Master thesis

Evaluation of the efficiency of using biodegradable waste as a component of the reclamation mixture

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Date(24/06/2021)

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Declaration of Authorship

„I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet.”

24/06/2021

Preface, Dedication, Acknowledgement

The author would like to thank Mr. Yuri Smirnov, associate Professor of the Department of Geoecology of the Mining University, for assistance in writing this MA thesis and Scientific and Educational center for collective use of high-tech equipment "Center for Collective Use" for their support with the scientific experiment.

Abstract

The master's thesis is devoted to the solution of the problem of the possibility of using the waste of 5 hazard classes to increase soil productivity. Waste of paper, newspapers, boxes, paper bags, and foliage are used as promising components of the reclamation mixture.

The work examines in detail the problem of the redevelopment of residential areas and the creation of landscaping objects in the urban environment. The problem of a shortage of green spaces with a low quality of environmental amenities is highlighted.

The level of knowledge of the problem of using biodegradable waste for reclamation purposes is analyzed in detail based on the works of Russian and foreign scientists. The existing examples of useful waste disposal are described in detail.

The experimental section contains the results of a laboratory experiment to create samples of biomat from a mixture of waste from a mixture of different types of waste that are generated in large quantities in urban areas and substantiate the prospects of its use in real conditions. Selection of technical equipment for the implementation of the proposed environmental action.

The economic page contains the calculation of capital and operational investments for the implementation of the proposed event and the calculation of the prevented environmental damage.

Zusammenfassung

Die Masterarbeit widmet sich der Lösung des Problems der Möglichkeit, die Abfälle von 5 Gefahrenklassen zur Erhöhung der Bodenproduktivität zu verwenden. Abfälle von Papier, Zeitungen, Kartons, Papiertüten und Laub werden als vielversprechende Komponenten der Rekultivierungsmischung verwendet.

Die Arbeit befasst sich ausführlich mit dem Problem der Sanierung von Wohngebieten und der Schaffung von Landschaftsobjekten in der städtischen Umgebung. Das Problem des Mangels an Grünflächen mit einer geringen Qualität der Umweltausstattung wird hervorgehoben.

Der Kenntnisstand des Problems der Verwendung biologisch abbaubarer Abfälle zu Rekultivierungszwecken wird anhand der Arbeiten russischer und ausländischer Wissenschaftler detailliert analysiert. Die bestehenden Beispiele für eine sinnvolle Abfallentsorgung werden ausführlich beschrieben.

Der experimentelle Teil enthält die Ergebnisse eines Laborexperiments zur Herstellung von Proben von Biomat aus einem Abfallgemisch aus verschiedenen Abfallarten, die in großen Mengen in städtischen Gebieten anfallen, und untermauert die Aussichten auf ihre Verwendung unter realen Bedingungen. Auswahl der technischen Ausrüstung für die Durchführung der vorgeschlagenen Umweltaktion.

Die ökonomische Seite enthält die Berechnung der Kapital- und Betriebsinvestitionen für die Durchführung der vorgeschlagenen Veranstaltung und die Berechnung des vermiedenen Umweltschadens.

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1 Introduction

The scientific and technological advances of today entail an increase in the amount of waste generated in colossal quantities. The President of the Russian Federation, in his message to the Federal Assembly on 15.01.2020, emphasizes that in the near future we must drastically reduce the amount of waste going to landfill and switch to a closed-cycle economy in general.

One glaring example of inappropriate waste management is paper products, which make up a quarter of the planet's waste. This is despite the fact that waste paper can be a fairly valuable material for various environmental monitoring and protection issues. The widespread recycling and further beneficial use of paper alone could save not only the lives of trees but also the Earth itself as a whole.

At the same time, the question of landscaping and a well-thought-out strategy for urban green spaces is of the utmost importance, as it is one of the most important aspects for the comfort of modern living. This problem of existing urban planning limits the full efficiency of human activity and contributes to the low level of attractiveness of settlements.

One of the main inventions in the field of land reclamation is biomats, which can both protect the fertile layer of soil from erosion processes and speed up soil re-vegetation in the shortest possible time of application, as well as carry out various kinds of fertilization on it.

To date, the variety of biomats on the market is not great. Fewer of the existing options are genuinely biodegradable as most offers contain synthetic substances which either do not biodegrade at all or only take a long time to decompose.

The research conducted in the course of this work aims to solve the urgent problem of useful waste disposal with the prospect of using it in the reclamation of disturbed land.

The aim of this master's thesis is to evaluate the effectiveness of using the waste of hazard classes 5 as reclamation mixture components. In order to achieve the set goal it is necessary to solve the following tasks:

- analysis of the existing system of waste management in Russia and abroad;
- to study scientific-theoretical issues considered in the given work (patent-literature analysis);

- assessment of the possibility of using waste as a component of biomaterial with the issuance of appropriate recommendations;
- development of a methodological approach to the assessment of the composition and design of biomats when choosing the most efficient option;
- development of a composition of biodegradable material to improve the productivity of disturbed land;
- assessment of prevented environmental damage through the implementation of the proposed method of solving the problem of reclamation.

The relevance of this study is due to the fact that for the revival of herbaceous vegetation in urban areas very inefficient methods, which include hydraulic seeding, are used. In hydroseeding, seeds often have a very low germination rate due to exposure to various types of influences: biotic, wind and water. The current negative ecological consequences on the fertile soil layer can worsen not only the environment but also the quality of life of mankind. And the enormous increase in waste due to scientific and technical progress leads to serious social and economic damage.

2 The problem of landscaping and the creation of greenery in the urban environment

Urban landscaping is an important aspect for a comfortable human life, but in spite of this, residential landscaping is one of the main current problems of modern urban planning.

Until recently, the anthropogenic impact on the environment was much lower than what we have today. Humanity's impact on nature in today's world can lead to global environmental change, and in some matters, this change has already begun and is advancing exponentially. Today the fate of all mankind depends on the nature of the relationship between man and nature. The colossal development of productive forces in the twentieth century has overshadowed the issue of livability. But, as you know, landscaping solves several problems of modern society: starting with the issues of landscaping areas and finishing all-round improvement of the environment.

Urban landscaping is a full complex of measures, which includes planning, construction, adoption of any engineering architectural solutions, implementation of special measures (for example, to combat litter or overgrowth), landscaping of new and existing settlements. Erection of recreation areas for adults and creation of special playgrounds for children, planning the car park, arrangement of green areas - all of these together will ensure safe and comfortable stay of citizens in the yard area. In other words, it is a set of activities that enhance the environmental qualities of the areas in residential developments.

High-quality landscaping - is a sign of the full life of modern man. After all, when the complex of landscaping is performed professionally, both the appearance of streets and courtyards and the environmental condition of the entire city are significantly improved. Moreover, a safe and aesthetically pleasing living environment increases the level of comfort of the citizens themselves and improves their psychological and emotional state, well-being and mood.

Figure 1: An example of urban landscaping

There is a certain chain of consistency: population increases, which leads to urban growth, which in turn leads to an increase in industrial activity, which ultimately leads to the problem of poor quality landscaping. The latter, often, requires the use of territorial resources in order to be finally resolved.

The problem of the improvement of urban areas needs constant attention from private entrepreneurs, public utilities, enterprises, and organizations of the city, chairmen of homeowners associations, and, directly, the population itself. The cleaning and beautification of the adjacent courtyard territories is a complex problem that should be solved when the financial issue is solved and the population and the authorities have the desire and free time.

Social housing is known to be the cheapest type of property in all countries. Yard spaces in different countries cannot be compared because of many basic differences - climatic, economic, political - but also because of differences in mentalities, traditions, and customs - everything that forms the basis of a person's living environment. Approaches to the improvement of residential areas in Europe, America, and Asia are quite different, but the aspirations are the same - to create a complete and safe environment that improves living conditions.

