Influence of Industrial Wastes and Natural Soil Zeolites on Identification of Herbage Response

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Abstract. Industrial wastes and the chemicals they contain significantly influence the ecological conditions of biogeoecosystems, leading to permanent changes and degradation of soils. This fact calls for the development of methods and technologies for the disposal of the industrial waste being produced. One of the aspects of waste disposal is the use of fertilizing properties of the chemicals that reside in them. The article presents the results of argenvironmental efficiency research for the use of fertilizing properties of industrial wastes and natural zeolites in grass lawn and landscape design. Grass growth and development patterns were studied for the soils improved with salt siftings of aluminum dross, sewage sludge, natural zeolites, and peat. The best composition of fertilizing substances was determined in order to provide for the biggest increase in herbage growth and yield. Data are presented on the proportion of the elements in the soil and in specific plant organs, the soil composition changes in the root zone and rhizosphere.

1. Introduction

One of the promising directions of the evaluation of plants’ need in fertilizer elements is the analysis of the vegetation. Different plant species need to receive different fertilizing elements from the soil. Thus, only the plant itself can correctly illustrate the availability of the fertilizers in the soil. For different plants, the amount of the fertilizing substances available will vary in certain development stages depending on external conditions [1].

In order to achieve the best yield and technological qualities of the plants, their nutrition regime must be constantly adjusted; they must be fed certain stimulators and inhibitors for specific metabolic processes. Having said that, it is impossible to predict all of the changes to the external factors. However, changes in the environment determine the plant’s need for nutrients, the behavior of metabolic processes, and plants’ chemical and biochemical composition. In order to assess factors...
limiting the yield (nutrient problems), the content and the state of the elements both in the soil and in plants are evaluated, vegetation response to fertilizing is evaluated in field experiments [18].

For practical purposes, it is necessary to have a general integrated land fertility specification, including the content and the state of the fertilizing elements; i.e. apart from plants, it is necessary to analyze soils and the relationships the soil and the plants [13]. Soil analysis brings extra information necessary to calculate equilibriums for the interaction of industrial waste and ameliorator based fertilizers and soils, as well as forecasting the changes in nutrient mobility and availability in seasonal dynamics depending on agricultural practices and the methods of fertilizer and ameliorator application [16].

All of the aforesaid makes searching for new ways of nutrient availability assessment for soils feasible [8]. This work suggests assessing nutrient availability in soils using feedback principles. First, industrial waste and natural zeolite-based fertilizers are introduced into the soil where plants grow. Then vegetation response is identified through the analysis of the soil and the plants. It shows whether there is a surplus of insufficiency of the elements in question in them [18].

The resilience of the soil mantle against degradation largely depends on its resilience against the anthropogenic impact on the vegetation [6]. If the vegetation is not resilient enough, soil resilience against degradation shrinks as well. Vegetation resilience against the anthropogenic impact is determined by the resilience of trees, bushes, and grasses against air pollution, acidic precipitation, poaching damage, the anaerobiosis, and the groundwater plane and the adverse properties of the soils emerging due to their degradation. The tolerance of the plants under analysis is determined by the type of their photosynthesis, their metabolic behavior, the morphology of their overground organs and roots, the sorption properties of root systems [4].

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Parkland grass and tree crops have various root system sorption properties. It explains their different resilience to flooding, poaching, acidic precipitation, and heavy metal contamination. The reduction of specific species resilience towards these stresses leads to the reduction of ecological sustainability of ground vegetation in general. At the same time, the reduction of vegetation sustainability necessarily leads to the reduction of soil resilient against degradation [10].

One of the disposal methods for secondary natural resources, including metallurgic waste consists in using them for the chemical amelioration and fertilizing of soils. Thus the agriculture receives relatively cheap fertilizers (in some cases, industrial wastes are very close to lime, phosphoric lime or micro fertilizers), and some of the environmental goals are achieved, such as the reduction of refuse barrows or contamination prevention [3, 17]. The prospects of using metallurgic slag in agriculture are determined by their content of macro- and micronutrients necessary for the growth and the development of vegetation, such as phosphorus, potassium, calcium, iron, boron, copper, molybdenum, cobalt, etc. There are known as ‘non-standard fertilizers’ [2, 19].

