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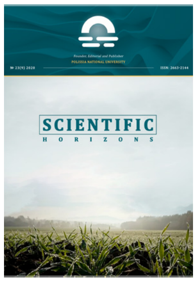

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Mulching as a restoration method of revegetation at ash and slag dumps of Burshtyn TPP

Uliana Semak*
Master of Biology, Lecturer
Vasyl Stefanyk Precarpathian National University
76018, 57 Shevchenko Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0001-6215-6252
Myroslava Mylenka
PhD in Biological Sciences, Associate Professor
Vasyl Stefanyk Precarpathian National University
76018, 57 Shevchenko Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0001-9249-8077

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Abstract. The study of the effect of mulching to establish vegetation cover at industrial sites is promising and relevant in terms of environmental restoration and reduction of environmental risks in the area of influence of industrial facilities. The study aims to investigate and evaluate the effectiveness of mulching and sowing seed mixtures as a method of establishing vegetation cover at ash and slag dumps of thermal power plants. To conduct the study, the soil cover of ash and slag dumps was assessed, and experimental plots were laid out for mulching and sowing seed mixtures. The study revealed that ash and slag dumps ecotopes are characterised by a high concentration of pollutants, namely heavy metals, which makes it difficult for vegetation to grow there. In the course of studying the ecological features of the ecotopes and phytodiversity of the territory, a list of species of native flora for seed mixtures was proposed. Mulching was done on the experimental plots and seed mixtures were sown. Mulching has proven to be an effective method for accelerating the processes of natural regeneration of vegetation in areas affected by anthropogenic impact. The results of the study can be used in practice by ecologists, environmental organisations, and a wide range of specialists to develop and implement measures to restore the ecological balance of degraded and technologically transformed ecosystems

Keywords: pollution; degradation; solid waste; reclamation; mulching; seed mixtures

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**Corresponding author*

INTRODUCTION

The environmental risks caused by the accumulation of multi-tonne waste generated by thermal power plants are of particular concern, as the accumulation of ash and slag in solid waste landfills leads to the transformation of natural geochemical cycles, aerogenic pollution and changes in the chemical parameters of surface and groundwater and leads to the withdrawal of significant areas. One of the largest thermal power plants in West Ukraine is the Burshtyn Thermal Power Plant (TPP), whose ash and slag dumps cover about 200 ha with an annual increase of 0.5 million tonnes. Ash and slag dumps as objects of increased environmental hazard require the development of measures to reduce environmental risks, reclamation, and rehabilitation of these lands to restore and maintain a favourable environmental balance at the regional and national levels.

The current state of the soil cover, which has undergone large-scale transformational changes due to human activity, requires environmental assessment and monitoring (Pichura *et al.*, 2023). The results of a study of the genetic and geographical features of degradation processes in the soils of Lviv region, as presented by N.M. Lemega (2020), indicate the need to implement comprehensive measures to preserve soil fertility. A more challenging issue is the rehabilitation of soils of anthropogenic origin – the so-called techno-soils, which include ash and slag mixtures. A possible way to solve the problem of soil degradation, in particular erosion, may be phytoreclamation, which, in addition to soil protection crop rotations, involves sowing buffer strips and backstage crops, strip or continuous mulching, leaving plant residues on the soil surface, as well as sowing crops in strips and sowing perennial grasses or annual crops between rows of perennial plantations (Tokhetova *et al.*, 2020).

A.O. Bozhenko (2020) analysed erosion processes in the Smotrytskyi Canyon and identified the need to implement a set of anti-erosion measures that would help stop the action of erosion factors. The research was moving from considering erosion processes in a specific area of the canyon to possible measures to reduce the impact of erosion factors on natural objects in a larger context. O.O. Svitlychnyi and A.V. Piatkova (2021) assessed the intensity of soil loss due to erosion in three main areas located within the right-bank Forest-Steppe of Ukraine. The researchers proposed to address the issue of rational land use by implementing soil conservation measures and establishing vegetation cover that helps to retain soil. Considering biological reclamation as an effective method of controlling water and wind erosion, a possible solution to the problem of ash and slag dumps may be the use of plants to create a protective cover at industrial sites exposed to erosion (Fedoniuk *et al.*, 2021). The study of the level of soil erosion degradation in the Western region of Ukraine by V.G. Gaskevych *et al.* (2023) provided valuable conclusions for the application of erosion control measures in various ecosystems. The anti-erosion measures identified by the researchers, such as conservation of highly erodible lands, and soil protection tillage techniques can be implemented in the practice of reclamation of man-made landscapes, in particular, ash and slag dumps of Burshtyn TPP.

