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P a r t 3

ASH AND SLAG HANDLING

3.5. Applications of ash and slag from power coals

3.5.4. Use of ash and slag for improving the properties of soil

3.5.4.1. Ash from stone coal as a source of ground biological layer for reclamation of devastated land

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ABSTRACT

The study was conducted on reclaimed ash-storage (N 53°13'10'', E 14°26'53''). Samples of ash from hard coal, sewage sludge and mixture of these two components produced in 2009 y., upon recommendation prepared by researchers from West Pomeranian University of Technology in Szczecin, were tested.

The selected physical properties profile top layer (0-30 cm) of the mixture applied to cover ash-storage show high volume of total porosity (56,9 %), and low value of bulk density (1,14 $Mg{\cdot}m^{-3}$) and dry bulk density (0,92 $Mg{\cdot}m^{-3}$). The ash as a component of mixture with sewage sludge seems to be suitable for plants root system development.

1. INTRODUCTION

Land reclamation - the process by which seriously disturbed land surfaces are stabilized against the hazards of wind and water erosion. The changes of the chemical and physical properties often create a hostile environment for seed germination and subsequent plant growth. Unless vegetative cover is established almost immediately, the denuded areas are subject to both wind and water erosion that pollute surrounding streams with sediment. In This Millennium, land reclamation and restoration projects must show coherence in terms of ecological, economic and social viability. Ecological restoration plays a major role in this activity, and provides an expansion of the area available for biodiversity of environment. The Polish government's Act (Dz. U. 2004 Nr 121 poz. 1266) describes degraded lands, as those which agricultural or forest management value was decreased especially due to the deterioration of natural conditions or changes in the environment, industrial activity and also faulty arable farming. Land which completely lost its agricultural or forest exploitation value, is called devastated lands.

By Polish law a land reclamation means restoration activities that are meant to restore a degraded or devastated land back to its natural value or management value, by shaping proper terrain relief, improving of the soils physical and chemical properties, regulation of soils water balance, strengthening the bank and rebuilding or building necessary roads. Land reclamation can be carried out for agricultural, forestry or recreational purposes.

The method of land remediation is chosen accordingly to the reasons for land degradation or devastation. For example soils that are acidified or polluted with heavy metals can be limed, to allow them to regain the proper pH or to lock the harmful particles. Also, enriching the sorption complex with organic matter [6] or clay can be applied to lock heavy metals in soils. Also phytoremediation where plants that accumulate heavy metals can be applied to remove them from soils. In cases of extreme soil pollution ex situ techniques are applied. The soil is removed and cleaned by the means of different physical and chemical processes [13, 14]. One of the major advantages of phytoremediation is its relatively low cost comparing to other remedial methods such as excavation.

Another reason for land devastation is the destruction and removal of the fertile humus layer overlaying it with waste. This type of devastation occurs inter alia in open-pit mines or at waste dumping sites (including coal ash dumping sites). In these cases the land reclamation goal is to restore the soil fertility by covering ground surface by a fertile soil layer or by enriching the existing soil by application of the organic matter [9,10].

The holes left after open-pit mining also consist a serious problem. They need to be leveled. In Poland the Waste Act (Dz. U. Nr 62, poz. 628) allows the application of wastes for terrain leveling as a way of recycling.

With hard coal as the main energy source Poland produces large amounts of ashes which need to be either deposited in dumping sites or recycled. There are several ways of recycling hard coal ashes. They can be used for making road embankments or caulking the landfills [4, 11]. Fly ashes can be used as additives for cement making [3]. One of the proposed solutions is using the hard coal ashes for devastated and degraded land reclamation [1]. This way of recycling the ashes allows leveling holes reminding ex open-pit mining operations and application of hard coal ashes as a substitute for earth masses.

Low concentrations of nitrogen, phosphorus, and organic carbon along with high concentrations of calcium and sodium make hard coal ashes a poor substratum for plants and microorganisms to live on (tab. 1). Adding organic matter to hard coal ashes is a good solution of the problem [1, 5, 12].

Table 1. **Properties of hard coal combustion residues**

PROPERTIES	FLY ASH	SLAG
CHEMICAL COMPOUND		
Components	share [%]	
SiO_2	46,94	55,54
Al_2O_3 +TiO_2	22,92	17,98
Fe_2O_3	8,50	11,80
Na_2O	1,61	1,00
K_2O	2,05	1,85
CaO	5,52	3,14
MgO	2,42	1,85
SO_3	1,24	0,24
volumetric density [$g{\cdot}cm^{-3}$]	1,82	1,83

Source: Brylska 2008

Sewage sludge can be a good source of organic matter for reclamation needs. In 2006, according to the Main Statistical Office [8] data, water purification plants in Poland produced over one million tons of sewage sludge and 106 thousand tons from this amount were used for agricultural purposes and another 287 thousand tons were applied for land reclamation. Over 36% of the total amount of sewage sludge produced was deposited in dumping sites. Due to the high content of organic matter and nutrient elements, after previous stabilization, sewage sludge can be used as fertilizer or reclamation substratum. Jackowska and Olesiejuk [7] found that the sewage sludge from Municipal Sewage-Treatment Plant in Lubartów was characterized with high fertile value comparable to manure (tab. 2).