For example, France has the Haute Qualité Environnementale (HQE), a green building standard based on the principles of sustainable development, first adopted in 1992 at the Earth Summit. The standard is overseen by the Association pour la Haute Qualité Environnementale (ASSOHQE). The standard is available in 23 countries and is adapted to the specificities of each country: climate, regulatory framework, construction practices, and process organization system. The standardization aims at minimizing the negative impact on the environment, reducing water and energy consumption and waste, and building a healthy and comfortable environment for the inhabitants. HQE certification is adapted to each type of building: residential, office, educational, healthcare, and others. It applies to buildings under design, renovation, and use, as well as to interior finishes.

Another striking example of high-quality improvement can be seen in Singapore, where the approach to the formation of the residential environment is largely determined by climatic features. Singapore's social housing complexes are comfortable and of high quality despite the scarcity of land and the density of development. Residential estates are fenced, heavily landscaped, and filled with leisure, sports, and recreational facilities. The grounds of the complexes usually contain decorative and swimming pools, sports and children's playgrounds, picnic areas with grills and tables, and many recreation areas. All possible types of landscaping are used - in-ground, retaining wall, vertical, container. Roof gardens are arranged.

In Japan, however, there are Standards for the Improvement and Development of the Urban Environment, which are mandatory. One example is the Greening Standard, which defines the amount of green space in the area to be developed. There is a scale of indices for the greening of the area. The minimum value of 1 is given to areas without greenery; farms, meadows, grassy lawns, fields, gardens have an index of 2 to 4; brush and bamboo thickets - 5; tree plantations - 6; young secondary (planted) forest - 7; old planted forest - 8; primary forest - 9; especially valuable primary forest - 10. After completion of the project, the average index of the developed area must not be lower than 6. Consequently, to compensate for areas poured over with asphalt, builders must plant trees.

2.1 An environmental amenities as a separate element of external landscaping

One of the main elements of external development is the green economy, which is responsible for the availability, maintenance, and development of green areas. In addition, the green economy is also responsible for the maintenance of various recreational areas, forest belts, green protection zones, and plant nurseries. Environmental landscaping is a complex system of measures that protect the natural components and is responsible for the environmental safety of the inhabitants of the city. It is one of the elements of the sphere of external landscaping, which is able to solve the environmental problem, which is reflected in a small number of green spaces, leading to the deterioration of the local microclimate and the entire level of ecology, in general.

Green areas can architecturally connect individual street segments, disguise unsuccessful developments, and, conversely, emphasize important buildings. Plantings that run along streets can accentuate the length of the street. Moreover, greenery plants perfectly decorate urban landscapes, being a certain color. With them, populated areas look smart and complete.

The lack of urban green spaces is one part of a complete urban redevelopment complex. This problem is a major aspect in addressing the low level of attractiveness of the area. This component is very important, as the current level of urbanization brings with it increased air pollution and the separation of man from nature. Green areas can improve this situation, as they can not only provide a nice place to rest and clean the air, but also protect the ground and pavements from overheating, and improve the microclimate as a whole.

The city is an organism in its own right, constantly evolving and changing in space and time. Today, the densification of the city center's residential blocks has led to a loss in the quality of the living environment, through insufficient ventilation, a lack of sunshine, and the reduction of greenery.

The choice of street greening should be influenced by the following factors: the intensity of pedestrian and vehicle traffic, the overall width of the streets, the width of the pavements, the orientation of the streets to the cardinal points, the set of adverse conditions which can be mitigated or eliminated by the greening. A variety of plantings (trees, shrubs, flowers, lawn) is recommended for landscaping. In-line plantings of trees are permitted in the lawn strip, but in these cases, species with superficial and highly branched root systems should not be used to avoid damage to the paving of pavements.

In today's world, the amount of exhaust fumes from road traffic is reaching unbelievable levels. This not only creates visual discomfort, but also leads to high levels of air pollution, increased noise pollution, and makes it difficult for pedestrians to get around. One of the best ways to solve this problem can be through hedges (trees, shrubs, etc.). A moderate amount of greenery is good for the physical and mental health of city dwellers. They play an important role in urban landscaping and can create a pleasant and aesthetic atmosphere in the courtyard and recreational areas. By increasing the number of green spaces, it is possible to significantly improve the ecology of the area, at least because plants can improve air quality.

Restoration of disturbed soil vegetation requires a fairly long period of time and huge capital investments. It takes hundreds of years to form a normally developed fertile soil layer under natural conditions, while its restoration (recultivation) requires from several years to several decades. Moreover, the restoration of soil fertility requires long-term active human participation, since it needs careful cultivation and improvement.

A sound greening strategy is the refurbishment of existing green spaces, including protection of retained green spaces, planning and sanitary cutting, and replanting green spaces. It is, in other words, the creation of a new planting system, taking into account the new functional planning and landscape structure of the territory and the development of optimal methods of planting for each site.

The amount of plants needed for a high level of livability must be an essential part of the city because green spaces are seen as a sufficiently important factor in protecting the environment and improving the quality of life. Plants planted within the city are able to create both microclimatic and hygienic conditions and define the architectural and artistic character of the city. Therefore, in urban areas, it is necessary to implement an integrated approach to the formation of the planting system, including both the creation of a new planting system and the reconstruction of existing preserved green spaces.

The creation of a new system of landscaping should be formed taking into account all existing modern trends in the development of landscape architecture, progressive methods of landscaping, the structure of existing preserved plantings, the basic principles of selection and combination of tree and shrub species, the current standards for planting material. For each functional element of landscaping (courtyard gardens, front gardens, pedestrian pavements, areas of different purposes, etc.) proper selection of species composition, conditions, and characteristics of planting material and rational planting standards should be implemented.

But nowadays, in urban environments, all plants are often planted by conventional seed sowing (Fig. 2), which subsequently leads to minimal germination due to their being eaten by birds. And with an even more common method, hydroseeding, the seeds, not having time to take root, are washed away by surface water or blown away by the wind, and we have to reseed the surface every year.

The above once again confirms the fact that it is necessary to invent a design that is easy to perform while being inexpensive and meeting all the regulatory requirements of the country in the field of land reclamation and restoration.

Figure 2: An example of the site improvement of residential areas in an urban environment

3 The problem of using biodegradable waste for reclamation purposes

Waste disposal is one of the most global problems of modern civilization, which has not only an impact on public health and the state of nature but also leads to serious social and economic damage. Here it is worth noting that the most popular method of disposal is the removal of waste to specialized landfills. But it should be understood that for the arrangement of these landfills, fertile land is often used!

Many industrial processes lead to a lot of waste. In the near future, waste management will play an important role in the conservation of natural resources. The problem of organic waste treatment and deposition has many aspects. Its negative consequences are noticeable both for public health and for components of the environment (air, water, soil, etc.) [36].

In 2019, Russia set an anti-record for the formation of industrial waste-about 8 billion tons, which is about 4 times more than in 2002. Only 40% is recyclable, and the rest is thrown into landfills [2].

At the same time, paper products are a quarter of all waste products of our planet's population. The pulp and paper industry (PPM) is a huge contributor to the mass of waste with an annual increase of up to 7 million tons that is still unrecycled [2]. Its recycling saves lives not only for trees but also for the Earth itself. Waste paper can do a lot of good if you learn how to use it correctly. For example, to give it a "second life" by transforming it into valuable and useful material for the reclamation of disturbed lands.

The Global Waste Management Outlook (UNEP 2015) estimates that total "urban" waste generation, including commercial and industrial waste, and construction and demolition waste, is about 7-10 billion tons per year. Even developing countries still face major waste management challenges, including uncontrolled waste dumping, open burning, and inadequate access to waste management services [8].

The Communication from the Commission to the Council and the European Parliament on Future Steps in Biowaste Management in the European Union (EU) indicates that biowaste is an underutilized material. While offering an excellent contribution to improve the resource efficiency of the EU and to improve the condition of carbon-depleted soils, in many member states the demand suffers from a lack of end-user confidence. To address this problem, the use of these materials must be regulated in such a way that adverse consequences do not arise. The Commission's analysis confirms that improved biowaste management in the EU has an untapped potential for significant environmental and economic benefits [36].

