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# The Utilization of Peat, Lignite and Industrial Wastes in the Production of Mineral-Organic Fertilizers

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**Abstract:** The results of chemical analyses of the composition of peat, lignite, turkey droppings and the potato industry effluent are presented. The results indicate that the substances can be used in mineral-organic fertilizer recipes. Although lignite and peat do not contain assimilable nutrients, from the ecology and pedology point of view they are valuable components of mineral-organic fertilizers. In order to determine the optimum turkey droppings and potato industry effluent dose in fertilizer biological studies using the germination tests were carried out. The demand for nutrients differs between plants. The mineral-organic fertilizer recipes were developed for sugar beet which is a highly demanding plant taking up large quantities of nutrients.

**Key words:** bro, peat, wastes, mineral-organic fertilizers

## INTRODUCTION

Although demographic factors, the development of science and technology and the progress of civilization contribute to the satisfaction of peoples' living needs and to the improvement of their standard of living they also contribute, as a result of the ill-considered and uncontrolled management of natural resources, to environmental degradation, climate change, waste generation and accumulation, removal of land from agricultural use, pollution of water bodies, changes in water conditions and so on. The considerable degradation of the natural environment affects the whole globe and because of its omnipresence its effects are felt both by the highly industrialized countries and poorer countries, e.g. the African countries.

The awareness of the global impact of environmental degradation on human life resulted in the movement for environmental improvement and the first major step was the creation of a legal basis for 'sustainable development' defined in 1987 in the report of the World Commission on Environment and Development (the Bruntland Commission). Sustainable development is defined there as a policy and strategy for economic development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The sustainable development concept was further developed at a series of international conferences on economic development and its effect on the environment. The most important worldwide was the proclamation of the Rio Declaration at World Conference on Environment Protection held in Rio de Janeiro in 1991[1]. All this work resulted in the publication of a political-economic report: 'Our Common Future' and in the formulation a global economic action plan for achieving durable and sustainable development and assuming responsibility for industrial and economic activities through the rational use of natural resources and reduction of the quantities of associated wastes. This program is known as action for Clean Production and its theses are contained in the adopted Agenda 21.

On the basis of the documents on sustainable development and clean production the European Union has created an environmental protection program comprising about 200 legal instruments[2].

In Poland the above issues have been reflected in such legal acts as: the National Ecological Policy, the Environmental Protection Law, the Best Available Technologies (BAT), ISO 14000 standards for environmental management and in numerous ecological programmes implemented in production plants. The directives and regulations contained in the documents are accordant with the legislative acts of the EU.

Similarly as any other economic activity, agriculture impacts the natural environment. Since the fertilizers

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used by farmers may become a source of serious environmental degradation regulations governing the sales and use of fertilizers have been introduced in Poland. The regulations have the form of the Fertilizer and Fertilization Act of 2000. In the light of the above legislation it became imperative to find a solution which would combine increased agricultural production with the rational management of wastes generated by industry and agriculture[3, 4]. A reasonable solution seems to be the processing of wastes into mineral-organic fertilizers[5]. In Poland the legal act which regulates the handling of wastes and their agricultural use is the Wastes Act of 27 April 2001.

