Forest recultivation of overburden dumps of the Kingisepp phosphorite field

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Abstract. The article is devoted to the study of the stages of forest recultivation of overburden dumps of the Kingisepp phosphorite field’s breed located in the North-West of the Russian Federation. 5 test areas with a total area of 63.7 hectares were laid to study the different stages of recultivation. In the course of the study, the author's team identified four conditional stages of the formation of the spruce community of the forest recultivation of overburden dumps breed. The first stage, which has the conditional name ‘10 years’ is newly planted spruce trees on the recultivation territory. The second stage of the formation of the spruce community (‘20 years’) is that the European spruce passes into the stand. The third stage of community formation (‘30 years’) consists in the growth of all plantings to the level of a stand and in the creation of a birch-spruce or spruce-birch forest, since at the age of more than 30 years European spruce in recultivation by itself territories can occupy up to 50% of the stand. At the fourth stage, spruces displace birch trees from the community, remaining almost the only representative of the tree layer.

1. Introduction
Worldwide, land degradation due to anthropogenic mining activities is a serious problem [1,2]. The most widespread, worldwide, way to restore natural landscapes is biological recultivation [3,4]. When analyzing Russian and foreign experience in recultivation of waste deposits, it can be concluded that, in general, recultivation measures in different countries are similar to each other [5-7].

Significant areas of phosphorite fields are widely distributed in the non-black earth zone of the European part of the Russian Federation. The largest of them are Yegorevskoe in the Moscow region, Polpinskoe in the Bryansk Region, Vyatcko-Kamskoe in the Kirov Region and Kingisepp in the Leningrad Region. The processes of forest recultivation are most studied in the territories of waste facilities in the Moscow region. The study of the possibility of creating forest stands on the dumps of open-pit fields of the phosphorite has shown that for afforestation it is advisable to use oligotrophic species, i.e. species that are not very demanding for soil fertility. An ordinary pine is widely used when planting on dumps not only in the taiga zone, but also in other forest zones. Common pine has been widely used for recultivation. However, early studies showed that although pine is used for recultivation on the dumps of phosphorite field in the taiga zone, it has weak growth due to mass
damage to the apical and lateral shoots. For the recultivation of dumps of overburden breeds of the Kingssepp field, European spruce has become widely used, unlike other areas.

In the west of the Leningrad Region, there is a unique object with a rich history of recultivation of disturbed lands - the Kingisepp phosphorite deposit. The industrial development of the Kingisepp deposit was started in 1963, on the basis of which the mining and processing enterprise Production Association Phosphorit was built (since 2002, limited liability company industrial group Phosphorit). The development of the deposit was carried out until 2006 and was closed in the same year due to a significant deterioration in the mining and geological conditions of the mine. In total, for more than forty years of industrial development in the region, disturbed lands cover a total area of 6000 hectares.

Since the development of the deposit, phosphorite ore has been mined in an open pit using a non-transport overburden system with the transshipment of peat from Quaternary sediments and blasted rocky limestones into the worked-out area. The latter were deposited in the lower part of the dumps, and Quaternary deposits – in the upper one, with their subsequent leveling and creation of a layer of potentially fertile soils up to 2.0 m. This technology of ore mining at the Kingisepp deposit using overburden rocks ensured effective recultivation of disturbed lands from mining operations. When processing ore, more than 0.4 million tons of product and more than 4 million tons of dressing tailings - fine-grained quartz-type sands were obtained annually as production waste.

The territory of the deposit has the following facilities designated for recultivation: tailing dumps, overburden dumps, phosphogypsum storage and open pits. The present study is aimed at studying the stages of forest recultivation on overburden dumps. Geologic formation exposed during mining is represented by deposits of the Cambrian, Ordovician and Quaternary geological periods, the average thickness is 18-22 m. The bulk of overburden is limestone and dolomite, as well as loam, clay, sandy loam and sand. Overburden rocks have different physical and mechanical composition and chemical properties.

The results of biotesting, preliminary chemical analyzes and the first experiments on afforestation of forest plantations on the dumps of the Kingisepp phosphorite deposit, carried out in the 80s by employees of St. Petersburg Forest Research Institute, have shown that technogenic groups (soils) have satisfactory physicochemical properties and are very suitable for forest recultivation. The content of toxic elements does not exceed the norm, and the content of nutrients is not below the limits, which are optimal for a number of tree seedlings, in particular those that are laid on experimental sites.

