

Part 3
ASH AND SLAG HANDLING

3.4. Beneficiation and ash management

3.4.1. Summary of coalash beneficiation in Russia

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ABSTRACT

In the paper brief data on coal consumption, generation, processing and landfilling of ash and slag from power industry in Russia from 1990 till 2010 are given. The paper includes information on traditional applications of ash and slag materials in various branches of the Russian economy. The basic standards covering ash and slag handling problem with their modifications are reflected. Besides, technologies of processing ash and slag from power generation in Russia meeting the requirements of technical standards are resulted. Results of the market analysis of coal ash after its beneficiation are presented too.

GENERAL INFORMATION

A problem of coalash handling becomes more and more sharp as hydraulic ash disposals of the most part of large power plants constructed in 1960-1970-ies are very close to their design filling. Construction and operation of new hydraulic ash disposals and expansion of ones being under operation are for the moment both very expensive measures and make irreparable harm to the environment. In connection with that soon hydraulic ash disposals will be filled up to their design elevation, there are some alternatives of solving this problem:

- building of new or expansion of operating hydraulic ash disposals. Their costs can make some hundreds

millions dollars for the large power plants leading to degradation of hundreds hectares of ground;

- raising the protecting dams of the existing hydraulic ash disposals that is also a rather costly action;
- ash and slag processing and their use in various branches of economy.

Thus, owners of power plants faced the need of choosing one of three mentioned alternatives. For more effective solution of coalash handling issues it is necessary to involve experts of the profile research organizations for working out the master plans of ash removal systems and recommendations on choice and introduction of the best available technologies of collection, transport, beneficiation, shipment and landfilling of the unclaimed ash part at the ash and slag disposals using ecologically sound ways.

In Russia about 85 % of coalash is transported by hydraulic ash removal systems, and only about 15 % — by pneumatic ash ones [1]. However, today the Russian power engineers start understanding the inevitable transfer from "wet" to "dry" ash handling systems, since introduction of wet ash removal systems can't result in beneficial and ecologically sound way of ash problem solution.

Data on consumption of power coals and formation of coalash in Russia for the last years are given in the table 1.

Table 1. Data on coal consumption in Russia; volumes of formation, processing, ash and slag landfilling at the ash disposals [2].

Data	Years									
	1990	1995	2000	2002	2005	2006	2007 ¹	2008 ¹	2009 ¹	2010 ¹
Coal consumption, million t of the natural /year	182,0	128,0	120,1	106,0	116,5	126,2	118,5	118,7	123,0	125,3
Average ash value, %	27,5	26,3	20,8	21,4	21,0	21,1	21,1	21,2	21,2	21,2
Ash production, million t	50,0	33,7	25,0	22,7	24,5	26,6	25,0	25,2	26,1	26,6
Ash processing, million t	4,5	1,9	3,1	3,3	4,0	4,2	4,4	4,6	4,8	5,0
Ash landfilling, million t	45,5	31,8	21,9	19,4	20,5	22,4	20,6	20,6	21,3	21,6
Relative volume of ash processing, % of the annual output	9,0	5,6	12,4	14,5	16,3	15,8	17,6	18,3	18,4	18,8

In total more than 100 coal ranks are burnt in power boilers at the Russian TPPs, but the main coals are taken from the following fields: Kuznetsky, Kansk-Achinsky, Ekibastuzsky. Berezovsky and Irsha-Borodinsky coals belong to Kansk-Achinsky coals.

Volume of ash processing includes ash, used for repair and expansion of ash lagoons under operation. Annually for these purposes from 1 to 1,2 million t of ash is used. It is mainly ash and slag mixture from ash lagoons of TPPs and heating boiler-houses. However, during construction of ash landfills self-hardening high-concentrated ash pulp with high Ca content from Kansk-Achinsky coals can be used. Such experience was gained during construction of ash disposal at Abakanskaya CHPP.

DIRECTIONS OF BENEFICIAL USE OF CCPS IN RUSSIA

Traditional and new applications of ash from the Russian power plants cover:

- construction and maintenance of roads and dams at ash disposals;
- road construction;
- production of building units from heavy and cellular concrete;
- production of hydraulic concrete;
- production of cement;
- production of dry building mixes;
- restoration of the open cast mines;
- applications in agriculture;
- production of porous artificial wood.

