The use of municipal sewage sludges and lignite coal fly ashes in the production of fertiliser granulates

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Introduction

Continuously rising prices of raw materials for the production of mineral fertilisers and of fertilisers themselves, reduced production of natural fertilisers and the expansion of agricultural land for growing cereals and industrial crops may lead to a disruption of the balance of organic matter and nutrients for plants in the soil, as well as to acidification of the plants.

In consequence, the fertility of the soils will be reduced and the harvested crops will be of substandard quality. Taking those factors into consideration, research has been initiated on the possibility of using certain municipal and industrial waste for fertilisation purposes. The objective is to obtain cost-effective and environmentally neutral sources of organic matter and nutrients in the soil that would produce economically justified results.

In consideration of the situation described above, research in the field has been focused on the development of methods of using municipal sewage sludge and high calcium fly ash from lignite coal with the addition of powdered SSP (single super phosphate), ammonium sulphate and potassium salt 60% for the production of fertiliser granulates enriching the soil with organic matter, nutrients and deacidification agents for plants.

Methodology

On the basis of research conducted by the West Pomeranian University of Technology in Szczecin and FOSFAN S.A. in Szczecin recipes for fertiliser mixtures were developed and the mixtures underwent granulation. The production of granulated fertiliser mixtures utilised the municipal sewage sludge from the sewage treatment plant in Stargard Szczeciński and high calcium lignite coal fly ash from the thermal power plant in Bełchatów, with the addition of single-element mineral fertilisers. Powdered SSP, ammonium sulphate and potassium salt 60% were added to the fertiliser mixture mass in order to facilitate the granulation process and provide easily assimilated nutrients for the first development phase of the plants.

The nutrients in the municipal sewage sludge and lignite coal fly ash were usually assimilable only to a small degree for the plants. Table 1 provides the material composition of granulated fertiliser mixtures, converted into percentage (%) of dry mass.

Table 1

Material composition of granulated fertiliser mixtures, converted into percentage (%) of dry mass

Mixture no.	Municipal sewage sludge	Lignite coal fly ash	Powdered single super phosphate (17% P_2O_5)	Ammonium sulphate (20.5% N)	Potassium salt 60% K_2O
1	40	40	10	5	5
2	45	35	10	5	5
3	40	30	15	10	5

Components listed in Table 1 were mixed in such proportions so as to obtain 30g of each mixture. Components were mixed with the use of mechanical high-speed agitator. The dominating component in the organic-mineral mixtures was the paste-thick municipal sewage sludge. Therefore, the obtained organic-mineral mixtures had the consistency of dark-grey paste.

The obtained mixtures were conditioned for 14 days in order to react the components and increase the dry mass content. Next, the organic-mineral mixtures were dried at 95°C. During the drying process the paste took the form of agglomerates in the size range of up to 6 cm.

After the completion of the drying process, the mixtures for granulation have 6-10% humidity. The agglomerates were powdered. The organic-mineral mixture no.1 for granulation was divided into four identical parts in order to test the granulation agents. The following granulation methods were applied to the organic-mineral mixtures:

- addition of water
- addition of post-absorption pulp from the production department of FOSFAN S.A. in Szczecin
- addition of post-absorption pulp + 5% m/m of sodium lignosulphonate
- addition of post-absorption pulp + 5% m/m of dextrin.

After the analysis of the results of the pivotal studies, the organic-mineral mixtures listed in Table 1 were granulated using only water or post-absorption pulp.

Results

The results of the analysis indicate that municipal sewage sludges may be used for fertilisation purposes. The sludges contain high volumes of organic matter and nutrients for plants. The factors preventing direct release of the mixtures into the soil may include excessive content of certain heavy metals or contamination with pathogenic microorganisms (*Salmonella* bacteria and intestinal parasites).

The physical and chemical properties of municipal sewage sludge are diverse; therefore, each batch should undergo physical, chemical and microbiological tests to determine the most appropriate use (Baran 2004, 2005; Baran & Turski 1999; Czekała 2004; Drab et al. 2004; Kalembasa 2003; Krzywy & Iżewska 2004; Łabętowicz 2011; Rosik-Dulewska 2008; Siuta & Wasiak 2001; Wołoszyk 2005).

