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Article

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DEVELOPMENT OF A METHOD OF UTILIZATION OF OIL AND GAS INDUSTRY WASTE AT PERESHCHEPYNO FIELD (UKRAINE)

The object of research is the technological solutions for the construction of sludge barns at the Pereschepyno field (Ukraine). One of the most problematic places is the lack of reliable insulation of sludge barns and storage facilities.

The study used a screen type «wall in the soil» of elements of soil cement, which prevents the filtration of the aqueous phase. The screen was built monolithic. It is proposed to arrange the shade between the centers of the curtain equal to 0.8 of the diameter of the element. It is proposed to make elements from soil cement by the brown-mixing method. After 28 days (hardening of the elements) up to 60 % of the soil was removed from the waste storage area. This is due to the fact that the proposed method of arrangement of waste storage has a number of features. Over time, the strength and permeability of the aqueous phase of soil cement increase. It is proposed to fill the storage with drilling waste after the enclosing elements have hardened. In order for the soil to have a suitable humidity of 4–5 %, it is proposed to dry it outdoors. It is proposed to build a cover over the soil dump. If the optimum humidity of the mixture is not obtained after drying and mixing the waste with the soil, it is proposed to add a drying additive (ash removal of Mykolayiv thermal power plant). The amount of additive is from 1.5 to 3 % depending on the type of soil. Next, it is proposed to seal the layers of sludge and loam by rammers. After compaction, the operation is repeated. Compaction of soil layers is proposed to be carried out at optimum humidity. In comparison with similar known methods, this method provides the following advantages: low cost of manufacture due to the use of a waterproof layer of soil as the bottom of the structure; high water resistance – W12; high compressive strength; environmental safety and durability.

Keywords: *soil cement, removal ash, soil protection, groundwater protection, sludge barns.*

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1. Introduction

The presence of waste is an integral part of the formation of the quality of the natural environment and people's lives. Production and technologies are constantly developing, their capacities are growing and they generate a significant amount of waste. Such circumstances require a comprehensive approach to solving the problem of processing, utilization and liquidation of industrial waste. Safe waste management is, first of all, the disposal of used resources that do not perform basic functions and cannot find a target application.

The practice of conducting drilling operations during oil and gas production has shown that the most significant problems from the point of view of their negative impact on the environment are the generation of a significant amount of waste from drilling and operation of oil and gas wells. Barns are built at oil-producing enterprises to collect waste from the site when drilling wells. In the process of drilling wells, they are filled with appropriate drilling and tamponage solutions, formation waters, drilling waste water and sludge, and solid household waste. The ratio between the components of the waste generated during drilling can be different. It depends on the technical condition of the equipment, geological conditions, and the operations being carried out. For example, to ensure optimal operation of the installation, the waste will consist of approximately 65 % water, 30 % mud (drilled rock), 5.5 % oil, 0.5 % bentonite and 0.5 % various additives [1]. Landfilling of drilling and well operation waste is the most widespread way of their elimination.

Drilling waste is disposed of in places designated for this purpose, in earthen storage facilities (barns) directly on the territory of the drilling site.

The dimensions of barns are designed individually, based on the volumes of waste and well drilling [2]. A feature of the construction of barns for storing drilling waste is the need to install insulation against their ingress into soil and wastewater. The lack of high-quality waterproofing leads to the entry of barn contents into groundwater and further migration of pollutants. Therefore, the problem of storage of drilling waste and subsequent reclamation of land on the territory of drilling sites is quite urgent.

Claying of the bottom and walls of storage facilities is used in a number of regions – artificial filling of cavities and large cracks in the massif of rocks or soil with clay. However, claying does not give the proper result. This method is quite time-consuming and non-technological.

A more ecologically safe way of disposal of drilling waste involves the construction of pits in the soil with waterproofing. Waterproofing of such sludge storage facilities protects groundwater from the ingress of toxic waste, ensures decontamination and safe burial of processed masses. For waterproofing, metal sheets, synthetic film, reinforced concrete slabs, bentonite mats, wooden shields with a bitumen coating or compositions based on clay, lime and cement are used [2].

