

## **Workshop on Environmental and Health Aspects of Coal Ash Utilization**

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### **Coal ash utilisation over the world and in Europe**

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#### **1. Introduction**

Coal combustion products (CCPs) are formed with the production of electricity in coal-fired power plants all over the world. The production of these CCPs is increasing worldwide by the higher demand for electricity due to growing population and economic development. In Europe, the production has been increased additionally by legal requirements for flue gas cleaning. The utilisation of CCPs is well established in some countries of the world, based on long term experience and technical as well as environmental benefits.

CCPs include combustion residues such as boiler slag, bottom ash and fly ash from different types of boilers as well as desulphurisation products like spray dry absorption product and FGD gypsum. The CCPs are mainly utilised in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mines. The majority of the CCPs are produced to meet certain requirements of standards or other specifications with respect to utilisation in certain areas. Due to different boundary conditions regarding climate, taxes and legislation the utilisation rate of CCPs is different across European countries and worldwide.

#### **2. Production of CCPs**

The first report on “Worldwide production of coal ash and utilization in concrete and other products” was published by Oscar Manz in Fuel in 1997 dealing with data collected in 1992. By this, the total production of fly ash and bottom ash totals 459 million tonnes. In 1992, China had the largest production followed by Russia and the US. Updated estimates by W. vom Berg in 2001 figures 480 million tonnes in total, listing China with an estimated production of 100 million tonnes, North America with 83 million tonnes, India with 80 million tonnes, Europe with about 90 million tonnes, Russia with 50 million tonnes, South Africa with 30 million tonnes, Japan with 8 million tonnes and about 39 million tonnes for other countries.

With new figures also on FGD gypsum in the world the total amount of CCPs will be much higher. The next updated statistics on production of CCPs will be set up by the newly formed Worldwide CCPs Network, a coalition of international ash organizations interested in information exchange concerning management and use of CCPs.

Since its foundation in 1990 ECOBA is carrying out an annual survey on production and utilization of CCPs by their European members. The statistics on production and utilisation of CCPs reflect the typical combustion products fly ash (FA), bottom ash (BA), boiler slag (BS) and fluidized bed combustion (FBC) ashes as well as the products from dry or wet flue gas desulphurisation, especially spray dry absorption (SDA) product and flue gas desulphurisation (FGD) gypsum. In the European Union of the EU 15 the production was about 65 million tonnes in 2003. Almost 68 % of the total CCPs is produced as fly ash. All combustion residues amount up to 81.9 % and the FGD residues up to 18.1 % by mass.

In the larger EU of 25 member states the total production is estimated to be about 95 million tonnes. Exact figures from the new member states are not available, yet.

### **3. Utilisation of CCPs**

CCPs are mainly utilised in the large volume building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes of open cast mines. Manz reported in 1997 that *“worldwide the major use of coal ash is in concrete, which exceeds any other single application”*. Furthermore, *“The state of the art is well established with respect to coal ash as a cement raw material, for use in blended cement and as a partial replacement for cement.”*

Based on updated single country or continent statistics the use of CCPs has increased by the years. Based on the “2004 Coal Combustion Products Production and Use Survey” prepared by ACAA CCP utilisation is estimated at 49.1 million tonnes, which is a 40.1 % overall CCP utilization rate. Most important use of fly ash in 2004 was as a substitute for portland cement in concrete products with an estimated amount of 14.1 million tonnes. In total more than 27 million tonnes were used (39 %), in addition to the use in concrete mostly used for structural fills and embankments and waste stabilization and solidification purposes.

The last reported data from Canada (2001) show a 22 % utilisation of fly ash for cement, concrete/grout and mining applications. The cumulative use percentage was 27%. In Australia the total ash production in 2003 was 13 million tonnes. About 2.5 million tonnes were used for cementing applications. Also in Japan about 9.5 million tonnes of coal ashes were produced and about 8.5 million tonnes were beneficially utilized, mostly in the cement industry.

In Europe (EU 15), most of the CCPs produced are used in the construction industry, in civil engineering and as construction materials in underground mining (52.4 %) or for restoration of open cast mines, quarries and pits (35.9 %). In 2003, about 8.0 % was temporarily stockpiled for future utilisation and 3.7 % was disposed of. The utilisation is directly depending on the characteristics of the CCPs, of their quality and especially their homogeneity.

Fly ash obtained by electrostatic or mechanical precipitation of dust like particles from the flue gas represents the greatest proportion of the total CCP production. Depending on the type of coal and the type of boiler siliceous, silico-calcareous or calcareous fly ashes with

pozzolanic and/or latent hydraulic properties are produced throughout Europe. The utilisation of fly ash across European countries is different and is mainly based on national experience and tradition.

In 2003, about 21 million tonnes of fly ash were utilised in the construction industry and in underground mining. Most of the fly ash produced in 2003 was used as concrete addition, in road construction and as a raw material for cement clinker production. Fly ash was also utilised in blended cements, in concrete blocks and for infill (that means filling of voids, mine shafts and subsurface mine workings).

With nearly 70 % of the total amount fly ash is the most important CCP. Approximately 33 % of the total fly ash produced in Europe is used as cement raw material, as constituent in blended cements and as addition for the production of concrete. By this they are a main constituent of the cement or they are replacing a part of the cement necessary for the production of concrete. - As the application as concrete addition covers the highest added value for fly ash the European Standard EN 450 "Fly Ash for Concrete" is particularly important for the marketing of fly ash. The standard was first published in 1994 and the revised standards EN 450-1 und EN 450-2 will be published this year by the National Standardization Bodies in Europe. The standard refers to siliceous fly ash, only. Calcareous fly ash as mostly obtained from the combustion of lignite cannot be utilised as concrete addition according to the EN 450. This fly ash is mostly used for filling of opencast mines.

