Impact of the Ash Usage from Individual Stoves on Selected Physicochemical Properties of Cultivated Grounds

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Abstract. The purpose of the work was to determine the suitability of adding ash from household furnaces to agricultural soils. The author took into account the properties of ashes and their usefulness in various fields. The paper presents the soil specification and the effect of ash on it. Also, the impact of ash on the growth of plants that have been fertilized and deficiencies and hazards resulting from this method of fertilization has been shown. The analysis of samples in which soil mixtures were made of ashes from hard coal and wood ashes was carried out. Research has been carried out in the presence of elements that have the greatest impact on plant growth.

1. Introduction

The progressing socio-economic development and regional limitations in access to network energy will lead to an increase in demand for solid fuels indispensable for heating residential buildings. This situation has caused an increase in the formation of waste products generated after the combustion of organic materials (mainly hard coal and wood), i.e. ashes. Incorrect disposal of this type of waste can lead to many damages related to environmental contamination, among others pollution of the atmosphere and nearby soils or groundwater [1].

According to GUS (Central Statistical Office) data, around 20-25 million Mg of ash from individual furnaces is generated annually in Poland. A significant part of this waste is sent to disposal by landfilling. In this case, the ash is collected selectively within the places where it is deposited, in which local soil contamination may occur.

One of the methods of ash management is their use as an additive for ceramic products and for road construction. These applications require that ashes meet the appropriate legal requirements. Possible uses of this material are also among others during micro-leveling, soil stabilization or construction of insulation barriers for underground storage [2]. One of the additional methods of using ashes is their use as a fertilizer [3] or an addition to concrete [4], [5]. This method allows not only local management of unwanted material but also leads to more efficient crop yields on farms. Ashes can be a rich source of macro and micronutrients. They can also be used for de-acidification of soils, although the use of high doses of ash may result in toxic effects for plants and lead to phosphorus deficits. The additional use of this material is the enrichment of soils with a powdery fraction.

The purpose of the work is to determine the suitability of furnace ash to improve the structure and properties of arable lands. The secondary objective of the study is to determine the differences between the chemical composition of the soil itself and the soil mixed in various proportions with ash.
The rationale for the article's purpose is the increasing amount of ash generated especially in domestic furnaces, which are unskilfully used.

2. Materials and Methods

For analysis were used ash from wood combustion, ash from hard coal combustion and soil with the granulometric composition of loose sand (humus layer). Ashes were obtained from burning wood and coal in domestic furnaces at 470°C.

Ten samples with different soil proportions, wood ash and coal ash, each with a total weight of 90 cm³, were used for analysis. The proportions of individual mixtures are presented in the table below.

| Order number of the mixture | Soil (Gl) [%] | Wood ash (P₁) [%] | Hard coal ash (P₂) [%] |
|----------------------------|---------------|-------------------|-----------------------|
| 1.                         | 100           | 0                 | 0                     |
| 2.                         | 0             | 100               | 0                     |
| 3.                         | 0             | 0                 | 100                   |
| 4.                         | 50            | 50                | 0                     |
| 5.                         | 33.33         | 66.67             | 0                     |
| 6.                         | 66.67         | 33.33             | 0                     |
| 7.                         | 50            | 0                 | 50                    |
| 8.                         | 33.33         | 0                 | 66.67                 |
| 9.                         | 66.67         | 0                 | 33.33                 |

In the first stage of the study, red fescue seeds were used to determine the toxicological impact of ashes on plants. This variety is resistant to unfavorable habitat conditions. It is characterized by relatively good tolerance for drought and frost [6], [7]. Ten red fescue seeds were added to each of the nine mixtures and incubated in an incubator for 14 days. All analyzes were performed in three replications (see Figure 1).

![Figure 1. Part of the samples prepared for incubation](image)
In the next stage of the research, another 9 mixtures were prepared in the same proportions (Table 1). For each developed composition, tests of selected chemical properties were carried out using the photometric method. It consists in comparing the intensity of the tested source with the intensity of the standard filament lamp. The photometer consists of an isosceles prism with white walls placed inside a blackened frame, and two light sources located on both sides of the frame. One of the sources is a reference source (with the known intensity of light) the other is the source being tested. The test source is placed at such a distance from the prism to obtain the same illumination of both surfaces of the prism. In the samples, Ca\(^{2+}\), Mg\(^{2+}\), Fe\(^{2+}\), NH\(_4\)\(^{+}\), NO\(_3\)\(^{-}\) and PO\(_4\)\(^{3-}\) ions were determined. All analyzes were performed in three replications (see Figure 2,3.)