A well-known method of installing waterproofing of sludge barns using geotextile membranes. According to this technology, after carrying out engineering searches and relevant calculations, the GEOFLAX geomembrane is laid in the sludge storage at the project mark. Then crushed stone is poured to create a layer of protection against flooding (drainage ditch), then the surface of the lower slope is sown with herbs. The GEOFLAX membrane is distinguished by its lack of toxicity and safety of use. GEOFLAX is resistant to ultraviolet rays and critical temperatures. Despite the complexity, the work is performed quickly due to the lightness and flexibility of the roll materials, however, damage to the membranes is possible under force. The main disadvantage of geomembranes as waterproofing during the construction of a slurry barn is the multi-stage installation.

The need to create sludge storage facilities is related to the prevention of pollutants entering the soil and groundwater. Therefore, special care and professionalism should be exercised during the construction of such structures. When erecting such structures, it is necessary to strictly follow the stages of construction of sludge storage facilities.

Another common material for waterproofing slurry barns is cement. However, it has a significant drawback – unstable, mobile soil can lead to the formation of cracks in the cement coating with all the consequences.

The author of the work [3] recommends installing waterproofing in two stages. At the first stage, a solution based on tamponage cement is applied to the walls and bottom of the barn. At the second stage, after the first layer has hardened, a layer based on polyacrylamide and tamponage cement is applied to reduce the likelihood of cracks.

The author of the work [2] proposes the arrangement of a sludge barn using soil cement technology by means of the production of elements by drilling and mixing technology, where the extraction of soil is excluded. According to this technology, wells are drilled around the barn. These wells are arranged from soil cement. In this way, let's obtain an anti-filtration screen. The listed methods of performing screens that prevent groundwater filtration are time-consuming and economically unprofitable. Over time, such screens can lose chemical resistance. Thus, technological solutions for the construction of slurry barns at the Pereshchepyno field (Ukraine) were chosen as *the object of the study*. *The purpose of the work* is to improve the technologies for arranging the storage of drilling waste (slurry storage).

2. Research methodology

It is necessary to improve the waterproofing of barns for temporary storage of drilling waste. Such isolation should ensure guaranteed protection of surface and groundwater from pollution and compliance with environmental safety standards. It is proposed to do this by insulating the walls and bottom of barns from soil and underground water with soil cement.

Soil cement is a multiphase system consisting of soil and hydraulic binder (cement). The soil has a polydisperse and polymineral composition. The gel formed during the hydrolysis of cement envelops the side surface of each mineral particle and forms a water-insoluble structure with it. In contrast to cement concrete, ground cement, as a rule, does not have large debris fractions (crushed gravel) in its composition. The strength of soil cement depends on the type of neoplasms (cement hydration products). They are formed by the interaction of the finely dispersed part of the soil and free silicic acid with lime released during the hydrolysis of cement. Let's consider technological solutions for the construction of slurry barns (storage facilities) at the Pereshchepyno field (Ukraine).

The Pereshchepyno field is a field that is currently under industrial development. The Pereshchepyno deposit is located within the southern part of the Dnipro-Donetsk oil and gas region, where industrial hydrocarbon deposits are found in a wide stratigraphic range from the Bashkir layer of middle Carboniferous deposits to the rocks of the crystalline basement.

By 2015, two operational wells 207, 211 and exploratory wells 300, 310 were put into operation at the Pereshchepyno field. As of September 1, 2017, gas-concentrate deposits of the horizons of the mountains are under development C-17, C-15, C-3, B-13b, B-10, B-8b, and B-6 [4].

According to the results of engineering and geological investigations conducted at the drilling site of well No. 309 of the Pereshchepyno field, after removing the fertile soil layer of washed light clay to a depth of 0.8 m, the approximate geological section (up to a depth of 10.0 m) is as follows:

– soil-vegetation layer: loamy humus with a thickness of 0.4 m;
– dark-gray, gray, humus-rich loams with plant roots and earthworks 0.3–0.4 m thick (I, Fig. 1);
– light-yellow-brown, hard, loams with thin layers of carbonates with a thickness of 2.2–2.6 m (II, Fig. 1);
– light-gray, fawn-colored loams, rigidly plastic, in a water-saturated state soft-plastic, impermeable with a thickness of 2.2–2.6 m (III, Fig. 1);
– yellow-brown, brownish-brown, light brown loams, semi-hard, with rare carbonate concretions, in the sole with layers of clay. The thickness of these loams is 2.1–2.8 m (IV, Fig. 1);
– fine, multi-grained, yellow-brown, yellow, gray, light-gray, medium-density and dense, moist and water-saturated sands lie to a depth of 10.0 m and deeper (V, Fig. 1).

