S.I.: Rational use and reclamation of disturbed lands [in:] Fomin S.I., Ubugunov E.L., Ubugunov V.L. Ulan-Ude: Buryat scientific center of Siberian branch of Russian Academy of Sciences, 2012, p. 87.
[5] Fomin S.I.: Rational conditions for opencast shovels. Fomin S.I., Donchenko T.V., Ivanov V.V. [in:] Scientific and industrial magazine Cement and its application". Spb.: 6/2007, p. 23-25.
[6] Komarov Y.A.: Justification of effective methods to stock halite waste, [in:] Prospects of innovative development for coal-mining regions of Russia. Summary of 4th International Scientific-Practical Conference. Prokopyevsk 2014, p. 45-49.
[7] Fomin S.I.: Productivity of opencasts and demand for mineral raw materials. Fomin S. I. S-Pb. Tema, 1999, p. 169.

Table 1

Relationship between the height of the salt pile and the slope angle at a constant cross section area

Slope angle, ^{o}	Pile height, m	Site width on the bench crest, m	Cross section area, m^2
40	97	268,8	37200
39	99	255,5	37200
38	100	244	37200
37	102	229,3	37200
36	104,5	212,3	37200
35	107,3	193,5	37200
34	110,8	171,5	37200
33	115,5	144,3	37200
32	122,2	108,9	37200
31	135,7	48,3	37200
30	144,3	-	36084

Source: Own work.

The decisive factor for the resulting slope angle is the minimal site width on the bench crest. Its minimal width is approximately 70 m and it is used to arrange a conveying belt and an autoroad for maintenance purposes.

Data from Table 1 demonstrate that the minimal slope angle, meeting this requirement, is 32°. Figure 1 presents the key properties of an open-cast mine designed with berms and meeting the mentioned criteria.

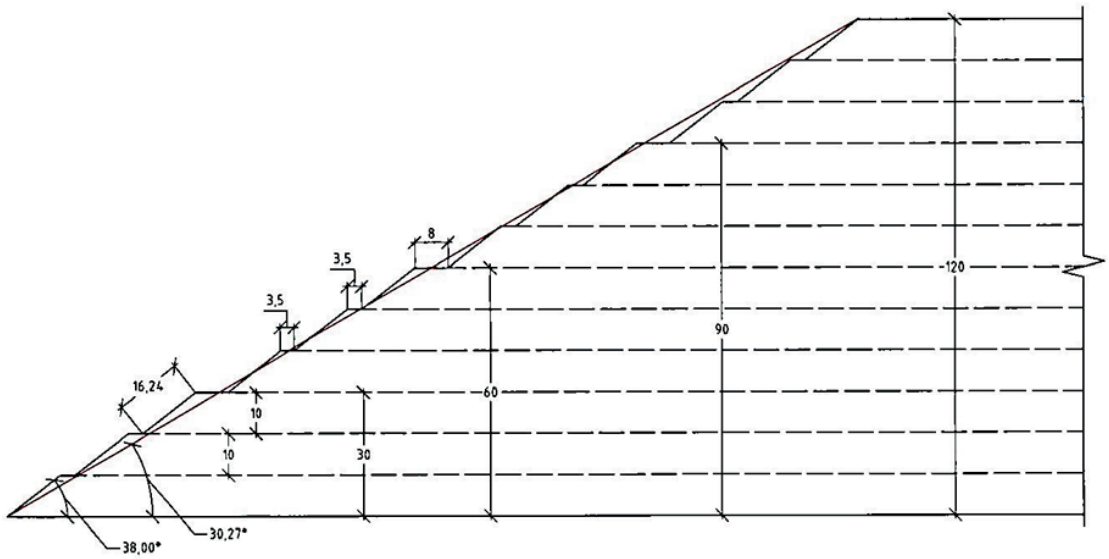

Fig. 1. Scheme of slope formation with berms
Rys. 1. Schemat tworzenia skarpy z nasypów
Source: Developed and offered by the authors

Berms are created in the rear and on the sides. The front part of the pile is provided with berms at the final stages of stocking. Berms are created from the bottom up: two technical ones, one for transport etc. The width of a technical berm is 3.5 m, a transport berm is 8 m wide. In the scheme the width of the berms is minimal, but all the technology requirements are met. The berms are created through hydraulic fill.