**Role of organic matter in soil:** Organic matter occurs in soil as a result of the dying of plants and animals. The main chemical compounds which make up both plant and animal organisms are: carbohydrates, proteins, fats, fatty acids and lignin. Depending on the climatic and biological conditions organic matter may undergo complete decomposition, i.e. mineralization, or transformation into humus, i.e. humification. It is assumed that about 3/4 to about 4/5 of the organic matter in soil turns into humus as a result of humification[6]. Humus is characterized by high hydrophilicity and sorption ability whereby it considerably participates in the physicochemical processes which take place in soils. Humus particles have a negative charge and are surrounded by cations. The negative charge is due to the presence of, among others, –COOH and –OH groups. The high adsorption ability is due to the fact that hydrogen in carboxyl and phenol groups can be replaced by any cations. The sorption capacity of humus is 15-36 times higher than that of clayey minerals. The extremely active role of organic matter is evidenced by the fact that it is a source of nutrients – over 95% of N, over 40% of P and about 90% of S originate from it[6]. Among humus fractions humic and fulvic acids are characterized by the highest reactivity towards soil's mineral and organic constituents. Humus functions as a regulator of most growth factors in soil, particularly water[7]. The effect of humus on plants is indirect and direct. Humus indirectly affects plants mainly by improving the physical properties of soil (primarily its structure) and thereby ensuring optimum conditions for the uptake of water (with nutrients absorbed and dissolved in it) and soil air. Soils with a high organic matter content are biologically active which manifests itself in increased release of $CO_2$ and in the water-air conditions. A major function of humus in the soil environment is its protective action stemming from the properties of organic matter: the latter is a quantitative and qualitative regulator of the uptake of nutrients by plants, increases the effectiveness of mineral fertilizers and prevents their rapid leaching. The formation of chelate complexes of organic matter constituents and heavy metals is of ecological importance for soil[8]. Humus also has a positive effect on the regulation of soil buffer properties. It constitutes a typical system of weak organic acids and their salts with strong bases. The sorption of $Al^{3+}$ ions, which are highly toxic towards plants, by humus does not result in the reduction of orthophosphates which become more readily available to plants. A significant feature of humus is its protective action towards biologically active compounds (vitamins, antibiotics and enzymes), extending their activity in soil. It has been found that the presence of organic matter in soil favourably affects the intensity of pesticides degradation. The most instrumental in the processes of microbiological decomposition of pesticides are the reactivity of the functional humic compounds, the reduction capacity of the humic and fulvic acids and the presence of free radicals.

## DESCRIPTION OF SELECTED WASTES

**Utilized wastes:** Peat and lignite, available in relatively large quantities in Poland, were used as the main source of organic matter for the research on the utilization of selected wastes for mineral-organic fertilization.

Similarly as lignite, peat formed towards the end of the Cretaceous period from the primeval coal-forming material as a result of transformations of plant matter through long-lasting deposition and incomplete decomposition of dead wetland vegetation when in the water environment with limited access to air the plant residue in the biochemical phase decomposes under the action of fungi, enzymes and aerobic and anaerobic bacteria. Depending on the degree of decomposition, highmoor, intermediate and lowmoor peat is distinguished. Most suitable for agricultural purposes is highmoor peat characterized by a low degree of decomposition, acid reaction, a high water and air capacity and good sorption properties. Lowmoor peat is more complex than the other kinds of peat. It contains about 80-90% of organic matter, 2.3-3.3% of nitrogen, 0.02-0.26% of phosphorous and 0.1-0.21% of potassium. Besides these major elements peat contains considerable quantities of calcium and magnesium and slight amounts of microelements. Because of the form of the bonds the above elements are practically unassimilable by plants due to the too long period of mineralization and humification[10].

Lignite formed as a result of the transformation of plant matter in the Miocene Epoch – the Tertiary period of the Cenozoic Era. Once the process of peat formation and decay ends, resulting in a low pH of the environment due to the forming humic acids, the peat formation process enters the stage of diagenesis and lignite is formed. The characteristic feature of lignite is the almost neutral pH. Depending on their physicochemical properties lignites can be divided into xyloid, soft and hard lignites. The organic carbon content in lignites amounts to 60-80%, the nitrogen content to 0.8-1.4% and the sulphur content to 1-4%. Similarly as peats, lignites contain quite large amounts of calcium, magnesium and microelements. They are characterized by a high water, air and sorption capacity[10].

