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Review article

Recent development on the uses of alternative fuels in cement manufacturing process

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ABSTRACT

Cement manufacturing is one of the leading energy consuming and heavy pollutant processes which is accountable for CO_2, NO_X, SO_2 emissions and some heavy metal discharge from the pre-calciner kiln system. In past few decades there has been an enormous amount of researches to reduce the energy and environmental cost by using alternative fuel and raw material. In recent years utilisation of alternative fuels in cement manufacturing has gained a wide attention due to its effectiveness in substituting the thermal energy requirement from fossil fuels and reducing the pollutant emission. Alkaline environment, high temperature and long residence time allow rotary kiln to burn a wide range of waste and hazardous material. Recent development on the usage of alternative fuels in cement industry is presented in this paper and many of the research articles relevant to this study is reviewed and discussed. Studies on the impact of alternative fuels on environmental emission have also been included in this review. This paper provides a thorough understanding and status of alternative fuels and their usage in cement industry and highlights their positive impact on environment. This study offers a guideline for planning and implementing alternative fuel usage in cement industry around the world, particularly in Australia. The paper revealed that meat and bone meal (MBM) could be the best alternative fuel option for Australia with a substitution rate of 40%.

Contents

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1. Introductions

The production of cement consumes large quantities of raw materials and energy (thermal and electricity). The manufacturing process is very complex, involving a large number of raw materials (with varying material properties), pyroprocessing techniques, and a variety of fuel sources. This process requires approximately 3.2–6.3 GJ of energy and 1.7 tons of raw materials (mainly limestone) per ton (t) of clinker produced [1,2]. Being an energy intensive industry, thermal energy accounts for about 20–25% of the cement production cost [3]. The typical electrical energy consumption of a modern cement plant is about 110–120 kW h per tonne of cement. In the process thermal energy is used mainly during the burning, while maximum share of electrical energy is used for cement grinding [3].

Generally fossil fuels such as coal, petroleum coke (petcoke) and natural gas provide the thermal energy required for cement industry. Due to environmental concerns, many researchers tried different alternative operating option for coal fired plant. To reduce the emission from coal fired plant different CO_2 capture technology can be adopted. Among them oxy-fuel combustion could be a viable option for cement industry. In oxy-fuel combustion technique primary fuel coal is burnt in oxygen rather than air with recycled flue gas [4,5]. Oxy-fuel combustion could potentially reduce the NO_X emission [4,6,7]. But it could also present some problem regarding the quality of the clinker since the carbon content of the fly-ash may increase in this process. An increase of SO_2 in the flue gas is also reported [4]. ECO-Scrub technology is another option which is a combination of partial oxy-fuel combustion and post combustion capture [7]. ECO-Scrub technology has been studied for large scale boiler and similar results of reduced NO_X emission was reported [8]. These CO_2 capture technology are only good to reduce the emission of CO_2 and NO_X but cannot ensure the quality of clinker and reduction of some heavy metal emission. Utilisation of alternative fuel offers cement manufacturer a better option to reduce the emission as well as to reduce the usage of fossil fuel. Increasing fossil fuel price is another reason for the cement producers to lean towards the alternative fuel to achieve the most economic and environment friendly fuel mix. In this perspective, the term "alternative fuels" stands for all non-fossil fuels and waste from other industries including tyre-derived fuels, biomass residues, sewage sludge and different commercial and industrial wastes [9].

At the beginning of the 1950s scrap tyres were used in Germany for the first time as a secondary energy source in the cement industry [10]. The two worldwide economic recessions during 1980–1982 and 1990–1991, directed many cement manufacturer to reduce their operational cost. As fuel cost covered a major part of production cost, the use of alternative fuel became attractive for achieving economic benefits. In the late 1980s and early 1990s, a number of hazardous waste fuels were burnt in cement plants at US and Europe. Over the years, the burning of non-hazardous waste fuels such as tyres also became well established and accepted as an alternate fuel in the industry [11].

A wide range of alternative fuel sources can be used in cement industries. Cement rotary kiln is able to burn a wide range of materials due to the long residence times at high temperatures, intrinsic ability of clinker to absorb and lock contaminants such as heavy metals into the clinker and the alkaline environment of the kiln. Materials like waste oils, plastics, waste tyres and sewage sludge (SS) are often offered as alternative fuels for the cement industry. Meat and bone meal (MBM) is another potential alternative fuel for cement industry which is produced from the slaughterhouse residues [12]. Apart from this, agricultural biomass, industrial waste and spent pot linings [13], are recently identified alternative fuels for cement industry.

Beside the economical benefit environmental advantage can be archived by substituting alternative fuels in the cement industry through the reduction of waste disposal sites. Main concern of using alternative fuel in cement industry is the pollutant emission. Cement industry is accountable for 5–6% releases of all carbon dioxide generated by human activities, which causes about 4% of global warming [14]. Emission of CO, NO_X and SO_2 from the cement industry contributes severe greenhouse and acid rain effects [15]. Heavy metal emission from the cement industry is another environmental concern and need to be controlled by appropriate measures. It is necessary to consider the environmental impact prior to adaptation and implementation of any alternative fuel.

The objective of this study was to review the available literature on different types of alternative fuel used in cement industry and their possible impact on the environment. Generally alternative fuels are selected for cement manufacturing on the basis of their availability in a particular region hence most of the studies were based on the type of waste and fuel available locally. Major alternative fuels in cement industry have been included in this review along with their level of application internationally, efficiency, barrier and the environmental impacts. A brief comparison of these fuels has been summarized which could be useful for experts in alternative fuels, cement producers and other researcher. On the basis of the comparison, meat and bone meal (MBM) is suggested to be best alternative fuel option for Australia while municipal solid waste (MSW) could be the second best option due to their availability.

2. Cement manufacturing process

The main process routes for the manufacture of cement vary with respect to equipment design, method of operation and fuel consumption [16]. The four basic processes can be classified as follows: