MATERIALS CHARACTERIZATION 61 (2010) 1342–1355

available at www.sciencedirect.com

www.elsevier.com/locate/matchar

Recycling hazardous jarosite waste using coal combustion residues

P. Asokan[a,*,1], M. Saxena[a], S.R. Asolekar[b]

[a]Advanced Materials and Processes Research Institute, CSIR, Bhopal-462064, India
[b]CESE, Indian Institute of Technology, Bombay-400076, India

ARTICLE DATA

Article history:
Received 19 May 2006
Received in revised form
22 September 2010
Accepted 23 September 2010

Keywords:
Jarosite waste
Coal combustion residues
Immobilization
Composites
Characterization
Waste recycling

ABSTRACT

Increase in environmental concern due to improper management of both hazardous and non hazardous wastes released from different industrial process prioritized the necessity for the innovation research. In this context, this paper deals with the immobilization of jarosite waste released from the zinc industry and converting it into a value added product using coal combustion residues (CCRs) through solidification/stabilization (s/s) and sintering process. Experiments were conducted using different ratio of jarosite waste and clay soil with varying concentration of CCRs. The optimized experimental results (using jarosite waste and clay soil ratio of one with 15% CCRs) showed that it is possible to make a composite having desirable mechanical properties such as compressive strength (50–81 kg/cm^2); water absorption (13–17%); shrinkage (11–32%); and density (1.6–1.8 gm cm^{-3}) to use as a construction material. Under solid state sintering process, with the application of CCRs, the mineral phases such as X $Fe_3(SO_4)_2(OH)_6$ [where X = K and NH_4], $2Fe_2O_3SO_3.5H_2O$, $PbSO_4$, $CaSO_4$ in jarosite waste were transformed into a silicate matrices. The leachate studies confirmed that the toxic elements such as Cd, Pb, etc. were immobilized in the jarosite waste composite and meeting the USEPA TCLP toxicity norms for safe utility. The composite product thus developed has showed potential for recycling jarosite waste in construction sector leading to cross sector waste recycling.

1. Introduction

1.1. Coal Combustion Residues Generation and Utilization

To meet the present and future demand of electricity, the world population greatly depends on the combustion of coal and as a consequence large quantities of coal combustion residues (CCRs) produced by thermal power plants universally became a major environmental concern [1–4]. India has about 211 billion tonnes of coal reserves and is known to be one of the largest resources of energy [5]. Presently, major CCRs producers are China (~160 million tons per annum—MPTA), India (~160 MPTA) followed by United States of America (~135 MPTA) ([6]; TIFAC, [7]). The United States of America (USA) is the world's highest per capita electricity consuming country [4]. More than one half of the electricity is generated from coal combustion in USA and utilizes about 43% of CCRs produced [8].

It is reported that during the year 2007, the European Union, comprising of 27 countries, produced about 100 million tonnes of CCRs annually [9]. Among the European Coal Combustion Products Association (ECOBA) member countries, CCRs generation in Germany, Poland, United Kingdom and Greece was

* Corresponding author. Permanent address: Advanced Materials and Processes Research Institute, CSIR, Bhopal-462 064, India. Tel.: +91 755 2459827, +91 9425600260; fax: +91 755 2457042/2459827.
E-mail addresses: asokanp3@yahoo.co.in, pappuasokan@hotmail.com (P. Asokan).
1 Present address: School of Engineering, The University of Waikato, Room # DG06, Hamilton, New Zealand. Tel.: +64 211372258 (mobile), +64 7 8384847 (office).

1044-5803/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.matchar.2010.09.005

34 MTPA, 29.5 MPTA and 15.5 MTPA and 10 MPTA respectively. During 2006, Australia produced 14.5 million tons (MT) of CCRs [10]. In Japan 11 MT of CCRs were produced. The CCRs consist of silica, alumina and iron oxide similar to soil [11]. Extensive research has been carried out by many researchers around the world on CCRs recycling. It is apparent from the earlier work that the CCRs has many potential uses in developing bricks, cement, concrete, adhesives, wall board, road embankment, wood substitute composites, paint and agriculture/soil amelioration and land and abandoned mine reclamation, etc. ([1,2,6,57–62]. During 2004, the USA utilized about 35.4% in 2004 [63] and presently using about 43% CCRs [3]. Australia utilizes about 4.1 MT of CCRs in various value added products [10]. Japan utilize maximum CCRs i.e. about 82% of 11 MT PA of CCRs production [12]. Developed countries have well defined qualities of segregated fly ash and utilize an average of about 45% of the fly ash generated in their country and further details of each application is reported and discussed elsewhere ([1–3,6,13,58–60]. In India, CCRs being produced from different thermal power station and CCRs stored in the ash pond have wide variation in their characteristics but they do not exhibit any harmful elements [11].