Table 2. Products made from coalash in Russia

№ of a product	Name of a product
1	Dry ash-clinker binders on the basic of acid, ultra-acid and high-basic ashes from TPP
2	Dry clinkerless binders on the basic of high-basic ashes
3	Fine sand on the basis of sieving the ashes from pre-chambers
4	Fine, medium and coarse sand on the basic of crushed bottom ash/slag
5	Multi-grade crushed stone on the basic of crushed bottom ash/slag
6	Dry building mixes for solutions of different applications (laying, plaster, spackling, glue, hydrophobic, overshot and so on) on the basic of products 1-4
7	Dry concrete mixes of different applications on the basic of products 1-5
8	Fertilizers for agricultural purposes
9	Deoxidants for acid soils, especially for Non-Black Soil Region, on a basis of high-lime coalash
10	At construction of highways using monolithic concrete – underlying dry filling from high-lime ash with high hydration thermal capacity and temperature of 80 ... 90°C, highly effective at road construction in conditions of rather low positive temperatures
11	Ash cenospheres of multi-purpose use
12	Dry ash and their mixes as additives in concrete, solutions and for production of blast-furnace cement at the cement factories

COMMENTS TO SOME APPLIED AND NEW TECHNOLOGIES OF USE ASH AND SLAG FROM POWER GENERATION IN RUSSIA

Production of porous artificial wood [3]. Employees of Irkutsk Technical University have developed the technology of production of porous artificial wood (PAW), having no analogues in Russia [4, 5]. PAW is a building material of a new generation. In the process of PAW manufacture wastes from polymer production and fly ash from TPPs and boiler-houses of the Irkutsk region will be used.

Artificial wood helps to solve one of the global problems such as rapid disappearance of natural forests - the "lunge" of our planet, and as a consequence, decrease in accumulation of carbon dioxides in the atmosphere, as well as recycling billion tones of industrial solid wastes. Until now, all commercial grades of artificial wood are very heavy and represent non-porous materials. The developed PAW exceeds technical and economic properties of wood plastic composites and some types of natural wood because it posses much higher fire and heat resistance, chemical and water resistance, biological stability (decay, termites, mold, etc.) and longevity. At the same time PAW cost is much less due to large content of polymer binder (the most expensive component) and significant amount (up to 70 %) of very inexpensive filler - fly ash.

PAW can be used in the following outdoor applications: sidings of houses, decking, docking, beams, garden furniture and sidewalks, patios, fences, roof slate, railway sleepers, marine piers.

PAW can be used in the following indoor applications: floors, ceilings, doors, interior windows and door frames, interior padding the walls, shelves, cabinets, furniture, veneer.

This technology makes it possible to produce PAW articles of any shape, length, color, odor, surface texture and any cross-sections: rectangular, square, round and oval logs, tongue-and-groove as well as hollow boards and logs.

Ministry of Natural Resources of the Irkutsk Region, Open JSC "Irkutskenergo" and JSC "Irkutskzoloproduct", and also the building companies – potential PAW consumers showed their interest in cooperation for introduction of this technology in industrial scale.

Production of aerated concrete blocks. In [6] experience of Kashirskaya SDPP in using nanotechnologies at

manufacture of aerated concrete blocks is presented. Kashirskaya SDPP is a branch of the Open JSC "Wholesale Generation Company №1" (Open JSC "WGC-1"), operated by the Open JSC "INTER RAO UES". The pilot batch production of the aerated concrete blocks in Orel displayed successful application of ash and slag materials instead of sand. Such replacement of 30 % of sand mass allows to increase compressive strength, frost resistance and make the blocks lighter. Within the limits of environmental policy of the JSC "WGC-1" and integrated approach to ash utilization problem a project of construction of the autoclave aerated concrete production factory with total replacement of sand by ash material was developed. It became possible because of application of multilayer carbon nanotubes. Such replacement became possible with application of multilayered carbon nanotubes which use makes only 0,0017 % of the aerated concrete block weight. The total designed cost of the first line construction is 260 million rub. Annual ash material consumption is 38000 tons, output capacity of the marketable and high-demanded product is 150000 m³. The use of steam from power plant and ash makes the cost price significantly lower. Operation of such a factory is beneficial both from the economic and social points of view due to creation of jobs, support of the governmental program "affordable housing" through cutting the cost of building materials, and also improving environment in the area of Kashirskaya Power Plant location. The project of constructing the autoclave aerated concrete production factory using coal ash from Kashirskaya Power Plant - a branch of JSC "WGC-1" was awarded with the prize of the Ministry of Natural Resources and Ecology of the Russian Federation as "The Best Ecological Project – 2008".

