Industrial Waste as Alternative Fuel in Cement Industry: Its Impact on Environment

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Abstract:- Cement manufacturing is a high energy consuming and highly polluting process. Cement producers are trying to reduce the energy and environmental costs by using alternative fuels and raw materials through their research and development. Alkaline environment, high temperature and long processing time allow cement kiln to burn a wide range of waste and hazardous materials. This paper summarizes and reviews literature on the usage of different types of industrial wastes as alternative fuel. It also discusses their advantages, disadvantages, selection criteria and impacts on environment. It is concluded from the literature review that none of the individual alternative fuels can claim as the best alternative fuel on the basis of their energy value, level of greenhouse gas emissions and operational merits and demerits. Rather, it is suggested that the maximum benefit can be achieved by using a blend of different alternative fuels together with fossil fuel with appropriate percentage of substitution, which needs to be quantified. Further research study is being carried out at the Central Queensland University (CQU) to determine the optimum blending ratios to achieve higher thermal efficiency.

Key Words:- Cement, Alternative fuel, Industrial waste, Kiln, Emission.

1. Introduction

The production of cement consumes large quantities of raw materials and energy (thermal and electricity). This process requires approximately 3.2 to 6.3 GJ of energy and 1.7 tons of raw materials (mainly limestone) per ton of clinker produced [1,2]. Being an energy intensive industry, in cement industry thermal energy is accountable for about 20–25% of the cement production cost [3]. In the process thermal energy is used mainly during the calcinations process.

Generally fossil fuels such as coal, petroleum coke (petcoke) and natural gas provide the thermal energy required for cement industry. Usage of alternative fuel (AF) becomes more popular to the cement manufacturer due to increasing fossil fuel prices, limited fossil fuel resources and environmental concerns. AF cover all non-fossil fuels and waste from other industries including tyre-derived fuels, biomass residues, sewage sludge and different commercial and industrial wastes [4].

The rotary kiln used in cement manufacturing is able to burn a wide range of materials due to the long residence time at high temperatures, intrinsic ability for clinker to absorb and lock contaminants into the clinker and the alkalinity of the kiln environment. Materials like waste oils, plastics, waste tyres and sewage sludge are often proposed as AFs for the cement industry. Meat and bone meal are also considered now as alternative fuel [5]. Several biomass and industrial waste, such as spent pot linings [6], are newly identified as potential AF for cement industry.

Cement industry is one of the heavy pollution industry and accountable for the 5–6% releases of all CO_2 generated by human activities, which causes about 4% of global warming [7]. Cement manufacturing process also release NO_X, and SO_2 in the environment. Those gasses are accountable for severe greenhouse and acid rain effects [8]. Heavy metal emission from the cement industry is another important sector that needs to be controlled by proper measure. Before employing AFs in cement manufacturing process environmental impacts need to be considered.

The objective of this study is to review the available literature on different types of industrial wastes which can be used as AF in cement industry. Literature search reveals that the environmental impacts of using these wastes as AF have been extensively studied. All types of research journals, conference proceedings, books, industrial sustainability reports and websites are included in the review. Most of the studies were found to be region based according to the availability of the waste in vicinity. Selected AFs have been discussed in detail with their efficiency, barrier and the environmental impacts. A brief discussion has been appended to compare these fuels. Concluding remark has been drawn on the basis of this discussion that could be useful for AFs experts, cement producers and the researchers.

2. Cement Manufacturing Process

The main process routes for the manufacturing of cement vary with respect to equipment design, method of operation and fuel consumption [9]. In this review only the dry process with pre-heater or pre-calciner has been considered. Cement manufacturing process basically includes quarry, raw meal preparation, preheating of raw meal, kiln, clinker cooling, grinding, storage and dispatch. The basic chemistry of the cement manufacturing process begins with the decomposition of calcium carbonate ($CaCO_3$) at about 900°C to leave calcium oxide (CaO, lime) and liberate CO_2; this process is known as calcination. This is followed by the clinkering process in which the calcium oxide reacts at high temperature (typically 1,400°–1,500° C) with silica, alumina and ferrous oxide to form the silicates, aluminates and ferrites respectively which forms the clinker. This clinker is then ground together with gypsum and other additives to produce cement. Figure 1 shows a basic process flow of cement manufacturing.