According to the results of engineering-geological surveys conducted at the site of wells No. 310, 309 of the Pereshchepyno field, the level of the first aquifer (groundwater) is at a depth of about 7.5–9.2 m from the surface [4]. According to the refined project of industrial development of the field, to prevent contamination with liquid waste from drilling the first aquifer, it is proposed to store them in earthen, waterproofed sludge barns. It is suggested to build storage facilities in soils with a filtration coefficient $K_f=1.16\cdot 10^{-5}$ cm/s [2]. The aquifer is located at depths of approximately 10.0–15.0 m.

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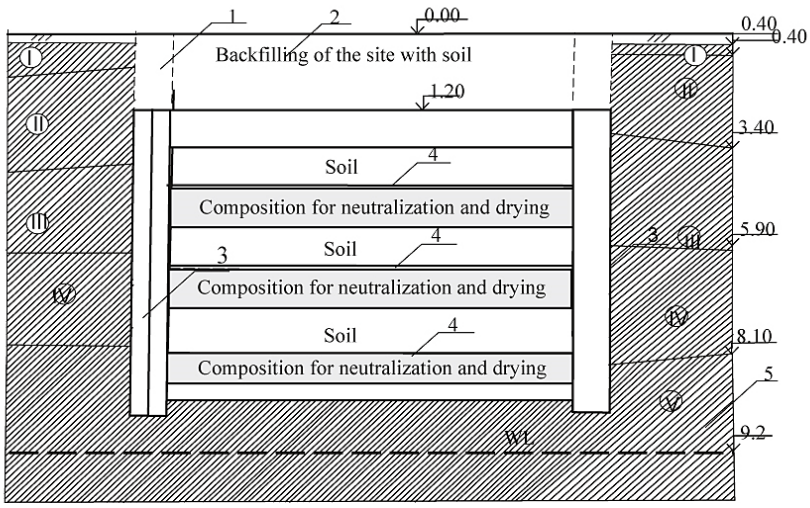

Fig. 1. Sludge storage of the proposed design: 1 – soil-cement element that can be dismantled; 2 – backfilling of the site with soil; 3 – soil-cement element of the sludge storage facility; 4 – composition for neutralization and drying; 5 – clay soil (water resistance); I, II, III, IV, V – corresponding engineering and geological elements

The volume of storage barns, which are arranged for the purpose of storing drilling waste and drilled rock, is calculated according to GSTU 41-00 032-626-00-007-97 and is 5061 m^3. Three earth storage barns with a volume of 1,690 m^3 each were designed for separate collection of sludge and spent washing liquid [4].

The first is for temporary storage of associated rock, collection of spent washing liquid. The second and third are for settling filtered washing liquid, collecting used technical water.

The first settling barn is built in such a way that the excess liquid overflows into the next second settling barn. The second barn is arranged in such a way that the excess of liquid coming from the first overflows into the third, from which the settled water will then be pumped out.

Along the perimeter of the barns, it is proposed to arrange a fence made of the soil of the construction site with a height of 0.5 m. It is proposed to arrange a colloidal-chemical anti-filtration screen on the bottom and walls of the barns. At the same time, a decrease in the soil filtration coefficient is expected (Fig. 2). Such a screen consists of an aqueous suspension of hydrolyzed polyacrylamide (HPAA) and bentonite clay. The width of the bottom of the barn is proposed to be 10.1 m. The width of the top of the barn, including slopes, is 16.1 m.

