Accelerated reclamation of iron ore enrichment waste

To cite this article: A S Vodoleev et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 411 012016

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Accelerated reclamation of iron ore enrichment waste

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Abstract. Reclamation includes a set of measures aimed at forming on the surface of industrial dumps a favorable root layer by various methods with subsequent use of this area. Conservation is the fixation of the dumps surface by mechanical means or by gardening the dumps surface with the preliminary application of a minimum layer of soil, peat, mineral fertilizers, growth substances, unconventional soil improvers – sewage sludge (SS). As a result of the work carried out on the surface of iron ore enrichment waste of Abagur Processing Agglomeration Factory, technosols were formed – artificial soils with a root layer of sown leguminous grasses, consisting of a mixture of SS and tailing material. The reclaimed areas have been created on iron ore enrichment waste, which ensure erosion stability of the tailing dump surface and conservation of enrichment wastes. The chemical and agrochemical parameters of the technosols over the two years of their development have changed. Some alkanization of the medium and a sharp decrease in the amount of organic matter and all forms of nitrogen in the substrate of the root layer of plants are observed.

1. Introduction

Any disturbed territory of technogenic origin passes in its development two phases – technogenic formation and a post-technogenic phase of development [1,2,3,4]. The leading mechanisms of transformation of man-made landscapes into natural ones are the biological processes leading to the restoration and development of biogeocenosis. The formation of cenoses of any level is determined by the soil-ecological effectiveness of reclamation, which depends on the level of utilization of reclamation resources. In connection with various purposes of reclamation, these or other technologies are used to create conditions for the development of soil-biological processes in disturbed areas.

Biomonitoring of reclaimed experimental sites makes it possible to optimize and accelerate the process of formation of crop phytocenoses on industrial waste, to monitor the condition and development of the grass stand, to monitor the restoration of fertility of disturbed lands, to predict and guide the development of succession processes in the reclaimed areas in the most expedient direction, to calculate the ecological and economic effect of the conducted reclamation works.

Now in Kuzbass and other industrially developed regions, huge production areas are occupied by industrial waste dumps, many of which may be near populated areas. At the same time, the stored waste causes great environmental damage to the environment and negatively affects the living conditions of the population. Their harmful effects can be neutralized in several ways: by recycling, reclamation or conservation.

Utilization is the secondary use of industrial waste in human economic activities. Reclamation includes a set of measures aimed at forming a favorable root layer on the surface of industrial dumps in various ways, for example by applying potentially fertile and fertile soil layers up to 1 m thick, followed by the use of this area for agriculture or other purposes [5]. Conservation is the fixation of
the dumps surface by mechanical means (film deposition, asphaltling, gravel covering, etc.) or by
greening the surface of the dumps [6] with the preliminary application of a minimum layer of soil,
peat, mineral fertilizers, growth substances, unconventional soil improvers – sewage sludge, etc. [7].

2. Object of the study

The investigations were carried out at the tailing dump No. 1 of Abagur Processing Agglomeration
Factory, which is located in Novokuznetsk. Abagur Processing Agglomeration Factory is a large
industrial facility, which activity significantly complicates and worsens the environmental conditions
of the environment and negatively affects the city environment and adjacent landscapes. Its vast
tailings are filled with sandy loamy substrata and are constantly exposed to water and wind erosion,
polluting the atmosphere, soils and water.

At the same time, the stored waste is a substratum containing a lot of valuable elements, which in
the future will be processed. Therefore, these tailings can be considered as technogenic deposits. For
this reason, radical reclamation works on these technogenic objects are inexpedient, it is necessary and
sufficient to fix their surface by biological methods by forming sanitary-protective plantations.

According to the technological scheme at Abagur Processing Agglomeration Factory the
production waste – tailings of magnetic separation in the amount up to 2.2 mln tonnes per year of iron
ore through the slurry pipeline are sent to the tailing dumps. At present, three tailing dumps occupy an
area of more than 350 hectares: tailing dump No. 3 is active, dumps No. 1 and No. 2 are isolated
plateaus up to 20 meters in height with a total area of about 190 hectares. The reserve of tailings stored
in them is estimated at about 100 million tons. By their chemical composition and properties, tailings
can be classified as industrial raw materials with a wide range of possible applications. At present, the
technology of extracting useful elements from the stored waste by the methods of gravitational
enrichment, plasma treatment, etc., is being explored. Large-scale processing for 30 years of existence
of tailing dump No. 1 has not been organized.

For the organization of reclamation works, it is possible to use the classification of disturbed
territories, which takes into account the specifics of technogenic objects, and determines the direction
of practical measures to restore this type of disturbances. According to the classification of industrial
dumps by V.V. Tarchevski [8], this industrial object by its origin refers to dumps of the processing
industry of a bulk type; by age – middle-aged (over 25 years); by shape – cup-shaped; by height –
medium (up to 25 meters); by mechanical composition of the surface substrate – coarse-grained and
sands (particles up to 0.1 mm); by acidity (pH) – acidic; by utilization – unused.