Pursuant to the applicable legal regulations, before release into the soil the municipal sewage sludges should be stabilised and hygienised (e.g. by granulation with other components).

The combustion of lignite coal produces process waste in the form of boiler slags, bottom and fly ashes. The dominating by-product of lignite coal combustion is the fly ash. The fly ash includes mainly high calcium ashes produced during the combustion of lignite coal with high limestone content. It is estimated that Poland produces annually approx. 4.5 million tons of high calcium ashes from lignite coal. This volume is the equivalent of approx. 900,000 tons of calcium oxide (Szymonek 2008). As many studies have shown, high calcium fly ashes from lignite coal can be used in agriculture for soil deacidification. Furthermore, those ashes increase the content of CaO and MgO and some micro and macro components in soils (Terelak & Żukowska 1985; Skalmowski 1999; Stankowski et al. 2003, 2006; Stolecki 2005; Berg & Fenebern 2006; Gibczyńska et al. 2007).

Table 2 provides certain physical and chemical properties of the analysed components.

Table 2

Certain physical and chemical properties of components used in the production of organic-mineral mixtures which then underwent granulation

Assay type	Component				
	Municipal sewage sludge	Lignite coal fly ash	Granulated SSP	Ammonium sulphate	Potassium salt 60%
pH H_2O	7.5	12.7	n/e	n/e	n/e
% of dry mass	22.5	98.0	n/e	n/e	n/e
	Total content in $g \cdot kg^{-1}$ of dry mass				
Organic carbon	422	none	n/e	n/e	n/e
Nitrogen	43.0	none	n/e	205	n/e
Phosphorus	21.6	2.48	7.84	n/e	n/e
Potassium	5.10	5.76	n/e	n/e	500
Calcium	24.5	225	n/e	n/e	n/e
Magnesium	2.90	12.0	n/e	n/e	n/e
Sulphur	5.95	2.95	116.0	n/e	n/e
	Total content in $mg \cdot kg^{-1}$ of dry mass				
Cadmium	2.95	1.95	n/e	n/e	n/e
Chromium	56.0	12.5	n/e	n/e	n/e
Copper	120.0	25.6	n/e	n/e	n/e
Nickel	24.3	12.0	n/e	n/e	n/e
Lead	59.7	14.2	n/e	n/e	n/e
Zinc	1,080	220.0	n/e	n/e	n/e

*Legend: n/e – not examined *acid soluble phosphorus form

Data provided in Table 2 indicate that:

- the pHH_2O value of the lignite coal fly ash was significantly higher (12.7) compared to municipal sewage sludge; both waste types can be applied to acidified soils; lignite coal fly ash can be used for soil deacidification
- municipal sewage sludge contained high volumes of organic carbon and total nitrogen; lignite coal fly ash did not contain those elements
- municipal sewage sludge contained higher volumes of total phosphorus, sulphur, cadmium, chromium, copper, nickel, lead and zinc compared to lignite coal fly ash; lignite coal fly ash contained higher volumes of total calcium, potassium and magnesium.

The heavy metal content in components (municipal sewage sludge and lignite coal fly ash) did not exceed the limits set forth in the Ordinance of the Minister of Environment (Journal of Laws of 2010, No. 134, item 924), authorising the use of those substances in agriculture and land reclamation.

The results of microbiological tests provided by the sewage treatment plant in Stargard Szczeciński indicate that the sewage sludge did not contain *Salmonella* bacteria or live ova of intestinal parasites.

Concluding, on the basis of obtained results and the Ordinance of the Minister of Environment (Journal of Laws of 2010, No. 134, item 924) it can be stated that the waste discussed herein can be used for fertilisation (released into soils or land for reclamation) without the risk of polluting the environment.

Table 3 provides the physical change occurring during granulation processes and physical properties of granulates obtained from the organic-mineral mixture no. 1 (Tab. 1).