In the context of erosion control measures, vegetation occurrence patterns and development on the territories of anthropogenic origin should be addressed. The vegetation formation on the territory of anthropogenic ecotopes, including ash and slag dumps, is a process of natural colonisation of plants from the surrounding ecosystems. Even though this process is long and can take several decades, it is a natural recovery that leads to the formation of plant communities with a high level of biodiversity. In addition, due to the remediation properties of plants, the development of vegetation within the framework of near-natural recovery plays the role of a meliorative and remediation factor that mitigates and reduces the toxic effects of pollutants (Gajic *et al.*, 2018; Guo *et al.,* 2024). Several studies have shown that the best plants for phytoremediation are indigenous species of local flora. Therefore, those native species identified on the targeted sites before the start of reclamation should be included in the phytoremediation project. Effective revegetation measures include sowing seed mixtures with regional species, as well as various agronomic methods of introducing target plant species to restoration sites: fresh hay transfer (mulching) and plants biomass or soil transfer containing seeds (Wagner *et al.*, 2020). Sowing seed mixtures of regional species, reforestation, and agricultural practices such as mulching, mowing, and other management measures are effective approaches to revegetation.

In previous studies, the effectiveness of mulching with natural materials such as sawdust, straw, and black and white agricultural fibres was noted for creating litter under fruit trees in difficult hydrothermal conditions due to the climatic regime (Malyuk, 2023). Burshtyn TPP is the main source of environmental pollution in the Carpathian region. The residual waste is stored in three ash and slag ponds, the total volume of which is currently almost filled (Zhumadilova & Zhigitova, 2023). These facilities are characterised by increased environmental hazards and therefore require particular consideration, reclamation, and remediation to reduce ecosystem risks in the region (Bidolakh, 2023). The study of plant communities at the Burshtyn TPP ash dumps provided an important theoretical basis for the development of revegetation measures in the study area, in particular, the phytodiversity and ecological and genetic features of the ash dumps' vegetation cover were assessed (Semak *et al.*, 2023).

Given the effectiveness of mulching for the restoration of vegetation cover, the testing of the technique in anthropogenic ecotopes is of considerable scientific interest. The study aims to investigate the application of mulching for the restoration of anthropogenic ecotopes, namely ash and slag dumps of thermal power plants.

MATERIALS AND METHODS

The study used research methods to assess the intensity of soil erosion losses in key areas, the use of which is established by Law of Ukraine No. 962-IV "On Land Protection" (2003). The study used methods of analysing the content of heavy metals, as well as methods of mulching with hay and sowing seed mixtures to increase soil fertility and preserve moisture, which helps to improve yields and reduce the risk of erosion and is also important for biodiversity conservation. The object of the study was the territory of ash and slag dumps of Burshtyn TPP (Halych district, Ivano-Frankivsk region).

The anthropogenic ecotopes of ash and slag dump of Burshtyn TPP are characterised by special physical and chemical properties and a certain concentration of radioactive substances (Kovaliv, 2013; Levchenko *et al*., 2013; Gneushev, 2013). The humus content in the 0-20 cm layer in the ecotope of the closed and operating ash and slag dumps ranges from 2.17-5.43%, and in the 20-60 cm layer – from 1.5-4.87%. A characteristic feature of ash and slag dumps soils is their salt acidity, which is 6.2-8.2; affecting the mobility of heavy metals, the acidity of the environment largely determines their phytotoxicity. The 0-60 cm substrate layer of the existing ash and slag dump at Burshtyn TPP contains many heavy metals: zinc, manganese, nickel, lead, copper, cobalt, cadmium and iron. These elements are classified as hazardous compounds of class I and II. When the content of these elements exceeds the maximum permissible concentration, environmental hazards arise for biotic components of ecosystems. Slag is also a source of heavy metals, with heavy metals being leached from slag. The behaviour of heavy metals and their localisation in soil horizons varies and depends on both external (agrochemical) conditions and the migration properties of the element.

