OPPORTUNITIES FOR UTILIZATION OF FLY ASH FROM THERMAL POWER PLANT, REPUBLIC OF MACEDONIA

Tena Sijakova-Ivanova[1], Zoran Panov[2], Vojo Mircovski[3]

[1,2,3]Faculty of Natural and Technical Science, University Goce Delcev, Stip, Republic of Macedonia

tena.ivanova@ugd.edu.mk

zoran.panov@ugd.edu.mk

vojo.mircovski@ugd.edu.mk

ABSTRACT

Fly ash is a potentially important raw material which can be extensively utilized. Numerous studies have been performed in order to find out application areas for the waste fly ash. In all of them highlight the widespread use of fly ash as raw material for production of ceramic tiles, glass industries, as additive in cement construction, in composite materials and sintered material, in acidic spoil and coalrefuse revegetation, as a soil amendment etc.

Every year in Macedonia 900 000 – 1 100 000 t of coal fly ash are produced. Only 10% of coal fly ash is used in cement products which are far below the global utilization. The restis disposed into ash dumps or landfill which is an inconvenient solution both from the environmentaland economical point of view.The use of fly ash contributes to preserve the natural resources and saves environment.

KEY WORDS

Fly ash, environment, waste

INTRODUCTION

The industrial revolution changed the world; it generated the great humanity progress. But, the industrialization is accompanied by the generation of wastes, which could be negative to the natural environment. Unfortunately, environmental issues were not remembered, as should be.

The current state of manufacturing processes consume enormous tons of different forms of natural resources like raw materials, energy, water, etc.

The giant amount of waste generated is still far from being used in its totality as a productor by-product, making technological alternatives needed in order to reduce its possible environmental impact. There are many reasons to increase the amount of waste being utilized or re-utilized. Firstly, disposal costs are minimized; secondly, less area is reserved for disposal, thus enablingother uses of the land and decreasing disposal permitting requirements; thirdly, there maybe financial returns from the sale of the by-product or at least an offset of the processing and disposal costs; and fourthly, the by-products can replace some scarce or expensive naturalresources [1].

In recent years, becomes extremely clear the importance of renewable resource for industrial applications with increasing emphasis on the environmental issues and waste disposal.

One major by-product is coal fly ash, landfill, which is unsatisfactory solution both from ecological and economic point of view. Therefore, there is continuing interest in establishing suitable processes in which fly ash can be efficiently reused.

Fly ash was recognized as a "suitable pozzolanic material" in the United States as early as 1914 [2]. Engineers found that they were able to control the temperature and increase the overall strength of the Damby replacing some of the portland cement with fly ash.

Over 120,000 metric tons of fly ash was used on the Hungry Horse Dam in Montana in 1948, [3].

Throughout the 1970's and 1980's, the U.S. Environmental Protection Agency (EPA) issued guidelines on fly ash and encouraged its use as a green material.

The fly ash is generated during the combustion of coal in thermal power stations. Its colour is generally *grey* and it depends on the proportion of unburnt carbon. The ash is composed of tiny and almost spherical particles.

The major constituents of fly ashes are silica, alumina, iron oxides, unburnt carbon etc. The principal group of minerals found in fly ashes are mullite, magnetite, haematite, quartz and glass.

The properties of fly ash depend on several factors which include: nature of coal; temperature of combustion; extent of pulverisation etc.

DISCUSSION

Every year in Macedonia 900 000 – 1 100 000 t of coal fly ash are produced. Only 10% of coal fly ash is used in cement products which are far below the global utilization rate (25%) [4]. Concentrations of heavy metals and physico chemical properties on fly ash from thermal power plant from Republic of Macedonia was investigated by [5]. The obtained results are given in Table 1 and Table 2.