Biological recultivation of ash disposal [7]. Since 2004 employees of the Novochoerkassk State Meliorative Academy have been carrying on a complex of actions on biological conservation of the worked out ash disposal of Novochoerkasskaya Power Plant. Since using the worked out ash disposals is not reasonable from the economic and ecological points of view, the prevailing application of their reclamation is a sanitary-hygienic, i.e. biological conservation.

Manufacture of ash bricks in Novosibirsk Region [8]. At the beginning of the next year the Open JSC "Kainsky brick factory" plans to start the largest factory in Russia manufacturing bricks from ash and slag from TPPs. The factory will be located in Kuibyshev between Barabinskaya

TPP and its ash disposal. Stocks of 3 million tones of ash and slag without landfilling are enough for 30 years of work of the factory. For today the manufacture production schedules are completely fulfilled, rights on ash and slag use are received, power is supplied, preparation of the industrial platform comes to an end. By the expert calculations a volume of output will make 30 million bricks of M100...M150 marks per year. The average sales forecasting for the next five years is 193 million rubles per year. Profitability of manufacture makes not less than 24 %. Payback period is 5 years. The cost price of production is 4,4 rubles per piece.

Manufacture of siliceous and calcareous brick from ash and slag in Omsk [9]. The factory is equipped with installation of the German firm "W+K" which allows producing 79 million brick pieces per year. Annually the factory will overwork up to 180 thousand ash tones. Siliceous and calcareous brick is easier than a traditional one, keeps heat better, has high durability. It can be used for constructing multistorey apartment houses and public buildings. In the long term the factory is planned to manufacture brick of various colors. For the moment such brick is delivered to Omsk from other Regions. Besides, a shop of dry building mixes producing 30 thousand tones per year is under construction. Since there are no own raw materials in the Omsk Region, ash and slag use is the demanded and effective development direction in building industry. It is already the second project of the Omsk power engineers on manufacture of building materials from ash. In 2008 Omsk factories "Industrial complex of porous materials" and "Siberian effective brick" started to manufacture building materials from ash.

Cellular autoclave concrete [10]. Cellular autoclave concrete made of cementing ash and slag were produced under typical schemes with replacement of cement or lime with activated cementing ash. As a rule, aluminum powder was used as a gas developing agent. The pilot batch of cellular concrete blocks was made of ash from the boiler-house of Krasnoyarsk machine-building factory and "burnt earth" from the same enterprise. Aluminum powder of PAP-1 mark was used as a gas developing agent. The formed products (blocks) were exposed to autoclave treatment. Indicators of the finished goods met GOST 21520-76, namely:

- volume density - 600...700 kg/m³;
- compression strength - not less than 2,5 MPa;
- frost resistance - 25 cycles.

For SPMU-3 (Krasnoyarsk) the pilot batch of cellular concrete blocks was made using the following technology: limy "milk" and water were fed to the turbulent mixer; ash and cement were supplied and the components were mixed for 2...3 minutes, then aluminum suspension was added. The total mixing time made 5,5...6 minutes. Then ready mass was spilled in the forms and maintained. After cutting the top, ready blocks underwent thermal processing at the temperature of 80...95°C.

From the pilot batch of the blocks produced, using the mentioned technology, the warehouse has been constructed.

Agriculture. Before the beginning of 1990-ies in the European part of the former Soviet Union dry coarse ash formed at slate combustion at the Baltic and Estonian SDPPs, in the volume of 2 million tones was annually used to improve agricultural soil. The ash contained not only high amount of calcium, but also a number of trace elements used by manufacture of fertilizers. Nowadays the level of coalash use in the Russian agriculture is much lower.

Construction and maintenance of roads and dams of TPP ash disposals. Ash and slag mix is traditionally applied at maintenance and expansion of hydraulic ash disposals as a backfill material.