The background gamma of ash and slag dumps is characterised by elevated levels of radioactivity and exceeds background levels by 2-3 times (Levchenko *et al*., 2016). Moreover, in combustion products, the concentration of radioactive compounds increases several times compared to the initial fuel – the specific activity of radionuclides in slag is twice as high as in coal. The storage of coal combustion products in ash and slag dumps creates a risk of wind erosion, which can carry dry ash. The main characteristics of ash in terms of its environmental impact are dispersion, miscibility, flowability, density, abrasiveness, and electrical conductivity. Ash dispersion of ash causes its dusting, with polluting particles being carried by wind currents and deposited in the surrounding areas in the form of spots (Penderetskyi, 2005).

The study analysed the content of heavy metals in ash and slag dumps soil mixtures. To assess the level of heavy metal contamination of ash and slag dumps' ecotopes of Burshtyn TPP, their content in the technogenic soils of the study area was analysed. Soil sampling was carried out by DSTU ISO 10381-2:2004 "Soil quality. Sampling. Part 2. Guidelines for sampling methods" (2006). The soil sampling was preceded by the preparation of a map of the study area with the indication of sampling points. Soil was sampled from a depth of 5-20 cm using the envelope method. The content of mobile metal forms in the soil was determined by DSTU 4770.1:2007 "Soil quality. Determination of the content of mobile manganese compounds in the soil in a buffered ammonium acetate extract with a pH of 4.8 by atomic absorption spectrophotometry" (2009).

Field studies were carried out on the territory of the ash and slag dump No. 1-2 of the BTPP. The study of the territory and the laying of experimental plots was carried out in 2021-2023. The study developed recommendations for restoring the vegetation cover of ash and slag dumps, compiled a list of species recommended for sowing on the territory, and tested the mulching methodology. In the course of testing the mulching and seed mixtures methodology, 6 experimental plots with a total accounting area of 140 m^2 were created (Fig. 1).

Figure 1. *Experiment sites*

Source: *photographed by the authors*

Mulching and seed mixtures were tested on the experimental plots.

The seed mixtures used are presented in Table 1 and Figure 2.

Table 1. *Seed mixtures for phytoremediation of ash and slag heaps*

Type	Grams	% in mixture
Seed mixture No. 1		
Perennial ryegrass (*Lolium perenne*)	100	18.2
Annual ryegrass (*Lolium multiflorum*)	50	9.1
Meadow fescue (*Festuca pratensis*)	50	9.1
Red clover (*Trifolium pratense*)	120	21.8
White clover (*Trifolium repens*)	50	9.1
Sweet yellow clover or common melilot (*Melilotus officinalis*)	50	9.1
White melilot (*Melilotus albus*)	50	9.1
Alfalfa (*Medicago sativa*)	80	14.5
Seed mixture No. 2		
Perennial ryegrass (*Lolium perenne*)	100	19.23
Annual ryegrass (*Lolium multiflorum*)	50	9.61
Meadow fescue (*Festuca pratensis*)	50	9.61
Red clover (*Trifolium pratense*)	120	23.07
White clover (*Trifolium repens*)	50	9.61
Sweet yellow clover or common melilot (*Melilotus officinalis*)	50	9.61
White melilot (*Melilotus albus*)	50	9.61
Alfalfa (*Medicago sativa*)	50	9.61
Seed mixture No. 3		
Perennial ryegrass (*Lolium perenne*)	100	21
Annual ryegrass (*Lolium multiflorum*)	50	9.1
Meadow fescue (*Festuca pratensis*)	50	9.1
White melilot (*Melilotus albus*)	50	9.7
Alfalfa (*Medicago sativa*)	80	14.5

Source: *compiled by the authors*

Figure 2. *Seed mixtures for phytoremediation of ash and slag dumps*
Source: *photographed by the authors*

The mixtures are based on grains: *Lolium perenne*, *Lolium multiflorum* and *Festuca pratensis*. Among the beans are *Melilotus albus*, *Melilotus officinalis*, *Trifolium pratense*, *Trifolium repens* and *Medicago sativa*. The area where plant biomass was harvested for mulching was the Druzhba Dendrological Park of Vasyl Stefanyk Precarpathian National University. Hay was harvested here from June to September. The fresh hay was dried and put into plastic bags on the day of transport. For mulching with fresh hay, the material was stored on the day of transport and brought to the study area.

