FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin. 2011, Agric., Aliment., Pisc., Zootech. 286 (18), 53–64

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USE OF ASH AND SLAG FROM POWER GENERATION IN AGRICULTURE OF RUSSIA

ZASTOSOWANIE ROLNICZE POPIOŁU I ŻUŻLA Z ELEKTROWNI W ROSJI

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Abstract. A practice of the global agriculture testifies that in areas with wash moisture regime it's impossible to create high fertility of soil without liming. For example, soil in the Far East of Russia, Krasnoyarsk Region is the most acidic, has a heavy grain composition and is often overdamped. Therefore, to improve the growing conditions of crops and their nutritive conditions, it is necessary to apply ameliorants. The main chemical ameliorants of acidic soil are carbonates – limestone and dolomite. In connection with increase in price for transport services and prices for imported fertilizers attention is now paid to use of the recycled materials, including use of local ash and slag in agriculture as ameliorants and fertilizers. Moreover, in many cases there are large amounts of ash accumulated at ash disposals near operating coal-fired TPPs. However, for using ash and slag for soil deoxidization relevant studies are to be carried out, taking into account specific properties of ash and slag materials and initial soil properties.

Key words: agriculture, ash and slag, coalash, disposal, land reclamation, lime fertilizers, soil liming.
Słowa kluczowe: nawozy wapniowe, rekultywacja gleby, rolnictwo, popiół z węgla, popiół i żużel, wapnowanie gleby.

INTRODUCTION

Ash disposals cause great harm to the environment and human health. Prevention and elimination of damage to the landscape caused by ash dumps, is achieved by the proper choice of their location and arrangement, taking into account their possible future use, as well as their remediation.

Nowadays the main directions of reclamation of the worked-out ash disposals are: agricultural, forestry-based and sanitary-and-hygienic.

Soil liming allows to reduce the process of agricultural chemicalization and is an environmental and energy saving factor. In soil with optimum PH factor the dose of nitrogen and phosphate fertilizers can be decreased by 15–20% (Bezdenezhnich et al. 2000), reducing contamination of soil and plants, saving mineral resources. In addition, decreased soil mobility and penetration into plants of many substances being toxic for humans (heavy metals, radioactive nuclides, pesticide residues, etc.) is happening in well-limed soils. Liming creates an optimal PH in soil and optimum levels of calcium in the soil-absorbing set.

In Russia, an area with excessive soil acidity is about 52 million hectares. Annual loss of crops in these soils due to lack of lime corresponds to a loss of about 20 million tons in terms of grain. It was established that for 5–7-year period one ton of limestone flour provides yield, which corresponds to an average of 0.5 tons of grain (Bezdenezhnich et al. 2000).

BACKGROUND OF USING ASH AS FERTILIZERS IN THE USSR

Shale ash can be used as a lime fertilizer (Turbas and Khiys 1971). In the Estonian Agricultural Academy, more than 20 years effectiveness and features of shale ash used as a lime fertilizer have been studied. Shale ash has an acid-neutralizing capacity, and contains a number of necessary plant nutrients. Data listed in Table 1 show that relating to nutrients shale ash contains calcium as well as sulfur, magnesium and potassium in a significant number.

Table 1. Chemical composition of different types of shale ash and clinker dust (average content, % of dry matter of samples) (Turbas and Khiys 1971)
Tabela. 1. Skład chemiczny różnych typów popiołu z łupków ilastych i pyłu z klinkieru (średnia zawartość, % suchej masy prób)