Table1. Data for the chemical analysis of coal fly ash samples from termal power plant of Macedonia

	%		ppm
SiO_2	40.49-48.61	Sr	471 -993
TiO_2	0.516-0.621	Ba	715 – 833
Al_2O_3	23.2-25.9	Cr	93-114
FeO	8.04-9.49	Zn	163-192
CaO	0.190-0.376	Cu	61-80
FeO	8.04-9.49	Pb	43-50
MgO	2.64-3.99	Ni	58- 68
Na_2O	1.20-1.50	Co	22 -26
K_2O	1.87-2.56	Cd	0,91-1.42

P_2O_5	0.343-0.410	As	5.75- 14,14

Table 2. Properties of fly ash from termal power plant, Republic of Macedonia

Cation exchange capacity (CEC	0.19-0.28 meq/ g
ammonium exchange capacity (AEC	0.17-0.33 meq/g
Ec	0.13-0.15mmhos/cm
Organic carbon	3.17-3.85
specific gravity	2.04-2.37g/cm^3.
pH	7.8-9.1

The obtained results were compared with the World standard value. It was concluded that they are within the limits of the World standard value. The concentration of heavy metals was comparated with concentration of havey metals in fly ash from Spain, Greece, India, Filipini and UK, given in literatures [6] [7][8] [9]. The concentration of As in the fly ash from thermal power plant in Macedonia is lower than the contents of this element in the fly ash in thermal power plants of Philippines and UK. The contents of other heavy metals is in range same as their.

According to ASTM C 618, two major classes of fly ash are classified on the basis of their chemical composition resulting from the type of coal burned in thermal power plants. It can be classified as Class Fproduced from burning of bituminous and anthracite coal. It has CaO less than 10%. Class C is generally produced from burning of sub bituminous or lignite coal. It has CaO greater than 10%.

Fly ash from Macedonia belongs to the class F because the contain of CaO is less than 10%.

This property of fly ash can be exploited to neutralize acidic soils. [10] [11] reported that while addition of fly ash improves soil pH on one hand, it simultaneously addsessential plant nutrients to the soil on the other hand. [12] observed that experiments with calcareous and acidic soils revealed that fly ash addition increased the pH. The use of excessive quantities of fly ash to alter pH can cause increase in soilsalinity especially with un-weathered fly ash [13]. In the present study, pH of fly ash sample was measured as 7.8-9.1; it indicates that fly ash was alkaline in nature and can be used for reclamation of acidic soil.

Electrical conductivity was measured from 0.13 to 0.15mmhos/cm. Thus it was found that this fly ash could be used as an additive / amendment material inagriculture applications. Many physical and chemical parameters of fly ash may benefit plant growth and can improve agronomic properties of the soil [14].

Fly ash application to acidic soils in coal mine areas increased the yields of different vegetation. Fly ash alone and in combination with press mud showed favorable conditions for growth of tree species.

Fly ash is an effective agent for chemical and mechanical stabilization of soils. It provides the following benefits when used to improve soil conditions: expedites construction by improving excessively wet or unstable subgrade; by improving subgrade conditions, promotes cost savings through reduction in the required pavement thickness; eliminates need for expensive borrow materials; can reduce or eliminate the need for more expensive natural aggregates in the pavement cross-section. Fly ash serves as a good fertilizer. It provides the uptake of vital nutrients/minerals(Ca, Mg, Fe, Zn, Mo, S and Se) to crops and vegetation, and can be considered as a potential growth improver [15].

The results obtained by [16] indicate that fly ash, when mixed with traditional raw materials, has the necessary requirements to be used as a raw material for production of ceramic tiles. The studies of [17] [18] are examples of the glass–ceramics obtained using fly ash. Various

