UDC [628.477:669.2/8]:502/504
DOI https://doi.org/10.32846/2306-9716/2022.eco.1-40.1

PHYTO MELIORATION OF TAILING PONDS TO ENSURE SAFETY OF POPULATION AROUND ENTERPRISES

Bozhenko A., Grygorieva L., Aleksieieva A., Makarova O.
Petro Mohyla Black Sea National University
68 Paratroopers Str., 10, 54000, Mykolaiv
voodoo@chmnu.edu.ua

This work is devoted to solving the problem of dust suppression at sludge storage facilities of metallurgical enterprises. In the process of choosing the direction of land reclamation it is necessary to take into account that the reclaimed lands and surrounding areas – after the completion of works, should be an ecologically balanced and optimally formed landscape area. As such, we are focusing on finding ways to transform sludge ponds into sustainable scenic landscapes that reduce hydrocarbon levels. At the moment, biological methods have already been developed and experimentally tested, which are suitable for reclamation of sludge storage, from which sludge is periodically withdrawn for sending for recycling. Now we have focused on phyto melioration of sludge storage at the stage when, for various reasons, regular sludge removal is no longer planned. In this case, you can start covering the beach of the sludge storage with a more diverse composition of plants, including shrubs. The world experience of biological reclamation of sludge dumps shows that plants with a high tolerance for heavy metals are capable of germinating on them. In the case of alumina sludge, alkaline tolerance is also important. The results of our analysis coincide with the empirical observations of other researchers that plants with fibrous and lateral types of root systems grow naturally in sludge storage facilities. Based on this and other criteria of adaptability, we have selected a list of shrubs which we recommend for starting research on the experimental detection of the most suitable species for the set goals. Shrubs with a lateral root system are considered in the first place, since it is cheaper to adjust the thin upper layer of sludge in terms of pH and mineral composition than to process it to the full depth. In this case, most likely one will have to fill up with inexpensive soils the top layer of the sludge storage facility in certain places. The main attention is paid to the repositories of red sludge at the Mykolaiv Alumina Refinery, but the main principles can be used in different enterprises. *Key words:* tailing ponds, dust suppression, phyto melioration, alumina.

Фітомеліорація шламосховищ для забезпечення безпеки життєдіяльності населення навколо підприємств. Боженко А.Л., Григор'єва Л.І., Алексєєва А.О., Макарова О.В.

Робота присвячена вирішенню завдання пилопригнічення на шламосховищах металургійних підприємств. У процесі вибору напрямку рекультивації земель необхідно враховувати, що рекультивовані землі й території, що їх оточують, після закінчення робіт повинні являти собою екологічно збалансовану та оптимально сформовану ландшафтну ділянку. Таким чином, ми концентруємося на пошуку способів перетворення шламосховищ на сталі живописні ландшафти. На даний момент вже розроблено та експериментально перевірено біологічні методи, які підходять для рекультивації хвостосховищ, з яких періодично вилучається шлам для відправки на повторну переробку. Зараз ми сфокусували увагу на фітомеліорації шламосховищ на етапі, коли з різних причин не планується регулярне вилучення шламів. У такому випадку можна розпочати покриття пляжу хвостосховища різноманітнішим складом рослин, включаючи чагарникові. Світовий досвід біологічної рекультивації шламосховищ показує, що на них здатні проростати рослини з високою терпимістю до важких металів. У разі глиноземних шламів важлива також терпимість до лужного середовища. Результати нашого аналізу збігаються з емпіричними спостереженнями інших дослідників, що природним способом на хвостосховищах частіше проростають рослини з мичкуватою та поверхневою типами кореневих систем. На підставі цього та інших критеріїв адаптивності нами підібрано список чагарників, з яких ми рекомендуємо розпочинати дослідження з експериментального виявлення найбільш відповідних видів для поставлених цілей. Чагарники з поверхневою кореневою системою розглядаються в першу чергу, тому що дешевше регулювати за pH та мінеральним складом тонкий верхній шар шламу, ніж обробляти його на всю глибину. При цьому, швидше рекомендується засипати недорогими ґрунтами верхній шар шламосховища в задіяних місцях. Дане дослідження зосереджується на хранилищах червоного шламу Миколаївського глиноземного заводу, але основні принципи можуть бути застосовані під час фітомеліорації шламосховищ різних типів виробництв. *Ключові слова:* рекультивація шламосховищ, пилопригнічення, фітомеліорація, глинозем.

Formulation of the problem. During the XX-XXI century, a lot of tailing ponds (TP) and sludge storages of various chemical composition have accumulated in Ukraine. Due to the fact that TP often occupy large areas, they undergo dust formation processes under the influence of meteorological conditions, which results in toxic dust and aerosolsspreading over large areas.