Lime material* Materiał wapnujący	Number of tests Liczba testów	$CaCO_3$	CaO	MgO	K_2O	SO_2	P_2O_5	SiO_2	R_2O_3	CO_2
Total content – Całkowita zawartość										
1	7		41.5	4.4	3.6	7.6	0.21	29.8	13.7	1.1
2	12		46.6	4.5	2.5	4.7	0.20	26.9	12.4	2.8
3	3		54.1	5.1	1.8	3.2	0.19	22.8	11.9	2.1
4	1		41.5	4.5	2.5	5.1	0.17	30.1	13.5	3.2
5	1		40.1	4.6	3.0	4.3	0.21	32.8	14.7	1.9
6	16		42.6	3.1	5.2	6.9	0.38	13.8	6.7	21.5
7	5		34.5	2.4	1.9	4.2	0.18	28.4	11.3	8.3
Soluble in 1n HCl – Rozpuszczalne w 1n HCl										
1	6	61.7	38.2	3.6	2.5	7.3	–	10.0	9.1	
2	13	81.6	44.4	3.9	1.7	4.5	0.14	10.6	8.8	
3	3	92.5	48.7	4.1	1.3	2.9	–	10.7	8.4	
4	1	68.9	37.3	3.6	1.8	4.8	–	10.1	9.2	
5	1	69.9	37.0	3.8	2.0	3.9	–	11.8	10.1	
6	16	74.9	41.6	2.6	4.8	5.6	0.34	5.1	4.5	
7	5	56.9	33.2	1.9	1.0	3.8	0.14	9.5	8.0	
Water-soluble content – Rozpuszczalne w wodzie										
1	6	19.2	12.6	0.2	0.4	2.4	traces			
2	12	19.0	12.0	0.2	0.1	1.7	"			
3	3	22.5	13.8	0.1	0.0	1.4	"			
4	1	20.1	13.1	0.1	0.1	2.4	"			
5	1	20.1	12.9	0.1	0.0	2.0	"			
6	16	1.9	2.6	0.2	3.8	4.2	0.04			
7	5	10.2	4.2	0.2	0.2	1.0	"			

* 1 – shale ash from ESPs of Baltic SDPP; 2 – cyclone shale ash from Baltic SDPP; 3 – chamber shale ash from Baltic SDPP; 4 – cyclone shale ash from Kohtla-Yanverskaya TPP; 5 – cyclone shale ash from Ahtme factory of construction materials; 6 – clinker dust from «Punane Kunda»; 7 – grate shale ash from various industrial enterprises.

* 1 – popiół z łupków ilastych z ESPs of Baltic SDPP; 2 – popiół lotny z łupków ilastych z ESPs of Baltic SDPP. 3 – popiół z łupków ilastych z komory z ESPs of Baltic SDPP; 4 – popiół lotny z łupków ilastych z Kohtla--Yanverskaya TPP; 5 – popiół lotny z łupków ilastych z fabryki materiałów budowlanych w Athme; pył klinkierowy z «Punane Kunda»; 7 – popiół paleniskowy z różnych zakładów przemysłowych.

They are relatively well soluble substances. Especially high neutralizing capacity is observed in shale ash dust, with the coarse ash dust having the highest neutralizing capacity, as well as the maximum content of calcium and magnesium. The finest ash has the lowest neutralizing capacity and the highest content of potassium and sulfur.

Dust collected in electrostatic precipitators of the cement plant «Punane Kunda», the so--called clinker or cement dust, has its composition and other properties similar to shale ash dust. Shale ash and clinker dust also contain some amount of micronutrients needed for plants, total content of which is characterized by the average data presented in Table 2.

Table 2. Content of trace elements in powdered lime materials mg · kg^{-1} (Turbas and Khiys 1971)
Tabela 2. Zawartość metali ciężkich w sproszkowanych materiałach wapnujących mg · kg^{-1} (Turbas and Khiys 1971)

Lime material Materiał wapnujący	Number of tests Liczba testów	B	Cu	Mn	Mo	Co	Zn
Shale ash from ESPs Popiół z łupków ilastych z ESPs	5	18	12	166	11	3	99
Shale ash from cyclone Popiół lotny z łupków ilastych	9	15	13	169	10	2	55
Clinker dust Pył klinkierowy	4	9	23	203	4	2	74

Numerous field and vegetative experiments have been carried out. For example, in the experiments conducted in 1964–1968, based on 22 records of yield of different cultures, the average yield after applying travertine (due to NPK-fertilizers) made 555 feed units, and after applying shale ash from ESPs made 808 fodder units per hectare, or increased by 45%.

The Estonian SSR was rich in limestone, dolomite, travertine and lake lime. Earlier in agriculture calcareous tufa was widely used, but since the beginning of 1950-ies grate shale ash formed at slate lumps combustion was also applied.