3. Alternative Fuels

Most natural and artificial materials contain some energy which can be utilised by the cement industries to meet the requirement of the thermal energy. The use of AF for cement clinker production is certainly of high importance for the cement manufacturer as well as for the environment. Alternative fuel utilization at commercial level in cement industry is as old as about 30 years now. In calciner lines, up to almost 100% AF firing at the precalciner was achieved at very early stage [10]. Use of AF in rotary kiln is still in progress. Reports show that in some kilns up to 100% substitution rates have been achieved [11], while the others are facing some barrier in regards to environmental, social and product quality issues. In any case, AF utilization requires adaptation by the cement industry. Modern multi-channel burners and thermograph systems help in controlling the AF feed rate and the flame shape to optimize the burning behaviour of the fuels [10].

Generally the cement producers choose the AF on the basis of price and availability. These criteria of selecting AF are not adequate. Rather, it is also necessary to know the composition of the fuel including the energy content, moisture and volatile contents. All forms of fuel materials such as: liquid, solid, semi-solid, powdered or in the form of big lumps need to be considered when dealing with AF. It requires a flexible fuel feeding system, trough which AF could be fed either directly into the burning zone at kiln or in the pre-heating system [5].

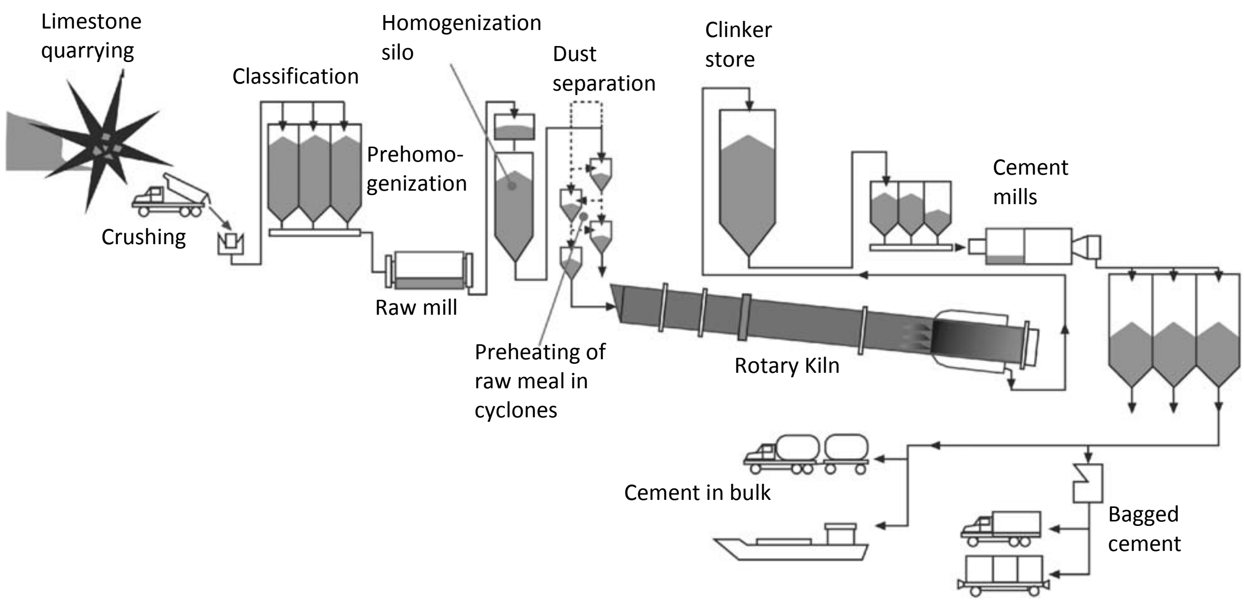

Fig. 1 Cement manufacturing process [5]

3.1 Criteria of Alternative Fuel

There are no set criteria of AF selection as on today. The specific criteria that a material must meet in order to be considered as a fuel is typically set by the individual cement producer according to their own needs. To cite an example the following criteria has been adapted by Lafarge Cement Polska group to use a substance as an AF [12]:

- Energy value – over 14 MJ/kg
- Chlorine content – less than 0.2 percent
- Sulphur content – less than 2.5 percent
- Polychlorinated Biphenyls (PCBs) content– less than 50 parts per million (ppm), and
- Heavy metals content – less than 2500 ppm.

The production of clinker requires an even combustion of fuels in order to consistently heat the raw materials. Considering this, the fuels must be processed and conditioned to have the following characteristics [13]:

- even particle size distribution
- high and uniform calorific value
- free of detrimental contents like some metals, glass, and minerals, and
- low moisture content.