**Figure 2.** Part of samples prepared for ion NO\(_3\)\(^{-}\) testing

**Figure 3.** Part of samples prepared for ion PO\(_4\)\(^{3-}\) testing

3. Results and discussions
The most favorable conditions for the germination of red fescue seeds were represented by the samples where only the soil was found. In each of the three trials, 100% seeds germinated. The soil mix with hard coal in the ratio of 2:1 and the mixture of soil and wood in the ratio of 1:2 slightly
worse. The average results of these blends are 80% and 70% respectively for three samples. Definitely, the worst conditions for plant growth were observed in mixes 2 and 3, where the average amount of germinated seed was 0% and 10% respectively for three samples. These mixtures were pure ashes.

Table 2. The average percentage of germinated seeds of red fescue from three trials [%].

| Order number of the mixture | The average percentage of germinated seeds of red fescue from three trials [%] |
|----------------------------|--------------------------------------------------------------------------------|
| 1.                         | 100                                                                           |
| 2.                         | 0                                                                              |
| 3.                         | 10                                                                             |
| 4.                         | 20                                                                             |
| 5.                         | 70                                                                             |
| 6.                         | 40                                                                             |
| 7.                         | 60                                                                             |
| 8.                         | 10                                                                             |
| 9.                         | 80                                                                             |

In the next stage, the analysis of the contents of Ca$^{2+}$, Mg$^{2+}$, Fe$^{2+}$, NH$_4^+$, NO$_3^-$ and PO$_4^{3-}$ ions in individual mixtures was analyzed. The average results for all mixtures from all three trials are shown in Table 3.

Table 3. The average content of individual ions in the tested mixtures

| Order number of the mixture | Ca$^{2+}$ [mg/dm$^3$] | Mg$^{2+}$ [mg/dm$^3$] | Fe$^{2+}$ [mg/dm$^3$] | NH$_4^+$ [mg/dm$^3$] | NO$_3^-$ [mg/dm$^3$] | PO$_4^{3-}$ [mg/dm$^3$] |
|-----------------------------|------------------------|------------------------|------------------------|----------------------|----------------------|------------------------|
| 1.                          | 520                    | 1100                   | 0.23                   | 0                    | 1.9                  | 1.5                    |
| 2.                          | 260                    | 360                    | 0                      | 0                    | 0                    | 0.1                    |
| 3.                          | 480                    | 1050                   | 0.1                    | 2.0                  | 0                    | 0.4                    |
| 4.                          | 240                    | 1070                   | 0.15                   | 0                    | 2.1                  | 0.1                    |
| 5.                          | 250                    | 1120                   | 0                      | 0                    | 2.3                  | 0.1                    |
| 6.                          | 240                    | 1300                   | 0.1                    | 0                    | 0                    | 0.4                    |
| 7.                          | 250                    | 1000                   | 0.24                   | 0                    | 0                    | 0.4                    |
| 8.                          | 230                    | 1220                   | 0.1                    | 0                    | 0.9                  | 1.0                    |
| 9.                          | 510                    | 1550                   | 0.15                   | 0                    | 0                    | 0.2                    |

Calcium is responsible for soil pH. The lack of this element causes deformation of younger leaves. In the analyzed samples, it naturally occurs in the soil itself. Only a mixture with the addition of hard coal in the ratio of 2:1 (blend No. 9) did not show a significantly reduced amount of these ions. Calcium ions are also found in the same ash from coal, while its growth was not observed in samples with wood ash. When fertilizing with ash, the possibility of calcium deficiency should be taken into account. This element does not occur in wood ash. For this reason, it should be added separately for the correct plant growth. The lack of calcium addition can cause poor absorption of other elements, which should be added after using ash [8], [9].

Table 3 shows the content of magnesium ions in individual samples. Magnesium is the main component of chlorophyll, a dye responsible for photosynthesis. The appearance of yellow leaves is caused, among others, by the lack of this element, which inhibits the growth and development of plants. In samples containing only wood ash, the significant deficiency of magnesium was demonstrated. Mixtures containing ash from hard coal had the correct content of this element.
Addition of ash from hard coal increased the amount of magnesium in the soil, whereas in the sample where wood ash itself was found, there was a significant decrease in the examined element. Soils with low magnesium content, after addition of ash, increase the abundance of the available forms of this element. The addition of ash in amounts larger in relation to the weight of non-fertilized soil can lead to the fertilization of plants.