RESULTS

The first step in the phytoremediation techniques is an environmental analysis, site inspection and planning. The territory of the mulching technology selected for testing was inspected during the growing season. A description of the phytodiversity of the study site was carried out, as well as an analysis of soil mixtures.

Among the analysed elements in the soils test samples, the exceedance of the permissible level was recorded for lead in four test samples. In general, the concentration of lead in the sample ranged from 0.7 to 8.9 mg/kg. The concentration of cadmium exceeded the permissible levels in two samples, with the concentration ranging from 0.21 to 0.83 mg/kg. One of the samples exceeded the permissible levels of copper. The concentration of copper in the test samples ranged from 0.14 to 7.35 mg/kg. Nickel and zinc do not exceed the permissible levels, their concentrations range from 1 to 8.4 mg/kg and from 0.4 to 2.4 mg/kg, respectively. For such elements as manganese and iron, no permissible concentration levels were established; the concentration of elements in the test samples ranges from 6 to 148.7 mg/kg and 9.5 to 124.6 mg/kg, respectively.

The content of mobile forms of heavy metals (mg/kg) in the substrates of ash and slag dump No. 3 is as follows: Fe(64.06)>Mn(50.28)>Zn(3.37)>Pb(3.18)>Cu (1.65)>Ni(1.35)>Cd(0.51). The average concentration of mobile forms of heavy metals (mg/kg) in the test samples compared to the permissible levels is shown in the diagram (Fig. 3).

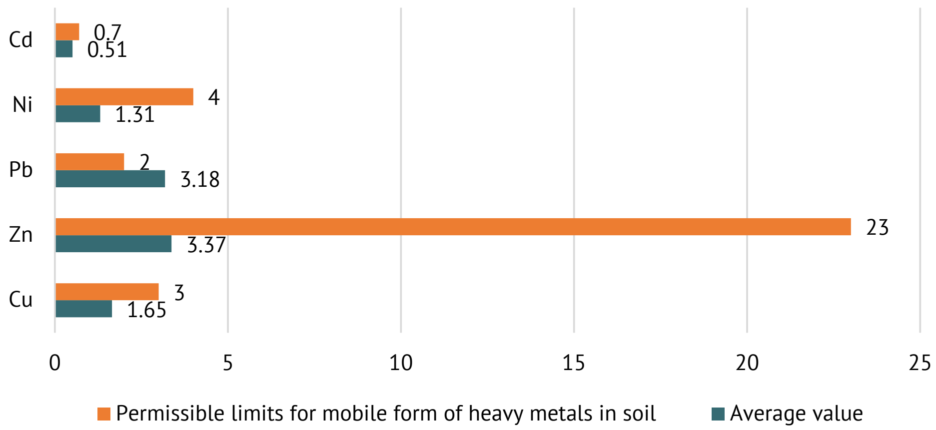

Figure 3. *The content of mobile forms of heavy metals (mg/kg) on the territory of ash and slag dump No. 3 of BTPP*
Source: *compiled by the authors*

As for the analysis of the phytodiversity, previous studies have shown that the representatives of the families *Asteraceae*, *Poaceae* and *Fabaceae* predominate in the flora diversity. A significant proportion of species belong to the *Brassicaceae* and *Rosaceae*. In terms of life cycle, the dominant species are perennial herbs that are pollinated by insects, and their seeds are also spread by insects. Thus, the key role of plant-insect interaction in the formation of the vegetation cover of the study area and its restoration has been shown earlier (Semak *et al*., 2023).

However, the presented study was conducted on the territory of ash and slag dumps 1 and 2, which were decommissioned more than 10 years ago. The study area revealed herbaceous vegetation with shrubs growing along the periphery of the ash dump. The area allocated for mulching is a former ash dump bowl. The vegetation here is formed on ash and is characterised by a continuous cover of *Calamagrostis epigejos* (L.) Roth. Other identified species include *Onagra biennis* Scop., *Trifolium pratense* L., *Inula hirta* L., *Medicago lupulina* L., *and Galium verum* L. There were also some young trees – *Betula pendula* Roth., *Salix* spp. The vegetation was a monodominant plant community dominated by *Calamagrostis epigejos*. The dense sod of *C. epigejos* did not allow other species to settle, which led to the blocking of succession for more than ten years. This situation is typical for neo-ecotopes of anthropogenic lands – the danger of blocking succession with the subsequent formation of monospecies communities was described earlier for post-mining sites (Řehounkova *et al*., 2011). For a comprehensive understanding of the state of phytocoenosis, it is important to assess the density and abundance of species, which requires further research.