ceramics systems have been shown to be suitable for producing products that are thermally and mechanically stable and exhibit good chemical durability [19].
The principal group of ceramic products having the possibility of development from fly ash are pottery products like glazed tiles, refractories including insulating materials, glass and ceramics, ceramic fibers and foams, iron exchangers etc.
[20] has developed a unique new process that can make building products, such as bricks, from fly ash. [21] gives a glimpse of various emerging global techniques for the production of different value added ceramic materials from fly ash glassy materials, porcelains, refractories etc.
Fly ash can be used as one of the raw material for wear resistant ceramics for ambient temperature applications. Fly ash in the range of 10-60 wt% has been used to replace calcined alumina in a wear resistant ceramic composition. The development of physical and mechanical properties is related with the formation of new phases such as corundum and mullite, and compact microstructure [22].
[23] [24] [25] [26] developed a glass-ceramic tile from fly ash. [27] developed another variety of glass ceramics from fly ash. [28] [29] [30] studied on the feasibility of formation of glasses and glass ceramics from fly ash.
New products have been developed, such as glass fibres and glass ceramics for potential architectural and decorative applications which have chemical and mechanical properties comparable to, if not better than commercialones [31].
Overall obtained results have indicated that the glass and the heat-treated glass samples produced from coal fly ash have several desirable properties that would make them attractive to industrial use in the construction sector. Microstructural, physical, chemical and mechanical properties of the produced glass-ceramic samples from fly ash are better than those which are the produced only from glass and ceramic samples [32].
The fly ash is proved to be a potential source for the production of low cost mullite glass ceramics when mixed with alumina at very high temperatures produced by plasma [33].
Porous ceramic samples containing the coal fly ash have excellent mechanical properties, making them feasible for use in water absorption and retention of porous ceramic applications [34].
[35] used binary mixture of fly ash and plastic clays to manufacture ceramic products with up to 50 wt% mullite and 16 wt% feldspar. The properties of mullite synthesised from fly ash and alumina mixtures were studied by [36].
Fly ash can be used as an insulating material due to its availability and low cost. In addition, creating insulating material from fly ash provides a productive use for an ordinarily undesirable by-product.
Two major sectors of fly ash utilization across the globe are cement and concrete. A number of engineering and environmental benefits are also gained by using the ash instead of multiple ingredients for construction works.
Fly ash is used in concrete admixtures to enhance the performance of concrete. The many benefits of incorporating fly ash into a PCC have been demonstrated through extensive research. Benefits to concrete vary depending on the type of fly ash, proportion used, other mix ingredients, mixing procedure, field conditions and placement. Some of the benefits of fly ash in concrete are: produces a high strength concrete that accommodates the design of thinner sections; reducing the risk of thermal cracking in large concrete applications; reduced heat of hydration; reduced permeability; improving concrete resistance to sulphate attack; increasing durability of concrete in high chloride environments; preventing alkali-aggregate reaction in concrete; permits design flexibility accommodating curves, arches and other pleasing architectural effects; ensures that the concrete will qualify as a durable building material; contributes to the aesthetic appearance of the concrete; increased durability; lowered costs.

According to [37] fly ash can be used in flowable fill. Flowable fill is a mixture of coal fly ash, water, and portland cement that flows like a liquid, sets up like a solid, is self-leveling, and requires no compaction or vibration to achieve maximum density. Flowable fill is also referred to as controlled low-strength material, flowable mortar. It is designed to function in the place of conventional backfill materials such as soil, sand, or gravel and to alleviate problems and restrictions generally associated with the placement of these materials. The benefits of using flowable fill include: allows placement in any weather, even under freezing conditions; achieves 100 percent density with no compactive effort; fills around/under structures inaccessible to conventional fill placement techniques; increases soil-bearing capacities; increases the speed and ease of backfilling operations; decreases the variability in the density of the backfilled materials; improves safety at the job site and reduces labor costs; decreases excavation costs.

Fly ash can be used as a borrow material to construct fills and embankments [38] [39] [40] [41]. When fly ash is compacted in lifts, a structural fill is constructed that is capable of supporting highway buildings or other structures. Fly ash has been used in the construction of structural fills/embankments that range from small fills for road shoulders to large fills for interstate highway embankments [42]. When used in structural fills and embankments, fly ash offers several advantages over soil and rock, for exemple: cost-effective where available in bulk quantities; can be placed over low bearing strength soils; ease of handling; compaction reduce construction time; equipment costs.

