

## ASH AND SLAG HANDLING

## 3.7. Analytics

## 3.7.29. The ash and slag waste market of Russia through the eyes of trader. Phoenix consortium

*A.I. Kalachev, Closed Joint Stock Company "ProfCement-Vector", the leader of Phoenix Consortium, St. Petersburg, Russia*

## ABSTRACT

The report presents an analysis of the complex situation regarding the utilization and sales of ash and slag wastes (ASW) from coal power plants in Russia. The problem of lack of 100% dry ash and slag removal system at coal power plants is under review. This article also addresses the issue of power engineers to be about getting rid of waste through ash storing at ash dumps, and not about its sales, as well as noncompliance of fly ash of Russian coal power plants to quality standards of the product and a problem of poor fly ash sales to consumers. A solution of the above issues is offered. Finally, it contains an overview of ASW market trends in Russia and the description of "Fenix" Consortium, which offers the turnkey solutions for this problem even today.

## INTRODUCTION

I have been a trader in the market of ash and slag wastes (ASW) of Russia for the last 4 years. Prior to that, I have worked at the Russian cement market for 11 years. I have delivered up to 350,000 tons of cement per year, both Russian and foreign manufactured. I have been dealing with supplies of shale electrical filter ash and cyclone ash manufactured by "Eesti Energia Narva Elektriijaamad" (Estonia) for 4 years already. This experience has allowed our team, working in "ProfCement-Vektor", CJSC/ "PCV" CJSC ([www.profcement.ru](http://www.profcement.ru)) to achieve certain results, which are expressed both in the geography of shale ash supplies (St. Petersburg, Moscow, Krasnodar, Samara, Yekaterinburg, Tomsk, Nizhnevartovsk, etc.), and in the price level (from 2,775 to 10,000 rubles per ton for the consumer). The price level is the best evidence of what one can obtain from ASW business in case of correct approach. At the same time, there are business projects both in the Urals, Siberia, and the Far East where the fly ash quality plays an important role, but the local coal power generations have simply nothing to offer. Therefore, this article has appeared, since I want to share a positive experience and vision of what needs to be done on Russian coal and thermal power stations to offer consumers a product and increase the proportion of ASW disposal in the Russian Federation.

## 1. WHY DO WE SELL ESTONIAN FLY ASH?

Preparing to sell any product, it is necessary to examine the potential market and potential competitors. Pursuing this stage of preparation for sales of fly ash, we found the following:

1. As far as our market is, first of all, St. Petersburg and the Leningrad region, we have been looking for the source of fly ash production in a radius of 500 km from the region. There were practically no such

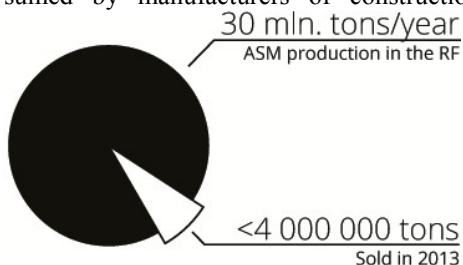
coal plants. According to the Energy Forecasting Agency, JSC (EFA), there are three major (more than 100 thousand tons per year) ASW manufacturers in the North-West Federal District. These are Severodvinsk TPP-1 (207,000 t.), Cherepovets SDPP (142,000 t.), Vorkuta TPP-2 (146,000 t.). But all these stations lack the dry ash extraction the consumers need, so we decided upon the shale ash from Estonia, which is produced 150 km from St. Petersburg.