The tailing dump is filled with the help hydrotransport, which led to the differentiation of material
according to the granulometric composition. In the soil-ecological relation, the material of the
processed tailing dumps is characterized by a very high heterogeneity of practically all chemical,
physicochemical, agrophysical and agrochemical parameters. This heterogeneity is determined by the
specifies of the technology of formation of hydrodumps, which differentiates the material both in the
area of the hydrodump and in its thickness. High density – 1.7 g/cm³ and higher, makes this substrate
almost root-impermeable, sharply reduces the volume of pore space and water permeability. For this
reason, reclamation of tailing dumps requires the introduction of a special technological element that
reduces this density, for example, mixing with other less dense substrates.

The tailing dumps substrate is classified as highly saline, phytotoxic. At the same time, the degree
of phytotoxicity reaches very high values. Factors of phytotoxicity are chlorides and sulfates. The
share of these salts is approximately the same. Their waste is classified as a class 4 toxicity.

The main reasons preventing the natural overgrowth of the surface of the Abagur tailing dump are:
• phytotoxicity due to salinization of the surface;
• high density of substrate;
• low content of plant nutrients;
• unfavorable microclimatic conditions, such as high temperatures in summer, insignificant
  accumulation of snow cover in winter, wind erosion, which not only carries out tailing
  material, but damages young shoots and leaves of plants with sand particles.
Phytotoxicity of rocks in combination with their high density are the main reasons for the long existence of technogenic desert of tailings.

For the formation of soil-vegetation layer, a technology of reclamation is necessary, which allows the conditions on the surface of the tailing dump to be improved and the long-term functioning of the phytocenosis in these microclimatic conditions to be ensured. Successful reclamation is possible by creation of a favorable root layer introducing organic-mineral mixtures during the technical stage and subsequent biological reclamation, i.e. creation of sustainable crop plants to prevent erosion and pollution of surrounding areas [9,10]. The creation of a grass cover on the surface of the tailing dump will radically improve the situation with snow accumulation in winter, which, together with the presence of organic substrate, will improve the efficiency of soil-plant layer restoration on its surface.

3. Technique of field experiment

It is known that the most rational way to restore the organic component of the dumps is to place on their surface a fertile layer of soil (FLS), removed during the construction of new dumps. This method was used for reclamation of slopes of the tailing dump No. 2. At the same time, a FLS removed from the tailing dump No. 3 was used. But this material is not enough for all areas that require reclamation. Therefore, to create a root layer of seeded leguminous plants on the surface of the tailing dump, sewage sludge of city treatment facilities was used. As a result of the work carried out on its surface, technosols were formed – artificial soils with a root layer of sown grasses, consisting of a mixture of SS and tailing material. Below are the results of the study of the properties and modes of technosols of experimental sites in Abagur tailing dump No. 1.

The goal of creating techno-systems was to study two soil-ecological effects. First, it was necessary to find out how the sharp differentiation of the profile of the technosols affects two layers with different granulometric composition for the restoration of soil functions and, accordingly, for biological productivity. Secondly, the effect of different deposition rates of the SS layer on the same parameters.

The variants of technosols included three series (A-1, A-2, A-3), which differed from each other in the amount of introduced SS (with thickness 30, 20 and 10 cm, respectively).

Earlier it was shown [7] that the first factor limiting the development of the cultivated phytocenosis in all variants of experiments is the phytotoxicity of the tailing dumps and SS because of chlorides and sulphates. In the case of technozomes belonging to the A series and having a profile differentiated by the rocks, the phytotoxicity of the rocks in the root zone is due to the salts contained in the SS, and in the underlying one – due to the tailing dump rocks. It was predicted that a pre-plowing of the tailing dump surface and loose build-up of freshly dumped SS will create conditions for substrate self-melioration in the root layer. The investigations carried out by us for the 2 years of vegetation of leguminous grasses and, consequently, the development of soil regimes and soil-ecological functions, confirmed this prediction.

4. Results and discussion

The results of the analysis of the salt composition of aqueous extract obtained from the substrate of the root zone of technosols of the considered experiment show that the degree of phytotoxicity sharply decreased (table 1). This was facilitated by a decrease in the proportion of dense residue and a decrease in the concentration in solutions of chlorides and sulfates, primarily magnesium and sodium.

It is necessary to pay attention to the fact that in different technosols of this option the degree of decrease in the concentration of phytotoxic salts is different. The largest it was in the series A-1, the smallest – in A-3. In other words, the lower the thickness of the SS layer, the higher the leaching rate of salts.

