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Environmental monitoring of the reclaimed sites of JSC “EVRAZ ZSMK” sludge dump

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Abstract. For conservation of technologically disturbed lands, various methods of reclamation are used to prevent their negative impact on the environment. At the same time, technological methods are used, including changing the technology of waste storage, changing the state of stored products using briquetting and granulation, creating mechanical barriers that prevent the spread of dust or continuous coating with non-dusting material, and the physicochemical method – creation of a protective layer using foam or hydro-dusting in order to stabilize a dusty surface. The most environmentally effective is the biological method – creation of a protective vegetation cover. This method is of particular relevance due to the phytotoxicity of the technogenic substrate for sludge dumps and the difficulties of creating a stable vegetation cover. Taking into account the industrial and environmental characteristics of the waste in sludge dumps of JSC “EVRAZ ZSMK”, an assessment of the physiological state was carried out as part of environmental monitoring and the chemical composition of plants growing in the reclaimed areas of this technogenic object was analyzed. A comprehensive assessment of the environmental safety of the use of sewage sludge from urban wastewater treatment plants on the substrate of the sludge storage facility as the main soil improver is given.

1. Introduction

Currently, in industrialized regions, as a result of the activities of industrial enterprises, technogenic ecosystems have formed that differ in the composition of the stored materials and the formation technologies. Basically, they are represented by various dumps and open-pit mines that are formed during minerals mining, waste from the concentration of sinter plants, tailings, sludges and ash dumps of thermal power plants. Technogenic ecosystems are formed by technical means and are fundamentally different from natural ecosystems that previously functioned in this territory. These differences are due to the special forms of relief, the properties of the stored substrates, and the almost total absence of biota [1]. Therefore, to restore ecosystems to their natural state, it is necessary to carry out a set of reclamation measures [2].

By the type of the work performed, measures for the restoration of technologically disturbed lands can be divided into:

- landscape reclamation (land reclamation) associated with the restoration of the disturbed landscape (terrain, soil and vegetation);



- environmentally friendly (environmentally protective), associated with the elimination and neutralization of the harmful effects of industrial waste on the living environment (soil, water, air).

The implementation of these measures can reduce the negative consequences of waste disposal and begin the formation of already natural-technogenic complexes on the site of disturbed lands, and it is very important to organize environmental monitoring in the reclaimed areas already at the initial stages of reclamation in order to assess the effectiveness of the work done and the condition of the reclaiming ecosystems.

Sludge dumps and tailings, as part of the technogenic landscape, occupy a special place in the framework of studies on the restoration of disturbed lands, in particular, in the development of ways and methods for their biological restoration. The main emphasis in choosing the direction of reclamation of sludge collectors is aimed at technological, mechanical and physico-chemical methods of combating dust, which are developed and recommended for technologically disturbed lands in metallurgical production.

When reclaiming sludge and tailing dumps, the following methods are used to combat surface dusting:

- Technological method. This method includes changing the storage method according to particle size or physico-chemical composition, as well as changing the composition and condition of the dumped products using briquetting and granulation.
- Mechanical method: creation of barriers to prevent the spread of dust or a continuous coating of non-dusting material.
- Physico-chemical method: creation of a protective layer using foam or water dedusting in order to stabilize the dusty surface.
- Biological method: creation of a protective layer from plants. This method is of particular relevance in connection with the phytotoxicity of the technogenic substrate of sludge and tailing dumps and the difficulties of creating a sustainable vegetation cover.

Biological reclamation of sludge dumps is limited by several factors:

1. The absence or critical lack of mineral nutrition.
2. Unsatisfactory water-physical properties due to the predominance of sand fractions in the beach area having high filtration properties.
3. Easy deflationary ability of particles, which complicates the fixing of seeds and seedlings of plants.

Modern physicochemical methods do not give a complete picture of the ecological situation in a particular area, so there is a need to use biomonitoring data and conduct bioindication studies. A change in the chemical composition of the habitat is accompanied by a mandatory change in the composition of the biota. Biological indication of environmental pollution may include methods for assessing the vital state of plants (physiological), the structures of the emerging phytocenoses (phytocenotic), migration paths and transformations of chemical elements entering the plants (biochemical).

2. Characteristics of the studied object

Sludge dumps is a technogenic facility for central collection, accumulate and settle the solid phase of pulps, sludge and wastewater from industrial wastes of JSC “EVRAZ ZSMK”, West Siberian Central Heating and Power Station, CPP “Kuznetskaya” and return of clarified water to consumers. The sludge dump has been in operation since 1964. Since the beginning of operation, more than 100 million tonnes of waste have been disposed.

The total area is more than 300 hectares with a dam height of about 25 m. On all sides, the sludge storage facility is surrounded by a dam composed of a mixture of coarse screening of coal processing waste and converter slag. The dam is of trapezoidal sectional structure, the outer slope of which is terraced. In total, two terraces are formed on the slopes of the dam, the flat surface of which is used for laying technological roads.

The width of the terraces ranges from 10 to 40 meters. The sides of the terraces are currently not fixed – their steepness is determined by the angle of repose – and for this reason are subject to destruction by water-erosion and deflation processes. A view of the sludge storage facility from space is presented in figure 1.



Figure 1. Sludge storage facility of JSC “EVRAZ ZSMK”, satellite view.