Table 3

Physical change occurring during granulation processes and certain physical properties of granulates obtained from the organic-mineral mixture no. 1 (Tab.1)

Granulation promoters			
Water	Post-absorption pulp	Post-absorption pulp + 5% m/m of sodium lignosulphonate	Post-absorption pulp + 5% m/m of dextrin
Granulation			
Relatively good granulation. Granules are light and crumble easily.	Relatively good granulation. Granules are light and crumble easily. Lower volume of fines, which enhances efficiency	Relatively good granulation. Granules are light and splice better. More thick granules	Relatively good granulation. Granules are light and splice better. More thick granules
After drying			
Granulate is firm and hard to crumble.	Granulate is very firm and very hard to crumble	The most firm granulate, very hard to crumble	The most firm granulate, very hard to crumble

The results provided in Table 3 indicate that fertiliser granulates can be obtained without granulation promoters. Therefore, in the granulation process of organic-mineral mixtures no. 2 and 3 (Tab.1) only water or post-absorption pulp was used. Table 4 outlines the physical change occurring during granulation processes and certain physical properties of granulates obtained from the organic-mineral mixtures no. 2 and 3 (Tab.1).

Table 4

Physical changes occurring during granulation processes and certain physical properties of granulates obtained from the organic-mineral mixtures no. 2 and 3 (Tab.1)

Organic-mineral mixture no. 2		Organic-mineral mixture no. 3	
Addition of water	Addition of post-absorption pulp	Addition of water	Addition of post-absorption pulp
Granulation			
Relatively good granulation. Granules are light and easy to grind.	Relatively good granulation. Granules are light and easy to grind. Lower volume of fines	Granulation good. Granules are light and easy to grind	Relatively good granulation. Granules are light and easy to grind. Lower volume of fines
After drying			
Granulate is very firm and hard to crumble.	Granulate is very firm and hard to crumble	Granulate is very firm and hard to crumble	Granulate is very firm and hard to crumble

All fertiliser granulates (Tabs. 3 and 4) were light (the risk of wind impact during release into the fields). During production an unpleasant odour of municipal sewage sludge is released. Therefore, further research should take into consideration the following solutions:

- loading down fertiliser granules produced from organic-mineral mixtures by introducing ballast into their composition or increasing the lignite coal fly ash content

- eliminating the unpleasant odour of municipal sewage sludge by using dried sludges. At the moment a technological change is taking place in municipal sewage sludge management. Sludges are dried and undergo thermal disposal processes. Dried municipal sewage sludges can be used to produce fertiliser granulates.

Table 5 provides the content of organic carbon, nitrogen, phosphorus, potassium and sulphur in fertiliser granulates produced with post-absorption pulp.

Table 5

Content of organic carbon, nitrogen, phosphorus, potassium and sulphur in fertiliser granulates. Data provided in w $g \cdot kg^{-1}$ of dry mass and % of dry mass

Fertiliser granulate number (Tab.1)	Organic carbon		Nitrogen		Phosphorus		Potassium		Sulphur	
	$g \cdot kg^{-1}$ of dry mass	%	$g \cdot kg^{-1}$ of dry mass	%	$g \cdot kg^{-1}$ of dry mass	%	$g \cdot kg^{-1}$ of dry mass	%	$g \cdot kg^{-1}$ of dry mass	%
No. 1	165	16.5	26.5	2.65	17.0	1.70	28.5	2.85	16.0	1.60
No. 2	180	18.0	28.5	2.85	18.0	1.80	28.5	2.85	16.2	1.62
No. 3	167	16.7	37.0	3.70	20.5	2.05	28.4	2.84	22.1	2.21

Analysis of data provided in Table 5 indicates that in terms of organic carbon and micro components (N, P and K) content the granulates can be classified as organic-mineral fertilisers, pursuant to the Ordinance of the Minister of Agriculture and Rural Development (Journal of Laws of 2008, No. 119, item 765).

Conclusions

Municipal sewage sludges and lignite coal fly ashes can be used to produce fertiliser granulates. Post-absorption pulp, sodium lignosulphonate or dextrin can be used as granulation promoters of organic-mineral mixtures.

In order to classify the granulates as organic-mineral fertiliser, 5-10% of mineral fertilisers containing nitrogen, phosphorus and potassium should be added during the production process. The recommended promoters include powdered SSP, which stimulates granulation process, and ammonium sulphate and potassium salt.

The obtained fertiliser granulates were light. In order to load down the granulates, granule ballast should be introduced into the organic-mineral mixtures.

During the granulation process of organic-mineral mixtures the unpleasant odour of sewage sludge is released. In further research raw sewage sludges can be replaced with dried sludges.

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