



Full Length Article

Physical and chemical changes in coal fly ash during acidic or neutral wastes treatment, and its' effect on the fixation process



Roy Nir Lieberman^{a,b,c,*}, Xavier Querol^a, Natalia Moreno^a, Yitzhak Mastai^b, Haim Cohen^{c,d}

^a Institute of Environmental Assessment and Waster Research (ID/EA), Consejo Superior de Investigaciones Científicas (CSIC), Barcelona, Spain

^b Bar Ilan University, Ramat-Gan, Israel

^c Ariel University, Ariel, Israel

^d Ben-Gurion University of the Negev, Beer-Sheva, Israel

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ABSTRACT

Coal fly ash (FA) is an abundant commodity in many countries using steam coal for power production. In some countries (e.g. Israel) all the FA is utilized whereas in some countries only low percentage is used (e.g. USA). The main mode of utilization is in the civil engineering industries as cement or clinker additive or for concrete production. In Israel (2014) 1.3 Mt of highly basic type F FA has been produced, mostly from South African and Colombian coals, in the utilities. A potential application for type F FA could be as an efficient scrubber for hazardous acidic wastes (e.g. the phosphate industry). The scrubbing efficiency of FA stems from interactions of the aluminosilicate surface of the particles with trace elements or with fine precipitates of ionic solids (e.g. SrCO₃). The process changes the chemical and physical nature of the FA surface. These changes have been studied using SEM, TEM, XRD and particle size measurements of non-treated, compared to treated FA with acidic or neutral aqueous solutions.

The results indicate that an appreciable part of the outer lime layer and part of the glassy aluminosilicate material is dissolved, revealing the mullite skeleton as well as Ti, and Fe species. Moreover, formation of mixed ettringite/thaumasite and halite particles is observed. Thus, this study can lead to a better understanding of the fixation mechanisms of the trace elements by coal FA.

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1. Introduction

Coal fly ash (FA) is produced *via* firing of coal in pulverized coal combustion (PCC) facilities worldwide. In Israel, coal is one of the most significant electricity sources (~63% in 2013 [1,2]), consuming ~13 Mt of coal annually. Israel has no coal resources and the bituminous coals are marine imported and stored in large open piles of 60–150 kt in the yards of the 4 major coal fired power plants. The annual amount of the FA produced is ~1.3 Mt of (in 2014) [2,3].

The pulverized coal particle (average size 30 μm) which contain ~10% mineral matter is injected into the boiler and undergoes 2 processes during the ~15 s residence time. A pyrolysis step, at ~800 °C, where the light hydrocarbon gases and molecular hydro-

gen are released and ignited [4]. During this stage some inorganic material melts, and solidifies down in the bottom of the boilers, to yield bottom ash (BA). In the second stage, the coal particle which is transformed into char and heats up to ~1700 °C, is burnt and small solid particles (1–17 μm)-the FA are formed [5]. The FA accounts for ~90% of the total ash formed during the coal combustion process [1].

Strict air quality regulations in Israel [6] regarding the emissions of pollutants to the atmosphere *via* the combustion process impose beneficiation of the imported coals prior to the transport (*via* washing with water), in order to reduce inorganic volatile pollutants such as S, Hg, As, and Cd. Moreover, in PCC plants injection of Ca compounds (e.g. CaO, CaCO₃) is used in order to reduce SO_x emissions *via* the Flue Gas Desulfurization (FGD) process. The result of the coal beneficiation process is an alkali and alkali-earth rich FA product, with pozzolanic properties and is defined as Class F FA [7].

The ashes produced in Israel (BA and FA) are utilized in the construction industry as cement additive or for concrete production, thus its' economic value is poor (≤15\$/ton) [8–20]. In order to

* Corresponding author at: Institute of Environmental Assessment and Waster Research (ID/EA), Consejo Superior de Investigaciones Científicas (CSIC), Barcelona, Spain.

E-mail addresses: 5dk32nl@gmail.com, roy.nir@idaea.csic.es, roynl@ariel.ac.il (R.N. Lieberman).

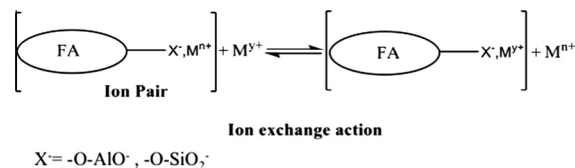
increase FA economic value, we have evaluated elsewhere the possibility of using it as an effective neutralization and metal fixation reagent for hazardous acidic wastes and low level radioactive waste [10,15,16]. The wastes studied were:

- (1) Acidic waste from the phosphate industry, which is a byproduct of phosphate rock treatment with either sulfuric or hydrochloric acid [16] (0.1–1 M acidity).
- (2) Extremely acidic waste (~10 M acidity) formed from the regeneration processes of used motor oil with Oleum [10].
- (3) Radioactive wastes (appropriate metal cations were used as simulants) that are formed from the fission processes of U [15].

