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Review Article

Accidents at Waste Storage Facilities: Methods of Struggle with the Consequences of Accidents

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Abstract

The article deals with such issues as storage of industrial waste, causes, examples and prevention of accidents, NGO operation and reclamation, and methods of dealing with the consequences of accidents. When storing industrial waste in large volumes, various complications arise, including accidents in waste storage facilities. The article provides examples of accidents for specific objects and analyzes their causes and consequences. The methods of dealing with the consequences of accidents and their prevention are considered. The materials of the article can help specialists improve the design and operation of waste storage facilities.

Storage of industrial waste

Industrial waste storage facilities (NGOs) belong to special hydraulic structures. These are ash and slag dumps (ash) and sludge dumps (SHO) of thermal power plants (TPP), sludge storage tanks, oilfield wastewater storages, tailings dumps of mining and processing plants (GOK), etc. Works related to the accumulation and storage of waste, with the elimination of the consequences of accidents at NGOs, etc. in northern Russia have specific features due to the harsh climate.

The waters of the settling ponds of the ZSHO TPP are complex multicomponent systems, the mineralization of which can reach several grams per liter. Along with the main mineralizers, represented mainly by sulfates, hydro-carbonates, hydroxides, and calcium carbonates, the composition of waters clarified from solid fuel ash includes microcomponents whose concentrations are milligrams and fractions of milligrams per liter. The danger of ash in contact with water is determined not by the very fact of the presence of a toxic element in it, but by its ability to pass into an aqueous medium, the chemical composition of which is formed by all water-soluble ash components [1].

The sedimentation ponds of the ZO TPP hold up to millions of cubic meters of mineralized water clarified from ash, used for hydraulic transportation of ash slag (ZSH) of the TPP to the ash dump.

Causes of accidents

Overflow of settling ponds above the design mark can lead to overflow of water over the crest of the enclosing dams and their breakthrough with a simultaneous discharge of huge volumes of water or ash mixture (man-made mudflow). The consequence of such phenomena is flooding of territories, destruction of buildings and communications, and pollution of soils and natural waters by both ash and water components and components of man-made objects involved in the flooding zone. In the event of an emergency, their contents enter the surface and groundwater of the adjacent territory due to direct discharges and leaks, as well as filtration processes through the bed and sides of the ZSHO.

An analysis of the state of modern multi-tiered NGOs in Russia allows us to identify the following features of these structures. NGOs are distinguished by a high accident rate. reaching 40% of the total number of these structures, which significantly exceeds the accident rate of industrial and hydraulic structures (0.2%). The probability of destruction of NGOs is about 1.5 x 10^{-2} units/year. The high accident rate of these structures is due to both errors made during the design and construction periods and the low qualifications of the maintenance personnel. The largest number of NGO accidents is associated with the destruction of enclosing dams and the breakthrough of the front line, i.e. with a hydrodynamic accident [2].

The analysis of information about recent serious accidents at NGOs in the Russian Federation and abroad allows us to identify the following 4 types of destruction of enclosing dams (primary, extension tier, separation, etc.):

1. Loss of stability of the dam slope
2. The development of a horizontal flaking crack at the contact of thawed and frozen zones in the body of the dam with its subsequent destruction.
3. Erosion of the body of the dam when water overflows over the crest of the dam.
4. The destruction of the dam with the loss of the filtration strength of the soils of its body and base.

In addition to the consequences of an accident on the earth's surface, geological consequences may occur in the area of the accident. When creating an NGO, the geodynamic situation characteristic of this territory undergoes signify-cant changes. The possibility of the emergence of new geological processes for a given area and the assessment of the intensity of their manifestation cannot be based on data from long-term observations, as is the case for natural phenomena. The influence of technogenesis on the state of the geological environment is multifactorial and often difficult to predict due to synergistic effects [3].

After completion of construction, during the entire period of operation, and in many cases after its conservation, geological processes unusual for the area are observed:

A significant rise in the groundwater level, accompanied by a change in their chemical composition and flooding of surrounding areas;

Decompression of clay soils in the lower part of the slopes and the occurrence of landslide phenomena;

Activation of karst processes in the presence of soluble rocks in the sides and bed;

A sharp increase in the rate of precipitation runoff from the catchment area due to deforestation and destruction of vegetation during the construction of a tailings dump and the laying of access roads, pulp ducts, etc.;

The occurrence of hydrodynamic pressures in the soils of the bases, springs in the sides and bottom of the beam below the dam

Examples of accidents

Shkapovskoye oil field: In 1960 - 1961, an oilfield wastewater storage pond was built on the territory of the field, in the valley of the Bazlyk River. Deluvial and periglacial clays and loams up to 10 m thick are developed at the base and left side of the valley [4].