Table 2. **Chemical composition of sewage sludge from Municipal Sewage-Treatment Plant in Lubartów**

Element	Year	
	2001	2002
	content in % DM	content in % DM
N-NH4	5,63	6,06
P	0,04	0,22
K	2,54	2,52
Ca	0,39	0,37
Mg	2,28	1,98
Nitrogen total	0,33	0,53
Organic matter	66,9	69,0
Ash total	33,11	31,0
Dry matter	12,8	12,0

Source: Jackowska & Olejsiuk 2004

The high content of heavy metals is the biggest problem of sewage sludge. Also, low content of potassium in sewage sludge may constitute a problem for growing plants [7]. Beyond the above the application of sewage sludge for land reclamation seems to be a great solution. While recycling the sludge one can reclaim devastated and degraded land.

2. MATERIALS AND METHODS

The study was conducted on reclaimed ahs-storage site near Dolna Odra power plant, in Poland, Nowe Czarnowo (N 53^{o} 13' 10'', E 14^{o} 26' 53''). The average annual precipitation is 530 mm and the average annual temperature is 8,1^{o}C.

The study area consists of six randomly selected sample plots (10 m x10 m) – on an ash-storage (total area was 21 ha) covered in September 2009 y., with 30 cm thick layer of mixture prepared upon recommendation of researchers from Dep. of Agronomy, West Pomeranian University of Technology in Szczecin.

The parent substrate for soil development was ash from power plant mixed with sewage sludge in 1:1 volumetric ratio, prepared in June 2009 y. In May 2009 in order to calculate for description ash, sewage sludge and mixture of this two components there were taken the six samples (n=6) of ash from storage, the eighteen samples (n=18) from loose ash, the fifteen samples (n=15) of sewage sludge and the eighteen (n=18) samples (mixture) of parent material for soil development.

The results give an idea about the excitability and reliability of the mixture produced from ash and sludge under recommended procedure.

Bulk density, dry bulk density and gravimetric water content of the ash were calculated by the core method, and given in tab. 3. Dry mass (DM), and pH value (actual acidity was determined by a pH meter with glass electrodes in 1/2.5 distilled water) of sewage sludge were measured and given in tab. 4. Bulk density, dry bulk density and gravimetric water content of the mixed ash and sewage sludge were calculated, and given in tab. 5. Within the study area in the selected places, one pit was dug in each sample plot. Soil samples were taken with a steel cylinder (100 cm^{-3}) from three different soil depths (0–10, 10–20, and 20-30 cm). All samples were collected in November 2009 and were brought to the laboratory of Dep. of Agronomy where weights were taken and the samples were dried at 105^{o}C until achieving constant weights. Bulk density, dry bulk density, total porosity and gravimetric water content of the substrate were calculated by the core method, and given in tab. 6. The values and volumes found for descriptive components were compared statistically at 0.05 significance level using nonparametric test statistical analysis. Additionally the value of variation ratio (V) was calculated for corresponding replication. Mean values found for all properties were shown in relevant tables.

3. RESULTS

The average actual bulk density (tab. 3) was higher for the ash samples taken from the dumping site (1,57 Mg·m^{-3}) which ranged 1,51-1,72 Mg·m^{-3} while the actual bulk density of the ash prepared for mixing ranged from 1,13 to 1,25 Mg·m^{-3} with mean value of 1,18 (Mg·m^{-3}).

Table 3. **The hard coal ash profile samples taken from loose ash (n=18) prepared for mixing, and from ash storage (n=6), mean values of actual bulk density, dry ash bulk density (Mg·m^{-3}) and moisture content (%)**

Object		Actual bulk density (Mg·m^{-3})	Dry ash bulk density (Mg·m^{-3})	Gravimetric water content (%)
Loose ash (n=18)	**Mean value**	**1,18 a**	**0,87 a**	**38,9 a**
	V (%)	2,9	10,0	6,0
Ash from the ash storage (n=6)	**Mean value**	**1,57 b**	**1,03 b**	**52,2 b**
	V (%)	13,2	10,6	17,7
Mean value		**1,27**	**0,91**	**42,2**
V (%)		13,9	12,4	16,6
$LSD_{0,05}$		**0,075**	**0,144**	**6,203**

A general characteristic of sewage sludge samples taken from different places was presented in tab. 4. The sewage sludge turned out to be a very nonuniform material. The average dry mass content was 24,12 %, but the range was very wide with values from 16,54 % to 31,13 %. Measuring the pH of sewage sludge proved to be problematic. The pH measured in H_2O had an average value of 7,84. The lowest value of pH_{H2O} was 7,37 and the highest - 8,21. The mean value of pH_{KCl} was a bit higher 7,85.