3. Based on knowledge of customer requirements regarding the cement market work and having studied the available regulations (TU 43-9-4014-78 TU 34-70-10347-81, GOST 21520-89, GOST 25818-91, GOST 31108-2003 GOST 31359-2007, GOST 24211-2008, OST 34-70-542-2001, FZ 184-2002, European standards EN-450, EN-206, Estonian standards EVS 636:2002, etc.) we came to the conclusion that Estonian shale ash can suit us the most.
4. We also revealed that none of 172 coal power plant of RF, producing over 100,000 tons of ASW per year and positioning themselves as potential suppliers of fly ash to the Russian market, do not correspond to the requirements of GOST 25818-91 "Fly ash from thermal power plants for concrete. Specifications." It is enough to mention, that there is no Russian station with a laboratory that would be able to define ash parameters according to the requirements of this standard. "Eesti Energia Narva Elektriijaamad", JSC, implements the fly ash production standard EVS 636:2002, which confirms the presence production system at this station, providing consumers with necessary conditions under which *the ash and slag waste* become *the ash and slag materials*. It is of importance that one can tailor the business right and achieve the result even at the stations built during the Soviet times (Baltic SDPP, 1961, Estonian SDPP, 1973).

## 2. WHAT IS HAPPENING ON THE RUSSIAN ASW MARKET?

According to the EFA, 172 large coal-fired power plant of RF burn about 123 million tons of solid fuel annually (coal of various deposits and brands). The average coal ash content makes about 25%. The annual ASW output in Russia is about 30 million tons. One should note that during the last 7 years, this information is not necessary for reporting and not all TPPs provide it. Therefore, the estimates of various experts range from 25 to 30 million tons per year. According to the different estimates, there are from 1.5 to 1.8 billion tons are stored in ash dumps. They believe that the average

utilization rate of ASW does not exceed 13%, i.e. makes not more than 4 million tons per year (Fig. 1). However, not everything is that univocal. For example, one of the market leaders - the "Irkutskzoloprodukt" Company annually sells approximately 950,000 tons of ASW. Of these, about 200,000 tons, is consumed by "AngarskCement" Company, specially designed in Soviet times to use the hydrated raw materials from ash dumps. The rest is used for recultivation and landscaping, and only about 60,000 tons of dry fly ash is consumed by manufacturers of construction materials.



If we talk of utilization structure, it basically is the use of hydrated ASW from ash dumps for recultivation and landscaping. It is caused by the lack of dry ash and slag removal system (DASRS) at the vast majority of coal power plants of the Russian Federation. Besides, there is no station, realizing the 100% of DASRS from all units, ensuring the dry ash extraction. This is the first problem to be solved, because the hydrated fly ash loses its application properties quickly. And ASW consumers use, primarily, the dry fly ash.

There are just a few stations able shipping dry fly ash to user market: "Irkutskzoloprodukt" (Irkutsk Energy), "Omsk TPP-4" and "TPP-5" (TGC-11), Krasnoyarsk TPP-1 and TPP-2 (Siberian Generating Company), Gusinozerskaya SDPP (Inter RAO UES), Reftinskaya SDPP (Enel Russia), TPP-22 (Mosenergo), Kashirskaya SDPP, Novocherkasskaya SDPP, Ryazanskaya SDPP, etc.

Were the ones to come down to creation of dry ash and slag removal at Reftinskaya SDPP the most productive way. Why it is so? First, it is the largest coal power plant in the Russian Federation, the annual ASW production rate of which is about 5.5 million tons. So, if it will continue working using the existing hydro ash and slag removal system (HASRS), then the capacity of ash dumps will be enough to run the power plant only until 2016. Second, the owner of the power plant in 2008 was the Italian energy concern "Enel", which, having an experience in solving similar problems in the European coal-fired plants, has quickly began to implement the HASRS system project, developed by one of the Russian Engineering companies.