Poultry droppings constitute a rich source of nutrients for plants. A thousand of turkeys by the second year of life excrete about 30 tons of droppings. The composition of poultry dung depends on the kind of birds, their age and the way in which they are fed. Poultry dung has a high nitrogen content and so it should be used in controlled quantities in order not to cause losses in yield as a result of overfertilization. Bird dung should be supplemented with mineral fertilizers. It is advisable to include superphosphate in a mineral-organic fertilizer, which besides supplying phosphorous reduces losses in nitrogen and hydrated lime (which absorbs water). In practice, before poultry droppings are used to fertilize plants they are often seasoned and dried or composted.

The starch effluent produced when potatoes are processed into potato starch, dried potatoes, syrups, starch hydrolysates and dextrins can be used in the production of mineral-organic fertilizers. The effluent contains large quantities of suspended organic matter ($30g/m^3$), nitrogen, phosphorous, potassium, calcium, magnesium and also microelements: copper, manganese, iron and zinc.

## CHEMICAL AND BIOLOGICAL INVESTIGATION

**Tests of chemical composition of investigated wastes:** Typical chemical analytics (described in the relevant standards) for mineral-organic fertilizers was used to test the chemical composition of the investigated wastes.

Table 1 shows the chemical composition of peat and lignite used in the developed mineral-organic fertilizer recipes while the fertilizer constituent content in the tested turkey droppings and in the potato industry effluent is shown in table 2.

Table 1: Chemical composition of peat and lignite used in investigations

| No. | Symbol of component | Peat % by wt. | Lignite % by wt. |
|---|---|---|---|
| 1 | $C_{org}$ | 76.23 | 67.23 |
| 2 | P | 0.21 | 0.03 |
| 3 | K | 0.075 | 0.07 |
| 4 | N | 0.98 | 0.78 |
| 5 | Mg | 0.084 | 0.90 |
| 6 | Ca | 4.47 | 2.05 |
| 7 | S | 0.91 | 1.60 |
| 8 | Cl | 0.78 | - |
| 9 | Cu | 0.005 | 0.006 |
| 10 | Fe | 2.34 | 0.67 |
| 11 | Mn | 0.02 | 0.015 |
| 12 | B | 0.006 | 0.004 |
| 13 | Zn | 0.023 | 0.011 |

Table 2: Chemical composition of turkey droppings and potato industry effluent

| No. | Symbol of component | Turkey droppings | Potato industry effluent |
|---|---|---|---|
| | | [%] by dry wt. | |
| 1 | $K_2O$ | 2.85 | 1.05 |
| 2 | $P_2O_5$ | 4.56 | 0.72 |
| 3 | CaO | 5.19 | 0.85 |
| 4 | MgO | 1.04 | 0.02 |
| 5 | N total | 3.76 | 5.72 |
| 6 | N (ammonium) | 2.10 | 1.10 |
| 7 | N (nitrate) | 0.01 | 0.004 |

**Biological-agricultural studies:** In order to determine the maximum content of the utilized waste in mineral-organic fertilizer, taking into account its toxicity and optimum composition, biological studies using the germination test were made. The tests were carried out in accordance with standard PN-ISO--R-65950:1994 and repeated four times. The substratum was medium-heavy soil free of germination limiting agents. The test plant was garden cress. The soil substratum was mixed with a proper amount of the evaluated wastes and wetted with redistilled water. 25 seeds were used in the first test series, 50 seeds in the second series and the same number in the third series. The seeds were placed in Petri dishes so that they did not touch each other and did not touch the vessels. The same moisture was maintained in all the objects. Germination capacity and the plants were evaluated after 10 days from setting up the test.

Series 1

Object 1: substratum made of medium-heavy soil.

Object 2: medium-heavy soil and the tested waste at a weight ratio of 3:1 (30g of soil and 10g of waste).

Object 3: medium-heavy soil and the tested waste at a weight ratio of 4:1 (30g of soil and 7.5g of waste).

Object 4: medium-heavy soil and the tested waste at a weight ratio of 5:1 (30g of soil and 6g of waste).