LEGAL REGULATION IN THE FIELD OF HANDLING ASHES FROM POWER GENERATION [11]

In the Russian Federation a basis of the legislation in the field of production and consumption waste handling make the Federal Law № 89-FZ from June 24, 1998 «About production and consumption wastes» and the Federal Law № 7-FZ from January, 10, 2002 «About environmental protection» together with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal of 1989 (further – the Basel Convention), ratified by the Federal Law № 49-FZ dated November 25, 1994.

In the Federal Law № 89-FZ from June 24, 1998 «About production and consumption wastes» the reference of wastes to the process of their origin is used: production or consumption. However, these processes do not cover all the range of activity resulting in waste production. But if the production process is in the frames of the common understanding, a sense of the consumption process leading to their formation is unobvious and, undoubtedly, needs to be described in detail. In connection with this in all the subordinate acts connected with realization of the present Federal Law, the concept «production and consumption wastes» has only the nominal meaning and is actually narrowed down to the concept "wastes".

In the legislation of the Russian Federation two complementary sources of terms and definitions in the field of the waste management are used: the Federal Law №89-FL from June 24, 1998 and the Basel convention. However, some concepts in these normative legal acts are duplicated, and their wordings are not coinciding.

It concerns a key definition – "wastes". Thus, given term used in the Federal Law, is more acceptable whereas the definition "wastes", given in the Basel Convention, answers the purposes of this international legal document on securing the safety at transboundary movements of dangerous and other wastes and the control over it.

Under waste handling a set of five operations with wastes, including the whole complex of possible actions, covering their full "life cycle", is meant. This group includes the activity resulting in waste production, and also activity on waste control, use, neutralization, transportation and disposal.

The Federal Law «About production and consumption wastes» and subordinate acts, accepted with a view of its realization, set various requirements for securing the ecological safety at the waste handling.

On December 30, 2008 the Federal Law №309-FZ «About modification of the article 16 of the Federal Law «About environmental protection» and certain legislative acts of the Russian Federation» were adopted. It changed the Federal Laws in the field of environmental protection and management of natural resources.

New concepts «waste collecting», «waste transportation» and «waste accumulation», directly used at licensing the activity on collection, use, neutralization, transportation, and disposal of dangerous wastes. Their absence in the legislation of the Russian Federation led to that almost all the economic entities should obtain the license on this type of

activity.

The concept «dangerous wastes» covering almost all the number of wastes is excluded and five classes of hazard are introduced. According to the criterias, established by federal authority, carrying out state regulation in the field of environmental protection, wastes are subdivided into 5 classes depending on a degree of their negative influence on environment:

- I class – extremely hazardous waste;
- II class – highly hazardous waste;
- III class – moderately hazardous waste;
- IV class – low-hazard waste;
- V class – virtually non-hazardous waste.

Issues concerning biological waste handling and wastes from prevention and treatment facilities regulated by the corresponding legislation of the Russian Federation are excluded from the sphere of legal regulation in the field of production and consumption wastes handling.

Wastes from the I to IV classes of hazard should have a passport, and the order of certification and typical forms of the passports are defined by the Government of the Russian Federation.

Since January 1, 2010 disposal of wastes at the objects which have not been brought into the state register of waste disposal objects is forbidden. This norm is not applied to the objects which are connected with disposal and neutralization of wastes, and which are put into operation or get a building license before the date when the Law is coming into force.

Licensing of the activity on hazardous waste handling was replaced by the law for licensing of the activity on collection, use, neutralization, transportation, and disposal of wastes of the I to IV classes of hazard. Activity on accumulation of wastes of the I to V classes of hazard, and also activity on collection, use, neutralization, transportation, and disposal of wastes of the V class of hazard is not subject to licensing.

From the number of objects of the state ecological expertise materials on substantiation of licenses for realization of activity on collecting, use, neutralization, transportation, and disposal of wastes were simultaneously excluded.

Design documentation of objects connected with disposal and neutralization of wastes of the I to V classes of hazard is simultaneously included in the number of objects of the state ecological expertise of a federal level.

