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Co-processing of industrial waste in cement kiln – a robust system for material and energy recovery

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Abstract

Waste management is a serious issue around the world. It is most prominent in the developing countries. Non–hazardous industrial waste is another aspect at 100 million tons/year with coal ash accounting for 70 million ton/year in India. It is the second highest waste stream ending up in landfill site. The quantity is projected to be increased at faster rate in coming years with increasing industrialization. This industrial waste has characteristics of municipal solid waste with percentage of non-biodegradable waste on the higher side. Co-processing of this waste for energy recovery and as an alternative raw material in cement kiln can be an effective management methodology for this waste stream. This is being practiced sustainably in number of countries but in India the process lacks proper implementation. The auxiliary technological requirement is less and the process is highly economical and effective. This study specifically shows the effectiveness of the co-processing in cement plants in India, as a way for an effective utilization of energy and recoverable raw materials locked in the industrial waste. The robustness of the co-processing of industrial waste has been analyzed based on three cases studies in India. The findings revealed that it can be one of the most effective industrial waste disposal techniques in India and in other developing countries considering other practices of waste disposal methodology in terms of zero ash generation, emission, less auxiliary technology requirements, less set up cost, etc. The robustness of the co-processing as a waste disposal technique was also revealed by the economic and environmental statistical analysis. The study shows the sustainability of co-processing as an energy and material recovery process and addresses the issues related to sustainable management of industrial wastes. Number of study is available in the literature but analysis based on multiple case studies specific to Indian scenario is scarce.

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Keywords: Co-processing; Cement kiln; Industrial waste; India; Sustainability.

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1. Introduction

India is the second largest producer of cement in the world. Cement production is an energy intensive process. The cement industry in India emitted 129.92 million tons of CO_2, which is 32% of the total CO2 emissions from the industry sector in 2007[1]. The production of cement is material and energy intensive and co-processing of waste-derived materials represents a common strategy to reduce the cost and environmental impact[2, 3, 4]. Coupled with resource conservation and reduced carbon emissions, co-processing technology is a preferable alternative for sound and environmental friendly waste disposal over incinerators & non-scientific methods. It is not only solution to the waste disposal menace, but also reduces burden on secured landfills[5]. The use of industrial wastes as an alternative fuel in the cement industry is a reality in several countries because wastes are removed and economic incomes are obtained preserving virgin materials[6]. The use of alternative fuels and raw materials (AFR) for cement clinker production is certainly of high importance for the cement manufacturer and also for the society as a whole. Traditional kiln fuels are gas, oil and coal. Materials like waste oils, plastics, auto shredded residues, waste tyres and sewage sludge (SS) are now being proposed as alternative fuels for the cement industry. Also the slaughterhouse residues are used as fuel nowadays in cement plant. The plant to use any of the AFR in a cement kiln, it is necessary to know the composition of the fuel and raw material. The choice is normally based on price and availability. The energy and ash contents are also important, as are the moisture and volatiles contents[7]. Alternative fuel and raw material utilization in cement kilns is still progressing. While in some kilns up to 100% substitution rates have been achieved, but in some cases other prevailing conditions do not allow for higher rates of AFR[8]. The cement industry has characteristics that make the burning of wastes viable, since it is characterized by high energy thermal process necessary to produce the clinker. The clinker is obtained from the grinding, homogenization and burning (high temperatures – 1450°C) inside rotary kilns with raw materials (limestone, clay, sand, iron ore). The next steps are the cooling of the clinker, grinding the clinker with gypsum and other additives to produce cement and finally storing, packaging and transporting the cement to the end user[9, 10]. In any case, alternative fuel utilization requires the adaptation of the combustion process, though modern multi-channel burners and thermograph systems allow controlling the alternative fuel feed rate and the flame shape to optimize the burning behaviour of the fuels[8]. Wzorek[11] showed that the fuels manufactured with the use of sewage sludge and waste materials offered a satisfactory energy values for the cement industry as specified for alternative fuels. According to IEA statistics, the OECD cement industry used 66 PJ of combustible renewable waste in 2003, around half of it industrial waste and half wood waste. Worldwide, the sector consumed 112 PJ of biomass and 34 PJ of waste. There is apparently little use of alternative fuels outside the OECD, although the comparison of country data from various sources with IEA statistics tends to imply that alternative fuel use is under-reported. From a technical perspective, the use of alternative fuels could be raised to 1 to 2 EJ, although there would be differences among regions due to the varying availability of such fuels[12]. Reusing industrial by-products is considered as the most promising and practical solution to reduce the portion going to the landfill. These by-products can be reused by mixing with raw materials and fed to cement process. Moreover these wastes can be substitute with clinker and can become a composition of final cement. Fly ash is an example of such material. In case of fly ash, the by-product not only contributes to reduce raw materials and energy requirement in the process but also able to improve concrete property. The organic part in the fly ash is burnt and acts as the source of thermal energy and the mineral part is integrated into the process and contributes as raw material and additive[13,14]. Blast furnace slag is another example of materials which are being utilized as a portion of feed. It consisted of silicates, alumina-silicates, and calcium-alumina-silicates thus it reduces need of limestone and in consequence mitigates CO_2 emissions due to limestone decomposition[15]. An overall assessment of the environmental effects of co-processing of cutting oil emulsions in cement plants through the quantification of emissions of key pollutants, namely NOx, CO and VOC was presented by Giannopoulos et al.[16]. Tiwary et al.[5] showed that co-processing is efficient, economized and environmental friendly, particularly for a populated country, such as India, as there was no adverse effect on quality of cement, stack emission and air quality of environment due to co-processing of variety of identified wastes in cement kiln. Many tests have investigated the influence on the emissions and the product quality when waste materials are used to replace either fuels or raw materials in clinker production. So far, no adverse impacts have been identified[17, 18, 19]. Yen et al. [20] produced eco cement from industrial waste like marble sludge, sewage sludge, drinking water treatment plant sludge, and basic oxygen furnace sludge as a replacement for limestone, sand, clay, and iron slag, respectively. The utilization of