The risk of deterioration of the sanitary and hygienic situation and undesirable environmental consequences occurs not only in the location of the TP [1, 2]. Toxic eco-pollutants cover vegetation, which contributes to their migration along biological chains.

This article focuses on biological methods of dust suppression of red sludge of the Mykolaiv Alumina

Refinery (MAR), but the basic principles can be applied during phyto melioration of tail ponds of different types of enterprises.

The relevance of research. In Ukraine today, all powerful metallurgical enterprises for processing and extraction of raw materials have tailing ponds and sludge storages. These include: Dnipro Aluminum Plant, Mykolaiv Alumina Refinery, Eastern ore dressing complex (SE "Vostgok") (Zhovti Vody) and others. Large areas (several hundred hectares of land) are allocated for tailings, they exceed the territory of the plant, so a large amount of polluted air, soil and water is formed around them.

Thus, the high intensity of extraction and processing of mineral resources, which is characteristic of the modern development of metallurgical, mining and processing enterprises, requires improvement of existing and development of new measures and ways to reduce environmental and human health impact with tailings.

Connection of the article with important scientific and practical tasks. This work is connected with two important scientific and practical tasks of today: dust suppression at the sludge storage facilities of metallurgical enterprises and the melioration of the territories occupied by TP to mace them mor friendly to local ecosystems, in this case, by transforming in the future scenic landscapes that prevent climate change and contribute to sustainable development.

Analysis of recent research and publications. The problem of sludge remediation has been studied quite actively around the world today. We will consider the experience of Ukrainian enterprises first of all.

Different types of sludge have different chemical composition. Some of them become gradually covered with vegetation in a natural way [3, 4]. The natural overgrowth of vegetation on alumina tailings is extremely slow though. Biological fixation of sludge storages depends on the composition and physical and chemical properties of raw materials processed in factories. Also a very important feature of the tailings, that defines the possibility of growing plants on them, is the lack of humic substances and bound nitrogen, without which the growth of plants is impossible. That is why to cover TP with vegetation it is necessary to cover their surfaces with at least a small layer of on bulk black soil (3-5 cm). This contributes to the dust suppression and ensures the creation of a stable grass cover with dense turf, capable of resisting the effects of wind deflation for about 1-2 years [1, 2].

The following methods of reclamation of disturbed lands are most common: forestry, agriculture, water management, recreation, construction, sanitation. This paper focuses on biological methods. Bioecological melioration is performed after the technical reclamation of a sludge.

One of the most popular methods of bioecological reclamation is phyto melioration with perennial grass [5]. Soil-producing crops usually have a high cover and a strong root system with a highly branched network of small roots that keep soil particles from water– and wind erosion. [1].

To improve degraded soils, the most commonly used methods of restoration with long-term use of perennial grasses with crop rotations, when under the upper layer of grass begins restorative succession due to the emergence of natural steppe groups [1, 5].

In the Czech Republic, in the process of restoring occupied disturbed lands, preference is given to the creation of special-purpose forest plantations: parks, forest parks, windbreaks, etc. Herbaceous and shrubby plants are widely grown in low-yielding lands [6].

Woody plants in the conditions of tailings grow and develop slowly. A shift of phenological phases is observed for these plants compared to the same species that grow on other zonal soils [7].

The choice of plants is generally based on the following principles [2]:

– environmental safety and no toxic and eco-toxic effects;

– resistance to specific meteorological conditions (considerable wind speed, severe deflation, icing) and aggressive conditions of the TP environment (pH=10-12);

– relative cheapness and ease of implementation.

For Mykolaiv, one of painful subjects is reclamation of a sludge storage of the Mykolaiv Alumina Refinery. Red sludge is a waste from the production of alumina from bauxite by the Bayer alkaline method, which in the form of dust enters the environment and the human body by inhalation and digestive tract. Previously, successful experiments were conducted on biorecultivation of certain areas of MAR TP with the help of reed mats and herbaceous plants. [1].

In this work, we also used the experience of research on the reclamation of sludge storage facilities of the Limited Liability Company “Ocean Shipbuilding Plant” [7]. Reclamation works at this enterprise are only at the initial stage, but it is planned to be carried out according to the same logical scheme as the reclamation of MAR.

Highlighting previously unsolved parts of the general problem to which this article is devoted. The article is devoted to the insufficiently studied method of using shrubs for dust suppression and reclamation in tailing ponds of alumina plants.