The study of the state of forest plantations created in the process of recultivation was carried out in the 90s by a team of researchers from St. Petersburg Forest Research Institute (Yu E Samkov, D V Ogievsky, T A Pardaev and others). Since the 2000s, St. Petersburg State University scientists Ya A Dmitrakova and E V Abakumov have been carrying out scientific research on the study of regenerative soil-forming processes in post-technogenic ecosystems of quarry-dump complexes, including the territory of the Kingisepp phosphorite deposit.

Analysis of the domestic scientific experience accumulated over the past 30-40 years has shown that the scientific literature poorly covers the issues of monitoring the growth and condition of forest stands at the age of 12-14 years, and also practically does not consider changes in forest conditions and interactions in the ‘soil-vegetation’ system on technologically disturbed lands.

The purpose of this study was to study the stages of forest recultivation of overburden dumps of the Kingisepp phosphorite deposit.

Assessment of the state of forest plantations 30-40 years after recultivation is an important area of scientific activity for the forestry industry. The study of the formation of stages of forest tree communities in technogenically disturbed areas reveals important features for subsequent recultivation in North-West Russia, as well as for other similar regions.

Preservation and restoration of forest ecosystems is one of the most important tasks of man at the present time [8,9]. The artificial reforestation should be considered as the fastest way to restore. But land areas are limited, and for effective reforestation on the scale of the biosphere, it is quite justified to use the former industrial lands, which are currently occupied by post-technological objects, such as overburden dumps, etc. [10].
2. Materials and methods
The Kingisepp phosphorite field is located in the Kingisepp district of the Leningrad Region in the interfluve of the Luga and Narva rivers. The territory is a swampy plain with absolute marks of 20-30 m and a general slope to the north. Structurally, the deposit is located on the southern slope of the Baltic Shield. There are no lands of environmental significance and other natural objects of special cultural value on the territory of the mine and adjacent areas. The climate of the district is moderately continental and damp. Average temperatures in January-is minus 9-11 °C, in July is plus 16-17 °C. The duration of the snowpack is 127-152 days. The average height of the snowpack is 41 cm. The depth of soil freezing is 0.5 m. The duration of the frost-free season is 126-155 days. The average annual precipitation is 557-609 mm. The maximum humidity in November-December is 88%, the minimum in May is 67%. From the south, the mine and recultivated areas are bordered by the Pyatnitsky Moss swamp.

The recultivated territory is located on the lands of the forest fund of the Kingisepp Forestry, belonging to the Baltic-Belozersk taiga district. The flora is represented by mixed forests. Of coniferous species a pine prevails and amounts 55.6%, spruce is 2.4%, larch is 0.7%.

The test plots were laid on September 5, 2020 in the process of carrying out research work to study the state of the environment in the area of influence of anthropogenic objects of the Phosphorit (Kingisepp, Leningrad region). To study different stages of recultivation, 5 sample plots were laid: from a full-fledged forest ecosystem, the stand age of which is 36-38 years, through younger ecosystems formed by later plantings to a meadow community where recultivation was not carried out.

The test areas are located on the overburden dump breeds. Overburden breeds are represented by limestones of the Volkhov formation. These are dolomitized glauconite limestones, variegated breeds of bright yellow, greenish-brown colors, alternating with clay-siltstone interlayers.

Geobotanical descriptions were carried out as follows: sites of 20 by 20 meters approximately in the center of the studied territory were selected. It was based on them that the description was carried out. The size of the recultivated territories is as follows: the first area (40-year-old spruce trees) is 15.8 hectares; the second area (30-year-old spruce trees) is 7.7 hectares; the third area (20-year-old spruce trees) is 12.4 hectares; the fourth area (10-year-old spruce trees) is 15.5 hectares; the fifth area (only grass sowing) is 12.3 hectares. These sample areas can’t be fully considered as consecutive successional shifts, but their physical and geographical conditions are very close. The only difference is that the second test area is located on the slope of the dump, and not on its upland soil.

Subsequent office processing was carried out in the Microsoft Excel package. Due to the small amount of data, complete statistical processing was not carried out; comparative and correlation analysis was used for the analysis. The critical value of the correlation coefficient at n=5 and p=0.05 is 0.878.