At the same time, these terraces play a protective role, protecting the dam from destruction by water erosion and deflation processes, although at the same time, their edges and steep slopes continue to collapse quite intensively. To prevent the destruction of the edges of the entire surface of the terraces, various methods of fixing the surface, in particular, methods of biological reclamation, are required. These methods should be aimed at improving the physical and chemical properties of the substrate, creating conditions for the development of phytocenoses, which in the end result should lead to the formation of a solid turf and surface fixation.

3. Assessment of the physiological state of plants at the sludge dump

The physiological parameters of woody plants (balsamic poplar, ash-leaved maple, goat willow, small-leaved elm) were studied during the growing season (July) located in the lower part of the second terrace of the reclaimed plot No. 5 in the morning from 9 a.m. to 12 p.m. The temperature was in the range of 20 – 22 °C, illumination from 25000 to 42000 lux. The state of stomata, the intensity of photosynthesis, and the chlorophyll content of experimental plants were studied [3].

The studies have shown that the state of stomata in the plants indicates sufficient water supply for their tissues, therefore water, as a participant in photochemical light reactions in this habitat, is not a limiting factor. The content of photosynthetic pigments is able to ensure the absorption of carbon at an average level, although the level of photosynthesis intensity does not reach its maximum. The reasons for this discrepancy may be the lack of nutrients available to plants, nitrogen and phosphorus, which

provide plastic and energy metabolism with their carbon nutrition. The previously performed agrochemical characterization of the dam rocks of the sludge dump at JSC “EVRAZ ZSMK” site confirms this assumption, while the content of mobile forms of potassium is quite sufficient, which ensures normal water exchange of plants and is confirmed by stomatal control.

The results obtained on the physiological parameters of woody plants indicate their adaptive capabilities, despite the high daily temperature, moisture deficiency, and the lack of optimal mineral nutrition. The correlation between the content of chlorophyll in the leaves of the studied plants and the intensity of photosynthesis is more pronounced during the July drought.

The introduction of non-traditional soil improvers – wastewater sludge (WWS) of urban treatment facilities into the technogenic substrate of the sludge storage facility of JSC “EVRAZ ZSMK” is accompanied by an increase in the content of organic substances and fractions of physical clay, which increases the sorption capacity of the formed organomineral substrate (technozem). In this case, a slight increase in the content of heavy metals is recorded. This is due, on the one hand, to an increase in their WWS content in the substrate, and, on the other hand, to an increase in the mobility of metals in the dam substrate, as a result of increased humidity and organic matter content. Subsequent decomposition of the organic matter of technozems leads to a decrease in sorption ability and an increase in the bioavailability of metals. The introduction of WWS is accompanied by a change in the pH value, which leads to a decrease in the mobility of metals as a result of complex formation, but conditions may arise for the formation of soluble organometallic complexes.

4. Chemical analysis of plant material in the sludge dump

When WWS is added to the sludge dump, the content of the main nutrient elements in the surface layer of the reclaimed areas increases: carbon – up to 12.3%, nitrogen – up to 0.92%. At the same time, the level of pollution with heavy metals decreases several times: vanadium – from 3 (medium) to 2 (low), tin and mercury – from 2 (low) to 1 (permissible). The indicators for arsenic, copper, nickel and zinc (low level), as well as for lead, chromium, cobalt, cadmium and fluorine (acceptable level) remain unchanged.

According to the content of mobile forms of heavy metals (copper, zinc, lead and nickel), the obtained mineral-organic substrate of the sludge dump is assigned to the second, low level of pollution. The content of cobalt and chromium is lower or corresponds to the permissible level ($MAC_p = 6.4 \text{ mg/kg}$).

The analysis of chemical composition of the biomass of herbaceous plants is an indicator of the possible removal of toxic elements from the root layer. According to the results of studies, the excess of the MAC of arsenic, lead, zinc, nickel, copper and antimony in slag+WWS was found. Comparison of the content of these elements in plants showed that arsenic was not detected in plants (cadmium, selenium, beryllium were also not found). The content in the plants of the experimental plots, mg/kg: lead – 0.3–1.4, zinc – 64–400, nickel – 0.7–1.2, copper – 3.7–9.2, vanadium – 0.7–2.7, manganese – 148–274, with a gross content of these elements in technozems (“rock + WWS” and “slag + WWS”), respectively, mg/kg: lead – 29 and 40, zinc – 239 and 191, nickel – 32 and 22, copper – 67 and 68, vanadium – 157 and 157, manganese – 563 and 7565. These data show that zinc is a potential hazard in terms of the removal of toxic elements. The taking of heavy metals by plants is maximum in the first years of the placement of WWS, over the years their concentration decreases and becomes comparable with the background indicators of the control plant material.

By microbiological characteristics, pathogenic microflora was not found in the studied material and corresponds to SanPiN 4630-88 [4, 5]. The introduction of WWS increases the level of microbial population to ecological and trophic diversity, therefore, WWS, as ameliorants, are classified as “polluted” in terms of “coli titer”.

5. Conclusion

Comprehensive monitoring of the environmental safety of WWS use on the rocks of the sludge storage facility of JSC “EVRAZ ZSMK” showed that this unconventional soil improver cannot be

considered as a source of additional pollution during reclamation work. The content of nutrients in the formed technozems during the placement of WWS is increased, which ensures survival and sustainable growth of vegetation. The selection of the species composition of plants is determined by their resistance to extreme conditions and soil-improving properties. This allows a stable phytocenosis in the face of adverse effects of metallurgical production wastes to be formed and helps to improve the environmental status of the suburban area of Novokuznetsk.

References

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