The novelty of the study. The practical novelty of the obtained results is the substantiation of the criteria for selection of shrubs for tailing ponds melioration in the South of Ukraine. Scientific novelty is to expand knowledge about the use of biological methods of TP surface reclamation.

Methodological and general scientific significance. Comparative and systematic methods, theoretical analysis of scientific literature sources, their synthesis and generalization of information were used as research

methods. For the analysis of the collected materials and information, qualitative evaluation methods were used in the first place. This paper focuses on popular practical methods of studying the environmental problems of tailing ponds. The general scientific significance of the work is to expand the ideas about the adaptability of shrubs in modern industrial landscapes.

Description of the study.

As one of the examples in the south of Ukraine, the Mykolaiv Alumina Refinery has considerable experience of bioecological reclamation of TP in non-ferrous metallurgy. Phyto meliorative experimental works performed at the sludge storage facility №1 of MAR on an area of 6 ha [1, 2] allowed to develop a method for assessing the dust-suppressing capacity and stability of plants and evaluate these indicators for removable biological agents. To do this, the upper layer of sludge was washed with clean water, which reduced the alkalinity to values of 7-7.5. Then layers of clay were applied to protect plants from alkali and other sludge toxicants. A layer of silt was applied to some areas in order to form a nutrient medium for the root system of plants. Then the surface of the soil was loosened with a harrow, the seeds of a mixture of herbaceous plants were sown. The result of the experiment is a turf formed from the sown herbaceous plants, which has a high level of dust suppression.

In present study, for even better dust suppression, soil melioration and the formation of visually pleasing landscapes, we recommend gradually complementing the grassy vegetation with shrubs. It is more effective to start planting them first along the perimeter [8], which is much easier to care for, and then to continue planting the species selected at the first stage in the format of forest belts.

One of the important problems when choosing plants for the steppe zone is that such plants are usually drought-resistant due to the tap or very developed fibrous root system, and in our case, it is desirable to select shrubs with the maximum surface occurrence of roots. It is cheaper to adjust the pH and mineral composition of a thin top layer of TP than to treat it to the full depth. Most likely, you will have to fill up the top layer of the sludge storage with inexpensive soils in the right places.

After analyzing various [3, 4, 6, 9] sources, we recommend starting experiments at the sludge storage facilities of the Mykolaiv Alumina Refinery with the following shrub species:

– Narrow-leaved Loch (Elaeagnus angustifolia L.);
– Sea buckthorn (Hippophaë rhamnoides L.)
– Tatarian Honeysuckle (Lonicera tatarica L.).
– Ordinary privet (Ligustrum vulgare L.)
– Western thuja (Thuja occidentalis L.).

The choice of plants is not limited to this list, and it will be possible to expand it by selecting shrubs with characteristics that are as similar as possible to those species from the list that will take root best.

The articles of the iron ore dumps researchers [3, 4] show that the overwhelming majority of plant species, naturally growing there, develop a lateral root system. Such a root system is especially characteristic for vegetatively mobile species. The roots of such plants lie at a depth of 5–15 cm and spread far beyond the projection of the plant crown. The uniformity of root systems in certain species resistant under conditions of different granulometric and physicochemical composition of the rocks of iron ore, chalk and coal dumps indicates a common adaptive strategy for the survival of these species in adverse conditions of technogenic ecosystems [3].

Having carried out an independent additional analysis of the morphological characteristics of the plants given in the source, we consider it necessary to clarify that in fact many plants mentioned in the article have a well-developed heart root system, which, although is not a tap root system still tends to grow well both to the sides and in depth. Nevertheless, in the process of our preparatory studies, we also came to the conclusion that plants with a lateral system should more easily adapt to the "soil" of tailing ponds, since the upper layer begins to undergo natural processes of erosion, leaching, processing by microorganisms, insects, etc. earlier than the rest. etc. We also found that many of the plants given in [4] belong to those that naturally prefer slightly alkaline soils.

Shrub seedlings are recommended to be planted at the age of 1-2 years with a well-developed root system of 26-28 cm long. Roots must be compressed tightly with soil, embedded in the soil in such a way that the root collar is 5–8 cm below the soil surface [10, 11].

A necessary condition for afforestation in steppe regions is the regular destruction of weeds and loosening of the surface layer of the soil, especially in the first years after planting, while seedlings are still weak, fragmented and unable to compete with weeds. In the absence of plant care, there is a risk of weed growth and soil compaction. As a result of it there is a high probability of plant death due to a lack of moisture (taken by other plants) and oxygen in the soil. In our case, the goal is to cover the surface of the TP as densely as possible with both woody and herbaceous plants; therefore, the above care is necessary, but with minimal damage to the bulk of herbaceous plants.