During the construction of the storage unit, it was assumed that the clay screen would be a reliable insulation and leakage through it, due to the weak filtration properties of the rocks, would be insignificant. However, already in the first year of its operation, saltwater griffins appeared below the dam, and salinization of sources previously used for water supply was observed. The area of saline freshwater distribution on the territory of the deposit is up to 500 km^2. In this regard, the operation of the storage pond was discontinued.

ZSHO Ulan-Ude CHPP-1: In August 1985, due to the overflow of the settling pond and the overflow of water over the crest of the enclosing dam, a dam burst occurred at the gully-type ZSHO. 100 thousand cubic meters m3 of polluted water was discharged from the clarified water basin through a hole up to 20 m wide in a few hours. In a radius of up to two km to a meter height, the downstream structures were flooded, and the territories of settlements and meadows were covered with ash and slag waste with a layer of 0.2 m – 0.5 m.

In addition, contamination of groundwater with chemical components of the water of the ZO was noted, which is a consequence of the filtration of water discharged from the dump through the soils. There was also a change in the relief - a channel 10 m - 15 m wide and 2.5 m - 3 m deep was formed in the sandy bottom of the log [5].

The Kachkanarsky GOK tailings dump: One of the largest is a hydrodynamic accident at a Class I retaining hydraulic structure. It consists of three compartments forming a cascade with a drop in the water mirror marks between the upper and lower compartments of 49 m with a maximum difference in the marks of the ridges of the enclosing dams of 54 m [6].

When building up the crest of the separation dam (6 times 1 m), the spillway threshold was increased by creating banquet spillway bridges near the rock overburden. Since, with each build-up, the banquet shifted towards the root slope, the newly built-up dam formed from the tailings, in the area adjacent to the spillway, was laid on a well-wa-shed rock outline, in which there were large voids. This led to the removal of sandy material from the upper (alluvial) part of the dam into the rock outline buried under it, subsidence of the body of the dam, and its subsequent destruction.

In November 1999, as a result of the overflow of water over the crest of the enclosing dams, the formation of holes in them, and the subsequent destruction of the dams, two mudflows formed, which poured into the river. They spread along its valley for a distance of more than 30 km, while there was an outflow of water and sludge with a volume of about 20 million m3. The accident caused serious destruction. Mudflows destroyed 3 automobile bridges, damaged power lines, and asphalt pavement of highways, disrupted the power supply, telephone network, and gas pipeline, and destroyed 5 dams of landfills.

The Udokan deposit of copper sandstones is located in the Kalarsky district of the Trans-Baikal Territory. The average long-term annual air temperature is minus 9 °C. The base is a rocky massif covered with a thickness of coarse-grained soils Within the work area located in the zone of distribution of continuous continental permafrost of a mountain type with a thickness of up to 200 m - 350 m with an average temperature of minus 3 - minus 4 °C, a fairly dense network of tectonic disturbances and faults has been revealed.

The tailings dump is surrounded by several dams. The western primary dam is a 39.5 m high stone-filled prism, class GTS - II. The anti-filtration element is a screen made of a hydromat. To exclude local filtration through the base and sides of the dam, an anti-filtration trench is provided from side to side with the laying of geocomposite material.

From December 2019 to May 2020, the body of the dam was poured out of rocky soils during the cold season with air temperatures close to the minimum annual values, therefore, the soils of the body of the dam are in a frozen state. An anti-filtration screen that prevents the penetration of water and thawing should contribute to the preservation of this state.

The initial filling of the tailings storage volume with water to control its condition began in May 2020. In June, a sharp decrease in the water level in the tailings pond was recorded. A visual examination revealed a water leak site.

As the water was filled, a melt zone formed in the non-rock soils of the base of the tailings dam and the Western Dam at low negative base temperatures. The warming of the base soils is also indicated by the presence of thermo-karsts and the subsidence of territories visually recorded in the summer of 2020. The absence of a continuous anti-fil-tration device at the base of the dam led to water filtration through the rocky massif of the base, characterized by high water permeability [7].

