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Suitability of leaching test methods for fly ash and slag: A review

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ABSTRACT

Fly ash and slag leachate pollution can be of great environmental concern due to generation of these wastes in huge quantities from their respective industrial units, mainly coal-based thermal power plants and iron and steel plants. For simulation of natural leaching in laboratory, various leaching methods are available, but selection of a method that can exactly simulate the real-life scenario for accurate estimation of various pollutants is challenging; particularly, the heavy metals present and impact due to reuse or disposal of these wastes. For choosing the most suitable leaching method according to specific situation, one must primarily consider the chemical and physical properties of wastes, the composition of the source, age of waste disposal, and the climatic conditions of the disposal area. Since these factors may not be specified, a variety of leaching methods with relevant equipment have been proposed by researchers; that are based on their required information to particular conditions in absence of a prescribed protocol and non standardization of equipment. The present review is an attempt to investigate the suitable leaching method for coal fly ash and slag.

1. Introduction

Industrial solid waste leachate pollution is one of the important environmental problems the world faces today. It is an issue that adversely affects the society economically, physically and everyday life of people. The contamination of the water sources and soil due to industrial solid waste leachate is also being linked to some of the diseases that are around currently. It is reported that, frequent ingestion of chromium contaminated water can cause anemia and stomach cancer. Iron ingestion in large quantities results in a condition known as heamochromatosis, where in tissue damage results from iron accumulation (Indian Minerals Yearbook, 2012). In central India, Chhattisgarh is a potential power hub having sufficient mineral resources with surplus energy generation and the largest steel plant in India, which attracts and supports many industries. Natural resources such as water and land are limited and their per capita availability is actually diminishing

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because of irrational exploitation of natural coal and iron ore resources. The biggest challenge that Chhattisgarh faces is the degradation of environment and natural resources, which is imposing an alarming health hazard.

Lack of efficient industrial solid wastes management, particularly in developing countries like India, has lead to severe environmental problems. Due to limited land for waste disposal, the current practice of uncontrolled dumping of fly ash near industrial belt of towns/cities has created a serious environmental problem due to leachate with presence of various toxic metal and ions (Nalawade, Bholay, & Mule, 2012). It is very important to know the characteristics of the surface water, rain water surrounding the waste disposal sites. The leachate immensely affects the sources of water near to dumpsites. (Singh et al., 2014).

Leachate is the liquid produced when water percolate through any permeable material. It can contain either dissolved or suspended material, or usually both (http://en.wikipedia.org/wiki/Leachate).

Leaching methods are categorized, often based on modes whether the leaching fluid is a single addition (static extraction tests), or is renewed (dynamic tests). Methods can also be classified as batch leaching, in which the sample is placed in a given volume of leachant solution, and as column or flow through systems, and as bulk or flow around systems for monolithic samples (Kim, 2005). Commonly used methods are developed by EPA or promulgated by ASTM.

The Washington State Department of Ecology's (December 2003, Publication No. 03-09-107) report (available online at http://www.ecy.wa.gov/programs/tcp/cleanup.html) indicates that the leaching of contaminants from fill material is a complex process and that the use of leaching test to predict these processes is an evolving area of science. As such, no one single laboratory leaching test can evaluate the leaching behavior of a wide variety of material in a broad range of management scenarios. However, when used within the proper framework, leaching test can provide useful information for environmental decision-making.

A thermal power plant generates large amounts of fly ash which may contain toxic metals and environmental risks associated with these coal fly ashes during wet storage in the ash ponds (Lokeshappa, Dikshit, Giammar, Luo, & Catalano, 2010). The disposal of coal fly ash subjects these metal rich materials to conditions that result in further sequestration of the metals or to their release to the environment (Lokeshappa & Dikshit, 2011). The release and transport of trace metals from coal fly ash material is an area of environmental concern because of the wet storage in the ash ponds. The volatilization, melting, decomposition and the formation of new materials and oxidation are the main mechanisms to transfer the metals from coal to fly ash (Kim, Kazonich, & Dahlberg, 2003). The major potential impacts of fly ash disposal either in ash pond or reused in the cement industry leads to leaching of potentially toxic substances into soils, surface water and groundwater. Environmental concerns regarding the potential contamination of soil, surface and groundwater due to the presence of soluble metal species in the ash pond leachate are of great concern (Praharaj, Powell, Hart, & Tripathy, 2002). The soluble salt content in ashes is closely related to the coal properties and the age of the fly ash and also to the pH and other environmental conditions (Jankowski, Ward, French, Groves, 2006). With respect to leaching, it is important to recognize that coal utilized by products, particularly fly ash, is not a homogenous material. Its elemental and mineralogical composition and its physical properties are a function of the original coal, the combustion temperature and post-combustion cooling rate (Kim, 2002). Volatilization, melting, decomposition, and the formation of new minerals, as well as oxidation, are the mechanisms that transform the minerals in coal (Ann G. Kim).

1.1. *Leaching test methods*

In general, leaching tests can be classified into the following categories (Environment Canada, 1990): (a) tests designed to simulate contaminant release under a specific environmental scenario (e.g., synthetic acid rain leach test or TCLP), (b) sequential chemical extraction tests, or (c) tests which assess fundamental leaching parameters. Many researchers have tried to simulate real-life scenario and suggested various leaching methods justifying the attempts. According to Kosson, van der Sloot, Sanchezand, and Garrabrants (2002) the tests that are designed to simulate release under specific environmental scenarios are limited because they most often do not provide information on release under environmental scenarios different from the one being simulated. This type of limitation has led to widespread misuse and misinterpretation of TCLP results. Reliance on simulation-based testing also results in treatment processes that are designed to "pass the test" rather than to improve waste characteristics or reduce leaching under actual use or disposal scenarios.

Summaries of many of the more commonly used leaching methods have been given by Sorini (1997), Wilson (1995), Kosson et al. (2002), Kim (2003), Hesbach et al. (2005); Menghini, Hornberger, and Dalberto (2005); Hassett, Pflughoeft-Hassett, and Heebink (2005), Kazi, Jamali, Siddiqui, Kazi, Arain, and Afridi (2006), Delay, Lager, Schulz, Horst, Frimmel, and Fritz (2007), Arain, Kazi, Jamali, Jalbani, Afridi, and Baig (2008), Kim and Hesbach (2009), Hesbach, Kim, Abel, and Lamey, (2010), Thorneloe et al. (2013), Kosson and van der Sloot (2014), Kosson, van der Sloot, Garrabrants, and Seignette, (2014), Kalembkiewicz and Sitarz-Palczak (2015). The International Ash Working Group (IAWG) based in Europe has done extensive work on the integration of a variety of tests into a comprehensive leaching system (Eighmy & van der Sloot, 1994; van der Sloot, 1998). Leaching methods are often categorized by whether the leaching fluid is a single addition (static extraction tests) or is renewed (dynamic tests). Various leaching methodologies applicable to a wide variety of waste forms have been reviewed (Garrabrants & Kosson, 2005) where it was noted that release from solid materials is most often estimated using the results of one or more extraction tests designed to measure COPC leaching from materials. Although more than 50 leaching tests have been identified for various purposes and materials, only a limited number address a range of test conditions. That is, most leach tests currently being used are designed to simulate constituent release under a single set of assumptions (EPA/600/R-10/170, November 2010).

Chemical aspects influencing the leaching relate to the fundamental processes controlling the solubility of solids.