The technological stage of salt pile reclamation includes both rough and final grading of the flat top and special treatment of the outer slope surface. Rough grading procedures imply initial leveling and the major share of grading, which is done following the frontal advance of waste stocking at a minimal lag ensuring the safety of operation. During rough grading the requisite ground profile is created at the flat top of the pile, which decreases the cost of the final grading stage. Final grading is aimed at creating favorable conditions for plants through designing a suitable microrelief on the flat top of the pile - it can be mono- or duo-pitch slope, a rolling or flat surface. After final grading is complete, a waterproofing layer is being formed to protect the salt pile from atmospheric precipitation.

Waterproofing of the salt pile implies creation of a waterproof protective layer, substantial in the given climate conditions. The specific character of salt waste waterproofing comes from the fact that these materials are subject to reaction with water and other atmospheric factors on the one hand and aggressive salts on the other[8]. Due to atmospheric factors the cover will periodically dampen and dry out, freeze and thaw, experience snowfalls and intensive water flows, heat and ultraviolet radiation. Salt corrosion can result in salt migrating

[8] Report on research activity. Survey on hydrophobic and film-forming materials to protect the surface of salt piles from dissolution in atmospheric precipitation. Leningrad 1974, p. 59.

through the pores to the surface (efflorescence), in flaking and cracking of the cover due to salt accumulation in the pores and salt volume increase when halite turns into its hydrohalite form[9].

Today application of impermeable membranes made of cutting-edge geosynthetic materials is the most reliable and widely used method to prevent contamination of the environment. Specialized firms, both in Russia and abroad, have enough expertise in designing polymer materials and constructing impermeable membranes of different complexity levels. Usually geomembranes constitute a part of a geocomposite structure, where a waterproofing element is combined with protective gaskets, increasing the resistance of the structure towards mechanical damage. As a protective gasket, one can use woven or non-woven geotextile[10].

Geomembranes are film materials made of synthetic polymers. They can be supporting or unsupporting. Supporting materials are made of woven or non-woven geotextile, glass fiber etc. The thickness of geomembranes is normally between 1.0 and 4.0 mm.

Modern geosynthetic materials have a number of significant advantages over other materials:

- take significant pulling stress;
- remain firm even under large deformations;
- are homogenous;
- are long-lasting (producers give a warrantee for 50 years or even longer);
- are technologically sophisticated and effective in construction;
- are applicable in all climatic zones from -70°C to + 50°C.

Figure 2 demonstrates the covering of a slope with waterproofing materials.

[9] Kopshtalev V.P., Slanevsky V.V.: Input data for developing measures to reduce sources of salt brine formation. ZAO VNII Galurgy, St. Petersburg 2013, p. 78.

[10] Slanevsky V.V., Smirnova V.S., Nikolaeva T.N.: Reclamation of salt piles as a method to protect the environment from salination. Scientific conference abstract, St. Petersburg State Mining Institute, St. Petersburg 1998, p. 188-189.

Fig. 2. Covering the slope with waterproofing materials
Rys. 2. Pokrywanie stoku materiałem hydroizolacyjnym

The unloading of fertile soil on the impermeable membrane is done "sparingly". The grading of the fertile soil cover on the flat top and on the slopes of a salt pile can be done by a special equipment "Ratrack". It has been successfully applied in turf development, landfill reclamation, mowing and mulching on delicate surfaces. The gradeability of the machine is up to 40^0 . In Figure 3 "Ratrack" is forming a fertile soil cover on the slope.

Fig. 3. Ratrack forming a fertile soil cover on the slope
Rys. 3. Rozkładanie warstwy żyznej gleby na stoku za pomocą ratraka

3. Conclusions

Therefore, to make a decision on maximum height, it is essential to bear in mind that as the height of the pile increases, so does the area of the slopes; and reclamation of slopes is much more difficult and expensive compared to the one of the flat top of the waste pile. Sanitary-hygienic reclamation of halite waste is the most feasible option, since it prevents the negative impact of the waste on the environment and cuts the costs of reclamation. High-pile storage of salt waste with creation of berms on the slopes should be designed using a principal scheme, allowing to obtain a resulting slope angle, meeting the safety and maintenance requirements. At the engineering stage of salt pile reclamation, parameters and shape of the flattened slopes should meet the requirements of the selected reclamation method and waterproofing conditions, reducing the leveling and grading procedures, increasing efficiency and safety of operations.

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Omówienie

Składowanie odpadów górniczych na nasypach zewnętrznych musi być przeprowadzone z uwzględnieniem kierunku dalszego użytkowania terenów rekultywowanych. Umieszczenie warstwy halitu na nasypach musi odbyć się z uwzględnieniem geologicznych własności złoża, obranego kierunku rekultywacji terenu i z myślą o jak najszybszym przywróceniu zaburzonego terenu do użytku w ramach krajowej gospodarki.