Fly ash also can be used in grouts for pavement. Grouts are proportioned mixtures of fly ash, water, and other materials used to fill voids under a pavement system without raising the slabs, or to raise and support concrete pavements at specified grade tolerances by drilling and injecting the grout under specified areas of the pavement. Fly ash grouts can be used to correct undermining without removing overlying pavement; be accomplished quickly with minimum disturbance to traffic; develop high ultimate strength. Fly ash grout is also cost effective when alternative suspension emulsion or solution materials are considered.

CONCLUSION

Fly ash from coal-fired thermal power stations is an excellent potential raw material.

Using fly ash has several beneficial impacts on the environment, some of which include: saving energy, reducing solid waste disposal, reducing air pollution and greenhouse gas, and mitigating global warming. Other benefits include the reduction of fly ash waste going to landfills or being stored in a retention pond, which can be hazardous and potentially dangerous. The bulk of fly ash generated, many hundred million tons a year, is disposed of in slurry ponds or reservoirs, causing environmental problems. Therefore, most nations encourage increased use of fly ash. Overall fly ash utilization in Republic of Macedonia stands at a fairly low level of about 10 per cent of the quantity generated.

Main factors contributing to the low level of utilization on fly ash are: lack of reliable quality assurance for fly ash products; absence of standards and specifications for fly ash products; poor public awareness about the products and their performance; lack of proper coordination between thermal power stations and ash users.

With the fly ash helping to preserve the environment through all its utilisations and the huge potential it has for the society and country, it can rightly be termed as an environment saviour.

The government has also a vital role to play by encouraging the entrepreneurs providing fiscal and other benefits for the adoption of the different developed technologies for the commercial production.

The fly ash is a resource, which should be utilised to maximum possible extent. Applications on fly ash helps to improve the quality of product, economise on the cost and saves environment. Fly ash products have several advantages over conventional products.

In general, after summarizing all the facts, we could say that, coal fly ash in Republic of Macedonia contains moderate quantities of heavy metals and its effects on ground water, soil health and uptake by plants are probably negligible. The fly ash in Macedonia can be used in agriculture for conjunction with chemical fertilizer to increase the yield of various agricultural crops, the dose of which will depend on the types of crops as well on the types ofsoils.

Also, this coal fly ash may be used as structural fill material in constructing high way embankments and roadbases as ingredient in an ultra high strength concrete (portland cement) that is almost as strong as steel, in waste stabilization, or in mining applications, for manufacturing concrete bricks and blocks.

Fly ash is now recognized as valuable substances which confers certain desirable characteristics in its many applications.

We hope that the these paper will contribute to increase the interest for the greater utilization of fly ash in Republic of Macedonia, because the use of fly ash contributes to preserve the natural resources and saves environment.

REFERENCES

[1] Ahmaruzzaman, M., 2010. A review on the utilization of fly ash. Prog. Energy Combust. Sci., 36: 327-363.

[2] Aggarwal et al: Concrete durability through high volume fly ash Concrete, Internacional Journal of Engineering Science and Technology Vol 2(9), 2010

[3] (FHWA, 1999).

[4] Rai UN, Pandey K, Sinha S, Singh A, Saxena R, Gupta DK. (2004). Revegetating fly ash landfills with Prosopis julifera L: impactofdifferent amendments and Rhizobium inoculation. Environ Int;30(3):293–300, 2004.

[5] Tena Sijakova-Ivanova et al. Investigation of fly ash heavy metals content and physic chemical properties from thermal power plant, Republic of Macedonia. International Journal of Engineering Science and Technology (IJEST)Vol. 3 No.12 December 2011

[6] Fytianos K, Tsaniklidi B, Voudrias E. (1998). Leachability of heavy metalsin Greek fly ash from coal combustion. Environ Int (1998).24(4):477–486, 1998.