Accident prevention

Various methods are offered to prevent accidents. For example, to discharge water in an organized manner if the situation is not yet critical, but there is a steady increase in the water level in the area. This approach is a necessary and unavoidable measure, but it is legitimate only under the condition of consistent development and implementation of technical measures aimed at reducing excess water in the hydrosol removal system.

The generally accepted technology of waste storage in the ZO determines their laying with significant porosity (up to 50%). Such irrational use of landfill areas exacerbates the problem of both land allocation and the environment. The latter lies in the fact that highly porous materials have insufficient particle adhesion strength and therefore cannot resist erosion, which in turn leads to dusting and contamination by ash particles of the surrounding area.

An increase in the density of the ZSM can be made by ramming or using an explosion. Ramming is performed with special rammers that are dropped onto the surface from a certain height. When compacted by an explosion, wells pass through the deposits in which charges are placed [8].

The greatest advantage of explosive compaction of the array is that in this case, it is possible to use concentrated incomparably more energy per unit volume of the compacted material and, consequently, to produce more intensive compaction than when ramming. In addition, the explosive sealing of the ZCO is easier to organize and conduct.

Experience shows that the maximum sealing by the explosive method can exceed 30% (with a theoretically possible 100% if the porosity of the material in the dumps is about 50%).

The experience of strengthening and building up the enclosing dam of the landfill for storing sewage sludge in the southern part of St. Petersburg is of interest [9]. The southern landfill is located on a flat site and consists of three reservoirs, dammed with dams up to 8 m high, erected from the soil of the base in a semi-excavation - half-embank-ment. The capacity of the landfill at the design mark was 2.1 million m^3.

The site of the landfill is composed of quaternary deposits - powdery sandy loams and loams with gravel of semi-solid and refractory consistency. The enclosing dams are composed of sandy loams. The conducted studies have shown that loams and sandy loams, in violation of their natural composition, reduce the bearing capacity, get wet when soaked, and according to the degree of frost heaving they belong to strongly heaving soils. The body of the dam has a very heterogeneous structure in terms of moisture and soil density.

When examining the enclosing dams of the landfill, it was found that longitudinal cracks up to 1.5 m deep and opening several tens of centimeters, uneven precipitation, slope deformations, etc. formed in some areas and on the ridge. The dams of the landfill were in extreme condition.

In this regard, the specialists of JSC VNIIG named after B.E. Vedeneev proposed technical solutions for strengthening, reconstructing, and building dams by an average of 3.5 m, by installing a screen of connected soils and erecting loading prisms from sand from the side of the lower slope. The main drainage device is a ditch located on the lower side of the dam. The landfill has been put into operation and is working successfully.

Here are some examples of proposed technical solutions, the use of which will help to avoid accidents [10].

1. Prevention of pollution of groundwater from the waste storage with a flat terrain can be carried out by placing drainage intake elements in the middle part of the storage in a permeable base below the surface

of groundwater and removing the liquid taken by drainage with an intensity that ensures the formation of a depression funnel at the base, accommodating the entire storage in the plan. This allows you to completely or partially abandon the creation of an anti-filtration curtain around the perimeter of the storage.

2. Anti-filtration two-layer waste storage screen consisting of two layers of clay soil separated by a drainage layer. A shallow liquid depth is established in the drainage layer, which ensures that the pressure gradient in the lower layer of the screen is reduced to a value close to one, and therefore a significant decrease in liquid filtration through the screen into the environment. Filtration through such a screen can be completely prevented if an anti-filtration layer is made at the base of the drainage layer from a compacted fine material characterized by an initial filtration gradient of greater than one, for example, from sodium-montmorillonite clay.

3. The enclosing ground structure of the hydraulic dump, consisting of a body, a screen with a droop, and a protective layer covering the screen and a droop and contacting the surface with the disposed waste. The screen and the bottom are poured out of clay soil, which is in a thawed state and brought to a condition in terms of granulometric composition, humidity, and density, or made of a polymer film. The protective layer is poured out of the same clay soil as the screen and the bottom, but not brought to condition with the assumption that frozen soil is included in it. The protective layer is made from the disposed waste, which reduces the filtration of liquid from the hydraulic dump due to its shielding ability.