The results have indicated that the FA is an efficient acid neutralization reagent and also a good fixation reagent to trace elements, thus concluding that FA could be used as a chemical scrubber and fixation reagent for these types of wastes. Furthermore, it was shown that the aggregate product formed from the acidic wastes (items (1) and (2) above) could be used as a partial substitute for sand and cement in concrete. In all these studies, the fixation quality of the FA was tested by three types of leaching procedures: USEPA TCLP 1311 [21], CALWET [22], and the European Directive (EN 12457-2). All leached trace elements concentrations were well under the CALWET, TCLP, EN 12457-2 [23] criteria, and also Israel drinking limits [24].

Three modes of fixation mechanism for the fixation of the metal cations by the FA functional groups have been suggested [15,25–29]:

- (1) **Cation-Exchange Mechanism** – anionic functional groups of the FA surface – aluminates ($-\text{O}-\text{AlO}^-$) and silicates ($-\text{O}-\text{SiO}_2^-$) that behave as cation exchange groups.



- (2) **Coordinative Bonding** – this is the mechanism in which a Lewis base material (the FA) is donating its lone pair electrons (mainly from O of the aluminates and silicates) to form a bond with a metal cation, which is equivalent to metal complexes formation.

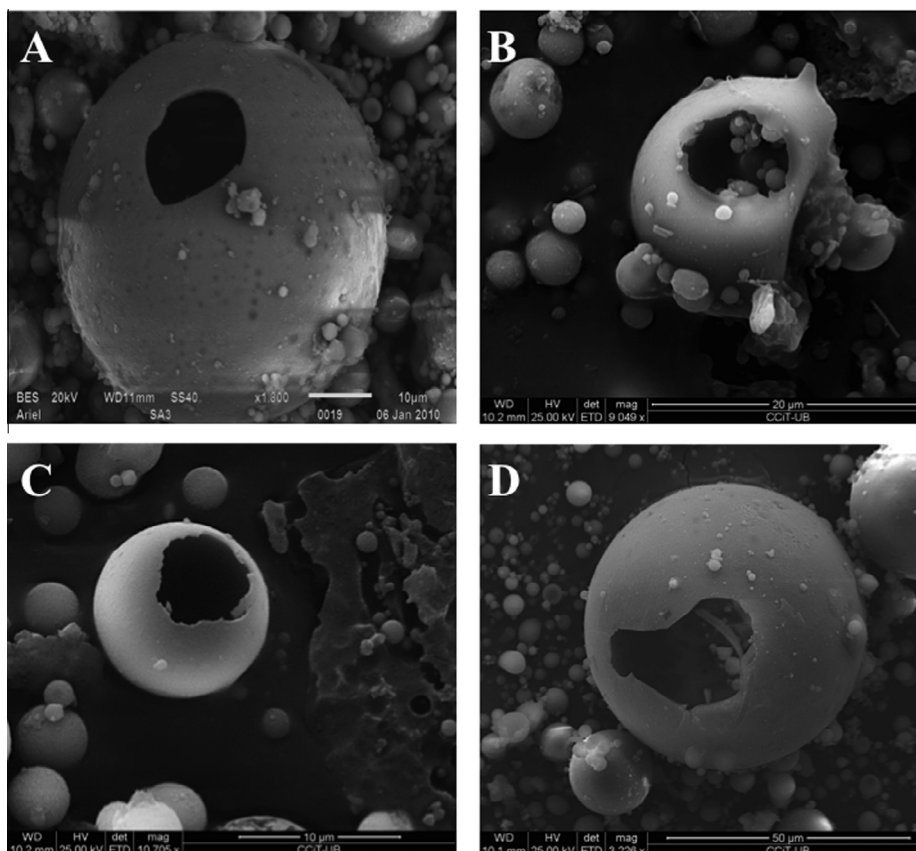
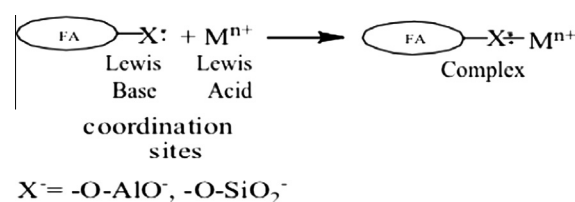


Fig. 1. Cenospheres and plerospheres of SAFSA (A,B) and COFA (C,D), respectively.

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