The characteristic of mixed hard coal ashes with sewage sludge prepared on May 2009 is given in tab. 5. Mean actual bulk density of the fresh mixture was 1,225 Mg·m^{-3}, whereas mean dry bulk density was 0,75 Mg·m^{-3}. Among measured parameters of the mixture the highest differences of data were found between moisture of samples. Variation ratio of gravimetric moisture was 29,0 %, while mean value was – 65,7 %.

Table 4. **The sewage sludge profile sampled in different places (for n=15) as a component for preparing a mixture with hard coal ashes – mean values of dry mass content (%), pH_{H2O} and pH_{KCl}**

Object		Dry mass content (%)	Sewage sludge pH in H_2O	Sewage sludge pH in KCl
Sewage sludge	**1**	28,49 b	8,06	8,06
	2	17,17 a	7,55	7,65

	3	29,67 b	7,81	7,71
	4	20,59 a	7,87	7,85
	5	24,70 a	8,19	8,26
Mean value		**24,12**	**7,84**	**7,85**
V (%)		20,8	65,5	48,9
LSD $_{0,05}$		**3,612**	·	·

Table 5. **Selected values of mixture ready to using for covering ash-storage – mean values (n=18) of actual bulk density, dry ash bulk density ($Mg\cdot m^{-3}$) and moisture content (%), May 2009**

Fresh mixture	Actual bulk density ($Mg\cdot m^{-3}$)	Dry mixture bulk density ($Mg\cdot m^{-3}$)	Gravimetric water content (% wag)
A	1,265 ab	0,68 a	87,6 b
B	1,280 b	0,85 b	50,4 a
C	1,177 a	0,71 a	66,5 ab
D	1,178 ab	0,75 ab	58,1 a
Mean	**1,225**	**0,75**	**65,7**
V (%)	6,2	11,8	29,0
LSD $_{0,05}$	**0,102**	**0,102**	**22,007**

Properties of the hard coal ashes storage cover after six months of natural setting are shown in tab. 6. Natural process of setting caused the increase of bulk densities and the decrease of levels moisture in the cover layer. Taking into the consideration properties of the cover at its different depths, there were found significant differences between measured bulk densities at different layers of the cover. The top 10 cm layer was significantly denser comparing to two bottom layers –bulk density of dry material was 0,95 $Mg\cdot m^{-3}$ whereas at medium (10 - 20 cm) and bottom (20 - 30 cm) layers it was 0,90 and 0,91 $Mg\cdot m^{-3}$ respectively. Moisture level and the total porosity of the covering layer were not dependent on sampling depth however variation ratio of these parameters indicates relatively high differences between samples taken from deeper two layers.

Table 6. **Chosen values of three layers (0-10, 10-20 and 20-30 cm) mixture covering ash-storage – mean values (n=18) of actual bulk density, dry ash bulk density ($Mg\cdot m^{-3}$) and moisture content (%), and total porosity (%), November 2009**

Depth of the covering layer (cm)		Actual bulk density ($Mg\cdot m^{-3}$)	Dry mixture bulk density ($Mg\cdot m^{-3}$)	Gravimetric water content (% wag)	Total porosity (%)
0-10	**Maean**	**1,45 b**	**0,95 b**	**52,7**	**56,5**
	V (%)	4,0	1,7	7,6	1,0
10-20	**Maean**	**1,41 ab**	**0,90 a**	**56,8**	**58,8**
	V (%)	2,7	4,8	16,8	5,0
20-30	**Maean**	**1,36 a**	**0,91 ab**	**50,9**	**55,4**
	V (%)	5,4	6,9	12,3	7,6
0-30	**Maean**	**1,41 ab**	**0,92 ab**	**53,4**	**56,9**
	V (%)	3,4	3,4	10,6	3,9
	LSD $_{0,05}$	**0,06**	**0,043**	**n. s.**	**n. s.**

4. CONCLUSIONS

1. The ash as a component of mixture with sewage sludge seems to be suitable for plants root system development. Higher values of bulk density, dry bulk density and gravimetric water content were measured in ash samples taken from ash-storage compared to samples taken from ash prepared for mixing (incoherent - non compacted).
2. Sewage sludge as a component of mixture appeared to be a difficult to establish right procedure to make suitable compound of ash-storage cover.
3. The ash from power plant and sewage sludge mixed with in 1:1 ratio can be recommended as a parent components of substrate for soil development. The results of fresh mixture bulk density (1,18-1,27 $Mg\cdot m^{-3}$) and dry bulk density (0,68-0,85 $Mg\cdot m^{-3}$) determination were differed.
4. The values of physical properties of the mixture used to cover ash-storage, calculated for top 0-30 cm layer, show high value of total porosity, and low values of both: bulk density, and dry bulk density.
5. The mixture prepared upon the recommendation of researchers from Dep. of Agronomy, West Pomeranian University of Technology in Szczecin can be recommended for reclamation of devastated land.

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