There was built a system priced at about 10.2 billion rubles, focused on storage optimization and not on optimizing the realization of dry ash extraction, but giving an opportunity to work using the existing ash dumps (according to engineers' estimates) up to 2040. The point of the system is a sharp (tenfold) decrease of water consumption used for ash and slag waste transportation to the ash dumps. The new system uses up to 30% of water by ASW weight, so that ASW would not

produce dust during its removal to ash dump with closed conveyor. Since the volume of the pulp, leaving the station, is reduced to the corresponding number of times and, therefore, the existing ash dump continues performing its function above the specified time. However, it turned out that the problems of ash dusting at the ash dump upon the natural water evaporation, if the ash has a low CaO content (less than 10%) and belongs to the category of chemical acids (GOST 25818-91) have not been solved. By the way, the design engineers base their calculations on the fact that up to 1.5 million tons of fly ash will be sold annually. But we believe that the existing system of Reftinskaya SDPP allows selling will no more than 500 - 600 thousand tons, although this is progress, because to date this station sells no more than 200 tons per year. The switch to the new HASR system is very slow and difficult. So, if the commissioning of the system is planned for the end of 2012, most likely it won't be done until the spring of 2014.

The second station, which plans to switch to HASR system is Berezovskaya SDPP (Sharypovo, Krasnoyarsk Territory), the German energy concern «E.ON». It is noteworthy that in both cases the owners are foreign companies that do not mentally imagine another ash removal system at their stations. In November 2012, the project has undergone the state examination. Familiarization with this project brought us to the conclusion that it is focused on the storage optimization of the existing ash dump. A study of consumer properties of fly ash of that station was conducted unprofessionally. It resulted in a conclusion that the ash is not suitable for use in national economy, and therefore it is necessary simply to store it, avoiding distraction from the main station tasks. Moreover, the patents were ignored (No. 2077516 dd. 08.09.1994), developed in the 90s and describing the production of non-clinker binder based on high-lime ash of Berezovskaya SDPP and local limestone raw materials. Experience of our company, supplying shale ash to Russia for 4 years already, which, according to industrial standard (GOST 34-70-542-2001), resembles the ash of Berezovskaya SDPP, suggests that there is a possibility of successful ash sales from this station. As a result of the project will be implemented, where all kinds of ash (cyclone, different electrofilter fields, bag filters) will be mixed in 2 silos with capacity of 3.5 million tons, and it will cause the mutual destruction of consumer properties of various types of fly ash and, as a result, marketing problems, as the cost of goods will fall sharply because of the reduced applicable scope of this ash and slag mixture. In June 2013, this technology has already been implemented at Reftinskaya SDPP, where all kinds of fly ash and slag are mixed in 2 silos of 22 tons. As a result, even the traditional ASW consumers have serious problems with the use of such ash, as there happened to be an admixture of slag, surface area of ash fell sharply, chemical composition has changed and the volume of ASW sales of Reftinskaya SDPP didn't exceed 190 thousand tons in 2013.

Switch to DASRS at other stations is very slow and erratic. Besides, there are no design solutions, ensuring the successful implementation of ASW.

### 3. WHO NEEDS A DECISION ON ASH AND SLAG WASTE USE PROBLEMS?

- Coal generation owners

Today, the situation with TPP ash dumps in Russia is critical. The ash dumps of approximately 110 of the 172 major stations have exhausted their capacity to receive ASW. The operating term of remaining stations does not to exceed 10 years. Construction of new ash disposals is costly, and the local authorities have started to actively resist it. Therefore, the power industry has no other way but to switch to DASRS. If, in this case, one will design a system focusing on 100% sales, rather than ASW storage optimization on the ash dump, it will both prolong the station's operation time, and increase its efficiency. According to the estimation of our experts, solving the ASW problem will increase the power plant profitability by 1.3-1.5 times.