There is a wide consensus on the requirements of energy worldwide, which is expected to increase rapidly in the near future. As a consequence, globally, CCRs generation is expected to reach 2000 MT per annum by the year 2020. During 1993, utilization of CCRs in India was only 2.3% out of the annual generation of 35 MT. However, lack of awareness among the users on the beneficial aspect of CCRs based products greatly influenced the rate of utilization. Now, in India availability of quality CCRs confirming to IS 3812 from modern Thermal Power Station (TPS) and various proven research work through demonstration trials on use of CCRs has substantially increased. As a results, presently fly ash has been used up to 45% of total generation in India in building materials, road and embankment, land development and agriculture, extraction of metal and cenospheric ash, paints and waste treatment. Keeping in view of the present growth, demand and necessity, it is expected that by the year 2020, CCRs utilisation rate may reach up to 60% in India. This would results in various environmental benefits including reduction in greenhouse gases and global warming. Perhaps, as per the news released on 10June 2010 in the Energy & Natural Resources [64] that the United States EPA Proposes Sweeping Regulation for CCRs disposal and the EPA is seeking comments on the proposed rules, considering CCRs as special waste category, especially according to the Regulation under Subtitle C that would allow EPA to closely regulate and control CCRs as well as on the Regulation under Subtitle D which is a very different approach to the problem [64].

CCRs, the so called fly ash, is the world's largest mineral resource, its processing, handling ultimate utilisation and safe management are the major concern for the environmental sound management and sustainable development. But, the CCRs is a universal waste being effectively used universally as a resource/raw materials in polymer matrix composites; metal matrix composites; cement–concrete and ceramic composites for many applications. Many industries like construction (building materials), ceramics, mining, agricultural industry etc. are the major industrial partners universally using fly ash. There is a growing demand as well as supply of CCRs universally and most of the country depends mainly on coal combustion process to fulfil their electricity requirement. And therefore, CCRs experts, universally, are to be involved in policy decision before implementation of any such regulation for the benefits of each and every citizen of the World.

1.2. *CCRs for Hazardous Waste Immobilization*

Wastes are the byproducts of any industrial process/product. Hazardous wastes may cause adverse chronic effects on environment or on human health when not properly controlled or managed [14–16]. In India, about 6.2 million tonnes of hazardous wastes are being released annually by different industrial operations. Out of these, about 1.7 million tonnes waste are recyclable; 1.89 million tons can be incinerated; and the rest is disposable in secured landfills [17,18]. There are several methods commonly used for disposal of hazardous wastes [65].

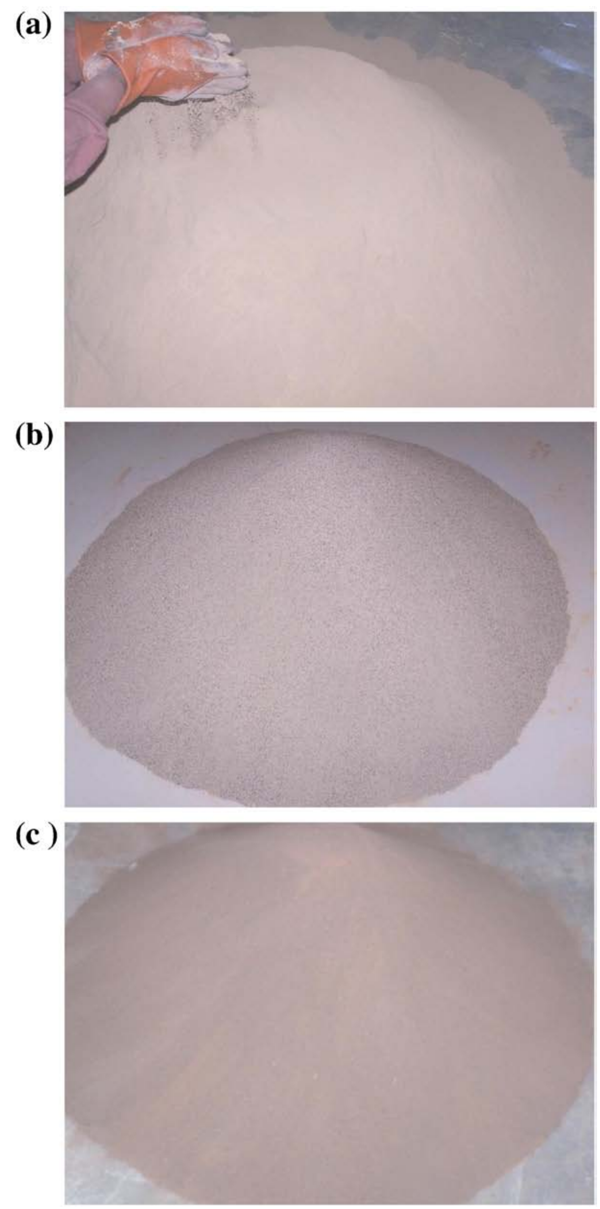

Fig. 1 – Processed raw materials (a) jarosite wastes, (b) CCRs, and (c) clay.