Both travertine and slate grate ash have their drawbacks: they often contain high amount of moisture and solid parts. All kinds of shale ash and clinker dust do not have these drawbacks. They are completely dry and perfectly fine, that became an obstacle in applying them for soil liming.

In 1964, the machine operators have developed a method of direct use of shale ash dust. Since that time, high-quality dustable wastes have been widely used in agriculture. The average yield after applying different grains increased within 5 years of tests and ranged from 31 to 92% in comparison with applying dust.

By 1965, in the Estonian SSR total amount of the received clinker dust (about 100 thousand tons, or almost 1/4 of the total amount of applied lime fertilizers) was used for soil liming, the rest part was shale ash. In 1968 dustable lime fertilizers (cyclone shale ash and clinker dust) made already 338 thousand tons or 73%, and grate shale ash was 122 thousand tons, or the remaining 27% of the total quantity of the applied lime fertilizers.

Ashes from TPPs can be used as lime fertilizers (Sonina 1971). By 1960-ies in the USSR were more than 55 million hectares of land with high acidity, harmful to most crops. To increase the yield it was necessary to apply about 35 million tons of lime fertilizers annually.

Northwest Research Institute of Agriculture, the Estonian Agricultural Academy, Urals Research Institute of Agriculture, VIUA and several other institutions studied shale, peat and coal ash.

Shale ash was used as a lime material to reduce soil acidity in areas of the nonchernozem belt.

Coal ash. From the results of chemical analysis of coal ash conducted in 1960-ies it became clear that ashes from the most power plants in the USSR were characterized by absence or low content of calcium and magnesium, so their study was not appropriate. Particular attention was paid to coal ash from Kansko-Achinsky basin. In 1963 VIUA tested a number of ash samples with CaO + MgO content changing from 12.5 to 42.5% in conditions of the pot experiment.

Data, presented in Tables 3–4, indicate the high efficiency of ash used as a lime fertilizer, applied to soil at the rate of hydrolytic acidity. Due to the presence of other nutrients in their composition, including micronutrients, there is an exceeded ash impact on the crop and on production quality compared to ground limestone.

Table 3. Coal ash impact on harvest crops (in conditions of the pot experiment) – Sonina 1971
Tabela 3. Wpływ popiołu z węgla na zebrane rośliny (w doświadczeniu wazonowym) – Sonina 1971

Ash from TPPs Popiół z TPPs	Culture Gatunek	Yield [g pot^{-1}] – Plon [g wazon^{-1}]		
		Control Kontrola	Lime Wapno	Ash Popiół
Nazarovskaya SDPP	Clover – Koniczyna	25.8	48.4	49.7
	Beans – Fasola	2.5	19.7	21.3
	Millet – Proso	No	21.1	24.8
	Peas – Groch	0.7	8.0	19.2
Krasnoyarskaya SDPP	Peas – Groch	6.4	25.8	21.5
	Millet – Proso	1.2	26.1	28.0
	Potatoes – Ziemniak	248.7	576.2	575.0
	Clover – Koniczyna	2.1	21.6	26.8
Kanskaya TPP	Millet – Proso	No	21.1	23.3
Raychihinskaya TPP	Clover – Koniczyna	8.5	58.8	72.7
Stupinskaya TPP	Millet – Proso	No	21.1	0.3

Table 4. Impact of coal ash on the survival of plants and production quality (Sonina 1971)
Tabela 4. Wpływ popiołu z węgla na przeżycie roślin i jakość produkcji (Sonina 1971)

Test options	Millet – Proso				Clover – Koniczyna					
	Survival of plants Przeżycie roślin	The yield of wheat Plon pszenicy	Total nitrogen Azot ogółem	Crude protein Białko surowe	Survival of plants Przeżycie roślin	Ca	Mg	Mn	Fe	Ascorbic acid Kwas askorbinowy
		[%]				[%]			[%]	
Control Kontrola	75	no harvest bez zbioru			90	1.29	0.34	100.1	78.0	42.5
Ground limestone Wapno naturalne	100	77.8	1.47	9.19	97.5	2.29	0.37	7.0	35.2	39.8
Ash from Nazarovskaya SDPP Popiół z Nazarovskaya SDPP	100	78.1	1.57	9.81	100	2.22	0.78	9.6	31.9	37.7
Ash from Kanskaya TPP Popiół z Kanskaya TPP	100	78.6	1.75	10.9	97.5	2.63	0.86	8.3	29.2	29.1
Ash from Kanskaya TPP Popiół z Kanskaya TPP	100	78.1	1.52	9.50	–	–	–	–	–	–
Ash from Stupinskaya TPP Popiół z Stupinskaya TPP	75	no harvest bez zbioru			–	–	–	–	–	–
Ash from Raychihinskaya TPP Popiół z Raychihinskaya TPP	–	–	–	–	100	2.35	0.59	9.3	41.4	37.2

