Oil Shale, 2003, Vol. 20, No. 3 SPECIAL
pp. 375-382
ISSN 0208-189X

https://doi.org/10.3176/oil.2003.3S.11

REDUCING THE ENVIRONMENTAL IMPACT OF BALTIC POWER PLANT ASH FIELDS

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Ash fields of Estonian oil-shale-fired power plants, especially ash hydro-transport system with its large amounts of high-alkaline waters, may cause great damage to the environment. The situation is particularly bad at the Baltic Power Plant whose ash fields and sediment ponds occupy more than ten square kilometers. The samples taken from the 2nd ash field were studied to determine their structure, pressure resistance and water filtration ability. Ash field material has a stratified structure, all layers contain $Ca(OH)_2$ *which, contacting with water, makes the latter highly alkaline. According to preliminary calculations, the ash field material binds only 10–20 % of* CO_2 *emitted at oil shale burning. Disconnection of the 2nd ash field from the ash field water-sluicing system would be the first and most practical way to reduce the amount of water to be added to the water system of ash fields.* $Ca(OH)_2$ *content of ash field material must be considered when making the projects for the 2nd ash field recultivation.*

Initial Data

When speaking about environmental impact of oil-shale power plants, one of the main questions is the problem of ash fields. The oil-shale ash from the power plants boilers as such is not toxic to nature, a fact proved by numerous studies and plant cover of the ash fields (Fig. 1).

The certificate [1] given to *Narva Power Plants* Ltd. by the Inspection Centre of the Plant Material of the Estonian Republic confirms officially that the oil-shale ash as fertilizer meets the quality and safety requirements established by the Estonian law about using fertilizers. Therefore alkaline oil-shale ash could be used for fertilising fields and reducing soil acidity.

The main cause of environmental impact of ash fields is the highly alkaline ash-transporting water used at present in the ash-handling system of power plants. The composition of this circulating water forms in the long run due to repeated contact with ash. Although the ions detected in that ash water are mainly the same as those occurring in the nature, high pH (12-13) makes this water environmentally hazardous.

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Fig. 1. The slope of the ash field of the Baltic Power Plant (BPP), October 31, 2001

Though the water used in the ash-handling system circulates, and in normal circumstances does not get out of the system, there is always a possibility that in the case of system leak large amounts of leaking high-alkaline water may bring about tremendous environmental pollution.

Sediment ponds (Fig. 2) of the oil-shale power plant ash fields (where the water is collected before its reuse) contain huge amounts of water, up to millions of cubic metres. Despite the facts that the ash when stored binds water (~0.6-0.7 cubic metres per ton of ash), and that at the same time evaporation takes place, it may happen that the amount of water in sediment ponds increases to the extent that it would be absolutely necessary to let the excessive water flow into the Narva River.

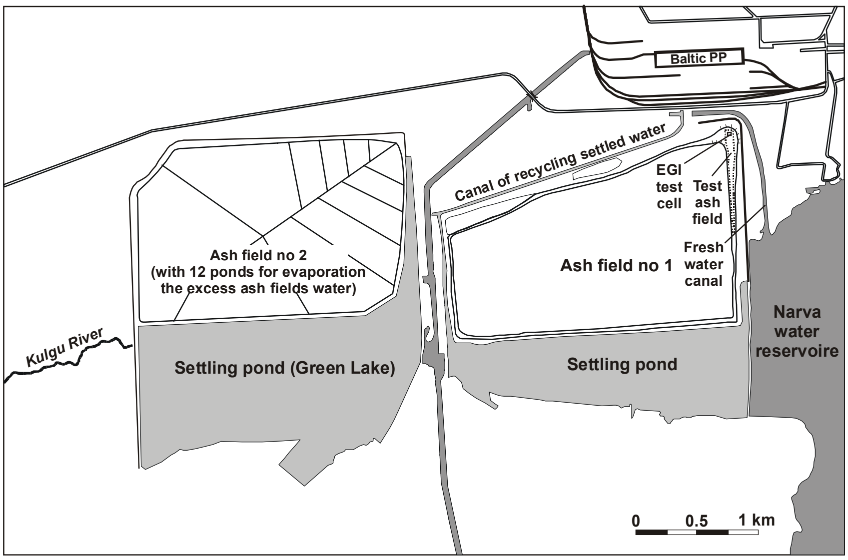

Fig. 2. Scheme of BPP ash fields and setting ponds placement

The above act always requires special permission and is heavily charged. The BPP has had a lot of problems with the excess water. The increase in water amount is usually caused by precipitation (rain, snow), and is therefore highly dependent on weather conditions (Fig. 3). The BPP has yearly let about 0–2 million cubic metres of water from its sediment ponds to the Narva River. In order to characterise the amount of precipitation falling on the ash fields, computational data on the BPP were used.