There is a huge amount of sewage sludge (SS) accumulated in the world every year, and their storage, treatment, and disposal present a pressing problem. Using SS in agriculture was seen as the most efficient disposal method in the last decades, due to the presence of organic material nutrients in them. On average, there are 60-80% of organic matter, 0.5-5% nitrogen, 0.5-2% phosphorus, and 0.2-0.6% potassium in sewage sludge [9, 13].

The goal of this research was studying the growth and the development of sown grasses in soils fertilized with various wastes, including sewage sludge (SS), salt siftings of aluminum dross, natural zeolites, and peat; as well as studying the changes to the soil composition in root zone and rhizosphere and the proportion of elements in the soil and specific plant organs.

2. Results and discussion
The sown grass growth data obtained in the experiment (Table 1) show that separate application of zeolite, peat and sewage sludge to the rate of 5 t/ha significantly increases the growth of herbage so that the control growth values made up 10.69%, 4.64%, and 16.73 % respectively. When the sewage sludge dosage was increased up to 10 t/ha and 20 t/ha, the herbage growth increased up to 20.48% and 30.56% respectively.
Table 1. The influence of different fertilizers on the lawn growth.

| Experiment options                  | Average growth, cm | Hay yield, dt/ha |
|-------------------------------------|--------------------|-----------------|
| 1. Control (no fertilizer)          | 24.80              | 13.95           |
| 2. Zeolite, 5 t/ha + peat, 5 t/ha   | 26.45              | 14.40           |
| 3. Zeolite, 5 t/ha                  | 27.45              | 15.23           |
| 4. Peat, 5 t/ha                     | 25.95              | 14.03           |
| 5. SS, 5 t/ha                       | 28.95              | 15.85           |
| 6. Zeolite, 5 t/ha + SS, 5 t/ha     | 27.60              | 15.20           |
| 7. SS, 10 t/ha                      | 29.88              | 18.08           |
| 8. SS, 20 t/ha                      | 32.38              | 21.15           |
| 9. Zeolite, 5 t/ha + SS, 10 t/ha    | 30.40              | 18.00           |
| 10. Zeolite, 5 t/ha + peat, 5 t/ha + SS, 5 t/ha | 31.55      | 20.45           |
| 11. Zeolite, 5 t/ha + slag, 5 t/ha  | 30.20              | 18.53           |
| 12. Zeolite, 5 t/ha + slag, 5 t/ha + SS, 5 t/ha | 36.40       | 24.00           |
| HCP05                               | 0.31               | 0.23            |

The biggest herbage growth increase was obtained while using zeolites together with sewage sludge and slag because the combination of zeolite and slag at the rate of 5 t/ha each gave the herbage growth of 30.2 cm and the controlled increase value of 21.8%. The combination of zeolite, peat and sewage sludge at the rate of 5 t/ha each gave the controlled herbage increase value of 27.2%. The best conditions for herbage growth were created when zeolite, slag, and sewage sludge were used together at the rate of 5 t/ha each. The average grass growth made up 36.4 cm, and the controlled increase value was 46.77%. It must be noted that the combination of sewage sludge and zeolite at the rate of 5 t/ha each (1:1) was less efficient than the same amount of sludge alone by almost 5.5%, but when the amount of sludge was 2 times higher than zeolite, the efficiency of the fertilizer increased. The growth increase made up 22.58%, which is better than the same amount of sewage sludge alone by 2.1%, and better than zeolite alone by 12%.

The best yield increase was obtained while combining three portions of zeolite, slag and sewage sludge. It composed 24.0 dt/ha, while this value for the combination of zeolite, peat and sewage sludge was only 20.45 dt/ha. The separate application of sewage sludge in increased increments of 5, 10, and 20 t/ha increased the evident dry yield over the years of research by 13.62, 29.61, and 51.61% as compared with the fertilizer free option. The use of high-ash peat at the rate of 5 t/ha did not provide for evident yield increase due to the insufficient moisture.

Thus the combination of zeolite, sewage sludge, and slag at the rate of 5 t/ha each allowed obtaining an extra of 1 t of dry grass per hectare, and the increase of sewage sludge portion to 10 and 20 t/ha increased the herbage yield by 4.1 and 7.2 dt/ha as compared with the control values.

Combining natural zeolites and industrial waste to fertilize grass lawns was efficient and eco-friendly, promoting the development of sustainable high-yield herbage over the years of use (24 dt/ha), the production of quality fodder for farm animals, satisfying the livestock regulations (table 2) and helping solve the problems of industrial and household waste disposal and environmental protection.

Soil properties determine the chemical and biochemical composition of plants. The proportion of elements in specific plant organs and the content of elements in different organs, the proportion of elements in the soil and the root zone show the response of the plants to the soil properties. All of these parameters can be used to assess the plants demand in nutrients, soil fertility and its degradation [5].
Table 2. The chemical composition of lawn plants.

| Experiment options | P   | K   | Ca  | Mg  | NO₃⁻ | Cu  | Zn  |
|--------------------|-----|-----|-----|-----|-------|-----|-----|
| 1. Control         | 0.27| 1.77| 0.69| 0.23| 82    | 1.6 | 10.2|
| 2. Zeolite + slag  | 0.31| 2.03| 0.62| 0.19| 252   | 3.3 | 15.3|

Due to this, we deem feasible the assessment of the element composition in specific plant organs, in the soil, in roots, stems, and leaves, as well as analyzing the root zone soil separate from the soil in general. The proportions can be found for the good the depressed state of the herbage, healthy and sick plants, and the crops fertilized with various substances. If the soil lacks some element necessary for plant development, this element is excessively consumed in the root zone, so that it has a smaller content of this element [11]. Thus, the differences in the root zone as compared with the entire soil mass indicate soil fertility level for the crop in question. The surplus or the lack of specific elements lead to their redistribution within plant organs. Thus, the proportion of various elements in plant organs is a valid indicator of their surpluses or insufficiencies.

The proportion of elements in the soil, roots, stems, and lower and upper leaves is informative for the assessment of the soil and vegetation relationships. Table 3 shows the data on (Ca+Mg):(Fe+Mn) and K:Ca proportions in the soil and specific plant organs.

Table 3. The proportions of elements in soil and specific plant organs.

| Plant state | Element composition | Soil       | Roots       | Stems       | Lower leaves | Upper leaves |
|-------------|---------------------|------------|-------------|-------------|--------------|--------------|
| Normal      | Ca+Mg               | 4.1 ± 0.4  | 1.6 ± 0.2   | 2.2 ± 0.3   | 0.8 ± 0.2    | 2.95 ± 0.2   |
|             | Fe+Mn               |            |             |             |              |              |
| Depressed   | Ca+Mg               | 1.5 ± 0.2  | 1.4 ± 0.1   | 0.7 ± 0.2   | 0.3 ± 0.15   | 1.95 ± 0.1   |
|             | Fe+Mn               |            |             |             |              |              |
| Normal      | K:Ca                | 2.1 ± 0.5  | 0.08 ± 0.03 | 8.5 ± 1.9   | 2.4 ± 0.6    | 4.9 ± 0.7    |
| Depressed   | K:Ca                | 0.9 ± 0.1  | 0.05 ± 0.02 | 0.9 ± 0.1   | 0.5 ± 0.1    | 1.95 ± 0.5   |