Figures 1-2 show the layout of the trial plots.
Figure 1. Location of trial plots (large scale). Kingisepp region, Russia. Coordinates: trial plot 1 – N 59,3664 E 28,4400, trial plot 2 – N 59,3643 E 28,4436, trial plot 3 – N 59,3626 E 28,4360, trial plot 4 – N 59,3612 E 28,4403, trial plot 5 – N 59,3594 E 28,4376.

Figure 2. Location of trial plots in relation to Phosphorit and Kingisepp (Kingisepp region, Russia). Coordinates: trial plot 1 – N 59,3664 E 28,4400, trial plot 2 – N 59,3643 E 28,4436, trial plot 3 – N 59,3626 E 28,4360, trial plot 4 – N 59,3612 E 28,4403, trial plot 5 – N 59,3594 E 28,4376.
3. Results
Indicators of the state of plant communities in the studied areas are shown in the table 1. The first test area where the oldest spruce forests about 40 years old are located on the top of the overburden dump breed (figure 3). In the tree layer is dominated by European spruce *Picea abies* (L.) H Karst.

| Number of a test area                  | The test area               |
|---------------------------------------|-----------------------------|
|                                       | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| Age of spruce trees, years            | 40    | 30    | 20    | 10    | 0     |
| Aesthetic value, units                | 5     | 2     | 3     | 3     | 4     |
| Position in mesorelief                | Top of the dump             | Slope of the dump | Top of the dump |
| Spruces in the tree stand*            | 10    | 5     | 1     | 0     | 0     |
| Birch trees in the tree stand*        | 1     | 5     | 10    | 0     | 0     |
| Willow in the tree stand*             | 1     | 1     | 0     | 0     | 0     |
| Pine tree in a tree stand*            | 1     | 1     | 0     | 0     | 0     |
| A stand closure, units                | 0.7   | 0.2   | 0.1   | 0     | 0     |
| Height of spruce trees, m             | 15    | 10    | 7     | 4     | 0     |
| Height of pine trees, m               | 17    | 7     | 4     | 3     | 3     |
| Height of birch trees, m              | 20    | 10    | 10    | 3     | 3     |
| Height of willow, m                   | 8     | 10    | 3     | 0     | 3     |
| Diameter of spruce trees, cm          | 25    | 7     | 10    | 5     | 0     |
| Diameter of pine trees, cm            | 20    | 10    | 5     | 5     | 5     |
| Diameter of birch trees, cm           | 30    | 10    | 10    | 5     | 5     |
| Diameter of willow, cm                | 10    | 15    | 5     | 0     | 5     |
| The presence of undergrowth           | no    |       |       |       | is available |
| The main in the undergrowth is spruce | no    | yes   | yes   | yes   | no    |
| The main in the undergrowth is willow | no    | no    | no    | no    | yes   |
| The value of spruces in the undergrowth* | 0    | 8     | 10    | 8     | 0.5   |
| The value of aspens in the undergrowth* | 0    | 2     | 0.5   | 0     | 1     |
| The value of birch trees in the undergrowth* | 0    | 0.5   | 0.5   | 1     | 2     |
| The value of willows in the undergrowth* | 0    | 0     | 0.5   | 0     | 7     |
| The value of pines in the undergrowth* | 0    | 0     | 0.5   | 1     | 0.5   |
| The forest stand closure*             | 0     | 2     | 4     | 4     | 1     |
| The projective cover of the grass-shrub layer* | 4    | 9     | 5     | 5     | 8     |

*Max=10

There are single specimens of common pine *Pinus sylvestris* L., pubescent birch *Betula pubescens* Ehrh. and willows *Salix sp*. Aesthetic value has the highest score – 5. The closeness of the tree tier on this area is 0.7. This is the largest of the studied ones. The height of spruce trees is about 15 m, the height of pines is 17 m, the height of birches is 20 m, the height of willows is 8 m. The diameter of the *Picea abies* on this site is 25 cm, *Pinus sylvestris* – 22 cm, *Betula pubescens* is 28 cm, willow tree – 12 cm. Undergrowth on this test area is not pronounced and almost absent. The projective cover of the grass-shrub layer is 40%, which is due to the formation of a ‘dead’ cover under old spruce trees. It would be like to note on the area of fireweed the presence of narrow-leaved *Chamaenerion angustifolium* (L.) Scop., which is not found or almost not found in areas with initial stages or with the
absence of recultivation. Also within the cover of the grass-shrub layer, there is a meadow sea lion *Succisa pratensis* Moench, which is not found in all descriptions on this dump of overburden dump breed. The colt’s foot *Tussilago farfara* L., which is a representative of the ruderal flora is abundant. This factor indicates that despite the recultivation the grass-shrub layer of spruce forests will not be close to zonal forests, and this is already a new formed anthropogenic-natural system (table 2). Moss-lichen layer is 90% green mosses.