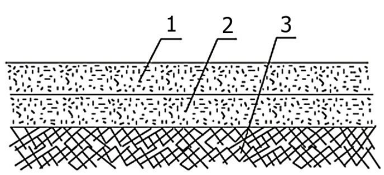

Fig. 2. Technological solution of the colloid-chemical screen: 1 – polymer-clay layer; 2 – diffusion layer; 3 – natural soil

The surface of the bottom and walls of sludge barns for applying a waterproofing layer, including slopes, was 2639.2 m^2. Material consumption per 1,000 m^2 of surface is: hydrolyzed polyacrylamide – 30–50 kg, bentonite – 600–800 kg, technical water – 10,000–12,000 kg [4].

The polymer-clay mixture is applied to the bottom and walls of the barn using this technology. The aqueous solution of HPAA is prepared in the appropriate containers of the cementing unit. The mass fraction of hydrolyzed polyacrylamide is 0.3–0.5 %. After obtaining a homogeneous solution of hydrolyzed polyacrylamide, bentonite clay is placed in measuring containers. The mass fraction of bentonite clay was 6–8 %. The resulting solution must be intensively mixed for 30–40 minutes. The solution is applied using a CA-320 pump unit (Ukraine). After drying of the surface, it is necessary to perform repeated processing.

In order to prevent cracking of the screen after drying, it is necessary to treat its surface with an aqueous solution of aluminum sulfate (5 wt. %).

Processing should be carried out with the help of a cementing unit by feeding the solution through the spray nozzle of the injection line.

At the same time, the optimal steepness of slopes 1:(2–3) should be preserved. The filtration coefficient of such screens based on bentonite and hydrolyzed polyacrylamide does not exceed 10–5 cm/s.

3. Research results and discussion

The design of the sludge storage facility is proposed, as shown in Fig. 1.

The construction of waste storage facilities begins with the removal of the upper soil-vegetation layer of the soil and its storage near the construction site. Then directly digging the protective structure and assembling the soil for its further use in the preparation of the solution, erecting a 0.5 m high embankment along the perimeter of the structure to prevent surface water from entering it.

A vertical curtain of the «wall in the soil» type is being constructed to prevent the filtering of harmful substances. During the construction of a waste storage facility, it is advisable to design the distances between the centers of neighboring soil elements 0.8 times the diameter of the soil-cement elements. Soil-cement elements are proposed to be manufactured by the drilling method [5, 6].

The main processes of the technology are mechanical destruction (shredding) of the soil, injection of a binder (stabilizer) into the soil, and mixing of the soil with the binding working body of the drilling machine.

The cement mortar is made in a mortar mixer and pumped with a mortar pump using a swivel to the loosened soil. It is possible to make cement mortar using mortar mixers when the conditions for ensuring the homogeneity of the suspension for soil consolidation are met [6].

For the production of soil-cement elements, it is possible to use construction diaphragm or drilling plunger pumps, which create a pressure of at least σ=0.5–0.7 MPa. The swivel consists of two parts – movable and stationary. The non-moving part is the body, cover and pipe outlet. The rotating part of the swivel consists of a trunk, which rests on bearings to center it relative to the body.

A thrust ball bearing is used as the main middle support. As the upper bearing, a tapered roller bearing is used, and the lower one is a sliding bearing. A steel casting is used as the body of the swivel, which is hinged with an earring [7].

On top is the housing cover, which is attached to it with bolts.

In the lower part of the housing there is an oil gland cover, which prevents oil from leaking out of the swivel housing. A pressure gland with a V-shaped cuff seals the gap between the barrel and the pressure pipe. The inner part of the housing is filled with oil through the hole located in the upper part of the housing. It is closed with a plug with a hole for the escape of oil vapors.

Soils are destroyed at the bottom of the well, and then cement mortar is injected into them and moved to a homogeneous state of the mixture. The quality of the mixing of the soil and cement mixture depends significantly on the speed of immersion of the agitator into the soil [8, 9].

The pressure auger allows adjusting the thickness of soil mixing, with its help it is possible to achieve the smallest thickness. It is recommended to use such a drill mixer when passing heavy loams and light clays. When using it, the best mixing of the cement and soil mixture is achieved. In this way, to get elements with a diameter of up to 0.8 m and a length of up to 30 m [1]. The antifiltration screen of the type «wall in the soil» made of soil-cement elements should be buried in the waterproof layer of the soil to a depth of at least 1 m, so that no filtering of harmful substances occurs. After 28 days, which is enough for the strength of the soil-cement elements in the storage, up to 60 % of the soil is removed [1]. Over time, it is possible to observe an increase in the strength and waterproofing of soil cement.