For normal herbage condition, a higher proportion of (Ca+Mg):(Fe+Mn) in the soil, stems, upper and lower leaves is characteristic of the soil and vegetation system as compared with the depressed state. The normal state plants have higher proportions of K:Ca in the roots, stems, lower and upper leaves. It corresponds to the higher proportion of K:Ca in the soil where normal state herbage grows. The lack of nutrients can be identified when comparing the ion content in upper and lower leaves. It is known that the insufficiency of elements is primarily evident in the younger leaves. The data we obtained show that in the younger leaves of the depressed herbage the proportion of (Ca+Mg):(Fe+Mn) and K:Ca is narrower, as compared with the normal herbage. In this case, the gradient of these proportions for upper and lower leaves is wider. That is, younger leaves of depressed herbage have less (Ca+Mg) than (Fe+Mn) and less K than Ca, as compared with the older leaves.

The changes of soil properties in the root zone as compared with the entire soil mass reflect the changes in ion activity, their proportions, the fractional composition of compounds, the shares of cationic and anionic composites. The scale of changes depends on soil properties and herbage development stages [7, 20]. In the series of experiments performed, significant quantities of objects in question were analyzed. For grass sward soils during the early blossoming stage, the root zone, rhizosphere, and above-root zone were studied under normal and depressed plants (table 4).
Table 4. The changes in soil composition in the root zone and rhizosphere.

| Herbage state | Na  | K    | Ca      | Mg  | Fe  | Mn   |
|---------------|-----|------|---------|-----|-----|------|
| root zone     |     |      |         |     |     |      |
| Normal        | 6.0±1.4 | 3.9±0.6 | 57.8±14.5 | 1.7±0.3 | 231.6±17.1 | 89.5±11.2 |
| Depressed     | 4.8±0.4 | 3.2±0.3 | 51.5±17.1 | 1.5±0.1 | 253.0±18.3 | 113.4±19.2 |
| rhizosphere   |     |      |         |     |     |      |
| Normal        | 6.3±1.3 | 3.6±0.4 | 41.3±6.5  | 1.6±0.1 | 259.8±21.4 | 103.6±6.9  |
| Depressed     | 4.4±0.3 | 3.3±0.2 | 38.1±4.7  | 1.4±0.1 | 217.9±18.6 | 107.1±16.2 |
| above-root zone |     |      |         |     |     |      |
| Normal        | 4.5±0.5 | 4.7±1.2 | 97.3±32.1 | 2.1±0.5 | 59.6±19.3 | 12.5±3.9   |
| Depressed     | 4.9±0.6 | 5.8±1.1 | 76.8±22.9 | 2.5±0.7 | 31.5±8.7  | 9.7±2.1    |

The analysis of the obtained data shows that the above-root zone has significantly more Ca and less Fe, Mn, which is obviously due to a higher degree of oxidation nearer the soil surface. The proportion of iron to calcium and sodium to potassium in the above-root zone is at minimum, while the proportion of calcium to magnesium is at its maximum. Root zone undergoes the strongest influence of plant roots. As compared with above-root and rhizosphere, it shows the extension of the sodium to potassium proportion due to the high intake of potassium by plants. The calcium to magnesium proportion is narrower than in the above-root zone due to the intensive intake of calcium, and the Fe:Ca proportion is wider due to the significant intake of Ca. The root zone and the rhizosphere of depressed herbage show the reduced mobility of potassium, calcium, and magnesium, as well as the increase in iron and manganese, as compared with well-developed plants.

3. Conclusions
The received data show that the changes of proportions in question can be caused by both the surplus of nutrients in the soils and the adverse soil properties in certain microzones. The combined use of methods regarded will help determine the causes of herbage depression while taking into consideration that the lack of some element in the leaves might not be due to its insufficient content in the soil. Only introducing the element in the soil and identifying proportions of elements in various parts of soil and plant system makes it possible to speak of the element insufficiency or surplus for the system in question. Using industrial waste-based fertilizers helps solve a number of practical problems, including resource economy, eco-safety, and biogeocoenosis resilience against the adverse environmental factors.

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