In the next step was presented the average iron content in individual samples. It is one of the elements of chlorophyll, responsible for photosynthesis. It is a very important element of plant construction, and the symptom of its deficiency is a disease called iron chlorosis and appears primarily on young leaves that fade and become white. In the samples that have been analyzed, iron decay can be observed. The ash affects the soil adversely in terms of the amount of this element. The largest iron deficiency is observed in samples of wood ash. Carbon ash has a more beneficial effect on the iron content in the samples. In a soil mixture with hard coal ash in the ratio of 1:1, the iron content does not change significantly in relation to the sample with the soil itself.

In literature, ash occurs as a carrier of toxic metals. Iron, which occurs in ashes, is collected as a fertilizer. Addition of small doses of ash enriches the soil with this element, at the same time not adding toxic ingredients to the soil. The addition of ash in the amount of 5%, in relation to the weight of non-fertilized soil, is sufficient to add the right amount of iron [10].

Column 5 of Table 3 shows the analysis of the content of ammonium ions in the tested samples. Ammonia is a preferred component of soil in small amounts. Ammonium ion has the ability to transfer other nutrients to the soil, e.g. nitrogen. Analysis of the samples showed that ammonia occurs only in samples containing hard coal ash. Samples containing only the soil and admixtures of wood ash do not contain it at all. The impact of ammonia on ash fertilization is invisible to the soil, or the amine can get into it in such small amounts that it does not affect it in any way [11].

Column 6 of Table 3 shows the average amounts of nitrates (V) in the mixtures, i.e. the main building blocks of proteins. It is considered the most important yielding component. Its deficiency causes a decrease in yield and hinders plant growth and development. This phenomenon is manifested by: the yellowing of the leaves and the fragile cut of the plant. The results show that the soil used in the research has a natural concentration of nitrates, while samples containing ash from coal cause a decrease in these properties. Samples with the addition of wood ash showed the closest nitrate content to pure soil samples.

Nitrogen is a relatively easily washable element, especially in light soils. The use of fertilizer with the addition of ash causes the relative retention of this element [12].

Phosphates take part in all the processes taking place in the plant. They are responsible for the process of photosynthesis, breathing, metabolism and the formation of proteins. Its deficiency causes serious weakening of the plant, and the roots of plants suffer the most. Based on the results of the content of phosphates in individual mixtures, it can be seen that most of the ions of this element are found in samples containing only soil. Analysis of samples containing ashes (both hard coal and wood), showed reduced phosphate content.

On the basis of the conducted research, it can be concluded that the presence of ash in the soil reduces the content of phosphates. It was observed that the higher the ash dose, the lower the phosphorus content in the soil.

To keep the right amount of phosphate, you need to know their initial value and the need for plants to select the right amount of ash for fertilization.

4. Conclusion
The basic sample, i.e. a sample containing only soil, is characterized by a magnesium deficiency. The addition of coal ash was the best solution with this deficiency. The results of the soil mixture with hard coal ash give an effect similar to the analyzed samples of the soil itself [13]. The mixture of ash from wood and soil reduces the value of elements needed for the proper development of plants.
On the basis of the conducted research, it can be concluded that ash is a good fertilizer for arable land. The land, which is found on most arable fields in Poland, is podzolic and brown soil. Such soil was used to carry out research [8].

Fertilizer from the ash could bring ammonia to the soil. If it is present in large amounts, it may threaten plants. When ammonium ions occur in negligible amounts, they do not affect the growth of plants. Moderate dosing of fertilizer with ash does not expose ammonia overdose. The most effective addition of ash is the amount of 10% in relation to soil weight. Thanks to this application, ash enriches the soil with the most needed micro- and microelements [12].

The tests and analyzes carried out allow to draw the following conclusions:

- The most effective mixture of soil and ash is sample No. 7 - soil mixture with hard coal ash in a 2:1 ratio;
- The elements needed for good plant growth are more concentrated in hard coal ash than in wood ash;
- When selecting hard ash from ash, separate nitrates and phosphates separately. The examined ashes have negligible amounts of these substances that are necessary for the proper growth of plants;
- Application of ashes to the soil negatively affects the concentrations of selected ions causing their dilution.

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