However, this does not mean that the 30-cm thickness of the SS layer is superfluous. First, at such thickness the phytotoxicity of the substrate decreased substantially to the level that does not interfere with the satisfactory development of cultivated phytocenosis. Secondly, there is reason to believe that the process of leaching of salts will further continue, and if this leaching mode is maintained, the
processes of optimizing the saline mode of the technozem will cover the entire thickness of the root layer. Thirdly, one of the most important goals of the experiment is to solve the problem of SS placement. Therefore, in the long term, in the soil-ecological plan, it is much more important to prevent the development of processes of secondary salinization, which can manifest itself quite realistically, provided soil drought and secondary compaction of the substrate in the root layer at any SS thickness.

Table 1. Comparative analysis of water extract of technozems in the root layer

| The year of experiment | Option | Dense residue, % | Content, mg-equiv/100g | Toxicity |
|------------------------|--------|-----------------|------------------------|----------|
|                        | A-1    | 1.731           | HCO₃⁻, 0.72 Cl⁻ 1.00 SO₄²⁻ 16.12 Ca²⁺ 14.65 Mg²⁺ 1.57 Na⁺+K⁺ 1.62 Cl⁻ 3.3 SO₄²⁻ 0.2 |
|                        | A-2    | 1.646           |                        |          |
|                        | A-3    | 1.753           |                        |          |
| The 2nd year           | A-1    | 1.006           | 0.96 0.52 7.59 7.23 1.23 0.61 1.7 0 |
|                        | A-2    | 1.070           | 1.00 0.65 8.16 9.50 1.36 1.05 2.2 0 |
|                        | A-3    | 1.125           | 1.28 0.70 9.45 10.73 1.45 0.75 2.3 0.1 |

After 2 years of self-development of soil-ecological functions, the parameters characterizing the physical state of substrate in the root layer changed, the density of soil increased noticeably, and the porosity decreased (table 2).

Table 2. Comparative analysis of the basic physical properties of technosols.

| The year of experiment | Option | Density of the solid phase, g/cm³ | Density of compaction, g/cm³ | Porosity, % |
|------------------------|--------|----------------------------------|-----------------------------|-------------|
|                        | A-1    | 2.28                             | 0.68                        | 70.2        |
|                        | A-2    | 2.20                             | 0.73                        | 66.8        |
|                        | A-3    | 2.25                             | 0.80                        | 64.4        |
| The 2nd year           | A-1    | 2.33                             | 1.03                        | 55.8        |
|                        | A-2    | 2.58                             | 1.18                        | 54.3        |
|                        | A-3    | 2.70                             | 1.05                        | 61.1        |

However, despite this, the named physical parameters remain within the limits close to optimal, and compaction itself should be considered a consequence of the natural subsidence. It is important, in terms of further monitoring studies, to trace at what level of density the subsidence processes will stop and whether they will go beyond the boundaries of the optimum zone. As a prediction it can be assumed that the subsidence will continue until the active humus accumulation processes begin to develop in the root layer of the technosols. At the current stage of development of technosols the thickness of the SS layer has practically no effect on the intensity of subsidence phenomena.

The chemical and agrochemical parameters of technosols changed after 2 years of their development (table 3).

Table 3. The main chemical and agrochemical parameters of Abogur tailings after 2 years of vegetation of perennial grasses.

| Option | pH  | C, % | The content of mobile forms, mg/100g of substrate |
|--------|-----|------|--------------------------------------------------|
|        |     |      | NH₄⁺ | NO₃⁻ | K₂O  | P₂O₅  |
| A-1    | 7.61| 3.5  | 3.5  | 7.1  | 32.8 | 40.9  |
| A-2    | 7.66| 4.1  | 3.2  | 6.4  | 33.0 | 38.5  |
| A-3    | 7.28| 5.8  | 5.3  | 3.0  | 32.7 | 41.2  |
Some alkalinization of the medium (pH values increase) and a sharp decrease in the amount of organic matter and all forms of nitrogen in the root layer are found.

At the same time, it is necessary to note the unusually high intensity of processes of organic substances mineralization contained in SS, and losses of various nitrogen forms. However, later on with the development of a stable crop plant, a certain balance of processes of humification and mineralization of organic substances will settle in the recultivated areas, which will also contribute to the stabilization of the nitrogen content in the root layer of technosols.

5. Conclusions

1. The carried out researches show that without reclamation measures the creation of a stable phytocenosis and the formation of a root layer of sown grasses in the tailing dump, which prevents the development of water and wind erosion, is impossible. The prospectivity of using SS as a soil amendments significantly improving the chemical and physical properties of iron ore enrichment waste was established.

2. Almost on all experimental sites there is a noticeable decrease in the intensity of the modes of biological activity and the functioning of the formed cultural phytocenoses.

3. As a result of SS introduction, the physical and nutritional modes on the surface of the tailing dump improve. In all options of SS placement methods, a positive effect has been achieved – the growth of terrestrial biomass of leguminous plants with an increase in the rate of SS introduction.

Thus, when depositing SS on the surface of the tailing dumps with sowing of grasses, the set goal of reclamation is achieved – the creation of a sustainable crop plant and the cessation of the transfer of pollutants to the adjacent areas.

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