Bottom ash is produced as granular material and removed from the bottom of dry boilers. Compared to fly ash it is much coarser but also formed during the combustion of coal. In 2003 about 6 million tonnes of bottom ash were produced in Europe (EU 15).

About 2.7 million tonnes of bottom ash were used in the construction industry. Out of this 48 % was used as a fine aggregate in concrete blocks, 33 % in road construction and about 14 % in cement and concrete.

Boiler slag is a vitreous grained material deriving from coal combustion in wet bottom boilers at temperatures of 1500 to 1700 °C. Due to high temperatures in the furnace a part of the minerals in the boiler melts and flows down into a water bath at the bottom of the boiler where it is cooled down rapidly and forms a coarse granular material with a maximum particle diameter of about 8 millimetres. Boiler slag is a glassy environmentally sound material of which about 55 % was used in road construction, e.g. as a drainage layer. Another 26 % was used as blasting grit and smaller amounts as aggregates in concrete and grouts. In 2003, about 2.1 million tonnes of boiler slag were produced in Europe (EU 15). The utilisation rate was 100 %.

Fluidized Bed Combustion (FBC) ash is produced in fluidized bed combustion boilers. The technique combines coal combustion and flue gas desulphurisation in the boiler at combustion temperatures of 800 to 900 °C. By this FBC ash is rich in lime and sulphate.

The amount of FBC ashes produced in Europe (EU 15) was about 1 million tonnes in 2003. Out of this 0.5 million tonnes were utilised in the construction industry and for mining purposes. About 52 % of the total FBC ash was used for infilling purposes, which means filling of enclosed voids, mine shafts and subsurface mine workings. About 13 % was used with the production of pavement base course as foundation material or as drying agent for wet soils and about 11 % was used for structural fill. In 2003, about 29 % of the FBC ash produced had to be disposed of.

In European power plants using spray dry absorption techniques for desulphurisation of the flue gases about 0.5 million tonnes of spray dry absorption product (SDA product) were produced in 2003. The SDA product is a mixture of the following minerals: calcium sulphite hemi-hydrate, calcium sulphate di-hydrate (gypsum), calcium carbonate, calcium hydroxide, calcium chloride and calcium fluoride.

In 2003, nearly 20 % of the total SDA product was utilised in the construction industry and in underground mining, for plant nutrition and as sorbent in wet FGD, 37 % was used for restoration purposes and about 44 % had to be disposed of in disposal sites.

FGD gypsum is produced in the wet flue gas desulphurisation process of coal-fired power plants incorporating the desulphurisation of the flue gas in the power plant and a refining process in the FGD plant including an oxidation process followed by gypsum separation, washing and dewatering. Studies have shown that FGD gypsum has the same properties as gypsum from natural resources regarding health aspects. Based on these results and because of its constant quality FGD gypsum is accepted in the gypsum and cement industry as a direct replacement of gypsum from natural sources. FGD gypsum has to meet the quality specifications of the gypsum industry.

The amount of FGD gypsum produced in Europe (EU 15) was approximately 11.3 million tonnes in 2003. About two thirds of this material were produced in Germany. Nearly 70 % of the total FGD gypsum produced in Europe is utilised in the gypsum and cement industry. In total 14 % of the FGD gypsum produced was temporarily stockpiled as a raw material base for future utilisation, mostly for plasterboard production, and only 0.7 % was disposed of.

FGD gypsum is used as a raw material for a number of gypsum products by the gypsum industry because of its purity and homogeneity compared to natural gypsum. For the production of plaster boards 4.9 million tonnes of FGD gypsum were used in 2003. Other applications include the production of gypsum blocks, projection plasters and self levelling floor screeds.

In the cement industry FGD gypsum is used as set retarder. The total amount of FGD gypsum for this application was about 0.8 million tonnes. To control the set retardation FGD gypsum is often mixed with anhydrite from natural sources in order to take advantage of the different solubility of both minerals.

#### **4. Conclusions**

Worldwide CCPs are produced formed with the production of electricity in coal-fired power plants. The total amount is estimated in 2001 to about 480 million tonnes. Updated figures are not available yet. In Europe (EU 15) about 65 million tonnes of Coal Combustion Products (CCPs) were produced in 2003. The annual production in EU 25 is estimated to amount to about 95 million tonnes. The CCPs include combustion residues such as boiler slag, bottom ash and fly ash from different types of boilers as well as desulphurisation products like spray dry absorption product and FGD gypsum.

Political intentions and legislation are influencing the utilisation of coal combustion products and are very important to power producers. Utilities are forced to utilise increasing amounts of CCPs from power plants. Worldwide the utilisation rate for CCPs ranges from about 20 to more than 80 %, for single CCPs also up to 100 %. In Europe, currently nearly 53 % of the total CCPs are utilised in the construction industry and in underground mining, while nearly 36 % are used for the restoration of open cast mines, quarries and pits. Only 12 % of the total CCPs were temporarily stockpiled (8 %) or had to be disposed of in disposal grounds (4%).

CCPs are mainly utilised in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mining. In the majority of cases CCPs are used as a replacement for natural materials. By this they contribute to sustainable development, because they offer environmental benefits by avoiding the need to quarry or mine natural resources. Therefore, CCPs help to reduce energy demand as well as emissions to atmosphere, for example CO<sub>2</sub>, which results from the manufacturing process of the products which are replaced, and they lead to energy savings when used in mixtures with wet raw materials.