On average, one European family generates about one tonne of waste per year. The entire United Kingdom produces 27 million tons of waste over the same period, Russia produces 150 million tons, and the United States more than 250 million tons. If we add the number of annual industrial wastes to these values, we get a figure of an incredible order of magnitude [33]. In the first seven months of 2016, an estimated 750 people died due to poor waste management in landfills (International Solid Waste Association 2016) [8]. And proper solid waste management through reduction, reuse, recycling, composting, incineration, or landfill disposal is one of the main conditions for environmentally sustainable cities [29].

About 4 billion tons of production and consumption waste is generated annually, and about 4 million hectares are occupied by permitted waste disposal facilities. More than 30 million tons of production and consumption waste are accumulated, of which more than 400 thousand tons are highly toxic. The amount of waste not involved in the secondary economic turnover is growing [18].

One interesting example of recycling can be seen in England. There, aerobic fermentation is practiced for composting garbage. The advantage of this method is that a large number of microorganisms, which are potentially harmful to human health, die. The mixture of carbon, which is utilized in this recycling, is used later as fuel, and the rest goes to fertilizer. Russia, for example, is practicing processing food waste into humus. At the end of this process, nitrogen-fixing bacteria and fungi transform the waste into black soil. Unfortunately, however, very few recycling companies are really working today - no more than three hundred across the country (in the U.S., for example, there are over a thousand).

In the modern world "reclamation" of already worked out pits (ravines, etc.) by filling them with different wastes of 3 to 5 classes of danger is very popular (Fig. 3). Often for this purpose, they use various slags, overburden rocks, construction wastes, soils from the excavation of pits, dewatered sewage sludge, etc. But even though in such cases the use of protective screens at the bottom of the waste space is envisaged, such an experience can be equated with the burial of the above-mentioned waste.

It is obvious that after this kind of manipulation, there is clear pollution of the environment. And such pollution is not much different from landfills and waste burial sites, because, in fact, the pollution of soil, soils, underground and surface waters, and the atmosphere is carried out in exactly the same way. Objects of this kind of reclamation can sufficiently change the feeding conditions of groundwater and distort the direction of its flows. It is worth noting that it is worth finding alternatives to such "use" of waste, which ultimately leads to such environmental pollution.

Figure 3: Reclamation of the quarry with construction waste in the Moscow region

First and foremost, the use of waste in reclamation should help restore the value and productivity of the land, rather than allowing as much waste as possible to be disposed of. But also, the improvement of environmental conditions should not fall by the wayside.

4 Biomats as a promising method of land reclamation

Today, the development of ecology around the world is gaining momentum and the state of the environment is becoming a priority. The interest shown in this area entails the emergence of a sufficient number of effective ways and technologies to protect the environment. One of such inventions is biomats. They allow not only to protect the fertile layer of soil from erosion processes but also to strengthen weak soils and to accelerate the restoration of the topsoil and carry out fertilization on it. Nowadays biomats are made of nonwoven basis (coconut, linen, sisal, or jute fiber).

Nowadays the term biomat, as a rule, means a volumetric structure consisting of several layers, which are qualitative protection of ground surfaces from adverse environmental effects and guarantee the appearance of a dense vegetation cover. At the same time, the composition of biomats should not use mineral, metallic or other materials that are alien to the environment and are not capable of decomposition in natural conditions [20]. According to the proposal of the International Geosynthetics Society (IGS), biotextiles and biomats are one of the types of geosynthetic products and are designated as "BT" [27].

Decomposable components, which are included in the fabric, after a few years (approximately 1-3 years) are included in the natural cycle of substances and completely decompose. It is this ability that distinguishes them from geomats, which often contain synthetic and artificial materials that upset the balance of the ecosystem [19].

Biomats can greatly simplify and reduce the cost of construction work and the reclamation process because there is no need for subsequent grass reseeding and laying of a fertile soil layer. After only one season after the use of biomats, the soil-vegetation layer is restored, and the ground surfaces are properly reinforced and protected from erosion processes since the beginning of application [7].

The advantages of the biomaterial include:

- a large number of applications;
- the natural basis of biomat allows it to be environmentally friendly;
- the presence of seeds and various fertilizers, tailored to the specific conditions of the region;

- the presence of moisture-retaining components leads to improvement of the water regime of the soil layer, which, thus, increases the resistance of slopes and slopes to erosion processes;
- ease of use and the lack of the need for any maintenance after installation of the material;
- economic benefit.

In addition to the above, it is worth noting that biomats contribute to the realization of various ideas of landscape design, and do not require the use of any technical means for laying, as they are very simple and universal in their use [3]. Also, biomats create "greenhouse conditions" for plant growth as the construction of the material used can effectively absorb and retain water [34].

Of all the variety of biomats, there are several parameters by which they can differ from each other: composition, the thickness of the material, type of fibers, method of bonding, surface density, and characteristics of the seed [23].

Replacing the traditional method of reclamation with the use of biomats reduces the cost of the whole process by 15-30% [34]. This can be substantiated by the following facts: there is no need for agrotechnical works on soil sodding, milling, reclamation works on lime application, and grass sowing; reduction of vegetation cover restoration period to one year [30].

One of the problems of traditional reclamation is the creation of a uniform cover both in terms of area and density of seed germination. One of the reasons is the fact that seeds are washed away from the soil surface by atmospheric precipitation, blown away by winds, and eaten by birds. Thus, erosion processes continue to occur in the seeded areas, as the formed glades are not able to fully resist the water flow, or at least to reduce its speed.

Today, the most common form of manufacturing biomats are rolls of length from 30 to 50 meters and a width in the range of 1.6 to 2 meters. The thickness of the mats varies from a few millimeters to a centimeter (depending on the component composition and design of the sheet). Finished rolls usually weigh up to 35 kilograms.

There is an official marking that indicates what material is used to make the given biomat:

1. BT-K - the biomat is made of coconut fibers.

2. BT-SK - the Biomate is made from a mixture of coconut fibers and straw.
3. BT-S - the biomate is made of straw [5].

Each of the listed types of bio-mat is characterized by some peculiarities. For example, the presence of straw in the composition will lead to greater filtration of the surface layer of the ground. Such biomat will be perfect for slopes because of its fast period of decomposition. Speaking about biomate made of linen, we should note that it is mainly focused on conditions of any large surface runoff, which has significant erosion. Since, on the contrary, it will decompose quite slowly, it is able to provide long-term protection of slopes from wind, rain, and temperature fluctuations [34].

Fields of application of biomats:

- as an anti-erosion coating of embankment slopes, slopes of drainage structures, slopes of railroad tracks;
- for soil reclamation after the laying of pipelines, cables, etc., after the collapse of gas and pipelines;
- for landscaping (gardens, squares, parks);
- in landscape design;
- arrangement of retaining walls in combination with gabion constructions;
- on soil embankments;
- on the slopes of quarries;
- improving the growth conditions for ornamental lawns (biomats retain moisture in the soil even on steep slopes, protect the seeds and the first shoots from washing out, blowing out, and pecking by birds, reduce the heat loss from the soil at night).

There is a certain classification of biomats, which, depending on the construction of the fabric, divides them into three groups:

1. Biomats, the layers of which are connected by water-soluble glue.

2. Biomats, which are made with needle-punched technology.

3. Stitched biomats.

The first variant is the most economical because it is simple to produce and has low labor costs. But one should take into account that the quality of such a construction leaves much to be desired since seeds in such construction have quite low germination capacity due to their direct contact with the glue. Also, such a biomat has a short shelf life (less than 3 years). Biomats, made by needle-punched machines, are of high price, which is the reason for their low distribution on the market at the moment. Such mats require more material for production, while the productivity of technical equipment for their production is very low. Biomats of the third group are more common, and there are a number of good reasons for that. Firstly, they require the least time for initial care, secondly, they do not require soil preparation, and thirdly, they do a great job even if there is not enough moisture [21]. But besides this, they have a disadvantage: the seeds can fall out of the biomat structure if the laying of the mat is not carried out well, which can lead to unevenly sprouted grass in the future [19].