NGO operation and reclamation

The problem of returning lands occupied by tailings dumps and landfills can be solved by recultivating disturbed lands and using GOK waste for recycling and extraction of useful components.

The enrichment waste is finely groundmass with a low content of basic and associated components. It is a soft and finely dispersed material, non-flammable, with a density from 2.0 to 4.6 t/m^3. During long-term conservation of waste, they undergo significant changes under the influence of natural factors, and internal physical and mechanical processes and cause great harm to the environment and the national economy.

The analysis of possible methods of preparation and processing of tailings dumps indicates that [11]:

Drainage of individual ledges using closed drainage ditches (trenches) is possible if they are located in stationary areas;

When draining working ledges, it is advisable to use open drainage trenches (peat deposits).

Of the possible mining methods - hydraulic (using hydraulic monitors and dredgers) and excavator, the most appropriate will be the excavator using draglines and dump trucks, since seasonality of work, low pH in reservoirs for floating dredgers (hydraulic method), the device of a complex drainage system and additional measures will entail large operational and capital costs.

The preparation of the area of the technogenic deposit is carried out for each layer to be removed. The most appropriate way of drainage in this case is systematic drainage, which is laid in areas with a calm relief. The sinking of drainage trenches (perpendicular to the zumpf axis) must begin 90 days before the start of waste excavation. This period is doubled for the winter period of work.

Each layer is opened by independent capital congresses. On each horizon, a whole piece of waste is left, the width of which is determined taking into account two-lane traffic and the possibility of slopes melting. The construction of roads from any crushed stone materials directly on waste is unacceptable, as this will lead to clogging of waste. It is possible to use preventive measures to reduce the humidity of waste. For example, freezing waste in the face can reduce its moisture content from 8% - 10% to 6% - 7%.

After working off the reserves of compartment No. 1, the latter can subsequently be used to dispose of waste after secondary flotation, having previously restored dams. Waste treatment may be accompanied by the release of gases formed as a result of processes occurring in the tailings storage facility. In this case, it is necessary to carry out advanced drilling of unloading wells. If the type of gases is known, it is possible to place neutralizing substances in wells.

The operation of the technogenic deposit will be accompanied by a negative impact on the environment. These are acidification of the earth's surface with soluble compounds with pH < 6.5, clogging with solid insoluble substances (waste), dusting with fine dusty substances, and gassing of the atmosphere with carbon oxides, formaldehyde and other substances formed as a result of motor transport.

To prevent all forms of environmental impact, polyethylene pipes should be used for the arrangement of open drainage, and pumps, valves, and other equipment should be acid-resistant. During the construction of highways, crushed limestone should be used, and highways built without limestone should be periodically watered with lime "milk". Highways should be cleaned, and waste from highways should be accumulated in designated areas fenced with geochemical barriers.

An approach to the reclamation of landfills for storage of liquid industrial waste [12] has been developed in the laboratory of filtration research of JSC VNIIG named after B.E. Vedeneev.

On a rectangular landfill with an area of about 75 hectares, there are map pits up to 20 m deep, already filled or filled with liquid toxic waste. A bypass channel has been dug around the landfill, with a depth of 2 to 4 meters, the runoff from which enters the reclamation channel, which in turn transports the runoff to natural watercourses. The base of the landfill site is composed of mixed-grained sands with a rare inclusion of gravel and boulders. The lower water barrier is dense loam at a depth of 1 m to 4 m. Below the loams are Cambrian clays with a Cf of no more than 10-6 m/day.

Liquid waste is stored in maps (excavation with collapse to a height of 2 m - 3 m). The high level of liquid in the maps leads to filtration from them into the bypass channels of the polygon. Some of the maps have been reclaimed (filled in). It is possible to drain polluted waters from these maps. As a result of snowmelt and rains, significant surface runoff is formed at the landfill, which is collected in a special pond, from which, when it overflows, it is pumped into an annular channel. Thus, surface water pollution occurs. The average annual polluted runoff through the by-pass channel is about 250 thousand tons. m3, and its ground component reaches 150 thousand m3. Utilization and recycling of these waters is an extremely expensive and practically impossible task.

The reclamation of the cards is ensured by filling them with a moisture-intensive (coarse-porous) filler having sufficient bearing capacity for waterproofing the surface of the card. At the same time, conditions must be created to ensure the consolidation of the masses filling the maps and to ensure the interception and localization of the squeezed liquid phase from the maps.