Conclusion

1. Biological methods of sludge storage facilities reclamation seem to be the most acceptable from the point of view of creating landscapes that are comfortable for the population of nearby settlements. Biological methods are especially suitable for reclamation of tailing ponds, from which it is no longer planned to regularly withdraw sludge for various types of recycling.

2. World experience in tailing ponds biological melioration shows that mostly plants with a high tolerance for heavy metals are capable of germinating on them. In the case of alumina sludge, alkaline tolerance is important. Plants naturally growing on podzol soils are still sensitive if the pH of the sludge is too high. It is recommended to combat this by chemical neutralization of pH with simultaneous selection of more and more resistant plant samples.

3. There is a tendency that plants with fibrous and lateral types of root systems grow naturally on tailing ponds. This must be due to the redistribution of chemical elements in the vertical horizon of the sludge storage. We believe that in this case, it makes sense to work on changing, first of all, the upper layer of sludge (1-2 m) in the direction more favorable for plants, which is cheaper than processing the entire mass of sludge.

Prospects for the use of research results. In the future, we expect selection work in the direction of breeding plant species capable of growing in the described conditions, for their mass introduction in sludge storage facilities of non-ferrous metallurgy enterprises. There is a possibility that such breeds will be bred only with the help of genetic modification, but at the local level it makes sense to use cheap methods for solving the problem..

References

1. Огородник А. М., Григор'єва Л. І., Томілін Ю. А., Кутлахмедов Ю. О. Використання різних методів пилопригнічення для зменшення надходження шкідливих полютантів у навколишнє середовище. *Наукові праці. Серія: «Техногенна безпека».* 2010. С. 26–32.
2. Зборщик Т. В., Томілін Ю. А. Методи рекультивації шламосховищ у кольоровій металургії на прикладі ТОВ «Миколаївський глиноземний завод». *Могилянські читання: Досвід та тенденції розвитку суспільства в Україні: глобальний, національний та регіональні аспекти. Екологія і сучасні екологічні проблеми*: праці XXII всеукр. наук.-метод. конф. (Миколаїв, листопад 2019 р.). Миколаїв. 2019. 92с.
3. Коршиков И. И., Красноштан О. В. Жизнеспособность древесных растений на железорудных отвалах Криворожья. Донецк. 2012. 280 с.
4. Коршиков И. И., Красноштан О. В., Пастернак Г. А. Видовое разнообразие древесных растений на промышленных отвалах степной зоны Украины. *Рекультивація складних техноекосистем у новому тисячолітті: ноосферний аспект*: матеріали міжнародн. наук.-практ. конф. (Дніпропетровськ, 29–30 травня 2012 р.). Дніпропетровськ. 2012. С. 315–320.
5. Григор'єва Л. І. Томілін Ю. А. Управління ризиком дефляційних явищ на хвостосховищах у системі ризик-менеджменту переробних підприємств: монографія. Миколаїв. 2016. 188 с
6. Vlasova E., Yandyganov Ya, Nikulina N. Ecolocical and economic sequrity is in aspect of interaction of contiguous territories (balance method of estimation). *The international collected scientific work by economic seguritys problem: society, state and region.* Valencia (Spain). Ekaterinburg (Russia). 2008. P. 188–196.
7. Smyrnov Victor. Recultivation of Disturbed Lands During the Liquidation of Sludge Storage Limited Liability Company "Ocean Shipbuilding Plant". *Climate change & Sustainable Development: New Challenges of the Century: Monograph* / Victor Smyrnov, Svitlana Smyrnova, Ruslana Babushkina. Mykolaiv, 2021. P. 382-395.
8. Воронов А. А. Рекультивация карт шламонакопителя предприятия по производству глинозёма: бакалаврская работа. Руководитель Н. В. Крук. Красноярск. 2018., 73 с. URL:
9. http://elib.sfu-kras.ru/bitstream/handle/2311/74335/diplom_voronov.pdf?sequence
10. Яковлев А. С., Карасева М. А., Краснов В. Г., Кириллов С. В. Лесомелиорация ландшафтов: учебное пособие. Йошкар-Ола: Марийский государственный технический университет, 2008. 128 с.
11. Yakovleva, O. (2018). Phytotoxicity of aluminum ions. Proceedings on applied botany, genetics and breeding. 179. 315-331. 10.30901/2227-8834-2018-3-315-331.
12. Новых Л. Л., Чендев Ю. Г. Изменение морфологических свойств черноземов в агролесомелиоративном ландшафте. Аридные экосистемы. 2014. Т. 20. № 1 (58). С. 18-24.