Coal Fly Ash as a Chemical Reagent for Scrubbing Industrial Acidic Wastes

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The use of coal as an energy source to produce electricity in Israel, entails the production of more than 3,000 tons of coal fly ash (CFA) a day. Fly ash is a reusable material, that must be under environmental control, which makes it ideal for building and infrastructure applications. Coal produces an ash, rich in compounds that undergo basic reactions with water (especially when the coal is also rich in calcium and alkali metals). The primary goal of this research was to test the capacity of fly ash as a neutralizer of highly acidic industrial wastes. Another goal was to test if its chemical properties and its large surface area can be used to fix the toxic elements in industrial wastes. An equally important goal is to gain a full understanding of the mechanisms behind the neutralization and fixation/adsorption processes of toxic trace elements. We also wanted to test the efficacy of using the product of fly ash-based industrial sludge fixation as a replacement for sand in producing concrete, while testing its fixation ability within monoliths. To investigate these issues, we prepared the fixation products via the reaction between fly ash with an highly acidic organic sludge from the factory of the Paz Oil Company. Likewise, the neutralization and fixation process of the acidic sewage from the Haifa Chemicals Company Ltd., a waste product of the phosphoric acid production process, was examined. The research revealed that the potential for the fly ash to release its basic/alkaline component to water, is a function of time. The shaking period in an aqueous solution must be of a long enough duration for the water to deeply penetrate the matrix of the fly ash particle (the structure of which is not uniform and whose particles reflect a wide range of shapes and cavities). Likewise, we tested fly ash capacity to fix toxic metals, because the toxic wastes discussed above contain substantial levels of environmentally dangerous elements (e.g., nickel, chromium, and lead). The stability of their fixation in the product under conditions of washing with water, was investigated for periods lasting from a half an hour and up to three months. Elucidation of the mechanism of metal–fly ash binding

(fixation/adsorption – sorption) was done via experiments in which a solution containing a bivalent metal cation was added to South African Fly Ash – (SAFA) raw material, SAFA prerinsed with water, or SAFA pretreated with acid. Bivalent cations M^{2+} (e.g., Cu^{2+}, Pb^{2+}, Cd^{2+}, Ni^{2+}, Co^{2+}, Zn^{2+}) fixation was examined for cation size dependence. For example, clearly the electric field induced by Cu^{2+} (radius 0.69 Å) is larger than that of Pb^{2+} (radius 1.20 Å). It was expected that the electrostatic interaction between the cation and fly ash surface area, would increase with decreasing ionic radius, and indeed the experiments revealed that copper was adsorbed in an electrostatic binding mechanism in which the fly ash functioned as an ion exchanger, while the lead ion underwent fixation via strong chemical coordination, that utilized a small number of binding sites. The fixation product was tested as a partial substitute for sand, in the production of concrete, and it was revealed that the mechanical strength of the monoliths produced was good up to a level of 15% exchange of the sand. The quality of fixation between the fly ash and the different waste products and within the monoliths, was determined via two standard leaching procedures. Fixation quality for such metals is excellent.

Based on the research, our main conclusions are:

A. Fly ash produced in Israel from the combustion of low sulfur bituminous coal has chemical reagent qualities effective in neutralizing highly acidic waste.

B. Fly ash is the most efficient chemical reagent for binding the toxic metals (those investigated in this research) found in the different industrial wastes tested in this study.

C. The research was based on understanding the three fixation/adsorption mechanisms of bivalent cations on fly ash. These mechanisms depend on the characteristics of the double layer of charge at the surface of the fly ash and of the solution around the fly ash. These values depend on solution pH and on the zeta potential that characterizes the behavior of a substance under different pH conditions, of which three ranges were identified. In the basic pH range, the insoluble hydroxide compounds formed adsorb to the fly ash surface. Coordinated covalent bonds with specific sites on fly ash particles occur at neutral pH values. And in the acidic pH range the elements undergo electrostatic interaction with the fly ash particles in an ionic exchange manner.

D. In its role as an alternative aggregate to sand, the fixation product can be used to partially replace sand in the production of concrete monoliths, which can be used in

the construction industry without any environmental limits (according to the regulations currently accepted by the Ministry of Environmental Protection in Israel).