3.2 Advantages and Disadvantages

Alternative fuels are generally cheaper than the fossil fuels. A mixture of fossil fuels and AF in optimal proportion is used to produce the thermal energy required in cement industry. The significant advantage of AF substitution is the preservation of non-renewable energy sources [14] and the reduction of waste disposal sites.

Switching to alternatives fuels presents several challenges as they have different characteristics compared to the conventional fuels. Poor heat distribution, unstable precalciner operation, blockages in the preheater cyclones, build-ups in the kiln riser ducts, higher SO_2, NO_X, and CO emissions, and dusty kilns are some of the major challenges which need to be addressed [15]. One potential constraint on the implementation of AF is the final clinker composition since the combustion by-products are incorporated into clinker [16]. The substitution of AF inherently requires initial investment costs associated with adjustment or replacement of burner, establishment of AF delivery systems, new fuel storage facilities, and fuel distribution systems [17].

3.3 Industrial Waste

Industrial symbiosis are investigated and practiced all over the world. As most of the cement manufacturing plants are situated in the regional industrial areas, it is easy to build up an industrial symbiosis with the industries in vicinity. Cement industry could be benefited by using industrial waste as alternative fuel since it will reduce the fossil fuel consumption. Beside this cement industry may even claim a tipping fee to dispose the industrial waste. This will reduce the production cost even more. Incineration in cement kiln is now being considered a viable option for the treatment of hazardous industrial waste. This process has been widely developed in Europe and the USA, and is now becoming popular in other countries. In this section several industrial wastes which are commonly used as alternative fuel have been discussed on the basis of efficiency, barrier and the environmental impacts.

3.3.1 Used Tyre

End life tyre is a waste from automobile industry and generally disposed off in landfills or stockpiles. Landfilling or stockpiling tyres has potential environmental, safety and health hazards. Amongst them rodent and insect infestation are well known. In mid 80's tyre became very popular to the cement manufacturer as AF to cope with the increasing fuel costs. High carbon content, high heating value of 35.6 MJ/kg [18] and low moisture content make tyre derived fuel (TDF) one of the mostly used AF in cement industry all over the world. TDF costs are significantly lower than natural gas costs and coal. Reinforcing wires of tyres can be consumed as a replacement of raw material containing iron [18] when the whole tyre is used as AF. Puertas and Blanco-Varela [19] reported that there exist no significant differences in the chemical composition of the clinker manufactured with TDF as opposed to fossil fuel.

Though the use of scrap tyres in cement kilns reduces resource consumption, it was intensively studied for its environmental impact. Contradictory results exist for SO_2 and NO_x emissions while using TDF in cement manufacturing. Prisciandaro et al. [20] reported that SO_2 and NO_x emissions increase in an Italian cement plant while replacing TDF up to 20% of fossil fuel. On contrast Carrasco et al. [21] found a decrease in NO_x emissions but an increase in SO_2 while studying Canadian cement factory that used combination of coal and scrap tyres. Schrama et al. [22] and Lemarchand [23] reported that the emission of NO_x decreased when whole tyres are used as AF.

Similar differing results in terms of metal and dioxin and furan emissions are also found in

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literature. In real plant scenario, Conesa et al. [24] showed that dioxin and furan emissions increased while using scrape tyre as AF. By contrast, Carrasco et al [21] found that using scrap tyres in cement kilns reduced the amount of dioxins and furans emitted. However, Prisciandaro et al [20] reported that the emissions of dioxins and furans were similar (and well below the limit).

CO emissions in most cases are found higher (average 35% higher) [25] when TDF is used. HCL emission was found to be higher than normal [21]. Zinc, which is added to tyres during rubber compounding to control the rate of vulcanization, has the potential to increase from an emissions standpoint [26].

3.3.2 Spent Pot Liner

Spent pot liner (SPL) is a solid waste produced from aluminium industry during the manufacture of aluminium metal in electrolytic cells. The lining of the cell is composed of carbon, which is backed by insulation and contained within a steel container called a potshell. The carbon portion of the lining serves as the cathode for the electrolysis process. After a certain period the cell lining become impregnated with fluoride-containing salts. Then the cathode lining material is removed from the potshell by mechanized digging equipment. This spent cathodic material is referred to as spent pot liner (SPL). The life cycle of a cathode typically varies from about 3 to10 years [27].

U.S.-generated SPL was recycled up to 79% in cement kilns in 2010 [28]. In 2009, 7449 tonnes of SPL were recycled in Australia, mostly in cement industry as AF [29].