Filling of the slurry storage with drilling waste is carried out after hardening of the soil cement. Before entering the storage, drilling waste needs separation of the aqueous phase.

It is proposed to fill the storage with waste in the following way: at the bottom of the storage it is necessary to place waste with a thickness of about 1 m, then cover this layer with the soil of the construction site, which has a moisture content of about 5 %. The thickness of this layer should be taken up to 1 m. In the Poltava region loam prevails. In order to reduce soil moisture, drying in the open air is recommended.

If it is not possible to obtain the optimal moisture content of the mixture after drying, it is suggested to add ash removed from the Mykolaiv Thermal Power Plant. The amount of additive is from 1.5 to 3 %, depending on the type of soil.

The thickness of the layers is selected and calculated to obtain the optimal moisture content of the mixture of sludge and soil. Then it is necessary to compact the layers of silt and loam. After sealing, the operation is repeated. Compaction of soil layers should be carried out at optimal humidity in order to obtain the highest compaction coefficient and place the maximum amount of waste in the storage.

In the case of mainly oil (gas condensate) pollution, a method is used in which neutralization is achieved by accelerating the decomposition of organic compounds. A composition containing phosphogypsum, straw and organic fertilizers are introduced into a barn isolated from the ingress of groundwater for storing drilling waste: phosphogypsum 2.0–3.0 wt. %; straw 1.0–2.0 wt. %; organic fertilizers 3.0–5.0 wt. %.

After neutralization, drilling waste is buried in earthen sludge barns. If there is a high level of contamination with oil and oil products and when it is a plastic strength of the soil of 0.68–1.00 MPa, add the biological preparation «Ekonadine» (Ukraine). It is a sorbent and destructor of oil hydrocarbons at the rate of 1–2 liters per 1 m^2. Then the surface is plowed. If the parameters of purified water do not comply with the normative ones, they are brought to the required quality by repeated treatment with coagulants and flocculants. Polyacrylamide (PAA) is often used as a flocculant. If the value pH<5.5, it is recommended to neutralize the wastewater with an aqueous solution of lime or soda ash.

The advantages of the construction of a mud storage facility with the installation of a soil cement coating, which is placed on drilling mud thickened to a rigid plastic consistency with the addition of construction site soil, is the low cost of manufacturing due to the use of a waterproof layer of soil as the bottom of the structure. After hardening, the waste storage cover is covered with a layer of site soil. Thus, it is possible to solve the problem of disposal of the soil removed during the construction of the storage facility.

It is proposed to store waste in the storage, as a mixture of sludge formed when drilling wells and soil (in the Poltava region, we often have rigid loam). When laying, layers of sludge and soil are laid alternately.

The limitation of the application of this method of setting up a waste storage facility is the condition of having a waterproof layer at the optimal depth from the surface (8–20 m). Also, to gain appropriate strength, natural soil must have a moisture content of more than 15 % [10]. In the future, it is necessary to investigate the improvement of the strength characteristics of soil cement and its behavior in a dry environment.

4. Conclusions

The paper proposes a procedure for the construction of a sludge storage facility, which includes the following main stages: construction of the storage frame from soil-cement elements; storage of drilling waste after neutralization in layers of about 1 m. Then, the site is covered with soil with mandatory compaction of the mixture at optimal humidity. After that, a covering of soil cement is arranged.

It was found that the given method of creating a technological solution is promising, provided there is a waterproof layer at the optimal depth from the surface (8–20 m).

The advantages of soil cement as a material for the construction of waste storage facilities, which has high waterproofing, have been confirmed; compressive strength and is safe.

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The necessity of adding a drying additive (ash removed from the Mykolaiv Thermal Power Plant) was discovered in order to obtain the optimal moisture content of the mixture of drilling waste with the site soil. The amount of additive is from 1.5 to 3 %, depending on the type of soil.

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