[7] Llorens JF, Fernandez-Turiel JL, (2001). Querol X. The fate of trace elements in a large coal-fired power plant. Environ Geol2001;40(4–5):409–16, 2001

[8] Liao HC, Jiang SJ. (1999). Determination of cadmium, mercury and lead in coal fly ash by slurry sampling electrothermal vaporizationinductively coupled plasma mass spectrometry. Spectrochim Acta Part B;54(8):1233–4, 1999.

[9] Wadge A, Hutton M, Peterson PJ. (1986).The concentrations and particlesize relationships of selected trace elements in fly ashes fromUK coal-fired power plants and a refuse incinerator. Sci Total Environ;54:13–27, 1986.

[10] Elseewi, A.A., Binghman, F.T. and Page, A.L. (1978). Growth and mineral composition of lettuce and Swiss chard grown on fly ashamended soils, in Environmental Chemistry and Cycling processes, Conf.760429, Adriano, D.C. and Brisbin, I.L.,Eds., U.S.Department of Commerce, 1978.

[11] Jastrow, J.D., Zimmerman, C.A., Dvorak, A.J. and Hinchman, R.R. (1979). Comparison of lime and fly ash as amendments to acidiccoal mine refuse: Growth Responses and Trace Element Uptake of Two Grasses. Argonne National Laboratory, Argonne, IL, 43,1979.

[12] Page, A. L., A. A. Elseewi and I. R. Straughan. (2005). Physical and Chemical Properties of Fly Ash from Coal-FiredPower Plantswith Reference to Environmental Impacts. Residue Reviews 71:83-120, 2005.
[13] Sharma, S. (1989). Fly ash dynamics in soil-water systems. Critical Reviews in Environmental Control 19(3), 251-275, 1989.
[14] Chang, A.C., Lund, L. J., Page, A.L. &Wameke, J. E. (1977).Physical properties of fly ash amended soils, Journal of Env.Quality, 6,267, 1977.
[15] Scott M Mackiewicz, E. Glen Ferguson Stabilization of soil with self cementing coal ashes World of coal ash (WOCA)Lehington , Kentucky SAD, 2005
[16] Zimmer, A.; Bergmann, C. P. Fly ash of mineral coal as ceramic tiles raw material.Waste Management (Elmsford), v. 27, 2007, pp. 59-68.
[17] Barbieri, L., Lancellotti, I., Manfredini, T., Queralt, I., Rincon, J.M. & Romero, M. Design, obtainment and properties of glasses and glass–ceramics from coal fly ash,Fuel, Vol. 78, No. 2, 1999, pp 271–276,
[18] Leroy, C., Ferro, M.C., Monteiro, R.C.C. & Fernandes, M.H.V.. Production of glass–ceramics from coal ashes, Journal of the European Ceramic Society, Vol. 21, No. 2, 2001, pp195–202;
[19] Palomo, A., M.W. Grutzeck, and M.T. Blanco (1999*b*), "Alkali-activated fly ashes, a cement for the future", Cement and Concrete Research, Vol. 29, pp. 1323-1329
[20] Liu H: Compacting fly ash to make bricks Final technical report NSF-SBIR Phase 1 Project No DMI -0419311, 2005
[21] Saikat MAITRA Ceramic products from fly ashGlobal perspectivesFly Asia Utilisation for Value Added ProductsEds. *B. Chatterjee, K. K.* Singh *& N. G. Goswami, NML, Jamshedpur, pp. 32-37 1999*
[22] S. K. Nath and Sanjay KumarWear Resistant Ceramics from Fly Ash**,** National Metallurgical Laboratory *Council of Scientific & Industrial Research*
[23] Bocaccini AR, Kopf M, Stunpfe W. Glass-ceramics from filter dustsfrom waste incinerator. Ceram Int 1995;21:231–5.
[24] Boccaccini, A. R., Bücker, M., Bossert, J., Glass and Glass-Ceramics from CoalFlyash and Waste Glass, *Tile and Brick International* 12 1996 515-518.
[25] Boccaccini, A. R., Glass and Glass-Ceramic Matrix Composite Materials: AReview. *J Ceramic Soc Japan* 109(7) (2001) S99-S109.
[26] Boccaccini, A. R., Rawlings, R. D., Glass and Glass-ceramic Matrix Composites:Academic Curiosity or Useful Materials?, *Glass Technol*. 43C, 2002 191-201.
[27] Barbieri, L., Corradi, A., Lancellotti, I., Thermal and Chemical Behaviour ofDifferent Glasses Containing Steel Flyash and Their Transformation into GlassCeramics, *J. Europ. Ceram. Soc*. 22 (2002) 1759-1765.
[28] Erol, M., Kucukbayrak, S., Ersoy-Mericboyu, A., Ovecoglu, M. L., Crystallisationbehaviour of glasses produced from fly ash, *J. Europ. Ceram. Soc*. 21 2835 -2841. 2001
[29] Kim, H. S., Kim, J. M., Oshikawa, T., Ikeda, K., Production and Properties ofGlass-Ceramics from Incinerator Fly Ash, *Mater. Sci. Forum* 439 (2003) 180-185.
[30] Kim, J.M., Kim, H.-S., Glass-Ceramic Produced from a Municipal WasteIncinerator Fly Ash with High Cl Content, *J. Europ. Ceram. Soc*. 24 (2004) 2373-2382.
[31] Karamanov, A., M. Pelino and A. Hreglich,Sintered glass-ceramics from municipal solidwaste-incinerator fly ashes-part I: The influence ofthe heating rate on the sinter-crystallisation. J. Eur.Ceram. Soc., 23(6), 827-832 (2003).
[32] Sheng J, Huang BX, Zhang J, Zhang H, Sheng J, Yu S, et al.Production of glass from coal fly ash. Fuel 2003;82:181–5.