A preliminary measure before mulching is the removal of unwanted vegetation in the study area or control of existing plant communities. It has been observed that establishment rates were higher in restoration plots where mowing was carried out than without mowing (Kiehl *et al*., 2010). Mowing, as well as mulching, suppresses competition from the herbaceous layer and promotes the establishment of other species (Wagner *et al*., 2020). Mowing is especially important in the presence of ruderal and invasive species. Areas with sparse vegetation or single plants do not require mowing. Guided by this approach, the grass was mowed on the territory of the experimental plots, followed by sowing seed mixtures and mulching.

Typically, commercial seed mixtures are low-species mixtures of cultivated grasses, often including annuals and perennials, as well as nitrogen-fixing legumes. The use of low-species seed mixtures leads to the formation of unstable, low-productive communities with reduced biodiversity (Kirmer *et al.*, 2011). Such communities are vulnerable to invasion by unwanted species and phytopathogens. In contrast, multi-species plant communities are more stable and resistant to invasion by undesirable species and other environmental impacts. The study proposed a list of species for seed mixtures from local species of native flora. The following criteria were used to select species:

- floristic status;
- ability to survive in the difficult microclimatic and edaphic conditions of ash and slag dumps;
- low nutrient requirements;
- resistance to heavy metals and pollutants;
- well-developed root system;
- long life cycle and herbaceous life form;
- competitive strategy.

The study of the area's phytodiversity resulted in the development of a seed mix. The list includes 20 perennials and 2 biennials, including 7 grass species and 5 legumes (Table 2). Despite the obvious advantages of annual species – habitat function for perennials and formation of organic matter after decaying, the authors did not include annual species in the list to avoid the risk of phytoinvasions and formation of low-value communities, since all identified annual species in the study area have the status of alien species. Grass species are widely used to restore vegetation cover during reclamation activities. The use of grass is explained by their potential to establish vegetation cover quickly and efficiently. In addition, the ability of some to withstand high concentrations of heavy metals when growing on ash and slag mixtures has been previously identified, and a species such as *Phleum pratense* is resistant to high acidity, and due to its ability to form deep and dense roots, it prevents erosion processes (Anca *et al.*, 2011).

***Table 2**. Seed mix for revegetation of ash and slag dumps*

No.	Type	Lifeform	Lifecycle
1	*Achillea millefolium L.*	Herbaceous species	Perennial
2	*Arrhenatherum elatius (L.) P.Beauv. ex J.Presl & C.Presl*	Grain	Perennial
3	*Campanula rotundifolia L.*	Herbaceous species	Perennial
4	*Centaurea jacea L.*	Herbaceous species	Perennial
5	*Dactylis glomerata L.*	Grain	Perennial
6	*Daucus carota L.*	Herbaceous species	Biennial
7	*Echium vulgare L.*	Herbaceous species	Perennial
8	*Festuca rubra L.*	Grain	Perennial
9	*Festuca pratensis (Huds.)*	Grain	Perennial
10	*Holcus lanatus L.*	Grain	Perennial
11	*Leucanthemum vulgare Lam.*	Herbaceous species	Perennial
12	*Melilotus albus L.*	Herbaceous species (legumes)	Perennial
13	*Melilotus officinalis L.*	Herbaceous species (legumes)	Perennial
14	*Phleum pratense L.*	Grain	Perennial
15	*Plantago lanceolata L.*	Herbaceous species	Perennial
16	*Poa trivialis L.*	Grain	Perennial
17	*Prunella vulgaris L.*	Herbaceous species	Perennial
18	*Securigera varia (L.) Lassen*	Herbaceous species (legumes)	Perennial
19	*Tragopogon pratensis L.*	Herbaceous species	Biennial
20	*Trifolium pratense L.*	Herbaceous species (legumes)	Perennial
21	*Trifolium repens L.*	Herbaceous species (legumes)	Perennial
22	*Veronica chamaedrys L.*	Herbaceous species	Perennial