Nowadays subjects of the small and medium-sized business should not develop and represent to the federal or enforcement authorities of the subject of the Russian Federation, authorized for waste handling according to their competence, draft waste generation norms and waste disposal limits. Instead of this the reporting about actual waste generation and its removal by ecologically sound way (including by means of disposing) in a notifying order is introduced for them. It excludes a necessity of working out and agreement with the corresponding federal or enforcement authorities of the subject of the Russian Federation of the labor-intensive document – the draft specifications on waste production and its disposing limits which working out requires considerable financial and time resources.

Together with this the Law strengthens an administrative responsibility of legal persons and individual businessmen for not meeting the ecological and sanitary-and-epidemiologic requirements at production and consumption waste handling.

It is necessary to mention that in the Federal Law № 374-FZ dated December 27, 2009 «On Amendments to Article 45 of Part I and Chapter 25.3 of Part II of the Tax Code and Other Laws of the Russian Federation and the Repeal of the Law “On Fees for the Issuance of Licenses for Realization of Activity Connected with Production and Turnover of Ethyl Spirit, Alcoholic and Alcohol-Containing Products» the size of a State Tax for the following activity: delivery of permissions for transboundary moving (dangerous wastes, ozone-destroying substances and products containing them); import of poisonous substances in the territory of the Russian Federation; license granting; renewal of the document confirming presence of the license; delivery of the duplicate confirming presence of the license and prolongation of a period of validity of the license is increased.

The state duty for permission delivery was simultaneously introduced.

ABSTRACTS FROM THE APPROVED LIST OF COMMISSIONS FOLLOWING THE RESULTS OF PRESIDUM MEETING OF THE STATE COUNCIL OF RUSSIA [12]

“1. To the Government of the Russian Federation:

a) submit draft federal laws to the State Duma of Federal Meeting of the Russian Federation directed to:

- perfection of system of standardizing negative influence on environment;

- working out legal and economic mechanisms, including tax, stimulating managing subjects on decrease in negative influence on environment, including introduction of the best technologies;

- economic stimulating of activity in the field of waste treatment with a view of reduction of the waste quantity and their usage in economy, including creation of a mechanism of accumulation and intended expenditure of means at the regional and local levels, payments for stockpiling the wastes, providing elimination of superfluous administrative barriers in this sphere;

Deadline – December 1, 2010;

n) carry out the analysis of performance by the Ministry of Education and Science of the Russian Federation of commissions of the President of the Russian Federation and Government of the Russian Federation, connected with development of ecological education, take measures to raise the efficiency of activity in this field, including entering the ecological education in a number of obligatory subjects of educational institutions of general and vocational education system, providing work out of corresponding state educational standards and study guides.

Deadline – November 1, 2010;

2. To the Government of the Russian Federation and enforcement authorities of subjects of the Russian Federation:

a) submit proposals on perfection of differentiation of powers in the field of waste treatment between federal enforcement authorities, enforcement authorities of subjects of the Russian Federation and local governments, on their authorization in the field of liquidation of the saved up ecological damage, and also on creation of mechanisms of economic stimulating of the managing subjects and financing the liquidation of the saved up ecological damage;

b) submit proposals on preparation of long-term target investment programs on solid and industrial waste handling, on realization of pilot projects of waste processing in subjects of the Russian Federation where waste removal prob-

lem is the most actual, first of all, in Moscow and Moscow Region;

c) carry on inventory and stocktaking of objects of the cumulative ecological damage and develop a complex of measures on its liquidation defining mechanisms and volumes of financing of these measures, including pilot projects of working off the technology of liquidation of the cumulative damage.

Deadline – December 1, 2010.”

ABOUT COALASH BENEFICIATION IN RUSSIA

There are three directions of coalash beneficiation in Russia:

1. beneficiation at the enterprises of commodity output manufacture;
2. beneficiation at the specially created enterprises;
3. beneficiation in the processes of fuel combustion in boilers and cleanings of flue gases in fly ash collectors.

Beneficiation at the enterprises of commodity output manufacture

According to the first direction ash beneficiation is a part of technological production process. Therefore, it isn't considered.