![Figure 3](image1.png)  ![Figure 4](image2.png)

**Figure 3.** Trial plot 1 (overburden dump, Kingisepp, Leningrad Region, Russia, N 59,366403 E 28,440017).

**Figure 4.** Trial plot 2 (overburden dump, Kingisepp, Leningrad Region, Russia, N 59,366403 E 28,440017).

**Table 2.** The state of the grass-shrub layer on the test area No.1.

| A plant               | A sublayer | Height, cm | Abundance by Drude | Projective coverage, % | Vitality |
|----------------------|------------|------------|--------------------|------------------------|----------|
| *Tussilago farfara*  | 2          | 25         | cop                | <5                     | 1        |
| *Chamaenerion*       | 2          | 25         | sp                 | <5                     | 1        |
| *angustifolium*      | 2          | 20         | sp                 | <5                     | 1        |
| *Calamagrostis*      | 2          | 20         | sp                 | <5                     | 1        |
| *epigios*            | 2          | 20         | sp                 | <5                     | 1        |
| *Succisa pratensis*  | 1          | 3          | sp                 | <5                     | 1        |
| *Anthriscus*         | 1          | 7          | sol                | <5                     | 1        |
| *sylvestris*         | 1          | 7          | sol                | <5                     | 1        |
| *Achillea*           | 1          | 12         | sol                | <5                     | 1        |
| *millefolium*        | 1          | 12         | sol                | <5                     | 1        |
| *Vicia cracca*       | 3          | 30         | sp                 | <5                     | 1        |

The second test area which consisting of spruce stands of about 30 years, is located on the slope of the overburden dump breed (figure 4). In general, throughout the territory of this natural and anthropogenic complex, the pubescent birch along with the *Picea abies* share a predominant role in the community. There are also single specimens of common pine and willow tree. The aesthetic value of the territory is 2. The closeness of the tree tier is insignificant and is 0.2. The height of spruces, birches and willows does not exceed 10 m, and pines have a height of about 7 m. At the same time the
diameter of spruce trees is insignificant is only an average of 7 cm, the diameter of pines and birches is approximately 10 cm, and willows have the largest diameter - 15 cm. The undergrowth on this test area is pronounced and is mainly represented by *Picea abies*. There is also an aspen and a *Betula pubescens*. The projective coverage of the grass-shrub layer is 90%. The dominant species in the grass-shrub layer are *Achillea millefolium* L., *Calamagrostis epigeios* (L.) Roth and *Avenella flexuosa* (L.) Drejer (table 3). Moss-lichen layer has 60% green mosses.

**Table 3.** The state of the grass-shrub layer on the test area No. 2.

| A plant                        | A sublayer | Height, cm | Abundance by Drude | Projective coverage, % | Vitality |
|--------------------------------|------------|------------|--------------------|------------------------|----------|
| *Lathyrus pratensis*           | 2          | 25         | sp                 | <5                     | 1        |
| *Achillea millefolium*         | 3          | 40         | cop1               | <5                     | 3        |
| *Taraxacum officinale*         | 2          | 15         | sp                 | <5                     | 1        |
| *Calamagrostis epigeios*       | 3          | 30         | cop1               | <5                     | 1        |
| *Avenella flexuosa*            | 1          | 7          | cop1               | <5                     | 1        |
| *Trifolium pratense*           | 1          | 10         | sp                 | <5                     | 1        |
| *Tusilago farfara*             | 2          | 20         | sp                 | <5                     | 1        |
| *Chamaenerion angustifolium*   | 3          | 60         | sp                 | <5                     | 1        |
| *Solidago virgaurea*           | 1          | 7          | sp                 | <5                     | 1        |
| *Leucanthemum vulgare*         | 3          | 40         | sol                | <5                     | 3        |
| *Dactylis glomerata*           | 3          | 60         | sp                 | <5                     | 3        |
| *Vicia cracca*                 | 3          | 50         | sp                 | <5                     | 3        |