The reclamation of the landfill territory as a whole involves the creation of two water regulation systems. 1. A system for organizing surface runoff that guarantees the removal of almost all surface runoff outside the landfill territory without contact with contaminated areas of the landfill territory and contaminated drainage waters, with further discharge (after appropriate post-treatment) into the natural hydrographic network. 2. The system of interception and regulation of groundwater, consisting of discharge (decompression) drainage, water-reducing drainage, and ring drainage, providing anti-filtration pressure. All drainage systems are combined by a common collector with a single collection of drainage waters, which are sent for pre-treatment and evaporation.

The complex measures for the protection of surface and groundwater in the area of the recultivated landfill consist of the following main elements. A waterproof diaphragm along the perimeter of the landfill for the full capacity of well-permeable Quaternary sediments, enclosed below in a roof of water-resistant Cambrian clays or dense water-resistant moraine loams. The top of the waterproof diaphragm is designed as the core of an enclosing embankment dam with a passage on top. The lowest height of the enclosing dam is assumed to be structurally equal to 1.0 m, the mark corresponding to this height is the mark of the crest of the entire dam.

The annular drainage along the perimeter of the landfill from the inside of the anti-filtration diaphragm is designed to provide anti-filtration pressure from the outside of the landfill, which can prevent the seepage of contaminated water beyond its limits. The channel along the perimeter of the landfill from the outside of the anti-filtration diaphragm is designed to create, together with the annular drainage, an anti-filtration pressure by providing a pressure between the water level in the channel and the groundwater level at the landfill at least 1.0 m. In this system, the main structure is a gateway regulator of the water level in the channel in the alignment of the existing discharge main channel.

Methods of dealing with the consequences of accidents

Since most accidents are a break in the body of the dam or increased filtration at its base, repair work consists of restoring destroyed anti–filtration devices - a screen on the pressure face of the dam, an anti-filtration curtain in the body of the dam or at its base. The screen, after the restoration of the dam, is usually created a new using thick polymer films. The designs and technology of the work are widely known. Therefore, let's consider the creation of anti-filtration curtains by various methods [13].

Injection fixation of non-cohesive soils: The sealing of non-cohesive soils is carried out by pumping solutions into them through an injector or a drilling well driven into the soil. Injection of the solution into ordinary cement is possible only in coarse-pored sand and in sandy-gravelly soils. For finer sands, solutions based on ground cement or dispersed were previously used, currently, solutions based on micro-cement are used.

To improve the properties of the injected solutions, various additives are introduced into their composition – stabilizing, reducing viscosity, setting accelerators, etc., and in some cases, fast-setting cement is used. The composition of injection solutions is usually selected in the laboratory, taking into account the characteristics of the materials used and the hydrogeological situation at the fixation site.

To fix sandy-gravelly soils, the method of "cuff" injection is currently widely used – injection of an injection solution into the soil through perforated sections of a pipe installed in a drilled well closed with rubber cuffs. An inject-table solution that, when injected, squeezes or tears the clip around the cuff, comes out from under it and, under low pressure, impregnates the surrounding soil, or under high pressure causes a rupture of its continuity and fills the resulting void.

When drilling and injecting wells in highly permeable soils, when a large amount of solution is lost, going a considerable distance from the well, solutions with an adjustable loss of mobility time are sometimes used to prevent this phenomenon [14].

You can also use the method of non-targeted or advanced injection. The well is drilled immediately to the full design depth with purging or washing with bentonite solution. The injection solution is pumped in small intervals (2 m) through the drilling column and the drilling shell as it is extracted from the well [15].

In recent years, a particularly fine binder (OTV) has been increasingly used for injection. This material is a finely ground hydraulic binder – micro cement, which does not contain organic additives. Micro-cement "Microdur" with a maximum particle size of 6 microns to 24 microns (6 times smaller than conventional Portland cement) has a high penetrating ability, which allows it to be used to strengthen and increase the water permeability of fine-grained soils [16]. However, it is impossible not to note the high cost of the material, which leads to the need to use it only in cases where the use of conventional cement is ineffective.

Chemical fixation of soils includes the method of double-solution silicatization, i.e. sequential injection of gel-for-ming and curing solutions, as well as gas silicatization, in which carbon dioxide, sodium silicate, and carbon dioxide are successively injected into the soil.