4.1 Creating a biomat from biodegradable waste

The author proposes to combine the two problems and find a solution: to give waste a "second life" by transforming it into valuable and useful material for the reclamation of disturbed land. Namely: to use biodegradable waste as a component of the reclamation mixture.

By recycling different types of waste you can solve several important problems at once: to free territories from garbage; reduce the risk of ecological imbalance; create a profitable zero-waste production; and restore disturbed land.

Completely destroyed components in one or three years are not able to disturb the balance of the ecosystem but can create favorable conditions for the growth of herbaceous vegetation. This is a full-fledged artificial alternative to the soil for the whole period of time until its final recovery [28].

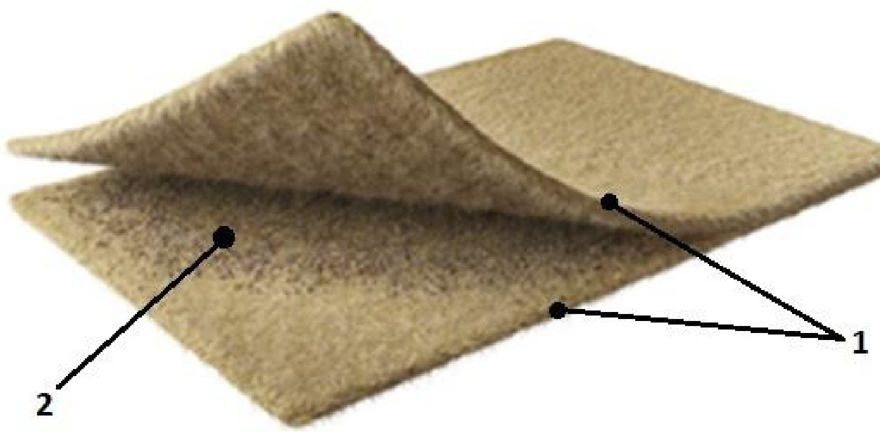

Figure 4: Biomat structure

1 – the base of the web; 2 – the filler of the structure in the form of specially selected seeds

It is proposed to introduce only biodegradable materials and seeds (in the range of 60-130 g/m2) into the basis of the proposed biomat (Fig. 4).

5 Development of biodegradable material to improve soil productivity

To start the experiment to create biomats, it was necessary to find soil for planting seeds and materials for making biomats.

5.1 Sample preparation and analysis of the soil for the presence of heavy metals

It was decided to look for soil close to urban areas, but not containing large amounts of heavy metals. To do this, a small amount of soil in the Leningrad region was collected and analyzed.

To begin, the soil was dried, crushed, and sifted through a sieve with a hole size of 1 mm. Next, the sample was manually subdivided by quarting. After that, samples were prepared for soil analysis by atomic emission spectrometry using an ICPE-9000 optical emission spectrometer (Fig. 5) according to the approved Methodology [22]. Decomposition of samples in determining the gross content of elements was carried out by the microwave decomposition method; in determining the mobile forms of elements in accordance with certain regulatory documents [12], [16], [17].

Figure 5: ICPE-9000 optical emission spectrometer

For the atomic absorption analysis, the samples had to be transferred into a solution. For this purpose 3 extracts were prepared: aqueous, ammonium acetate, and nitrogen.

The result of soil analysis for heavy metals in it is presented in tables 1 - 3.

Quantity	Element name
≥1 mg/l	Al, Ca, Na, Si
≥1 μg /l	Ag, Au, B, Ba, Cd, Co, Cu, Er, Fe, I, K, Mg, Mn, Nb, Ni, P, Pr, Rh, S, Sr, Ti, V
<1 μg /l	Li, Yb, Zn
Not detected	As, Be, Bi, Ce, Cr, Cs, Dy, Eu, Ga, Gd, Ge, Hf, Hg, Ho, In, Ir, La, Lu, Mo, Nd, Os, Pb, Pd, Pt, Rb, Re, Ru, Sb, Sc, Se, Sm, Sn, Ta, Tb, Te, Th, Ti, Tm, U, W, Y, Zr

Table 1: Results of semi-quantitative analysis of water-soluble elements by atomic emission method

Quantity	Element name
≥1 mg/l	Al, Ca, Cs, K, Na, Rb, Si
≥1 μg /l	As, B, Ba, Cd, Co, Cr, Cu, Er, Fe, I, La, Mg, Mn, Nb, Ni, P, Pb, Pr, S, Sc, Se, Sr, Th, Ti, Tl, V, Y, Zn
<1 μg /l	Be, Li
Not detected	As, Au, Bi, Ce, Dy, Eu, Ga, Gd, Ge, Hf, Hg, Ho, In, Ir, Lu, Mo, Nd, Os, Pd, Pt, Re, Rh, Ru, Sb, Sm, Sn, Ta, Tb, Te, Tm, U, W, Yb, Zr

Table 2: Results of semi-quantitative analysis of active forms by the atomic emission method

element / type	**Al**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**
	mg/l							
water	1,95	0,0109	<0,0005	<0,005	0,0031	0,0490	0,562	0,0286
ac-am	49,6	1,91	<0,0005	<0,005	0,0249	0,0905	1,44	0,592
blank	0,22	<0,001	<0,0005	<0,005	0,0155	0,044	0,32	0,0055
gross1	204	4,20	0,0280	0,0260	0,121	0,168	27,4	0,817
gross2	213	4,19	0,0296	0,0280	0,0128	0,175	28	0,826
element / type	**Mo**	**Ni**	**Pb**	**Sr**	**Ti**	**V**	**Zn**	**As**
	mg/l							
water	<0,005	<0,005	<0,01	0,0643	0,0988	0,0129	0,0111	<0,05
ac-am	<0,005	0,0097	<0,01	0,307	0,160	0,0133	0,344	<0,05
blank	0,011	<0,005	<0,01	<0,005	0,0869	0,0074	0,0417	<0,05
gross1	0,0408	0,0163	<0,01	0,623	24,9	0,189	0,336	<0,05
gross2	0,0387	0,0156	<0,01	0,523	27,2	0,199	0,325	<0,05

Table 3: Results of quantitative soil analysis by atomic emission method

*water - sample decomposition for the determination of water-soluble forms of elements; ac-am - acetate-ammonium extract for the determination of active forms of elements; blank - blank solution; gross 1, gross 2 - two parallel extractions to determine the gross content of elements.

Further, the obtained values in mg/l were recalculated to mg/kg and compared with the values of MAC (maximum allowable concentration) and TAC (tentative permissible concentration) found in the regulatory documentation (Table 4) [31].

Al			**Ba**			**Cd**		
mg/kg			mg/kg			mg/kg		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,0097	0,2458	21,42	0,000054	0,0095	0,419			0,00288
								2_{TAC}
Co			**Cr**			**Cu**		
mg/kg			mg/kg			mg/kg		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
		0,00269	0,00002	0,00012	0,1089	0,0002	0,00045	0,0127
	5_{MAC}			6_{MAC}			3_{MAC}	132_{TAC}
Fe			**Mn**			**Mo**		
mg/kg			mg/kg			mg/kg		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,0028	0,0071	2,7353	0,00014	0,00293	0,0815			0,0029
					1500_{MAC}			
Ni			**Pb**			**Sr**		
mg/kg			mg/kg			mg/kg		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
	0,0005	0,00159				0,00032	0,00152	0,0572
	4_{MAC}	80_{TAC}		6_{MAC}	32_{MAC}			
Ti			**V**			**Zn**		
mg/kg			mg/kg			mg/kg		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,0005	0,00079	2,5998	0,00006	0,00007	0,0186	0,00005	0,0017	0,0289
					150_{MAC}		23_{MAC}	220_{TAC}

Table 4: Comparison of actual data with normative data

*W – water-soluble form, A- active form, G-gross content.