- Citizens of the country

For people living in the areas of advanced coal power, the problem of ASW is the question of ecology normal habitat. Here is an excerpt from the book of one of the leading Russian ASW experts Zyryanova V.V.: "One can quote from Adeeva's dissertation only about one geographic area - the Omsk Region. When combusting the Ekibastuzsky coal, there is produced about 1860 thousand tons of ASW per year (data as of 2000) (1600 thousand tons as of 2012), which amounts to 80% of all solid waste. Omsk air pollution level is rated as very high. Total emissions of pollutants to the atmosphere makes 554 thousand tons. Power plants contribution is 50%. Purification efficiency of exhaust gases from the solids is 96.6%. Purification of waste gases from CO, sulfur and nitrogen oxides is not performed. Morbidity of the population older than 14 years due to disorders of endocrine system, immunity and metabolism has increased by 1.9 times. The growth of oncological diseases made 35%, while the average percentage for Russia during the same period is 13%, the number of respiratory diseases made 65-70%, coronary heart disease - 65-70%, blood diseases - 60-61%, etc. The situation in many cities, which burns a lot of coal, especially the ones with high ash content, doesn't differ from Omsk much - this example is simply a good presentation of available research results in this particular region. Ecological situation in Kuzbass, Krasnoyarsk, Chelyabinsk and other cities of Russia, where the active coal is burned, is no better". [1] To sum up, we can conclude that for the citizens the solution of ASW, is, above all things, a question of a healthy life.

- The country

Studying the issue of worldwide coal power industry development trends, one cannot ignore the following facts:

- For more than 30 years no nuclear power stations have been built United States. Emphasis is made on coal-fired power industry;

- Germany has declared off the nuclear energy development and is planning to close the existing plants. This decision was preceded by the creation of the environmentally friendly coal power plant project, which caused an engineering and construction of 5300 MW coal-fired generation plant.

The issue of ASW and exhaust gas purification is a condition that, on the basis of coal and shale rock resources of the Russian Federation, will give our country a chance to get a cheap and environmentally friendly energy. We should not forget that mankind has little experience in storing the nuclear waste, and hydrogen technologies, even according to official schedule, should take effect at the end of the XXI century.

At the turn of 80-90s in the USSR there were already established the technologies to design and build an environmentally safe coal power plant. There were attempts to implement the technology for purification of waste gases from sulfur and nitrogen oxides through electron-beam method on Cherepetskaya SDPP and TPP-15 in St. Petersburg. It failed due to the lack of government funding during complicated 90s. This technology allows transforming sulfur dioxide into ammonium sulfate, and nitric oxide into ammonium nitrate, ensuring the purification of up to 99% waste gases. Thus, modern coal-fired power plant can produce not only electricity and heat, but also ASM construction materials (ash and slag materials) and a great fertilizer. In this case, the efficiency of the energy business on such a power plant can increase by 1.8-2.0 times already.

By implementing this technology and basing upon the achievements of Soviet and Russian science, best global practices, the Russian Federation has a chance to make a breakthrough and become a leader in global power industry.

- Coal suppliers

Representatives of this branch of industry should be primarily interested in solving the ASW problem, because it is a real stumbling block on the way of coal-fired power industry development, which affects the increase in coal sales on RF domestic market.

- Manufacturers of construction materials

Ash solves an important task for manufacturers of construction materials - it reduces cement content in concrete system and thus improves the concrete properties such as strength, frost resistance, water resistance, acid and sulphate resistance, flexibility, and, moreover, reduces the net cost of concrete and mortar. This way the consumer's dream becomes true - cost saving while improving quality.

Having studied the modern western concrete handling experience, we can say that almost no regular, and even special concrete mix can't go without the use of 20-30%, and sometimes 70% cement replacement with fly ash. A regular concrete is usually mixed with ash for saving, and a special one - for special properties. Sometimes you can hear the statements that Russia has no market for ASM. An elementary calculation shows that at the average European cement replacement in concrete system equal to 25% of the market share for ASM

in the Russian Federation, only in this direction makes 17-19 million tons (in 2012 there was about 70 million tons of cement used in the Russian Federation). And there is still recultivation, landscaping projects, road construction, soil stabilization, agriculture and other areas.