Due to the development of the chemistry of organic polymers, extensive research has been conducted on the use of various resins for fixing soils. Urea-formaldehyde (carbamide) resin turned out to be the most accessible for use. Hydrochloric and oxalic acids were used as a hardener. However, some current and high costs limit the use of the mobilization method.

Polyurethane foams (PUF) are used to fix the soils. Foamed PU foam has great mobility and seals cracks and seams well, despite periodic changes in their opening.

An outstanding example of the application of chemical soil fixation was the creation of an injection curtain up to 170 m deep in the body and base of the high-altitude Aswan dam, for which specially developed solutions based on sodium silicate and aluminate were used.

In the following years, many new injection compositions appeared, that used polymer components. For example, we can name the elastic polyurethane resin "Apiflex-injection WX", as well as "Urenate 5449", which has a high penetrating ability.

Jet cementation is the loosening of the soil with a jet of water, followed by the supply of cement mortar to this zone to mix it with loosened soil. Water injected under high pressure (up to 60 MPa) and flow rate (up to 250 l/min) exits the monitor nozzle located at the bottom of the drilling column at a high speed, for which this method is called "jet grouting". The well can be drilled both by conventional drilling and by a vertically directed high-pressure jet [17].

As a result of the use of one-, two– or three-component technology, ground concrete is formed - a durable (up to 30 MPa) waterproof material, which allows using this method to create load-bearing soil-cement piles with a diameter of up to 2.5 m, as well as anti-filtration curtains. When the monitor rotates, round columns of fixed soil are formed. If the monitor does not rotate, flat "panels" are obtained.

The advantages of this method of soil strengthening are namely, high productivity, the ability to fix low-permeable soils, work in winter, and the ability to control and set the parameters of the fixed soil. Difficulties in closing piles due to deviations from the design position when drilling at great depth are overcome by the installation of additional piles in the areas of the detected "windows".

“The wall is in the ground”: The "wall in the ground" method is widely used to create concrete or reinforced concrete piles when fencing pits and creating walls of buildings and structures under construction. Recently, this method has been used for pressure hydraulic structures, first as a way to repair failed anti-filtration curtains, and then to create new ones in the body and base of groundwater dams [18]. The curtain is made of drilling piles of large diameter (0.6 m - 1.2 m). These piles are formed when drilling wells of the appropriate diameter are filled with a clay-ce-ment-concrete mixture, which, when setting and hardening, acquires strength and deformation characteristics of the host soil, which allows the dam to perceive the acting loads and deform as one with the curtain.

The great advantage of this method, which is not very cheap, is that the curtain can be performed after the completion of excavation work, in a finished structure, unlike the core of clay materials, which is performed during the filling of the soil in warm dry time, which is sorely lacking in areas with harsh climatic conditions. The composition of clay cement concrete is selected in the laboratory taking into account the characteristics of materials coming to the con-struction site and checked at the work site, since their properties sometimes change greatly during transportation and storage of raw materials.

Attempts are also being made to combine various methods and technologies at one facility. Their diversity makes it difficult for the designer to choose the optimal method and composition of solutions for specific hydrogeological conditions. And here, as is customary in construction practice, the decision should be made using variant design and technical and economic calculation.

An economic comparison of various methods of installing an anti-filtration curtain shows that the "wall in the ground" method is approximately equal in cost to the injection method, and sometimes somewhat more expensive, which depends on the specific construction conditions: climate, remoteness of the area, etc. At the same time, this method has a serious advantage, it allows you to create a continuous, almost impenetrable curtain, which is especially important for hazardous waste storages.

From an ecological point of view, the disadvantage of chemical soil fixation is the need for careful selection of materials for injection in order not to cause damage to the surrounding area and groundwater. The methods associated with the use of cement, in this sense, are practically safe, since cement chemically binds to other ingredients of clay- c ement-concrete or injection solution and becomes an integral part of the resulting solid and environmentally friendly material.

Conclusion

A reliable and optimal design of the dam enclosing the NGO can be successfully developed with detailed conside-ration of the engineering and geological conditions of the landfill site, the physical and mechanical properties of the soils of the body and base, the conditions of construction and operation, and the results of geotechnical control du-ring the construction of the structure.

Accidents can be avoided by applying the above measures. When eliminating the consequences of an accident, it is recommended to use modern injection methods and a "wall in the ground".

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