Series 2

Object 1: substratum made of medium-heavy soil.

Object 2: medium-heavy soil and the tested waste at a weight ratio of 10:1 (40g of soil and 4g of waste).
Object 3: medium-heavy soil and the tested waste at a weight ratio of 15:1 (40g of soil and 2.7g of waste).
Object 4: medium-heavy soil and the tested waste at a weight ratio of 20:1 (40g of soil and 2g of waste)
Series 3
Object 1: substratum made of medium-heavy soil.
Object 2: medium-heavy soil and the tested waste at a weight ratio of 50:1 (40g of soil and 0.8g of waste).
Object 3: medium-heavy soil and the tested waste at a weight ratio of 100:1 (40g of soil and 0.4g of waste).
Object 4: medium-heavy soil and the tested waste at a weight ratio of 200:1 (40g of soil and 0.2g of waste).

The results of the biological tests for turkey droppings and the starch effluent are shown in table 3. The germination capacity for series 1 objects 2, 3 and 4 with turkey droppings was 0%, i.e. no germinated seeds at all. Turkey dropping in this dose are toxic for plants. In series 2 the germination capacity was about 10% lower than in the control test without any waste addition, but the plants were characterized by poor growth and were very weak. The best results were obtained in the case of series 3. The plants were high and had thick stalks.

For the potato industry effluent the germination capacity in series 1 was limited, ranging from 4 to 32% of germinated seeds in the respective objects. Better results: 46-82% were obtained in series 2. The plants were higher, better rooted and had thicker stalks then the ones in series 1. The effluent dose was optimal for object 3 in series 3. The plants were shapely and well rooted.

## DEVELOPMENT OF MINERAL_ORGANIC FERTILIZER COMPOSITIONS

Because of the high content of fertilizer constituents in the investigated wastes a very demanding plant – sugar beet – was chosen to develop fertilizer compositions. Sugar beets, at an average sugar beet yield of 35 ton per ha, take up about 200 kg of nitrogen, 60 kg of $P_2O_5$, 260 kg of $K_2O$ and 160 kg of CaO from soil. The average amounts of nutrients taken up by 1 ton of sugar beets are: 6 kg N, 2.40 kg $P_2O_5$, 2.40 kg $K_2O$, 3.20 kg CaO, 2.35 kg MgO and 8.30 g B, 2.60 g Cu, 31.5 g Mn, 0.20 g Mo, 14.9 g Zn. For their cultivation sugar beets require rich soils with a deep humous topsoil layer with balanced water relations. They are highly sensitive to changes in temperature and watering, particularly in the initial period of growth[11]. Recipes for mineral-organic fertilizers with micronutrient additions were developed on the basis of the waste chemical composition determinations and the sugar beet nutritional requirements data. The missing mineral components were made up with mineral fertilizers and mineral matter. The recipes were developed for 1000 kg of fertilizer.

The proposed mass fractions of macroelement components in 1000 kg of mineral-organic fertilizer, based on peat and turkey droppings, for sugar beet cultivation are shown in fig. 1. The recommended fertilization – 7900kg/ha.

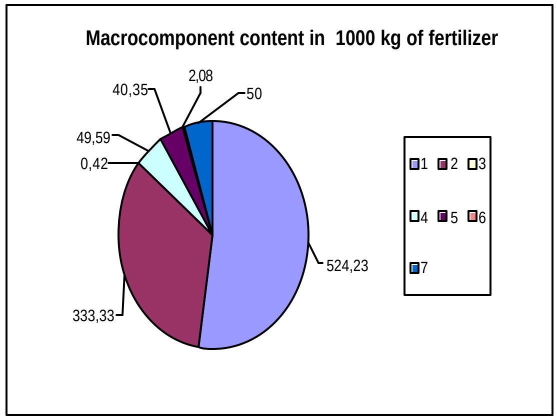


Fig. 1: Mass fractions of macrocomponents in mineral-organic fertilizer based on turkey droppings and peat. (1- turkey droppings, 2- peat, 3- $(NH_4)_2SO_4$, 4 - $K_2SO_4$, 5- CaO, 6 - $MgSO_4 \cdot 7H_2O$, 7 – microcomponents)

Figure 2 shows the proposed mass fractions of macroelements components in 1000 kg of mineral-organic fertilizer, based on lignite and turkey droppings, for sugar beet cultivation. The recommended fertilization – 6600 kg/ha.