- Local authorities

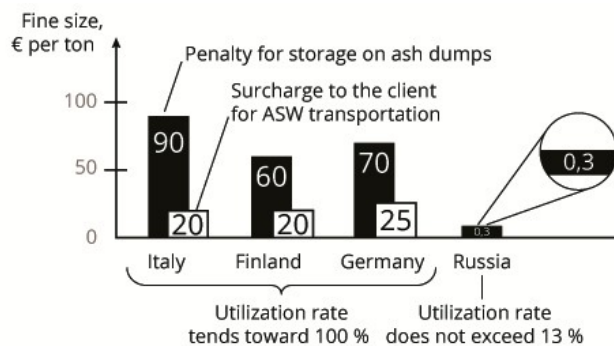
Officials may return to the land turnover about 28,000 ha of land occupied by ash dumps today. As far as many electrical and thermal power plants were built in 50-80th, sometimes these ash and slag dumps are located within the city boundaries. Solving the ASW issue will greatly enhance the ecology of life on this territories, which is indispensable for the development and welfare of residents.

Despite the fact that a lot of people need to solve this problem, measures directed towards its resolution are not taken. This is due to the fact that this problem has both historical and technological background. It so happened that in the USSR no one ever paid systematic attention to this issue, and today's coal-fired generation plants inherited what they have got. However, during the last 5-6 years, the development of economic affairs and the growth of environmental culture within the state and society has, finally, risen the interest in problem. There are certain issues in regard to the technical part of the problem, and they are due to the fact that non of DASRS projects has been implemented in the territory of Russia. The specialized designing structures lack the experience to address this problem effectively.

#### 4. WHAT TO DO?

This question in respect to ASW problem already has a solution generated in Western Europe. About 15-20 years ago, the situation in Western Europe was similar to ours.

To solve the problem the scheme of environmental fines was simplified. When transporting a ton of ASW to ash disposal site, one had to pay from 60 Euro (Finland) to 90 Euro (Italy) (Fig. 2). When disposing of ASW (recultivation, landscaping, selling to consumers) no fee applies. At the same the hazard class of ASW does not matter.



As a result, first energy industries began to pay consumers up to 30% of these fines for each acquired ton, which proved to be beneficial. Consumers solved the market issues all by themselves. This helped only par-

tially, since the furnace yielded the product with different chemical and physical properties. Then the electric power and thermal power plants started mass construction of DASRS. A new manufacturing process was introduced on the stations - the production of ash and slag materials. Namely the material, because yesterday's ASW have obtained stable properties. This resulted in a very important side effect. Impossibility of ASM production with stable properties from coal with constantly changing characteristics, i.e. that didn't pass the quality coal preparation (beneficiation, blending), led to an increase in technological discipline and efficiency of the plants themselves, the emergence of stable regimes of coal burning, focused on, without limitation, the target values of fly ash. In Germany, power-generating unit undergoes certification for ash production (!). Quality of ASM and quantity of its sales began to determine the effectiveness of technology and station management.

Russia has laws mainly corresponding to European Union canons, for example, the Decree of the Government of RF dd. 12.06.2003 No. 344. "On norms of payments for emissions into the atmospheric air by stationary and mobile sources, discharge of pollutants into surface and underground water bodies, disposal of industrial and consumer waste." But this law did not solve its main task - to reduce emissions of waste and increase their recycling. It is imperative to improve this decree, because it is made in a way that makes it possible to reduce the fee for waste disposal to the level that is almost imperceptible to the economy of enterprises, generating such waste.

Apart from introducing fines, there was determined a deadline to stop the operation of ash and slag dumps (5-7 years since the launch of the new penalty system). Otherwise, the station was closed. As a result, today Czech Republic and Poland sells up to 70% of ASM. Western European countries utilization makes 100% and it resulted in virtually no ash dumps. Of course, this process took a certain degree of political will and the processes dictated by the development of market and environmental relations in these countries, but a powerful boost to solving the ASW problems was due to the new system of penalties for ash emission to the ash dumps.