The third test area (the age of the plantings is approximately 20 years) is located again on the top of the overburden dump breed (figure 5). Only single representatives of the *Picea abies* are found in the tree stand. The tree tier is mainly represented by *Betula pubescens*. This area has an average value of aesthetic value which is 3. The closeness of the stand does not exceed 0.1. The largest specimens of spruce reach 7 m, but they are isolated. Birch trees can also reach 10 m in height. The main mass of recultivation plantings is still at the level of undergrowth (about 4 m). At the same time the diameter of *Picea abies* trees became even larger than in the previous area on the slope - about 8 cm. The diameter of the birches is the same - 8 cm. The undergrowth on this area is pronounced and is represented by plantings of *Picea abies*. Also in the forest there are aspen *Populus tremula* L., *Betula pubescens*, *Pinus sylvestris* and Salix sp. The closeness of the undergrowth is greater than the closeness of the stand - 0.4. The projective cover of the grass-shrub layer is half the area (50%). On this square there is also a fireweed. In addition to fireweed, in the grass-shrub layer there are also nosebleed *Achillea millefolium* L., meadow peavine *Lathyrus pratensis* L., meadow clover *Trifolium pratense* L. (table 4). Moss-lichen layer has 60% green mosses.

The fourth test area is the territory where recultivation was carried out about 10 years ago (figure 6), this is the top of the overburden dump breed. There is no tree layer, there is only undergrowth. The aesthetic value of the territory is 3. The plantings slightly exceed the human height. The height of all tree species in the forest: 2-4 m. This is mainly a *Picea abies*, but there is also a *Betula pubescens* and *Pinus sylvestris*.

The diameter of the undergrowth does not exceed 5 cm. At the same time the plantings are quite dense and the closeness of the undergrowth is 0.4. The projective coverage of the grass-shrub layer is the same as on the previous site - 50%. There is no fireweed in this area, there is *Succisa pratensis* (5 cm high), a *Calamagrostis epigeios* (in the third sublayer of the grass-shrub layer it is about 40 cm high), a sylvan horsetail *Equisetum sylvaticum* L. The coverage of mosses on this area is quite insignificant – no more than 5%.
Table 4. The state of the grass-shrub layer on the test area No. 3.

| A plant                                  | A sublayer | Height, cm | Abundance by Drude | Projective coverage, % | Vitality |
|------------------------------------------|------------|------------|--------------------|------------------------|----------|
| *Lathyrus pratensis*                     | 2          | 25         | sp                 | <5                     | 1        |
| *Calamagrostis epigieos*                 | 3          | 40         | sp                 | <5                     | 1        |
| *Chamaenerion angustifolium*             | 2          | 20         | sp                 | <5                     | 1        |
| *Achillea millefolium*                   | 2          | 15         | sp                 | <5                     | 1        |
| *Trifolium repens*                       | 1          | 7          | sp                 | <5                     | 1        |
| *Tussilago farfara*                      | 2          | 15         | sp                 | <5                     | 1        |

Figure 5. Trial plot 3 (overburden dump, Kingisepp, Leningrad Region, Russia, N 59,366403 E 28,440017).

Figure 6. Trial plot 4 (overburden dump, Kingisepp, Leningrad Region, Russia, N 59,366403 E 28,440017).

It would be like to note that the abundance of *Lathyrus pratensis* according to Drude is cop1, which means that *Lathyrus pratensis* is the dominant species in the grass-shrub layer in this area (table 5). It is quite likely that during the recultivation of *Lathyrus pratensis* the superimposed soil was sown as a strengthening perennial herbage that promotes the accumulation of nutrients in the soil (in particular, nitrogen).

Table 5. The state of the grass-shrub layer on the test area No. 4.

| A plant                          | A sublayer | Height, cm | Abundance by Drude | Projective coverage, % | Vitality |
|----------------------------------|------------|------------|--------------------|------------------------|----------|
| *Lathyrus pratensis*             | 3          | 30         | cop1               | <5                     | 3        |
| *Tussilago farfara*              | 2          | 20         | sp                 | <5                     | 1        |
| *Succisa pratensis*              | 1          | 5          | sp                 | <5                     | 1        |
| *Equisetum sylvaticum*           | 2          | 20         | sp                 | <5                     | 1        |
| *Calamagrostis epigieos*         | 3          | 40         | sp                 | <5                     | 1        |
The fifth test area is located on the top of the overburden dump breed and no forest recultivation was carried out on it. There is only perennial grasses were sown (figure 7).