From the table, we can see that the actual content does not exceed the allowable content in any of the parameters. That's why it was decided to take this very soil for the experiment and 15 kg of soil were collected from the same place (Fig. 6, 7).

Figure 6: Soil collected for the experiment

Figure 7: Soil drying

5.2 Sample preparation and analysis of constituent components for the creation of a biomat

Wastes of 5 hazard classes were used in the work: paper waste from clerical activities and office work, uncontaminated packaging paper waste, uncontaminated packaging cardboard waste, vegetative waste in the care of tree and shrub plantings, and newspaper waste. A sampling of wastes and their laboratory storage is carried out in accordance with the state methodological recommendations PND F 12.1:2:2.2:2.3:3.2-03 [26].

The mass of all materials used in the experiment:

- A4 paper waste (206.1 g);

- waste packaging cardboard (106.8 g);

- Waste packaging paper (199 g);

- newspaper waste (75.3 g).

Also, it was decided to use such an organic component as leaves. Leaves were collected in the city limits and dried in the open air, without the use of any dryers. 100g of leaves were burned in a muffle furnace at 550°C to produce ash, which was subsequently used to determine the gross element content. Next, the prepared leaves (Fig. 8) were analyzed for their content of heavy metals by atomic emission spectrometry according to GOST R 53218-2008 [15]. Excluding the mass sent for analysis, 200g of leaves were prepared to create biomats.

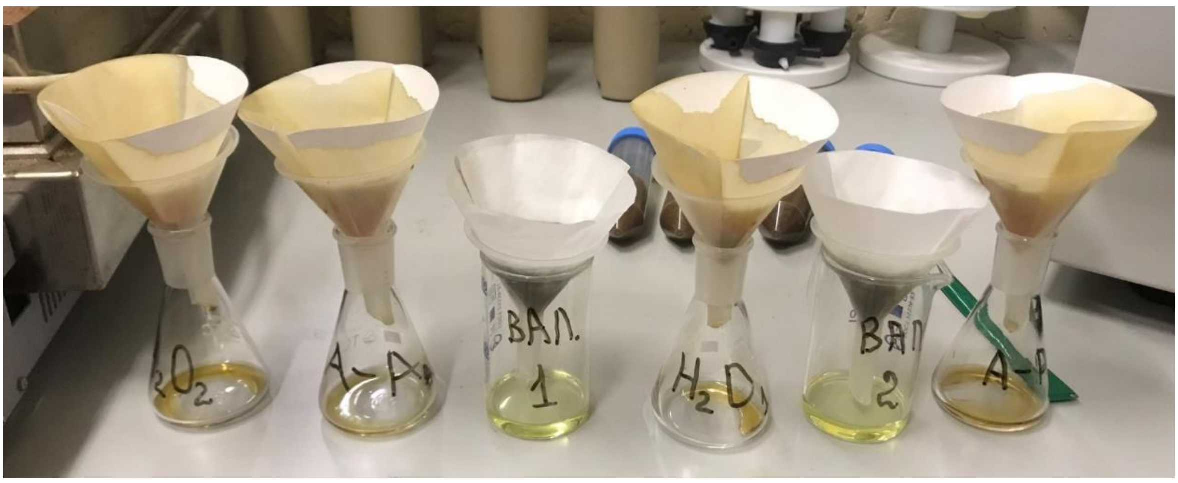

Figure 8: Filtration of foliage solutions for atomic emission analysis

The collected plant waste during the care of tree and shrub plantings was analyzed by the atomic absorption method in accordance with GOST R 53218-2008. For this purpose, the samples were previously dried and mineralized. After salting, the samples were transferred to solutions. The results of this analysis are shown in summary table 5.

element / type	Be	Ba	Cd	Co	Cr	Cu	Fe	Mn
	mg/l							
water		0,048	0,00144	0,00044	0,000635	1,19	0,0482	0,805
ac-am$_1$		0,0722	0,00434	0,00064	0,00117	0,677	0,0415	2,03
ac-am$_2$	<0,001	0,0647	0,00451	0,00072	0,000989	0,713	0,0928	1,85
gross$_1$		6,00	0,0161	0,02754	0,145	1,42	68,8	37,6
gross$_2$		5,84	0,0153	0,02808	0,145	1,06	63,8	36,4
element / type	Sb	Ni	Pb	Sr	Ti	Se	Zn	Hg
	mg/l							
water		0,006	0,00026	0,0899	0,418		0,0383	
ac-am$_1$		0,009	0,00032	0,189	0,915		0,387	
ac-am$_2$	<0,001	0,0083	0,00039	0,165	0,503	<0,005	0,182	<0.005
gross$_1$		0,162	0,10983	10,2	2,68		5,76	
gross$_2$		0,174	0,09383	9,97	2,31		5,19	

Table 5: Results of quantitative analysis of plant waste by the atomic emission method

*water - sample decomposition for the determination of water-soluble forms of elements; ac-am$_1$, ac-am$_2$ - acetate-ammonium extract for the determination of active forms of elements; blank - blank solution; gross$_1$, gross$_2$ - two parallel extractions to determine the gross content of elements.

Further, the obtained values in mg/l were converted to mg/kg (Table 6). Since the used leaf litter in the course of this experiment becomes an alternative to the soil until its full recovery, the analysis results obtained were correlated with the normative values of permissible concentrations of chemical substances in the soil (SanPin 1.2.3685-21). The actual content of heavy metals does not exceed the normative values, which gives the right to use the collected plant waste as a component of the reclamation mixture to improve soil fertility.

Ba	Cd	Co

W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,000597	0,000840	2,958809	0,000018	0,000054	0,007847	0,000005	0,000008	0,013899
Cr			**Cu**			**Fe**		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,000008	0,000013	0,072471	0,014793	0,008537	0,619734	0,000599	0,000828	33,13649
Mn			**Ni**			**Pb**		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,010007	0,023814	18,49254	0,000075	0,000106	0,083967	0,000003	0,000004	0,050894
Sr			**Ti**			**Zn**		
W	*A*	*G*	*W*	*A*	*G*	*W*	*A*	*G*
0,001118	0,002172	5,040473	0,0005196	0,008683	1,246983	0,000476	0,003482	2,736377

Table 6: Results of the analysis of plant waste, [mg/kg]

*W – water-soluble form, A- active form, G-gross content.

5.3 Algorithm of biomat samples creation

1. The material collected for the creation of biomats is crushed manually, then - with a laboratory mill MF 10 basic with a cutting-grinding attachment MF 10.1 (Fig. 9) at the Department of Geoecology at the Mountain University to a size of 1 mm (Fig. 10, 11).

Figure 9: The process of grinding material with the MF 10 basic mill

Figure 10: Shredded paper and cardboard waste

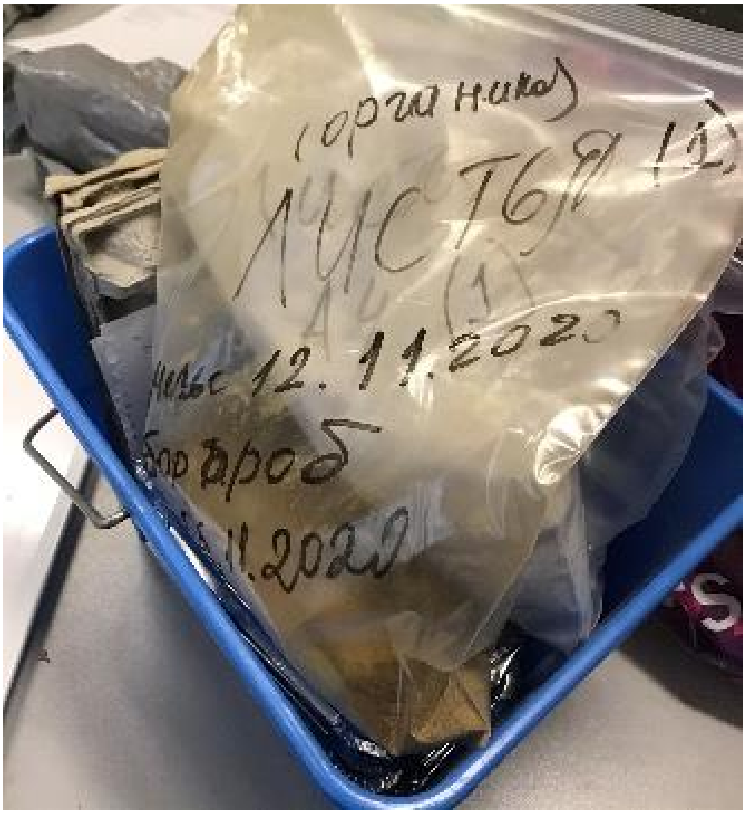

Figure 11: Shredded plant waste

2. Weigh a certain amount of component on analytical scales OHAUS PA-64 (Fig. 12).

3. The components selected for the creation of the biomat are mixed (fig. 13) and brought to a homogeneous state by adding water.