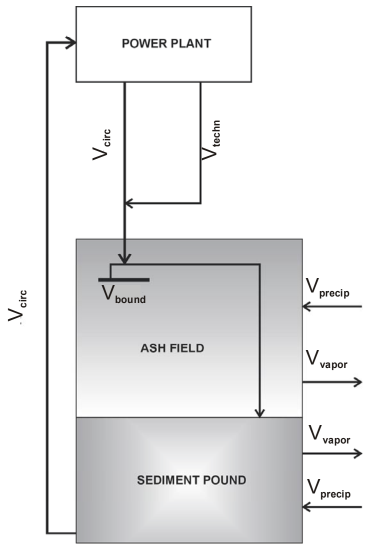

Fig. 3. The water added to or removed from the ash fields (schematic diagram):
V_{circ} – the water used for ash handling, which is together with the ash returned to the ash field;
V_{techn} – water given to the ash fields through different technological proceedings (e.g. chemical treatment) and other sewage;
V_{bound} – the water bound to ash;
V_{precip} – water fallen to the fields in the form of precipitation;
V_{vapor} – water evaporated from the ash fields, sediment pound system and ash-handling system

Proceeding from the long-term data given in the Estonian Encyclopaedia on the average precipitation in the town of Narva (584 mm/year) one can calculate that in the area of the ash fields and sediment ponds of the BPP (~10.65 square kilometres) the average amount of precipitation water falling to the ash fields is about 6.2 million cubic metres per year. Interestingly enough, the Estonian Power Plant where the areas of ash field and sediment ponds are smaller (in total ~8.1 square kilometres), and the amount of ash bound by water is more than twice larger, has had no problems with excess water.

The given scheme demonstrates that in order to minimize the environmental hazardousness of the ash fields the amount of water added to the system of ash fields is to be decreased. It would be wise to start to use the ash-handling systems, which use less water. As already said, the excess water in ash fields is mostly the problem of the BPP, and therefore this paper deals with the experience gained there.

Reducing Environmental Impact of BPP Ash Fields with the Help of Dense Slurry Technology

To reduce the amount of excess water one can either minimize the area of ash fields and sediment pounds or increase the amount of water to bind stored ash. The Hungarian company EGI offered the BPP both of these possibilities. They suggested the technology of dense slurry that according to their idea had to:

1. Cover the ash field surface with an even and non-soluble layer of ash stone. As the precipitation falling on that kind of surface will not be contaminated with mineral salts, precipitation water may be let straight to the nature, not to sediment ponds (their area will be reduced)
2. Guarantee that the water that is used for ash handling will be bound with ash stone which will, in turn, result in reducing the amount of water in the ash field water system and eventually, together with the possibility given in the previous paragraph, will in the long run enable to empty sediment ponds

In addition, this technology would help to reduce the amount of water needed for ash handling as the planned ash and water ratio in the slurry is 1 : 1, compared to the amount of water 10–20 cubic metres per ton of ash in the present hydro-ash-removal system. As the suggestion seemed enticing, a contract was concluded to install a test facility to prepare dense slurry, and to set up a small test ash field (Fig. 4) and test cartridge in the 1st ash field of the BPP in order to carry out additional research work.

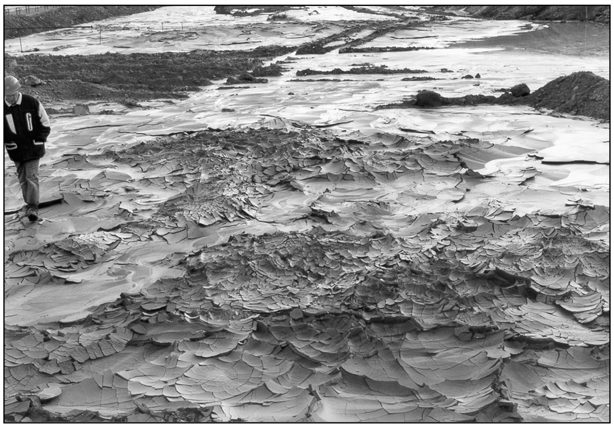

Fig. 4. The surface of the test ash field of the BPP, Oct 19, 2000

However, the further laboratory analysis of drilling samples taken from the ash fields as well as visual observation of test ash fields showed that the expectations to make ash fields environmentally friendly through this new technology will not be realised. The ash in the ash field did not form an even and firm layer due to large amounts of free lime that, reacting with water, produces heat. As lime slaking is a long process, it did not end in the slurry-making unit passing on in the ash field elevating the temperature and causing uneven bulging and cracking of the stored ash layer.