CHANGES IN CHEMICAL AND MINERALOGICAL COMPOSITION OF SOIL

In accordance with (Ecology in Power Engineering 2003), studies conducted by the Russian experts on environmental impact of ash with high content of calcium oxides, have shown that in areas of intensive deposition of ash its long-term influence changed PH in soil solutions from slightly acidic to slightly alkaline, resulted in accumulation in soil of high calcium content, iron and magnesium, reduced organic carbon content, i.e. significant change in soil properties occurred, which affected the plant world.

Trees growing in such soils absorb magnesium, iron and copper more intensively, and have a lack of manganese and barium, which leads to metabolic disturbances. This is expressed in gigantism of young pine trees, and dwarfism of timber shoots and needles and the final result is withering away of the shoots. Changing the chemical composition of grasses as a whole is similar to the change in the composition of tree species: reduced content of manganese and barium and increased content of magnesium and copper. But unlike trees, grasses absorb calcium more intensively and therefore, calciphobous plant suffer much stronger, while the life of calcicolous plants becomes a little bit better: they have a well-developed root system and increased biomass.

It is notices, that high-lime ash applied in the appropriate doses improves the growth and the yield of plants such as potatoes and wheat, as compared with control plots. At higher doses (for wheat – more than 75 g $\cdot$ ha^{-1}) negative impact of ash occurs: the roots of plants form a surface system, and the plants themselves become dwarfs.

Compared with the alkaline ash the acid one, in excess of certain concentrations in the initial acidic soil, affects the plants stronger: content of manganese, vanadium and cobalt is 4–10 times more, content of potassium, sodium, nitrogen and calcium decreases, the yield of forage herbs and their nutritional value becomes lower.

In some experiments, the plants, planted in a mixture of low-lime ash and soil absorbed the increased amounts of arsenic, aluminum, manganese and molybdenum, concentrations of those reached potentially hazardous levels for both plants and animals consuming them fresh or canned.

Application of acid ash into soil reduces PH factor, which affects such trees as birch, growing well at PH of 5.8–7.5 and calcicolous plants. PH is an important factor influencing the heavy metals absorption by plants – accumulation of these elements at low (2.5–3.0) or high (9.0–10.5) PH is much more intensive than in neutral soil.

Coalash materials from the biological point of view are sterile substratum, devoid of organic matter and traces of nitrogen. Content of mobile phosphorus and potassium in these materials is also not enough for plant nutritionin, there are micro-organisms in ash providing sustainable soil fertility and normal soil and mineral nutrition of plants.

Adverse physicochemical properties of ash cause slow self accretion of ash disposals, particularly in areas of insufficient humidity and strong winds. The first plants appear at the disposals in two-three years after decommissioning. As a rule, they are representatives of local fauna. The plants are located in the lower places, and turfness of surface does not exceed 10–20%.

EXAMPLES OF COALASH USE IN AGRICULTURE

Use of ash from Kansko-Achinsky coal (KAU) (Bezdenezhnich et al. 2000). The Open JSC «SibVTI» by VTI and other leading institutions (VIUA, VNIPTIHIM, CINAO, VNIISHR, Krasnoyarsk Research Institute of Agriculture, and others) studied properties of dry ash from Kansko-Achinsky coals (KAU) as ameliorant and as raw material for production of granulated lime fertilizer.

At the first stage dry ash dust was studied as an ameliorant. One of the most important properties of KAU ash is its neutralizing capacity. It is determined by the total involvement of different calcium compounds in exchange reactions with the soil-absorbing complex and is expressed as a percentage in terms of $CaCO_3$, which is very convenient for comparison with the standard ash ameliorant – limestone flour and chalk.