#### 5. THE SITUATION CONNECTED WITH ASH AND SLAG WASTE USE IN RUSSIA

Since 2008, in the Russian Federation the dynamics in solving ASW problems is observed. Its bright representatives are professionals such as Kozhukhovskiy I.S. ("EFA" CJSC), Putilov V.Ya. (MPEI), Zyryanov V.V. ("NPF Nanopowder Technologies" LLC), Vishnya B.L. (ECAR of the Urals), Tselykovsky Yu.K. (All-Russian Thermal Engineering institute), Shevtsov R.V. (TGC-11), etc.

In June 10-11 of 2008, in Novosibirsk, with the assistance of the Presidential Representative of the RF in the Siberian Federal District, "EFA" CJSC, "Siberian Agreement" MA, the all-Russian meeting on processing and use of ASM ashes from thermal power stations took place, where the problem was discussed, the gained ex-



perience was summarized, and the solution vector for this problem was formed. Practice of holding such forums adopted by Moscow Power Engineering Institute, where the Director of Information and Analytical Center "Ecology of Power Engineering" Putilov V.Ya., Ph.D., was the initiator of the movement. The 4 International research and practice workshops have already took place and the preparation for the fifth in conference format is in progress, which is planned for April 2014. Our company is the General sponsor of this conference.

In December 2012, EFA, "Siberian Generating Company" LLC and "Vostok" LLC have registered the "National Association of manufacturers and consumers of ASM" which has become a real "platform" for market participants communication among themselves and the government. Association is developing, the new members enter into it, and there is a communication with the Ministries of the Russian Federation and its legislative bodies.

Analyzing the documents of these activities, one can't fail to notice a one important fact. The speakers talk about ASW as a ready, but unclaimed product. In our opinion, it is the main mistake. The product has not been created yet. And this is the responsibility of power engineers. One cannot blame the consumer that he does not buy the product if the seller does not have it.

Goods are the product that corresponds, primarily, to 2 key conditions: it has stable properties specified by various standards, it must be steadily present on the market and available for consumers. Only upon the realization of these two fundamental conditions, one can place reliance upon successful sales. The fact is that the existing standards suggest a monitoring of ASM manufacturing process on the station that requires systematic screening and analysis of a large number of samples with respect to a single station unit. It means that the station must be equipped with a special laboratory, sampling devices, the daily monitoring of ash quality and administration of factors that affect its stability should be carried out. None of the RF coal stations is equipped with such a complex.

## 6. "PHOENIX" CONSORTIUM

In order to solve the ASW problems, in March 5, 2013 the international "Phoenix" consortium was created ([ksfenix.ru](http://ksfenix.ru)), ([ksfenix.ru](http://ksfenix.ru)), comprised of: "Giprocement" OJSC (St. Petersburg, Russia) - the oldest institute of cement industry of the Russian Federation, Group E-4 (RF) - the largest power engineering company in Russia, the "Renaissance Construction" Company (Turkey, Russia) - the largest privately owned construction company in Russia, "SM Pro" LLC (Moscow, Russia) - the leading analyst firm of construction materials market in the Russian Federation, the "IBAU HAMBURG" Company (Germany) - the Europe's leading company dealing with pneumatic conveying and silo equipment, "ProfCement-Vektor" CJSC (St. Petersburg, Russia) - the market participant of Russian ASW since 2009. The leader consortium became "PCV" JSC. The synergistic effect of professionalism

and expertise has enabled the consortium members to bring a new product to the Russian market - a comprehensive ASM recycling "Phoenix" system. We have studied and summarized the facts needed to solve the ASW problems at specific power plant and have included the following into "Phoenix" system:

1. Full research of ASW station for 12 months to identify the major, including seasonal, factors affecting the stability of chemical and physical characteristics of ASW. Research of possible use cases of ASW in the production of construction materials, soil stabilization, agriculture and other areas. Development of recommendations for use for the consumers. Creation and description of quality monitoring system of fly ash at a given station. Certification of ash and slag materials. Creating an enterprise standard on ASM production. Creating a draft specification for DASRS engineering;
2. DASRS engineering;
3. Construction of DASRS;
4. Ash and slag materials marketing operations in the radius of up to 1000 km from the station.