***Source:** compiled by the authors*

However, when selecting grass species for colonisation of devastated areas, their cenotic impact, especially their competitive ability, should be considered, since highly competitive grass species (*Festuca rubra, Arrhenatherum elatius* and *Calamagrosti epigejos*), when colonised by spontaneous succession, form monodominant communities and prevent other species from colonising the area. In the proposed mixture, the most competitive species are *Poa pratensis*, *Dactylis glomerata*, *Arrhenatherum elatius* and *Elymus repens*. The distribution of these species and their competitive impact should be controlled through regular monitoring of the restored areas and appropriate technical biodiversity management measures, which will be described in the next section. In general, the assessment of the competitive strategy by J. Grime (1974) shown that most of the proposed species for the seed mixture are competitors/stress-tolerators, competitors/stress-tolerators/ruderals and competitors/ruderals – this reflects a highly competitive potential and at the same time tolerance to environmental factors, and therefore these species have the promising potential to grow in adverse conditions of ash and slag dumps.

Favourable soil conditions are an important condition for species settlement, which can be improved by nitrogen-fixing legumes. The authors included such legumes as *Trifolium* spp., *Melilotus* spp. and *Securigera varia* in the seed mixture. *Trifolium repens* is widely used in seed mixtures, in particular for revegetation after intensive grazing (Skousen & Zipper, 2018). Due to its deep roots with a tasselled root system that develops near the surface, *Trifolium pratense* prevents erosion. Representatives of the *Melilotus* genus also play a positive role in the formation of vegetation cover. The authors included such species as *Melilotus officinalis* and *Melilotus albus* in the proposed mixture – these species are widely used in phytoremediation due to their drought resistance and soil formation ability. One of the most popular species for phytoremediation is seed alfalfa (*Medicago sativa*). Considering the reclamation properties and potential of *Medicago* spp., the use of *Medicago sativa* and other species of the genus in the experimental plots is a desirable measure. In the course of the experiment, seed mixtures were sown, and mulching technology was applied to the experimental area. In total, the following experimental plots were established: 25 m^2 – mulching with dry hay + seed mix No. 1; 20 m^2 – seed mix No. 1, mulching with fresh hay; 25 m^2 – mulching without sowing seeds; 25 m^2 – mulching with dry hay. Hay + Seed Mixture No. 2; 20 m^2 – mulching with dry hay (without sowing seeds); 25 m^2 – Seed Mixture No. 3 + mulching with fresh hay (without mowing).

The authors of this study believe that mulching and sowing seed mixtures is a promising method for restoring vegetation of anthropogenically transformed ecotopes. The results of the impact of seed mixtures and mulching within the experimental plots can be assessed in the long term. However, the applied methodology had an immediate impact, which consists of reducing erosion, introducing organic matter, and preserving moisture in the experimental sites.

DISCUSSION

Analysing the obtained results, the authors of this study concluded that the presence of such pollutants as heavy metals in the soil cover significantly complicates the plant survival and formation of vegetation cover. At the same time, mulch improves seed germination and plant survival. Given the environmental hazard posed by ash and slag dumps, the assessment of environmental risks, in particular soil erosion, in these ecotopes is a topical issue.

S. Stefanidis *et al.* (2023) analysed changes in the average annual rate of soil erosion due to rainfall erosion over the period 1980-2018. This study used hay mulching to create vegetation cover on ash and slag dumps and focused on the use of mulching as a means to prevent soil and water erosion, improve local environmental conditions and maintain biodiversity. The results show that mulching is effective in preventing erosion. A study by A. Kavian *et al.* (2020) analysed the impact of two types of straw mulch rapeseed and corn to reduce the activation of soil loss and runoff in sandy loam soils. The researchers determined that straw mulching reduced soil loss and sediment concentration by 99%, especially under certain moisture conditions and mulch types. R. Li *et al.* (2021) analysed the impact of organic mulching on soil and water loss. It should be noted that the study conducted by the researchers used the straw mulch method and the method of measuring the rate of reduction of soil loss and runoff. The study focused on aspects such as maintaining soil structure, reducing erosion, and the impact on water resources through reduced soil and runoff losses.