![Figure 7. Trial plot 5 (overburden dump, Kingisepp, Leningrad Region, Russia, N 59,366403 E 28,440017).](image)

Therefore, there are no *Picea abies* plantings on it. The aesthetic value of this meadow community is high and has an indicator 4. *Pinus sylvestris*, *Betula pubescens* and *Salix* sp. are found in single, detached specimens from the undergrowth. The height of the undergrowth does not exceed 3 m. The diameter does not exceed 5 cm. Moreover, the predominant role in the community in the forest is played by willows (more than 70% of all tree species). Due to the focal nature of the spread of undergrowth, its closeness is less than 0.1. The projective coverage of the grass-shrub layer is high – about 80%. It is interesting that there is no firewood in this meadow community. In the grass-shrub layer there are tufted vetch *Vicia cracca* L. (in the 3rd sublayer it is about 40 cm high, vegetates), common nosebleed (in the 3rd sublayer it is about 30 cm high, blooms), meadow peavine (in the 3rd sublayer it is about 60 cm high, blooms), awnless brome *Bromus inermis* Leyss, millet grass *Milium effusum* L., spiked wood rush *Luzula pilosa* (L.) Willd. There is no moss-lichen layer. The meadow peavine is again knocked out as the dominant in the grass-shrub layer, the abundance of which is cop1 according to Drude (table 6).

| A plant            | A sublayer | Height, cm | Abundance by Drude | Projective coverage, % | Vitality |
|--------------------|------------|------------|--------------------|------------------------|----------|
| *Lathyrus pratensis* | 3          | 60         | cop2               | 50                     | 3        |
| *Achillea millefolium* | 3          | 30         | sp                 | <5                     | 3        |
| *Calamagrostis epigeios* | 3          | 40         | cop1               | <5                     | 1        |
| *Tussilago farfara* | 2          | 25         | sp                 | <5                     | 1        |
| *Bromis inermis*    | 3          | 60         | sp                 | <5                     | 3        |
| *Vicia cracca*      | 3          | 40         | sol                | <5                     | 1        |
| *Millium effusum*   | 3          | 60         | sp                 | <5                     | 3        |
| *Lusula pilosa*     | 3          | 45         | sp                 | <5                     | 3        |
4. Discussion
Within the framework of this study, we can distinguish four conditional stages of the formation of a spruce community on overburden dumps by means of forest recultivation. The first stage, which has the conditional name ‘10 years’, represents recently planted spruce on the reclaimed territory, which had previously passed the technical stage of recultivation and long-term sowing with herbs. The various breeds of undergrowth and their representation in the community are shown in figure 8. The end of the first stage is marked by the emergence of the tallest individuals into the tree layer (over 6 m). The second stage of the formation of the spruce community (‘20 years’) is that European spruce passes into the stand. Moreover, at the age of 20, only single specimens of spruce enter the arboreal layer of the community. The third stage of community formation (‘30 years’) consists in the growth of all plantations to the level of the stand and in the creation of a birch-spruce or spruce-birch forest, since at the age of more than 30 years, European spruce in the territories reclaimed by it can occupy up to 50% of the composition stand. The composition of the stand at all five sites is shown in figure 9. At the fourth stage, spruces displace birches from the community, remaining almost the only representative of the arboreal layer, beginning to form the fifth stage, which is not yet represented in the study area - dead-cover spruce forests. In the area of Kingisepp, on dumps of overburden - dolomites and limestones - spruces reach the fourth stage by about 40 years.

![Figure 8. The composition of the undergrowth on five test areas.](image)

![Figure 9. The composition of the stand on five test areas.](image)

The opposite situation is observed with the role of downy birch in the community where spruces were planted. At the age of 20 years, birch trees occupy a predominant role in the community. However, by the age of 30, birches already occupy only 50% of the composition of the community, and at the age of 40 years of spruce, birches are only single units. Willow and Scots pine appear in the stand only at the third stage of community formation, despite the fact that in the undergrowth, willow and pine accompany spruce and birch from the first stage. Probably, the abundance of planted fir trees does not allow the development and increase in the abundance of pines and willows. Stand density gradually increases from 0.1 at the second stage to 0.7 at the fourth stage.