While studying an impact of ash and limestone flour on reduction of acidity of the soil positive results have been gained. Hydraulic acidity of the soil after liming by limestone flour decreased from 7.3–7.1 to 3.2–3.8 mg per eq. per 100 g soil, and after applying the equivalent ash doses, it decreased to 2.3–2.7 mg per eq. per 100 g soil. Thus, KAU ash being an ameliorant improves chemical and physical properties of the soil, increases its fertility, yield and production quality.

However, the dry dust-like ash has some negative characteristics preventing its use in the existing liming technology, it is high-dust powder with a high degree of dispersion.

At the second stage the Open JSC «SibVTI» conducted studies of KAU dry ash as a raw material for production of granulated lime fertilizers, they developed the technology of fertilizer production and studied agrochemical, environmental and hygienic properties of granular ameliorant-fertilizer and its effect on yield and quality of agricultural products. Granulated ash differs significantly from dry ash dust relating to physical and mechanical properties. It does not cake during storage, is not dusty, and meets the requirements for granular fertilizers.

VNIPTIHIM conducted pot experiments using sod-podzolic soil (PH = 4.05). The doses of the studied and traditional ameliorants determined on the basis of complete neutralization of acidity. Neutralizing capacity of the used ameliorants in terms of $CaCO_3$ were the following: limestone flour – 94%, Stoilensky chalk – 100%, granulated ash from Irsha-Borodinsky coal – 44.2%, Nazarovsky coal – 65.3%, Berezovsky coal – 78.7%. Nitrate, double superphosphate and chloride potassium were added into the soil as the background elements.

In the pot experiment # 1 barley was cultivated in the first year. Barley crop was collected after its full ripeness. In the second year in experiment # 1 corn was grown, and in the third year – a clover. The experimental results show that the granulated KAU ash being a chemical ameliorant is not less effective than limestone flour. As a result of applying the granulated KAU ash into soil, the agro-chemical properties of acidic soils are improving, determined by actual, exchange, and hydraulic acidity. In this case, actual acidity changed from 5.1 to 6.55, the exchange one – from 4.05 to 5.85, hydrolytic one – from 10.1 to 3.3 mg per eq. per 100 g soil. Improving physical and chemical properties of the soil led to increasing of the yield of crops: barley in the first year – 2 times, maize in the second year by 20%, clover after 2 cuts in the third year – by 30%. Similar results were obtained in the pot experiment # 2.

In experiment # 2 in the first year clover was grown, which was removed three times during the growing season. In the second year corn was grown, and in the third year – barley. Yields of clover increased by 46%, the corn – by 20%, the barley – by 35%.

Studies of the effect of the granulated KAU ash on the harvest of fodder beet were carried out at COS VIUA on sod-podzolic heavy loamy acidic soil with PH = 3.9–4.3. Application of the limestone flour increases the yield of sugar beet by 40%.

Studies of the effect of the granulated KAU ash on crop yields under field conditions were conducted by KNIISH on sod-podzolic and dark-gray forest soils. Experimental plots were planted with rape, barley and oat after applying a complete fertilizer and ameliorant from KAU ash in doses calculated to complete neutralization of acidity. As the background ammonium nitrate, double superphosphate and potassium chloride were added. Yields of all crops in the options with granular ameliorants from KAU ash were higher: rape by 7%, barley by 21%, oat in different experiments by 39.1, 44.8, 15.5.

Improving crop yields can be explained not only by neutralizing capacity of KAU ash, but also by influence of macro- and micro-nutrition elements contained in ash (potassium, manganese, phosphorus, boron, strontium, molybdenum, selenium, etc.).

Thus, manganese, barium and strontium are the most prominent substances in KAU ash table 5, 6). Boron content is lower and the content of lead, zinc, cobalt, chromium, nickel and copper are even lower. Number of radionuclides introduced into the soil with ash, are below their permissible concentration in drinking water. Therefore, the content of natural radionuclides in soil does not increase (Bezdenezhnich 1992).