Figure 22: Weighing components

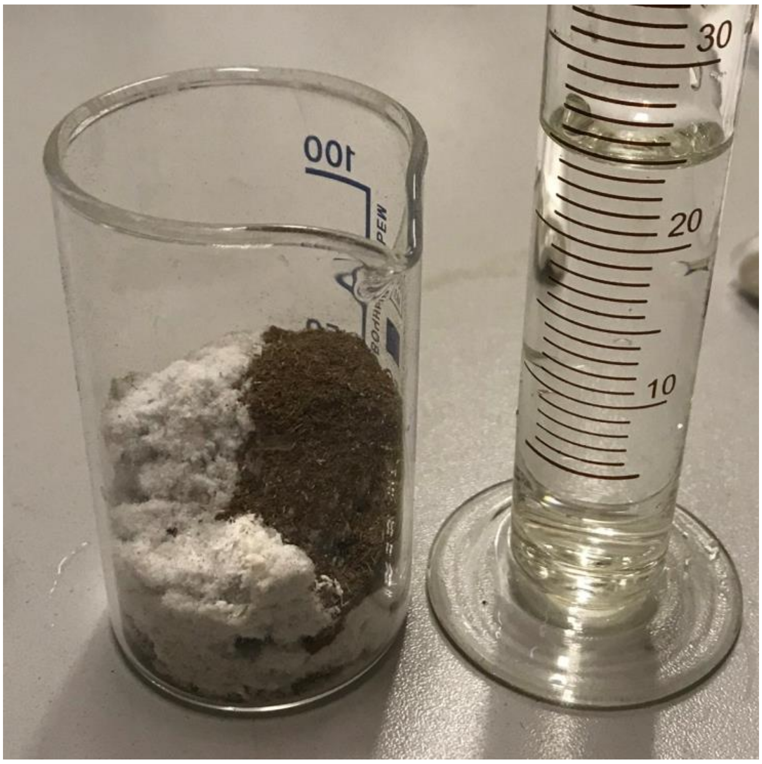

Figure 33: Mixing components

4. Next, the mixture is placed on a cellophane bag, covered with another layer of cellophane, and rolled by hand with a rolling pin to the thinnest possible layer (about 1 mm).

5. Next, the sheet is left to dry in the open air for about a day.

According to this algorithm, 33 sheets of degradable waste were created (Table 8), which were subsequently used for the experiment. Some of them were used in the final form, some of them were combined into a two-layer biomat.

6 Conducting an experiment to improve soil productivity through the use of the developed biomats samples

For planting, aluminum molds were purchased, in the bottom of which drainage holes were made with the help of needles. Further, 40g of drainage was put on the bottom of the mold and 220g of soil on top. When planting, in each of the forms, 320 ryegrass seeds (1g) were used (Fig. 14-17).

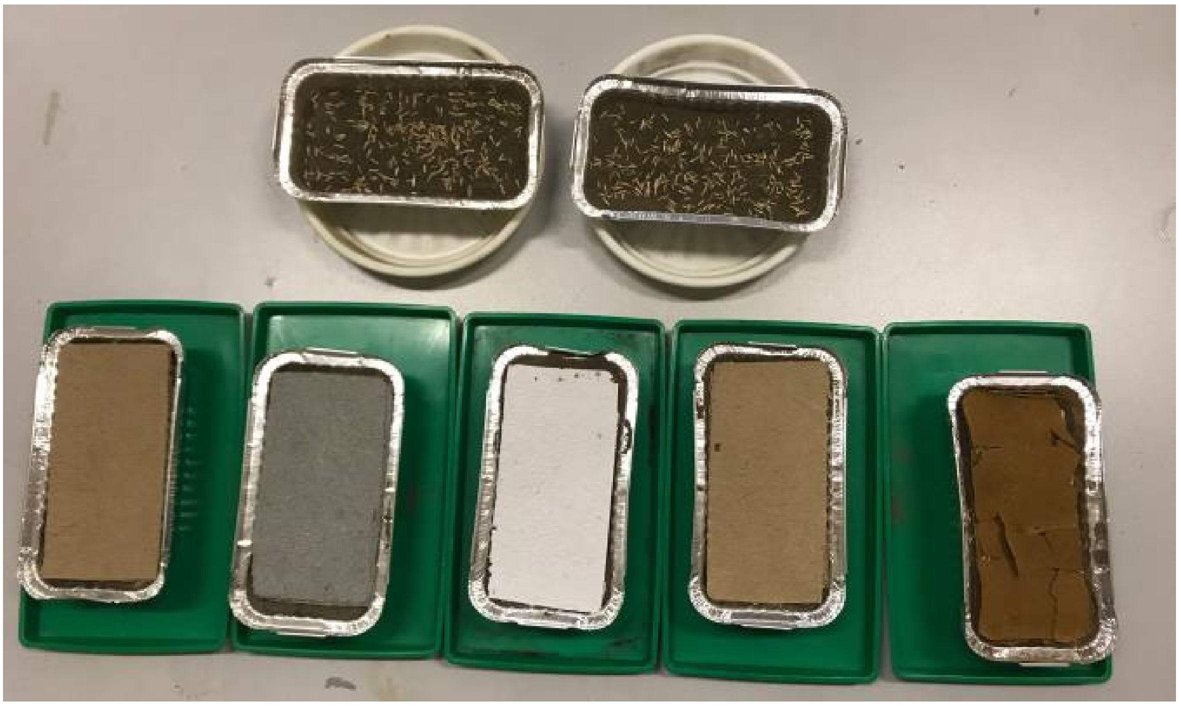

Figure 44: Samples of applied biomats before the first irrigation

Samples were watered every three days. Once a week, seedlings that penetrated the top layer of biomat were counted (Table 7). Also, as the seedlings grew, they were cut more than 10 cm in length.

In regular irrigations, it was possible to establish that mats from newspapers and boxes have low wettability and have a low speed of water conduction. Consequently, when using biomats made of newspapers or boxes, moisture during irrigation or rainfall will roll off the cloth, and its penetration to the seeds and soil will be clearly difficult. This fact can affect both positively (if the biomat will be used in areas with a lot of precipitation in order to protect loose soils), and negatively (for example, when using the manufactured material in areas with insufficient moisture).

Component	Number of layers	Number of seedlings that have broken through the biomat	
		10.12.2020	17.12.2020
Waste paper	1	29	49
	2	155	171
Packaging paper waste	1	28	52
	2	56	57
Waste of packaging cardboard	1	32	55
	2	151	178
Plant waste	1	21	24
	2	21	41
Newspaper waste	1	107	124
	2	44	49
A mixture of paper waste and plant waste	2	-	3

Table 7: Sprouting data

Figure 55: Samples after the first watering

Also, zonal wetting was observed when watering the bio-weed from the paper bag, and that is why more vigorous seed germination was also noted in some places. A good result of the reclamation process when using such a composition of bio-mat will be possible only with the help of additional watering or irrigation in certain places of the material.