In addition, mulching has an important impact on soil moisture, which has also been shown in several studies (Prysiazhniuk *et al.*, 2022). J. Liu *et al.* (2023a) analysed the dual effect of the amount of straw mulching and mulching periods on moisture gain and loss. According to the results of the analysis, it was found that mulching with straw in the amount of 0.8 kg/m^2 at the three-leaf stage had a positive effect on moisture characteristics. The effectiveness of the double effect analysis method is confirmed by the fact that this method addresses the interaction between the amount of straw mulching and the periods of mulching and determine its impact. T. Singh *et al.* (2024) determined the optimal level of irrigation in conjunction with mulching for spring corn. The results show that the dry hay (seedless) mulching method can retain moisture well, prevent weed growth and protect the soil from erosion. However, it has the disadvantage of decomposition of densely packed hay, which can lead to reduced air access to the soil.

H. Duanyuan *et al.* (2023) investigated the effect of rice straw mulching on soil fertility in agroforestry systems, soil carbon (C) and nitrogen (N) content, and enzyme activity. The researchers employed straw powder mulching, straw segment mulching, and mulching without straw as control. The results show that the organic carbon content in the soil increased significantly due to the use of mulching with straw powder and mulching of straw segments in the upper 0-10 cm soil layer compared to the method of mulching without straw. Y. Yang *et al.* (2023) conducted a field experiment using the long-term deep tillage method and straw mulching.

The long-term deep tillage method can have a positive effect on soil quality and stability over a long period. In addition, deep tillage improves plant access to nutrients and water. However, there is also an advantage to the method of the study, which is that hay mulching can be less costly than deep tillage.

It should be noted that mulch can be a different material, both of plant and artificial origin. S. Liu *et al.* (2023b) conducted a study of straw mulching, co-cultivation, and their interaction. This study found that the hay mulching method was more effective than the straw mulching method because hay decomposes faster than straw, which can lead to faster nutrient delivery to plants. This indicates a significant advantage of hay material compared to other organic materials. In addition to plant material, the use of biodegradable film has significant prospects. Y. Zhao *et al.* (2023) studied fields with film mulching over the past 10 years (mainly from 2019 to 2023). The results of the study of plastic film mulching demonstrated a positive impact on improving water, temperature, and nitrogen in the soil. However, it is worth noting that the method used in mentioned study, namely hay mulching, had a positive effect on the activity of microorganisms in the soil, which is beneficial for its biological activity.

W. Sun *et al.* (2022) studied the production of biodegradable mulching film from biomass materials to reduce environmental pollution caused by plastic. Thus, the results of the study indicate that the liquid mulch film and solid mulch film showed high mechanical properties, UV resistance, water resistance, ageing resistance and biodegradation. P. Kumar and V.P. Usadadiya (2023) examined the impact of plastic and organic mulching materials and methods on soil and the environment, which affects crop productivity. The researchers' results showed that organic mulching materials are inexpensive and environmentally friendly. In the study conducted, hay mulching was used, while in the study by the researchers, mulching methods were applied with grass clippings to preserve soil moisture and suppress weed growth, as well as plastic biodegradable film to control the soil environment and increase yields.

A common practice is to use seed mixtures together with mulching. G.L. Wu *et al.* (2023) conducted an experiment on field restoration that combined the sowing of three types of grasses, using grass clippings as mulch, to restore alpine meadow vegetation. According to the results of the study, soil moisture, plant germination density and vegetation cover density increased in the soils and seed plots. In both studies, the method of sowing several types of grasses using grass clippings as mulch was used. The herbaceous plants selected in the study were legumes: meadow clover, sweet clover and seed alfalfa. The advantages of using the grasses used in this study were their ability to interact with bacteria, fixing nitrogen in the soil and improving its fertility. Regarding the advantages of herbaceous plants such as wheatgrass, annual bluegrass and fescue used in the study by the researchers (Robins & Bushman, 2020).

Thus, numerous studies have confirmed the effectiveness of mulch in enhancing the development of vegetation cover and plant establishment. The additional use of seed mixtures will enhance the process of establishing vegetation cover and enriching biodiversity. Despite the pollutants present in the soil, this method will allow for the formation of vegetation cover in ash and slag dumps and thus help reduce the environmental risks of the industrial facility.