Worst of all, diffusion of the slurry on the ash field surface was so unsatisfactory that the bulldozers were used to even the surface, which in turn destroyed it. The test samples of water taken from the ash fields were far from pure, and contained, as the leaching tests showed, even more than 2 % components leachable by water. And finally – the water-binding ability of the ash stone did not surpass the water-binding ability of the hydro ash removal (0.6–0.7 m^3/ton). The comparison of the samples taken from the test field and the ordinary ash field showed that they did not differ much in both their composition and quality.

Therefore the expectations to reduce the amount of excess water or to empty the sediment ponds turned out to be unrealistic. That was the reason why the BPP decided to give up the idea of using dense slurry technology in ash handling.

About the Possibility to Reduce Ash Field Areas

When speaking about reducing the precipitation area of the BPP ash field, first of all taking disconnection and recultivation of the 2nd ash field is considered. While the 2nd ash field has not been in use for storing ash for a long time, its disconnection from the present system does not need much rearrangement. At present the 2nd ash field is used to evaporate the excess ash field water (Fig. 5). That is why twelve evaporation ponds equipped with sprinkling devices and separated from each other by dams have been formed in the ash field. Alkaline water (pH = 10–12) is pumped from there to the water-system of ash fields.

It has still been impossible to avoid additional excess water completely, and apparently it would be wise to start recultivation of the 2nd ash field in the nearest future. That would avoid the pollution of precipitation with water-soluble ash components and would enable to separate that water from the present water system and let it out to the nature.

It is worth mentioning that before founding evaporation ponds, the area of the 2nd ash field had partially covered itself with different flora, mostly with birch brush. It confirms once more that the ash fields, which have not

Fig. 5. The excess water evaporation system (sprinkling devices) in the 2nd ash field of the BPP

been in use for a long time, are not too toxic to the nature. That allows to assume that water-soluble chemical compounds (chlorines and sulphates of alkaline metals and free CaO), initially present in ash, have mostly been leached and carried away from the ash field with precipitation water. This suggests that the surface of ash fields that has had no contact with fresh ash for a long time has become considerably inert, less water-soluble or possibly not soluble at all.

What would disconnection of the 2nd ash field from the general ash field water system give us? The area of the 2nd ash field (~4.09 km^2 without sediment pond) makes up about 38 % of the total (10.65 km^2) area of the BPP ash fields and sediment ponds. When the 2nd ash field will be disconnected from the whole system of precipitation collection, the amount of additional precipitation water, considering the share of that area, would decrease by 38 %, or more than $2 \cdot 10^6$ m^3/year. The absolute decrease would depend on weather conditions (more in rainy, less in dry weather). As the annual amount of the additional excess water in the BPP is 0–$2 \cdot 10^6$ cubic metres, the decrease by such an amount of water means that the water balance in the ash fields will become negative and that will enable to empty the sediment ponds during plant operation, which, in turn, will create preconditions for recultivation of sediment ponds in the future.

About the Situation in the 2nd Ash Field

In order to learn the situation in the 2nd ash field and get necessary data to work out a recultivation program, a special research was carried out during which some drilling samples were taken to determine their chemical and mineralogical composition, water-solubility, pressure resistance and filtration module. (Besides the Department of Thermal Engineering of TTU, the labs of the Estonian Geology Centre, Estonian Environment Research Centre and Material Research Centre of TTU were asked to participate in carrying out the analyses). As the drilling samples were not taken all over the ash field, the results are approximate and give only a very general estimate on the state of the ash field.

The main conclusions made on the basis of the research characterize the situation of the BPP 2nd ash field as follows:

1. The ash field is of stratal structure. The density, strength and composition of layers may differ to a great extent. There are no certain tendencies in composition and quality of layers depending on the depth. It is probably caused by the fact that the composition and quality of ash layers depend on the conditions of separation of ash particles, which were prevailing in the flowing slurry during the formation of the ash layer (which ash fractions subsided at the given place) and by the composition of the ash in the slurry. When the flowing conditions of ash slurry in the ash fields change, the composition and quality of ash layers will change as well.