Table 5. Contents of substances in KAU ash samples [$mg \cdot kg^{-1}$]
Tabela 5. Zawartość składników w próbach popiołu KAU [$mg \cdot kg^{-1}$]

Pb	Zn	Cj	Cr	Ni	Cu	B	Mo
20–200	60–300	10–60	20–100	20–150	50–300	300–1000	2–5

Table 6. Contents of substances in KAU ash samples [$mg \cdot kg^{-1}$]
Tabela 6. Zawartość składników w próbach popiołu KAU [$mg \cdot kg^{-1}$]

V	Mn	Ba	Sr	Ti	Zr	P
2–8	1000–10000	2000–10000	3000–10000	3000–8000	80–200	500–800

The Open JSC «SibVTI» developed the technological scheme and a project of the pilot plant for production of granular fertilizers from KAU ash. The technological scheme is shown in fig. 1.

Ready granular fertilizer can be shipped to the consumers in two ways: packed in paper bags or directly into the carbody.

Dust control at ash disposal of the Omsk TPP-5 using a biological method (Sidorov and Tyryshkin 2007). In 2006–2007 the Open JSC «Ecoflora» performed the work on dust suppression using biologically active surface of the operating ash disposal of the Omsk TPP-5 with the area of 50 ha by growing a closed canopy preventing from wind and water erosion without causing topsoil.

Contents and requirements for the work: application of a complex mineral fertilizer, inoculation of seeds, dust control efficiency should make at least 85%.

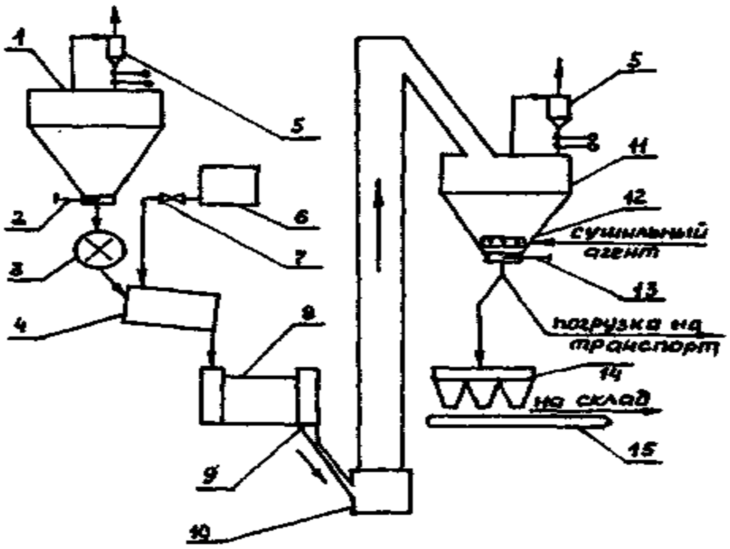

Fig. 1. The technological scheme of production of granular fertilizer from KAU ash

1 – dry ash silo; 2 – gate; 3 – ash feeder; 4 – ash-water mixer; 5 – aspiration device; 6 – water tank; 7 – water dispenser; 8 – ash granulator; 9 – receiver of granules; 10 – elevator bucket: 11 – granulated ash hopper; 12 – aerating device; 13 – thick gate; 14 – packaging machine; 15 – conveyor belt.

Rys. 1. Schemat technologiczny produkcji nawozu granulowanego z popiołu KAU

1 – zbiornik na suchy popiół; 2 – zasuwa; 3 – dozownik; 4 – mieszalnik popiół-woda; 5 – aspirator; 6 – zbiornik na wodę; 7 – dozownik wody; 8 – granulator popiołu; 9 – odbiornik granulatu; 10 – przenośnik kubełkowy; 11 – zbiornik granulowanego popiołu; 12 – zespół napowietrzający, 13 – zasuwa; 14 – pakowarka; 15 – przenośnik.

Methods of implementation: creation of conditions conducive to plant growth and development in the short term. It's achieved by selecting of the fast-zoned agricultural grasses and legumes, use of bacterial growth promoters, optimal doses of the complex fertilizers, use of traditional and conventional agricultural technologies.

Effectiveness of use of scientific and technological products means stop dusting of ash disposal on the area of 60 hectares.