The heating value of SPL is 25.2 MJ/kg [30] which is almost equal to bituminous coal. The total SPL generation in the world was about 800,000 tons in the year 2003 which implies the availability of SPL as AF [30]. Scant literature was found in regards to environmental impact of SPL while using it as fuel in cement kiln. At 20^oC the cyanide content of SPL is 0.033% [30] and a test study showed that almost 99.9% of the cyanide is destroyed when it is used as AF in a cement kiln [31]. Lechtenberg [6] reported a reduction of NO_X and CO_2 emission while using SPL. Lechtenberg [6] indicated that use of SPL would also be a supplement of raw materials such as silica, alumina and ferrous components. SPL has high fluorine content, and hence handling and transportation of SPL could be an issue.

3.3.3 Plastic Waste

Plastic waste is considered as one of the most readily available potential candidates for AF in cement industry due to their high calorific value 29-40 MJ/Kg [32]. Plastic wastes are available as municipal waste as well as industrial waste. The only concern of using it is the Chlorine content which is mainly found in PVC.

According to Al-Salem et al. [33] the accepted particle size for the incineration process is 10×10×10 cm and a shredder is needed when larger parts are offered in the kiln. Isolation of materials from plastic waste and retrofitting requires additional capital and labour costs. Use of chlorinated plastics can affect clinker quality [34]. The chlorine content of plastics can also be the cause of HCl emissions. Emission of dioxins and furans can be increased by the presence of chlorine under specific conditions [35]. Al-Salem et al. [36] mentioned that the NO_X emission, while burning plastic waste, depends on the nitrogen content of the plastic and some other issue such as the flame temperature and air quantity.

3.3.4 Sewage Sludge

A large amount of sewage sludge is produced worldwide during wastewater treatment. Landfill, used in agriculture as organic fertiliser and soil conditioner are the main conventional methods of disposal, most of which are not environmental friendly [15]. The most common sewage sludge disposal alternative is to incinerate it in cement kiln and confine the ash in the clinker. Werthera and Ogadab [37] suggested that the maximal sewage sludge feed rate should not be more than 5% of the clinker production capacity of the cement plant.

Main advantage of using sewage sludge in cement kiln is the reduction of landfill which may cause human health and environmental risks. The heating value of sewage sludge depends on the moister content and with 5% of moisture content it is 15.8 MJ/kg [5]. The ash from the sludge substitute raw material in cement manufacturing hence reduces the production cost [38].

One study [34] showed that NO_X emissions are reduced while using sewage sludge compared to the fossil fuels. Cartmell et al. [39] reported an increment of SO_2 emissions. Conesa et al. [24] stated that there was no correlation between sewage sludge using rate and heavy metal emissions. But Cartmell et al. [39] reported earlier that sewage sludge causes an increase in heavy metal emissions compared to fossil fuels. More intensive studies are needed to increase the reliability of these findings.

3.3.5 Solvent and Spent Oil

Solvent and spent oil from different industries generally have high calorific value and those can be used in cement kiln as AF with minimal processing cost [40]. De Vos et al. [40] mentioned that the maximum and minimum calorific values of solvent and spent oil were 29 MJ/Kg and 36 MJ/Kg respectively and the variation occurred due to the ratio of different chemical in it. As mentioned earlier most of the time the cement plants are established in the vicinity of industrial area which makes the solvent and spent oil a highly acquirable fuel in minimum transportation cost.

Storage is the major issue for solvent and spent oil as there is a possible chance of volatile organic compound (VOC) emission [40]. Solvent and waste oil contain less mineral/s compared to petcokes and coal hence a little additional raw meal is needed to ensure the quality of the cement [40]. One study showed a reduction of nitrogen oxides when using spent solvents as compared to fossil fuels [41]. De Vos et al. [40] reported that CO_2 emission was reduced while solvents and paint sludge were used as AF. The literature is inconclusive with respect to the changes in SO_2 emission. Mlakar et al [42] showed a reduction in mercury emissions while Seyler et al. [41] showed a reduction in heavy metal emissions when waste solvents were mixed with fossil fuel.

3.3.6 Others

Apart from the above-mentioned industrial wastes there are varieties of other AFs which can be found in literature. Amongst them carpet waste, oil soaked rags, automobile shredded residue, fluff, textile waste, paper residue, packing boxes are few to name. Unfortunately not much information regarding their uses and impact are available and there is a need for more research to justify their candidature.

4. Discussion

The use of industrial wastes in cement kiln is less desirable option over recycling or reusing. But this disposal option is a useful alternative to landfill. Selected five industrial wastes which are currently used in cement industry as AFs have been discussed in this article. The environmental impact from emission standpoint has been extensively studied by different researchers. This review summarized most of the research efforts made towards the AFs in the recent past.