All services are performed by great professionals, which have long been known as market participants. The composition of the consortium is not accidental.

The presence of cement market specialists was dictated by the fact that ASM pretends, primarily, to be the substitution of the cement in the concrete system. In addition, the cement industry of the Russian Federation is now actively invaded by new technologies that can be successfully implemented in electric power plants, for example, sectional silos to store various types of ash in one silo and many other things, that have already been tested and used by the consortium members.

Group E-4 is able to provide the harmonious integration of DASRS to the infrastructure of operating electric power plant taking its technological features into account.

"SM Pro" Company cooperates with the leading banks of the Russian Federation concerning the analysis of construction materials market in Russia, and can create an adequate business plan that meets all bank and business standards.

The "Renaissance Construction" Holding is acknowledged to be a highly professional construction structure, using the latest construction technologies and implementing the most complex objects in Russia. It is also accredited for the construction of nuclear power stations by Rosatom system.

The "IBAU HAMBURG" Company is on the global market for 38 years already, and during that time it has equipped the tens of cement plants all over the world and electric power plants in Europe with silos and pneumatic conveying equipment, which are the essential part of DASRS.

The "PCV" CJSC successfully sells ASM in Russia, has developed a system of research and application of fly ash, and can arrange sales and distribution of ASM from particular station.

We are confident that our system will be oriented exactly to 100% ASM sales, rather than to optimizing the ASW storage at existing dumps. The consortium is

able to build DASRS in 27-29 months since the beginning of research. Thus, the owners of coal-fired generation receive a comprehensive service to address the ASW problem.

In November 2012, with the support of «ALITinform», the Consortium has held a roundtable “ASW Market in Russia”, which was attended by about 50 participants from Russia and Europe [2]. Moreover, the “Phoenix” has the following asset: a program on research phase for Nazarovskaya SDPP, participation in tender for Barnaul TPP-3, negotiations on cooperation with Omsk TPP-4 and TPP-5, studies of fly ash of Reftinskaya and Gusinozerskaya SDPP and Krasnoyarsk TPPs. Participation in designing of new Khabarovsk TPP-4.

## CONCLUSIONS

1. The state should tighten and simultaneously simplify the environmental legislation of the Russian Federation to create incentives for power engineers to solve the ASW problem. The best platform to identify the key regulatory decisions on ASM turnover in the Russian Federation and the development of legislative recommendations can become a "National Association of Manufacturers and Consumers of ASM";
2. The members of electric power industry should see the benefit in shifting from their stations to DASRS, oriented 100% sales of ASM, and start their active construction.

3. It is necessary to fully explore and use the experience of the countries that have either already decided (Western Europe, Poland) or successfully solve (India, China) the ASW problem, increasingly attracting the ASM professionals.

4. To create a state program that would stimulate both the members of power industry, and the market to actively use ASM in the national economy.

It is impossible to include everything into one review. This issue is very complex and crosscutting. It requires a close attention of the government and the development of suggestions by the professional community of the country. However, this process is gathering its pace, and Russia, no doubt, will be able to solve the ASW problem in the next 7-10 years.

## REFERENCES

1. **Зырянов В.В.** Зола уноса-техногенное сырье. М.: НПЦ «Маска», 2009. С.211-212.
2. **Круглый стол** «Использование золошлаковых отходов тепловых электростанций при производстве цемента и бетона» // Международное аналитическое обозрение «ALITinform: Цемент. Бетон. Сухие смеси», 2013, №1(28). С. 64-67.

**A.I. Kalachev.** The ash and slag waste market of Russia through the eyes of trader. Phoenix consortium // Proceedings of the V Conference “Ashes from TPPs: removal, transport, processing, storage”, Moscow, April 24–25, 2014 — М.: MPEI Printing House, 2014. P. 137 – 142.