CONCLUSIONS

The study assessed the territory, including the condition of the soil cover and phytodiversity. The results of the study showed that the man-made ecotopes of ash and slag dumps were contaminated with hazardous pollutants, particularlyheavy metals. This fact indicates the potential environmental hazard of these facilities, as the fine dispersion and dusting of ash and slag heaps cause the dispersion of pollutants in the surrounding ecosystems. The presence of heavy metals in soilsmakes it difficult for vegetation to grow here, which is a factor in erosion protection. The results of the assessment of the phytodiversity of the studied areas showed the presence of monodominant communities with *Calamagrostis epigejos*, which indicates the blocking of succession and makes it impossible for other species to appear here. Considering the phytodiversity of the territory, a list of native species for the preparation of seed mixtures was proposed.

The study examined mulching and seed mixtures. The results showed that the using mulch without ruderal and invasive species contributes to the formation of plant communities by creating favourable conditions for seed germination: it reduces soil erosion and retains moisture, creates a physical substrate and protection for seeds, and is a source of seeds and diasporas. The use of green hay accelerates the development of vegetation and leads to the formation of species-rich plant communities. Thus, the use of mulching as a step towards natural restoration proved a successful strategy for ash and slag dumps at Burshtyn TPP. Areas for further research on the mulching and seed mixtures method may include studying the impact of different types of mulch (organic, inorganic, biodegradable) on improving soil quality, evaluating the effectiveness of different combinations of seed mixtures, and growing conditions, analysing the impact of the mulching and seed mixtures method on soil microbial biodiversity and microbiological processes in the soil to restore the soil cover of a potentially hazardous site.

The algorithm for applying the restorative methodology of mulching and seeds mixtures in anthropogenic ecotopes is as follows: assessment of environmental risks of the territory – preparation of the territory for mulching and/or sowing of seed mixtures – mulching and/or sowing of seed mixtures – monitoring of the experimental plots. It would also be advisable to introduce clear coordination of soil erosion monitoring programmes between the main technosphere objects at the regional (local) and national levels, unification of the regulatory framework and measurement methods, and scientifically based adjustment of the programme and observation sites depending on specific local conditions.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Мульчування як екологічний метод відновлення рослинного покриву на золошлаковідвалах Бурштинської ТЕС

Уляна Йосипівна Семак
Магістр, викладач
Прикарпатський національний університет імені Василя Стефаника
76018, вул. Шевченка, 57, м. Івано-Франківськ, Україна
https://orcid.org/0000-0001-6215-6252
Мирослава Миронівна Миленька
Кандидат біологічних наук, доцент
Прикарпатський національний університет імені Василя Стефаника
76018, вул. Шевченка, 57, м. Івано-Франківськ, Україна
https://orcid.org/0000-0001-9249-8077

Анотація. Дослідження ефекту мульчування для встановлення рослинного покриву на промислових майданчиках є перспективним та актуальним з погляду екологічного відновлення та зменшення зниження екологічних ризиків в зоні впливу промислових об'єктів. Метою дослідження є вивчення та оцінка ефективності мульчування та висівання насіннєвих сумішей як способу встановлення рослинного покриву на золошлаковідвалах теплових електростанцій. Для проведення дослідження попередньо здійснено оцінку ґрунтового покриву золошлаковідвалів та закладено експериментальні ділянки, на яких здійснювалося мульчування та посів насіннєвих сумішей. Під час проведення дослідження було виявлено, що екотопи золошлаковідвалів характеризуються підвищеною концентрацією полютантів, а саме важких металів, що ускладнює появу тут рослинного покриву. У ході вивчення екологічних особливостей едафотопів та фіторізноманіття території запропоновано перелік видів аборигенної флори для насіннєвих сумішей. Здійснено мульчування на експериментальних ділянках та висівання насіннєвих сумішей. Мульчування зарекомендувало себе як ефективний метод для прискорення процесів природного відновлення рослинності територій що зазнали антропотехногенного впливу. Результати дослідження можуть бути використані на практиці екологами, екологічними організаціями та широким колом спеціалістів з метою розробки та впровадження заходів що сприяють відновленню екологічного балансу деградованих та техногенно трансформованих екосистем

Ключові слова: забруднення; деградація; тверді відходи; рекультивація; мульчування; насіннєві суміші