Figure 66: Samples after 3 weeks

Figure 77: Samples after 3 months

Since the aim of the work is to create the most effective and universal biomat for the reclamation of disturbed lands, it was decided to use paper and leaves as the main components. During the experiment, it was found that with a two-layer construction of the mat the seeds germinate and penetrate the upper layer of the mat much better.

And that is why another sample biomat was created from a mixture of paper and foliage.

№	Component	Number of layers	m_{comp}, g, 1st comp.	m_{comp}, g, 2nd comp.	V_{H2O}, ml	Germination, %, after 1 weeks	Germination, %, after 2 weeks	Destruction, %, 3 months after
1	Waste paper	1	4,0	0	30	9,1	15,3	20
2		2	4,0		30	38,4	43,4	10
			4,0		30			
3	Packaging paper waste	1	6,0		45	8,8	16,3	45
4		2	4,0		25	17,5	17,8	35
			6,0		35			
5	Waste of packaging cardboard	1	4,0		30	10	17,2	75
6		2	4,0		30	27,2	35,6	50
			4,0		30			
7	Plant waste	1	5,0		25	6,6	7,5	40
8		2	5,0		25	6,6	12,8	20
			5,0		25			
9	Newspaper waste	1	4,0		30	33,4	38,8	15
10		2	4,0		30	13,8	15,3	5
			4,0		30			
11	*A mixture of paper waste and plant waste*	*2*	*3,0*	*3,0*	*20*	14,7	45,6	55
			3,0	*3,0*	*20*			
12		1	*3,0*	*3,0*	20	-	0,9	20
13	*Planting in the open ground*					20	30	

Table 8: Data on the effectiveness of biomats

Thirteen studies with different compositions of biomats were conducted, which are presented in Table 8. The effectiveness of this experiment was monitored by the following indicators:

- germination of seeds 1 week after their planting;
- germination of seeds after 2 weeks after their planting;
- destruction of the biomat structure 3 months after planting the seeds.

Based on the results of the experiment, a summary table of the data (Table 8) with the determination of the percentage value of germination of the planted seeds and the destruction of the biomat structure was compiled. High indicator of germination and destructibility of composition №11 allows to conclude that components used in the composition and their ratio of components are effective enough to increase soil productivity restoration.

It is worth noting that for the comparison experiment, planting seeds in the soil exposed to biotic, wind, and water influences were taken. Plant germination under such conditions varies from 20 to 30% (№13 in Table 8). Therefore, exceeding these values indicates a high anthropogenic resistance of the developed samples of biomat.

Thus, the biomat from a mixture of plant waste and waste paper from office work and paperwork has shown high efficiency in increasing soil productivity, and the proposed biomat is more natural than known analogs since no artificial or mineral additives are used in its composition. Moreover, this design ensures uniformity of seed germination, and its decomposition period does not exceed one year.

7 Recommended hardware design of the technical solution

When implementing this technical solution, it is proposed to follow a certain production technology and use a specially selected production line of selected equipment.

As stated above, the initial raw materials for production are vegetable waste and waste paper from clerical and office work. To obtain high-quality biomats should use relatively clean waste that contains only a small amount of sand, dust, and other impurities. Of the paper waste excellent go print drafts or old paper, and speaking of plant waste, it should be noted that the leaves should be collected away from harmful industrial sites and highways. For example, fallen leaves from parks or other recreational areas of the city would be excellent.

One of the advantages of the proposed production technology is the fact that the technological cycle does not require complex operations of sifting and selection of raw materials, washing, and chemical treatment. Despite the fact that the work proposes a full-cycle production, the production line includes only three sections:

1. Raw material preparation section from previously collected wastes (pulp);
2. Web production section (using a paper machine);
3. Section for final product processing.

To begin with, the prepared raw material has to be cut to a suitable size. This can be done in the pulper (Fig. 18), which immediately implies the additional addition of water to get a ready pulp. Hydropulper is the main equipment for processing waste paper into the necessary mass for subsequent production. It is recommended to mix the raw materials and to prepare the pulp with the addition of water only, because, firstly, it meets the necessary requirements for the manufacture of products, and secondly, it allows the production of completely natural biomat without any artificial or mineral additives. The recycled water can be reused and the rinse water is discharged into the sewage system. The power of the proposed vertical hydraulic pulper is 7.5 kW.

A hopper and clean water pump are mandatory for the operation of the selected pulper. The resulting mixture is filtered through a 3 kW high-frequency sieve, which sifts out foreign inclusions and large particles.

To create the required quality of biomat canvases it is proposed to use an automated paper-making machine. The paper machine (PM) makes it possible to create the desired canvas from a highly water-diluted slurry. Due to the fact that the planned production product is a two-layer structure, it is proposed to use a cylindrical type paper machine. Compared to table machine types, circular type machines differ in the device for releasing the slurry onto the screen and in the casting of the cloth itself.

Figure 88: Highly concentrated hydraulic pulper

After the first production stage, the prepared pulp is evenly fed into a special bath in which the cylindrical screen drum of the paper machine is located and rotates. The pulp is evenly deposited on the screen and the water is sucked off into the drum by vacuum. The moist layer is transferred to the next part of the paper machine under defined pressure from the top roll.

The fabric is then transferred to the press section of the machine, where it is compressed between rollers, allowing the material to be dewatered and compacted. The fabric then enters the drying section. There, the final dewatering of the fabric takes place. Also, in the second half of the drying section, it is necessary to place the unwinding and reeling machine, which ensures the application of the surface layer of the seed. In addition, on the proposed machine with the help of special blocks, the two layers of the prepared material canvases are joined (soldered) to each other.

The estimated additional costs for the production of biomats include:

- -consumption of electricity ≈ 200 kWh;
- -water consumption ≈ 10 tons (80% of the water can circulate);
- labor force of 4 people per shift (one attendant for each production area of the line and one loader-warehouse man).

Figure 19: An example of a proposed biomat production line

To accommodate both the production line and warehousing areas for finished products and raw materials, it is perfect to build a prefabricated production hall. It represents a collapsible structure, which can be moved from one place to another when the work or any other need arises. Raw materials for the production of biomats are stored in a warehouse with an unlimited supply. Vegetable and paper waste is stored in a fenced area.

8 Economic assessment of the implementation of the proposed environmental protection measure

8.1 Calculation of capital investments

When designing the implementation of the proposed measure investment costs for the project are determined by capital investment in fixed assets.

Capital investments are calculated by the formula:

$$C_{cap}=C_{eq}+C_{tr}+C_{in}+C_{ad}$$

C_{eq} - cost of equipment, rub;

C_{tr} - cost of transportation of equipment, rub;

C_{in} - cost of installation and commissioning, rub;

C_{ad} - additional costs, rub.

The structure of capital expenditures is presented in Table 9. Capital expenditures for the modernization of the equipment are equal to 3 700 000 rubles.

Name of capital investment	**Number of units**	**Cost, rub.**
Construction of a warehouse	288 m^2	1000000
Costs of main equipment		
Highly concentrated hydraulic pulper	1	380000
High-frequency vibrating screen	1	120000
Paper Making Machine	1	1000000
Unwinding apparatus for unwinding a bobbin	1	700000
Installation of equipment		300 000
Equipment delivery		100 000
Other additional costs		100 000
	Total:	3 700 000

Table 9: Capital expenditure structure

8.2 Calculation of operating costs

Operating costs include annual operating costs associated with the implementation of the implemented measure. The operating costs are calculated according to the formula:

$$C_{op} = C_m + C_s + C_{in} + C_o$$

C_m - material costs, rub;

C_s - salary costs, rub;

C_{in} - insurance premiums for obligatory social insurance and insurance against accidents at work, rub;

C_o - other expenses, rub.