[33] Suriyanarayanan,N.,Kanan Nithin,K.V.,Enrico Bernardo:Mullite glass ceramics production from coal ash and alumina by high temperature plasma, ournal of Non-Oxide Glasses, Vol. 1, No. 4, 2009,p. 247- 260

[34] Niyazi Ugur Kockal: Properties and microstructure of porous ceramic bodies containing fly ash Journal of Building Physics, vol. 35, 2012; pp. 338-352.,

[35] Queralt. I. Use of coal fly ash for ceramics: a case study for a larg Spanish power station pp 786-791, 1997

[36] X. Huang, "The Final Report of Fly Ash Processing and Utilization, Section-4 Ceramic Products Technology Development," Michigan DNR SWAP project, MDRD-1-31-20025. 1993

[37] Christopher Swan Gerald Topping,Moshen Kashin Flowable fills Developed with high volumes of fly ash World of coal ash (WOCA)Lehington , Kentucky SAD 2007

[38] DiGioia, Anthony M., Jr. and William L. Nuzzo. "Fly Ash as Structural Fill," Proceedings of the American Society of Civil Engineers, Journal of the Power Division, New York, NY, June, 1972.

[39] Lamb, D. William, "Ash Disposal in Dams, Mounds, Structural Fills and Retaining Walls," Proceedings of the Third International Ash Utilization Symposium, U.S. Bureau of Mines, Information Circular No. 8640, Washington, DC, 1974.

[40] Martin, Joseph P., Robert J. Collins, John S. Browning, III, and Francis J. Biehl. "Properties and Use of Fly Ash for Embankments," Presented at the 22nd Annual Mid-Atlantic Industrial Waste Conference, Philadelphia, Pennsylvania, 1989.

[41] Kinder, D.L. and R.E. Morrison. "An Engineering Approach for Using Power Plant Ash in a Structural Fill," *Proceedings of the Fifth International Ash Utilization Symposium,* U.S. Department of Energy, Report No. METC/SP-79-10, Atlanta, Georgia, February, 1979.

[42] Ayse Pekrioglu, Ata G. Doven, d Mehmet T. Tumay, Fly Ash Utilization in Grouting Applications,Proceedings Grouting and ground treatment, pp 1169-1179,2003.