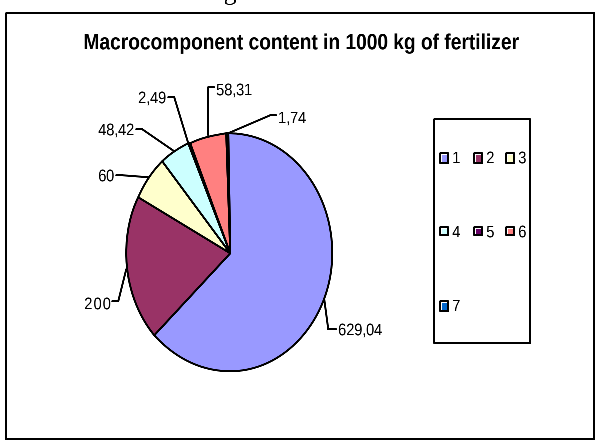


Fig. 2: Mass fractions of macrocomponents in mineral-organic fertilizer based on turkey droppings and peat. (1- turkey droppings, 2- brown coal, 3- $(NH_4)_2SO_4$, 4 - $K_2SO_4$, 5- CaO, 6 - $MgSO_4 \cdot 7H_2O$, 7 – microcomponents)

Table 4 shows the proposed mass fractions of the microelement additions in 1000 kg of mineral-organic fertilizer, based on peat and turkey droppings, for sugar beet cultivation.

Table 4: Proposed mass fractions

| Symbol of compound | Peat | | Lignite | |
|---|---|---|---|---|
| | Amount of added compound [kg] | Microcomponent content [%] | Amount of added compound [kg] | Microcomponent content [%] |
| $Na_2B_4O_7 \cdot 10H_2O$ | 0.326 | 0.0037 B | 0.392 | 0.0044 B |
| $CuSO_4 \cdot 5H_2O$ | 0.051 | 0.0013 Cu | 0.061 | 0.0016 Cu |
| $MnSO_4 \cdot H_2O$ | 0.434 | 0.014 Mn | 0.52 | 0.0168 Mn |
| $Na_2MoO_4 \cdot H_2O$ | 0.002 | 0.0001 Mo | 0.003 | 0.0001 Mo |
| $ZnSO_4 \cdot 7H_2O$ | 0.361 | 0.0079 Zn | 0.361 | 0. 0079 Zn |

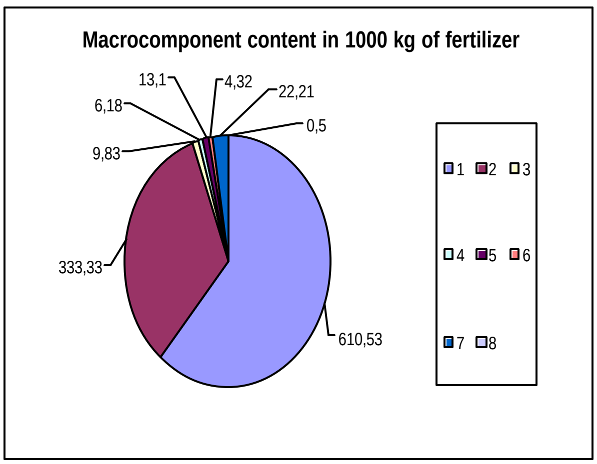


Fig. 3: Mass fractions of macrocomponents in mineral-organic fertilizer based on turkey droppings and peat. (1- starch effluent, 2- peat, 3 - $(NH_4)_2SO_4$, 4 – $KH_2PO_4$, 5 - $K_2SO_4$, 6 - CaO, 6 - $MgSO_4 \cdot 7H_2O$, 7 – microcomponents)

Figure 3 shows the proposed mass fractions of macroelements in 1000 kg of mineral-organic fertilizer, based on peat and the potato industry effluent, for sugar beet cultivation. The recommended fertilization – 22000 kg/ha.