2. The density and strength of ash layers depend on the characteristics of ash fractions forming them. Fine-grained ash whose binding properties are considerably better than those of coarse-grained ash fractions, form thick, firm and nearly impermeable layers, while the ash layers formed from coarse-grained ash fractions are gravelly and weather rather easily.
3. Laboratory tests on strength of the drilling samples taken from dense hard ash layers showed that their pressure resistance (between 2.4 and 10.3 MPa), more or less matches the pressure resistance of sandstone, most widespread in Estonia (1–10 MPa basing on data of Geology Centre lab).
4. Water-permeability tests of the above-mentioned drilling samples showed that the filtration module of such thick and hard ash layers ranges from $0.15 \cdot 10^{-9}$ to $16.1 \cdot 10^{-9}$ m/sec, i.e. the layers belong either to water-permeable or impermeable ash layers [2, 3]. Observation of the samples showed that there are many thicker or thinner, practically impermeable ash layers in the ash fields. Unfortunately these facts do not enable to draw conclusions about the ash field permeability as the whole because of the small number of drilling samples not covering the whole area.
5. Speaking about the chemical and mineralogical composition of the ash field material, it was not possible to elicit any regularity in its chemical or mineralogical composition depending on the depth of taking the samples. The occurring differences are very irregular. Obviously it is caused by the reasons pointed in 1.
6. The fact that all the drilling samples, without exception and independent of where and how deep they were taken in the ash field, contained $Ca(OH)_2$ deserves particular attention. It shows that a large amount of initially free lime of CaO has reacted only with water, and the ash field material contains, in spite of the decades long storing time, a lot of a strongly alkaline compound. Content of $Ca(OH)_2$ in the samples examined ranged from 4.18–14.27 %, and the content of $Ca(OH)_2$ in the 1st and 2nd ash fields was more or less the same. This could probably be caused by the fact that the contact between air (and of course with its CO_2) and ash during its storing in the ash field is hindered due to the water flowing on the ash surface, and the ash layers remain under new ones before CaO has had a possibility to fully react with CO_2.
7. As shown by the leaching tests of the drilling samples carried out at the ash : water ratio of 1 : 5, the material of the 2nd ash field contained up to 2 % (in some samples 0.43–1.92 %) water-soluble substance. The water solution obtained after leaching was strongly alkaline (pH mostly 12). It is caused by the water-soluble $Ca(OH)_2$ present in the ash field material. As the samples contained different amounts of $Ca(OH)_2$ and leaching substance then it is obvious that due to the high pH of the water solution the insoluble $Ca(OH)_2$ could not dissolve completely in leaching tests. In order to get a full picture of how contamination occurs and for how long time the ash field material can influence e.g. precipitation water, further research work is to be carried out.

Conclusions

The following conclusions can be drawn summing the discussed ideas about reducing environmental impact of the BPP ash fields:

1. The use of dense slurry technology of ash handling in our oil shale power plants suggested by the Hungarian company EGI did not give the desired results. The formation of non-quality ash stone coating layers, bad flowing properties of the dense slurry on the surface of ash fields, and the fact that the water-binding ability of the ash stone did not exceed the water-binding ability of stored ash when the usual method of hydro ash removal is used were the main reasons.
2. Disconnection of the 2nd ash field from the whole ash field water system and field recultivation would be the first and most practical way to reduce the amount of water added to this system.
3. The 2nd ash field recultivation project has to take into account the fact that the ash field material contains a lot of alkaline $Ca(OH)_2$ which, when contacting with water, can pollute it. That is why it would be better to cover the ash field.
4. Considering that ash field consists of dense and strong layers of ash, one can assume that the inner layers are not in a good contact with the precipitation water falling on ash fields, and their influence on the precipitation water from the point of view of pollution will be minimal.
5. In addition to the direct laboratory research, calculations were carried out to determine the amount of CO_2 bound by the ash fields. The calculation was based on the amounts of oil shale ash produced by power plants interim 1981–1995, its content of carbonate CO_2, the share of the stored ash in its total amount, and CO_2 content of the drilling samples. The calculation showed that the ash stored in the ash fields binds about 10–20 % of the CO_2 produced at carbonates' decomposition in the furnace at burning and thereafter emitted into the atmosphere.

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