In the meadow community, willows play a predominant role, and in these physical and geographical conditions, it is more expected to see a small-leaved forest under natural overgrowth. By planting spruce, a person, in turn, makes his own adjustments to the development of natural complexes. However, from the point of view of the currently widespread anthropocentric approach to nature, it is the goal-setting of a person in relation to a certain territory that is the key point by which we can assess the sufficiency of the restoration of the natural-anthropogenic complex. Natural restoration has a justified aspect only in specially protected areas, in other lands it is the intended use of the land that determines which landscape needs to be formed. Therefore, the formation of a spruce forest seems to be appropriate.
European spruce is one of the main tree species used for recultivation of overburden dumps. Plantations of 40 years old at the top of the overburden dump grow according to bonitet classes III-IV, and plantations of 20 years old, growing in similar conditions, grow according to IV-V bonitet classes. Possibly, a lower bonitet class in younger plantations is associated with a greater competitiveness of spruce plantations with other tree species. On the slopes of the overburden dump, 30-year-old spruce stands grow according to bonitet classes IV-V, and the youngest 10-year old ones - according to the V bonitet class. The lower bonitet of spruce stands of slope facies can most likely be explained by the lack of nutrients due to the leaching water regime.

Correlation analysis showed, on the one hand, the expected results, and on the other, it showed an interesting pattern. As expected, a significant correlation was found between the age of spruce stands and their diameter, height, proportion in the community, as well as the height of the main accompanying species in these landscape conditions - white birch. A positive significant correlation was also found between the age of spruce trees and mosses coverage. At the first stage, the moss-lichen layer takes 5%, at the second and third stages - 40-60%, and at the fourth stage - almost 90%. The currently unexplained correlation is an increase in the abundance of bay willow with an increase in the age of the willow trees. At the first stage of the community (and at the meadow stage as well), there is no bay willow in the HDSL. At the second stage of community development, single specimens of fireweed appear. And starting from the third stage, according to the abundance of Druda, bay willow takes the position sp. True, when compared with scientific data on the succession of spruce forests, it can be assumed that in the future, with the development of the community, the abundance of bay willow will begin to decrease.

From the point of view of using disturbed areas (such as overburden dumps), forest recultivation is the best option, since in the future such areas can be used as recreational areas. This is clearly seen in the example of recultivation of dumps near Kingisepp after the extraction of phosphorites. Currently, the territories where planted spruce forests are located are used by local residents for their own purposes - fishing, collecting non-timber forest products (berries, mushrooms). At the same time, the attendance of reclaimed spruce forests is higher than that of naturally grown spruce and birch forests of the Ivango district forestry, which were also studied in parallel by the authors of this article. Therefore, in further research, it is worth taking into account the observation that the local population aesthetically perceives forest plantations more positively than naturally renewable forests, and prefers to visit precisely reclaimed territories, despite their industrial history.

It remains an open question whether reclaimed forests will be able to approach natural forests in their species composition, since at the moment the grass-dwarf shrub layer of natural forests and forests on overburden dumps differs significantly, despite similar physical and geographical conditions. The abundance of impurities in the composition of the community in the form of ruderal species does not disappear even 40 years after recultivation. Perhaps only the restoration of a complete soil cover identical to the natural one can contribute to the formation of a zonal HDSL.

5. Conclusion
This study has shown that the recultivation of overburden rocks consisting of dolomites and limestones of the Obukhov and Volkhov formations of the Ordovician period can be divided into five stages. The present study considered the recultivation of European spruce.

The first stage is the planting of fir trees. The second is the formation of a viable layer of undergrowth, consisting of planted spruce trees. The third stage is the transformation of the undergrowth layer into a tree layer, which, in addition to spruce trees, includes other species (mostly small-leaved). The fourth stage is the formation of a monocultural spruce community. Achievement of the fourth stage at the dumps of the Kingisepp phosphorite deposit is possible by the age of 40. The fifth stage - potential -is the formation of dead-cover spruce forests.

The creation of a plant community at the site of post-technogenic objects should be based on the targeted use of future forested lands. Overburden dumps do not contain high concentrations of
pollutants and can be a substrate for forest complexes intended for recreational activities of the local population.

The herb-dwarf shrub layer of forests in reclaimed territories requires additional study. The abundance of coltsfoot in 40-year-old reclaimed spruce forests may indicate that a completely new type of forest is being formed, different from the zonal herb spruce forests, bilberry spruce forests and sorrel spruce forests. It is quite possible that anthropogenic activities in the extraction of minerals, leaving behind post-technogenic complexes with unique physicochemical conditions, make it possible to form, in the process of recultivation, new natural complexes that are not found in nature.

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