Material costs represent the cost of electricity to service the proposed production, the cost of transporting plant waste and waste paper to the place of production, and the cost of purchasing seeds for the creation of biomats. Since the required service life of the equipment does not exceed one year, an annual depreciation rate is not calculated. This leads to the fact that in the calculations made it is not necessary to take into account the depreciation charges.

Electricity costs are determined by the formula:

$$C_{el}= N·T·P·C$$

N - duration of work for 1 year, working days;

T - operating time of the equipment, h;

P - total capacity of all the equipment, kW;

C - electricity tariff, rub/kW·h (based on the Regulation of the Tariff Committee of St. Petersburg Government №244-p of December 16, 2020 "On setting electricity tariffs for households and equivalent consumer categories in St. Petersburg for 2021").

$$Cel = 20·8·200·4,98 = 159360 \text{ rub}$$

The cost of waste transportation will be 80000 rubles. The cost of seed purchase is 50000 rubles.

Total material costs are:

$$Cm = 159360 + 80000 + 50000 = 289360 \text{ rub.}$$

Salary costs: To the process of maintaining the production line joined 4 people with a schedule of 5/2 (40-hour workweek). The formula for the amount of deductions for the payment of wages and salaries, including contributions to the social insurance fund, wages, and salaries:

$$C_s = S \cdot N \cdot (1+R1+R2)$$

S - monthly salary of an employee, rub;

N - number of employees, people;

R1 - percentage rate of deductions for social insurance;

R2 - percentage rate of deductions for insurance against accidents at work.

$$C_s = 20{,}000 \cdot 4 \cdot (1+0.3+0.03) = 106400 \text{ rub.}$$

Other costs, unless otherwise specified by the company, it is assumed to determine the rate of 3% of material costs without regard to depreciation charges.

$$C_o = (289360+106400) \cdot 0{,}03 = 11872{,}8 \text{ rub.}$$

Thus, the operating costs will be:

$$C_{op} = 289360+106400+11872{,}8 = 407632{,}8 \text{ rub}$$

8.3 Calculation of prevented environmental damage

Due to the implementation of the proposed zero-waste production technology a certain prevented damage is achieved, the amount of which is the sum of the prevented losses and losses due to the failed environmental pollution. The prevented environmental damage from the pollution of the environment as a result of waste disposal is an assessment in the monetary form of possible negative consequences from the storage of waste, which in the considered period of time was avoided as a result of the environmental protection measure. The calculation is made according to the temporary methodology of prevented environmental damage determination [6].

The value of the prevented ecological and economic damage due to the termination of soil and land degradation can be determined according to the expression:

$$D_d = (V \cdot S \cdot C_e \cdot C_s)$$

V - normative value of lands, thousand rubles/ha (for St. Petersburg and Leningrad Oblast - sod-carbonate; sod-podzolic; alluvial sod, peat lowland and transitional cultivated soils = 263 million rubles/ha);

S - area of soils and lands preserved from degradation during the reporting period as a result of environmental measures, ha;

Ce - coefficient of ecological situation and ecological significance of the territory (for the North-West economic region the coefficient is taken as equal to 1.3);

Cs - coefficient for specially protected areas (for other lands is taken equal to 1.0).

$$\mathrm{D_d} = (263 \cdot 150 \cdot 1{,}3 \cdot 1) = 51285000 \ \mathrm{rub/y}$$

Assessment of the amount of damage prevented as a result of environmental protection activities from land littering by unauthorized dumps is carried out according to the formula:

$$\mathrm{D}_s = \sum_{i=1}^{N} V \cdot S_5 \cdot C_e \cdot C_s$$

V - normative value of lands, thousand rubles/ha (for St. Petersburg and Leningrad Oblast - sod-carbonate; sod-podzolic; alluvial sod, peat lowland and transitional cultivated soils = 263 million rubles/ha);

S5 - area of land that was prevented from littering with type 5 waste during the reporting period, ha;

Ce − coefficient of ecological situation and ecological significance of the territory (for the North-West economic region the coefficient is taken as equal to 1.3);

Cs - coefficient for specially protected areas (for other lands is taken equal to 1.0).

$$\mathrm{D}_s = \sum_{\mathrm{i}=1}^{\mathrm{N}} 263 \cdot 1 \cdot 1{,}3 \cdot 1 = 341900 \ \mathrm{rub/y}$$

The total amount of prevented damage from deterioration and destruction of soils and lands in the areas under consideration is determined by summing up all types of prevented damage:

$$\mathrm{D} = \mathrm{D_d} + \mathrm{D}_s = 51285000+341900=51626900 \ \mathrm{rub/y}$$

It should be noted that the proposed measure does not imply economic benefit, and calculation of the economic effect is not possible. This environmental measure is intended for its implementation by municipalities and is aimed at preventing environmental damage. The above-calculated value of the prevented damage is a rather high indicator (in comparison with the capital and operating costs for implementation of the measure), which is strong evidence of a high level of the environmental effect of its implementation.

9 Ending

Technogenic impact on the natural environment entails a low rate of self-restoration of landscapes, as well as contributes to the activation of the processes of water and wind erosion, gully formation, etc. Application of traditional reclamation technologies is not possible in all conditions and is often ineffective. That is why biomats, which can be used in conditions of reclamation of disturbed lands, are of special interest. They can not only protect and strengthen ground surfaces from erosion processes, but also restore the soil-vegetation layer during the first season of use without any additional laying of a fertile layer of soil and seed seeding in the following years. Application of biomats significantly simplifies recultivation and reduces the cost of operating costs. Absence of nondegradable substances in the composition of biomats is a basic requirement for minimizing the ecological footprint.

To date, the variety of biomats available on the market is not great. This indicates the perspective development of this topic, its relevance and, unfortunately, still incompletely studied.

As a result of evaluation of the current state of study of this problem, Russian and foreign experience of using biodegradable waste for reclamation of disturbed lands was analyzed, separate attention was paid to the problem of choosing the initial material for creating bio-mats used for increasing soil productivity.

During the preparation of the master's thesis, a theoretical and laboratory justification of the possibility of useful use of waste of hazard classes 5 as constituents of biomaterial was carried out. Also, a laboratory experiment was carried out, according to the results of which the most effective composition of biomaterial from degradable waste of hazard class 5 was revealed by determining the percentage value of germination of planted seeds and destructibility of the structure. Thus, the components used in the composition and their ratio are effective enough to increase soil productivity. At the same time, the proposed biomat is more natural than known analogues, because no artificial or mineral additives are used in its composition. Moreover, this structure ensures uniformity of seed germination, and its decomposition period does not exceed one year. The developed composition is the result of the research, which is the basis of the master's thesis.

As an environmental protection measure, the thesis proposes a ready-made apparatus design of the technical solution. The proposed measure will prevent environmental and economic damage due to the cessation of soil and land degradation and land littering by unauthorized dumps.

The economic assessment demonstrates a high efficiency of the environmental protection measure. The calculated prevented ecological damage from deterioration and destruction of soils and lands is 51626900 rubles/year.

The proposed approach to using waste as components of the reclamation mixture solves the following problems:

- liberation of the territory from waste storage;
- useful waste recycling;
- reducing the risk of ecological imbalance;
- creation of a profitable non-waste production;
- reclamation of disturbed lands.

Published works on the topic of the master's thesis include 3 articles in the leading peer-reviewed scientific journals of the Russian Federation and filing a patent for invention.

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ASSOHQE	Association pour la Haute Qualité Environnementale
EU	European Union
g	Gram
GOST	All-Union State Standard
h	Hour
ha	Hectare
HQE	Haute Qualité Environnementale
IGS	International Geosynthetics Society
kg	Kilogramme
kW	Kilowatt
m	Meter
MAC	Maximum Allowable Concentration
mg/kg	Milligram per Kilogram
mg/l	Milligrams per Liter
ml	Millilitre
PM	Paper Machine
PPM	Pulp and paper industry
rub	Rouble
SanPin	Sanitary Rules and Regulations
TAC	Tentative Permissible Concentration
UNEP	United Nations Environment Programme
µg/l	Microgram per Liter