Figure 4 shows the proposed mass fractions of macroelement components in 1000 kg of mineral-organic fertilizer based on lignite and the potato industry effluent. The recommended fertilization – 18600 kg/ha.

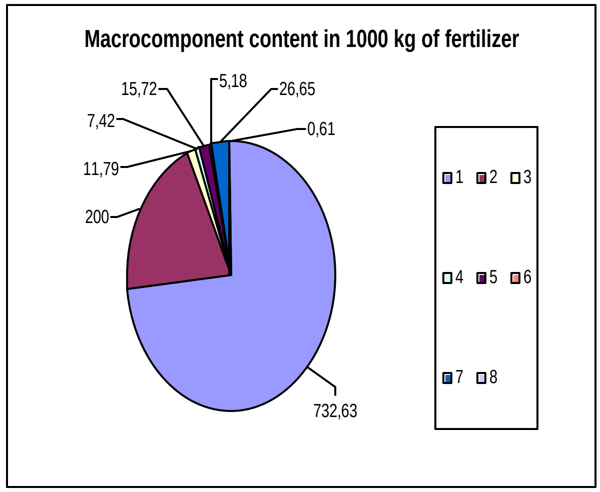


Fig. 4: Mass fractions of macrocomponents in mineral-organic fertilizer based on turkey droppings and peat. (1- starch effluent, 2- brown coal, 3 - $(NH_4)_2SO_4$, 4 – $KH_2PO_4$, 5 - $K_2SO_4$, 6 - CaO, 6 - $MgSO_4 \cdot 7H_2O$, 7 – microcomponents)

Table 5 shows the proposed mass fractions of microelement additions in 1000 kg of mineral-organic fertilizer, based on peat and the potato industry effluent, for sugar beet cultivation.

Table 5: Mass fractions of microelement components in 1000 kg of mineral-organic fertilizer based on peat and potato industry effluent

| Name of compound | Peat | | Lignite | |
|---|---|---|---|---|
| | Amount of added compound [kg] | Microcomponent content [%] | Amount of added compound [kg] | Microcomponent content [%] |
| $Na_2B_4O_7 \cdot 10H_2O$ | 0.115 | 0.0013 B | 0.138 | 0.0016 B |
| $CuSO_4 \cdot 5H_2O$ | 0.018 | 0.0005 Cu | 0.021 | 0.0005 Cu |
| $MnSO_4 \cdot H_2O$ | 0.152 | 0.0049 Mn | 0.183 | 0.0059 Mn |
| $Na_2MoO_4 \cdot H_2O$ | 0.003 | 0.0001 Mo | 0.002 | 0.0001 Mo |
| $ZnSO_4 \cdot 7H_2O$ | 0.106 | 0.0023 Zn | 0.127 | 0. 0028 Zn |

## CONCLUSIONS

The presented test results and the proposed recipes of mineral-organic fertilizers for sugar beet cultivation indicate that both turkey droppings and the starch effluent combined with peat or lignite can constitute a valuable source of nutrients for plants. By utilizing peat and lignite in fertilizer production not only their waste quantities from industrial extraction can be managed but also the soil's structure, properties and water conditions can be improved. Thanks to their sorption action and complexing constituents, peat and lignite enable the optimum utilization of fertilizer mineral components, reduce the toxic action of heavy metals and owing to their high organic matter content, contribute to an increase in the biological activity of the soil.

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