It is really difficult to claim a particular AF to be the best amongst the discussed candidates in this paper. The reason being these are neither tailor made nor factory produced where constituents types and their quantities could be controlled. In regards to calorific values plastic waste is the best option but presence of dioxins and furans emissions pose some restrictions on their usage. Solvent and spent oil also has high calorific value and it reduce the green house gas emission. Still recycling and reusing of solvent and spent oil is preferred over the incineration in cement kiln.

TDF is widely used in cement industry for a long period of time. Literature reports TDF usage more than 30% of the kiln fuel may alter the chemistry of the cements and affect hardening process adversely. The usage of SPL is restricted due to high florin content. SPL is relatively new in cement industry as AF and its impact on environment has not been studied extensively yet. Among the discussed AF sewage sludge has lowest calorific value but the ash derived from the sludge substitute raw material which is an additional advantage.

Research indicates that none of the aforementioned AFs can solely replace the entire fossil fuel used in cement manufacturing. In fact a perfect blend of different AF can be the substitute of traditional fuel. Cemex UK's South Ferriby cement plant in Lincolnshire has replaced 100% of the fuel by AF which is a blend of industrial liquid waste (paint, solvent etc.) and Climafuel, which is made from household residue and commercial waste [11]. Scant literature is available in the area of the emission from cement industry as a result of using blend of different AFs. There is not enough evidence of research in the direction of optimal proportion of AFs and fossil fuels available in the literature. It is true that it is difficult to determine a correct proportion due to unknown composition of AFs, further research is needed in this direction.

Currently a research group at Central Queensland University (CQU) has undertaken a project to investigate the feasibility of using different industrial wastes as AF for cement industry and to optimize their usage. Process engineering software ASPEN PLUS is being used to model the heating system of a full-scale cement plant, using different AFs on the basis of combustion mechanism. This software is focused on clinker chemistry, thermodynamics in the rotary kiln and also the effect of AFs on material flow, emissions and product quality. Through simulation the usage of industrial wastes will be maximized along with controlling the above factors. ASPEN PLUS could also be used to calculate the heat balance of the entire process using established thermodynamics principles of material and energy conservation.

5. Concluding Remark

In this review several AFs that are being used in cement manufacturing have been discussed. These fuels have been critically analysed on the ground of their calorific values, advantages, disadvantages, greenhouse gas emissions and environmental impact. In a preliminary study undertaken by CQU research group, different fuels were evaluated based on the data available for their suitability in cement kiln. The study showed that SPL is one of the most promising candidates for further research. It is proposed that a blend of AFs and fossil fuel can be used in different proportions for characterising the fuel for its performance under different operating conditions in a kiln of a local industry.

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The cement industry in Finland has a great interest in studying to what extent fuel (usually coal) can be replaced by alternative fuels, e.g. processed industrial waste materials. Alternative fuels provide opportunities for reducing production costs. Further benefits are environment-related: reduction of emissions, utilisation of energy from alternative fuels etc. A project in this field started in Finnsementti OY. So far experiments have been carried out in Parainen / Pargas, Finland in a 2000 tonnes/day kiln.Â The aim was to verify the suitability of shredded tyres as additional fuel in the riser duct of a 4-stage cyclone preheater rotary kiln. Download full article. Most popular related searches. The cement industry worldwide is seeking to increase the use of alternative fuels for production, both to decrease energy dependence on conventional fossil fuels and to mitigate the adverse environmental impact. The use of waste as alternative fuel in the cement industry began in the 1970s, and the number of cement factories using alternative fuels and materials has since grown worldwide. The waste treatment process development has particularly accelerated in Germany, as well as in many other EU member states, since the adoption of the Landfill Directive in 1999, as well as tight biodegradable Waste fuels, such as hazardous wastes from industrial or commercial painting operations (spent solvents, paint solids), metal cleaning fluids (solvent based mixtures, metal working and machining lubricants, coolants, cutting fluids), electronic industry solvents, as well as tires, are often used as fuels in cement kilns as a replacement for more traditional fossil fuels (Gabbard 1990). The use of alternative fuels to displace coal reduces reliance on fossil fuels, reduces emissions of carbon dioxide (CO_2) and other pollutants, and contributes to long-term cost savings for cement plants.Â Whether to co-process alternative fuels in cement kilns can be evaluated upon environmental and economic criteria.Â additional emissions and negative impacts on.