Ash and slag use at Nazarovskaya SDPP for reclamation of land disturbed during mining processes (Trokhovtseva 2007). Nazarovskaya SDPP with installed capacity of 1400 MW generates 320 thousand tons of ash and slag per year. To store them in 1957 at the river Chulym an ash disposal area was arranged, that is currently in the water protection zone and in the city, causing serious environmental conflicts, by that during the period of operation building of the II and III dam layers has been made. The ash was referred to wastes of the 5th class of hazardous, which according to SNIP 2.01.28–85 is allowed to transport to «municipal waste storage fields» (SNiP 1985; Federal Law №309-FL 2008). However, volumes of municipal solid waste storage fields of Nazarov town were also limited.

Solving the problem of Nazarovskaya SDPP ash disposal is only possible through storage of ash in the worked out open cast mine of Nazarovskaya coal mine, where there are large volumes for disposal of low-toxic wastes. Activity on mining reclamation of OPU «Achinskiy» includes the following: ash storage, laying out the backfilling layer, flattening of slopes of the disposal front (after completion of ash and slag storage), applying the recultivation loam layer; renting the land to land user.

Ashes are landfilled up to the mark of 2 m below the existing elevations relative to the flat surface of the disposal near the experimental-industrial site from the west. In one year, after shrinking of ash and slag disposal the reclamation layer of loam is put. After flattening of the slope loam is applied, leveling and planning is made. To isolate ash and slag with the loam layer of 2 m 244.6 thousand m^3 of the imported soil is needed.

In the process of restoration of the disturbed lands landscape is formed and specific environment is created – in this case environmental issues are solved:

1. Applying ash and slag into disposals under certain conditions, provides them with engineering reclamation: in disposals it is possible to create horizontal layered textures like primary overburden have. Ash layers will create an anti-infiltration effect for atmospheric precipitation infiltration and, thus, provide more favorable moisture regime in the root zone of disposals optimizing conditions for bioremediation.
2. In general, application of ash and slag into disposals will have a positive environmental and geochemical meaning. Ashes will create an alkaline reaction of water, preventing migration of many chemical elements into water. Applying ash and slag into disposal will contribute to an increase in pH, reduce the acidity level of disposals, the number and concentrations of toxic elements in water.
3. The plot «Achinsky» is located in an agricultural area with favorable soil and climatic conditions. Breed overburden are suitable for the forest restoration. The cost of 1 ha of reclamation of the disturbed land that could be used for the forest needs is four times lower than for arable land.
4. One of directions for improving natural environment is creation of green areas near Nazarovo town.

These activities are aimed at improving the environment and have favorable effects: plantations growing at the disturbed land contribute to clean air, regulation of hydrological and climatic conditions, but also have an aesthetic value.

Biological recultivation of the second worked off section of the ash disposal area of Novocherkasskaya SDPP (Biryukov et al. 2010). Studies at the second worked off section of the ash disposal of Novocherkasskaya SDPP have been carrying out since 2004, the second worked off section of ash disposal with an area of 76 ha is 8 km to the south-east from Novocherkassk between two villages Krivyanskaya and Zaplavskaya. To determine the most adapted species of plants suitable for forming stable phytocenosis on the ash disposal area, laboratory studies in vegetative vessels have been carried out. The experiments foresaw observations for growth and developing of 2-, 3- ($N_{9\text{-}10\%}$; $P_{25\text{-}26\%}$; $K_{25\text{-}26\%}$) was applied as a mineral fertilizer. The norm of fertilizer application in experimental options was calculated depending on an area of the vegetative vessel and doses of $N_{60}P_{120}K_{90}$ fertilizers in kg of active matter (a.m.) per ha.

Couch grass + awnless brome + Hungarian sainfoin grass mixture was sown in the second decade of April 2004. Seeding rates were 40%, 40%, 20% for couch grass, awnless brome and Hungarian sainfoin, correspondingly. All grasses are perennial, have quick acclimatization, high resistance to unfavorable conditions of microclimate and to negative physical and chemical properties of ground. They are able to develop a strong root system and have symbiosis with microorganisms. They can grow during 6 and more years.

Total sprouts of grass mixture appeared in the early May, and in the late July sodding of ash disposal surface was observed, that fully excluded forming of sand storm on its area. In the late August additional fertilizing of the grass mixture with ammonium nitrate in the rate of N_{60} kg · ha^{-1} a.m. was carried on. In the early October a complex fertilizer – ammophos was applied.

To restore the disturbed plot forest reclamation practices were used as well. In autumn 2004 tree and shrub vegetation was planted on the recultivated area: three-row forest reclamation belt – diagonally and four-row forest belt. In total, more than 10000 trees and shrubs of 17 species were planted on the restored area.

Inspection in the early spring 2005 showed that grass mixture plants passed the winter well. During the grass mixture vegetation monitoring on the dynamics of linear growth and the depth of root system penetration had been carrying out. The data received indicated that the mean height of plants was more than 80 cm and the depth of root system was 30 cm.

Nutritive regime for grass mixture was stimulated by additional nitrogenous fertilizing in the rate of $N_{60–90}$ kg · ha^{-1} a.m. in spring while at the end of the growing period complex fertilizers were applied.

In spring 2006 good wintering of plants was also recorded. After the winter period mean safety of grass mixture plants was 93.6%. Fertilizer applying in rates N90P90K60 kg · ha^{-1} a.m. favoured good growth and development of grass mixture plants.

In 2007 field studies on the ash disposal area were continued. After the winter safety of grass mixture was over 89%. In the early growing period fertilizers were applied in calculated rate $N_{90}P_{90}K_{90}$ kg · ha^{-1} a.m. By the end of the vegetation mean height for Hungarian sainfoin had been 82 cm, that for couch grass and goat's-rue had been 123 cm. By the end of growing period 2007 the depth of root systems had been 38…46 cm and penetrated into ash dump substratum (table 7, 8). After the winter of 2007–2008 mean safety of plants was 85%.

Table 7. The results of agrochemical analysis of samples from recultivative layer of the second worked off section of Novocherkasskaya SDPP ash disposal (2008 year)
Tabela 7. Wyniki badań agrochemicznych prób z warstwy rekultywacyjnej drugiej zamkniętej sekcji składowiska popiołu w Novocherkasskaya SDPP (rok 2008)

Horizon [cm] Poziom [cm]	Nitrate nitrogen Azot azotanowy [mg · kg^{-1}]	Labile phosphorus Fosfor rozpuszczalny [mg · kg^{-1}]	Exchange potassium Potas wymienny [mg · kg^{-1}]	Humus Próchnica [%]	pH
0…20	0.9	нет	20.0	0.07	8.48
20…40	2.5	44.6	48.0	2.69	8.32

Table 8. Content of heavy metals in samples of the recultivative layer of the second worked off section of Novocherkasskaya SDPP ash disposal (2008 year)
Tabela 8. Zawartość metali ciężkich w próbach z warstwy rekultywacyjnej drugiej zamkniętej sekcji składowiska popiołu w Novocherkasskaya SDPP (rok 2008)

Horizon [cm]	Heavy metals – Metale ciężkie [mg · kg^{-1}]				
Poziom [cm]	Cu	Cd	Zn	Ni	Pb
0…20	2.32	0.008	8.76	1.53	3.12
20…40	6.47	0.25	18.45	9.17	6.23

At the end of vegetation in 2008 average plant heights of grass mixture were: for Hungarian sainfoin 95 cm, for cereals – 137 cm. The depth of penetration for root systems was 48–53 cm for Hungarian sainfoin and 45–56 cm for couch grass and awnless brome.

CONCLUSION

Nowadays, a level of utilization of ash and slag from power generation in agriculture is low, it is much less than it was during the Soviet times. However, there are some works in this direction that deserves more attention and support from the state.

The main barrier to coalash use in agriculture is that in Russia about 85% of coalash is transported by hydraulic ash removal installations with subsequent landfilling of ash and slag at hydraulic ash and slag disposals. Nowadays, many ash disposals are close to their project completion. There are two options to solve the created problem: construct new ash disposals that will cause irreparable damage to the environment and people living near power station, spending huge sums of money for their construction, or use ash and slag in different branches, including agriculture.

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