Beneficiation at the specially created enterprises

An example of practical implementation of ash beneficiation technology at the specially created enterprises is a factory on beneficiation of cenospheres, which is under construction in Kemerovo Region near Belovskaya SDPP. Cenospheres are formed at coal-fired slag-tap boilers burning Kuznetsky coals. In Siberia many power plants equipped with slag-tap boilers burning Kuznetsky coals are under operation. Therefore the factory on beneficiation of cenospheres is under construction in this Region. The initiator of this project is the Russian Division of the company Omega Minerals Group (Germany). Investors of the project are Omega Minerals Group and the Open JSC «Siberian coal energy company» (Open Society «SUEK»). The factory will be put into operation at the end of 2010 – beginning of 2011. Beneficiation in the processes of fuel combustion in boilers and cleanings of flue gases in fly ash collectors

Beneficiation in the processes of fuel combustion in boilers. Today the Open JSC “INTER RAO UES” is considering a question of financing in 2011 working out of the pilot project on ash quality management at the staged coal combustion in power boilers of Kashirskaya SDPP together with application of pneumomechanical bottom ash removal technology and technology of the company Separation Technologies (STI) on separation of the unburnt carbon from fly ash. This issue was considered in detail at the III International Scientific and Practical Workshop «Ashes from TPPs – removal, transport, processing, warehousing» held in Moscow on April, 22-23, 2010 [13].

Beneficiation in the processes of cleanings of flue gases in fly ash collectors. At large TPPs of Russia, constructed in 1960-1970-ies electrostatic precipitators (ESPs), having 4-5 fields, are applied. Schemes of dry ash discharge installations provide fractional extraction, transport and landfilling of dry ash to customers according to their requirements. At designing of these installations customers' requirements for dry ash used as replacement of natural mineral raw materials were considered on the basis of research of a commodity market of dry ash. As a rule, dry ash is discharged on three groups of fractions: coarse ash is selected from ESP pre-chambers; medium-sized ash from the

ESP fields #1-2; fine ash from the ESP fields #3-5. Thus, ESP is not only intended for flue gas cleaning, but is also applied as the natural-fractionating device.

THE BASIC STANDARDS ON COALASH HANDLING

Using ash in building materials and products is reflected in a variety of operating normative documents: GOST 379–95, GOST 530–2007, GOST 6133–84, GOST 9128–97, GOST 9757–90, GOST 10178–85, GOST 16557–78, GOST 17608–91, GOST 20910–90, GOST 22266–94, GOST 23558–94, GOST 25485–89, GOST 26644–85, GOST 28013–98, GOST 30491–97, GOST 31108–2003, and etc.

In Russia the standards defining requirements for ash, slag and ash and slag mixture from power generation for use in various economic sectors are the following:

1. GOST 34–70–542–2001. Fly ash from TPPs. Normative characteristics. Put in force 01.07.2001. M.: Open JSC «VTI», 2001.
2. GOST 26644–85. Rubble and sand made of slag from TPPs for concrete. Technical specifications. Put in force 01.01.1987. M.: Publishing house of standards, 1986.
3. GOST 25818–91. Fly ash from TPPs for concrete. Technical specifications. Put in force 01.07.1991. M.: Publishing house of standards, 1992.
4. GOST 25592–91. Bottom ash/boiler slag mixtures from TPPs for concrete. Technical specifications. Put in force 01.07.1991. M.: Publishing house of standards, 1992.
5. GOST 31108–2003. Standard cement. Technical specifications. Put in force 01.09.2004. M.: FGUP CPP, 2004.
6. GOST 20910–90. Heat-resistant concrete. Technical specifications. Put in force 01.07.1991. M.: Publishing house of standards, 1991.
7. TS 34–70–10347–92. Ash and slag wastes from TPPs for cement production. Technical specifications. M.: NII-cement, 1992.
8. TS 21–31–2–82. Ash from TPPs as raw material for production of agloporit gravel, ceramic bricks and stones. M.: VNIИstrom, 1982.
9. BSN 185–75. Technical instructions for use of fly ash and ash and slag mixtures from combustion of various types of solid fuel for the road bed, road base and topping of road. Put in force 01.08.1975. M.: Ministry of transport construction USSR, 1976.

Suitability of ash and slag as the basic raw materials for production of building materials and concrete of different destinations as a filler or instead of a part of binders if defined, first of all, by absence or limited content of the harmful components in them, worsening physical and mechanical characteristics of building materials and concrete, worsening their operational and technical properties or complicating technological production processes and limiting the scope.

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