VOLUME - 10, ISSUE - 08, AUGUST- 2021 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper | Environmental Science

ENVIRONMENTAL ADVANTAGES OF USING ALTERNATIVE FUELS IN CEMENT MANUFACTURING USING GREEN CHEMISTRY

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ABSTRACT One of the most energy consuming, and intensive polluting process is the making of cement.It results in emissions of NOx, CO2,SO2, and certain heavy metals from the pre-calciner kiln system. Every ton of Portland cement manufactured emits an equal amount of CO2. There has been a tremendous amount of study in recent decades to minimize environmental and economic costs by employing raw materials and alternative fuels. In the manufacturing of cement, alternative fuels have gotten a lot of attention in recent years because of their success in replacing fossil fuels for thermal energy and lowering pollutant emissions. This paper examines recent developments in the utilization of alternative fuels in the production of cement. This review also includes various research on the influence of alternative fuels on environmental conditions.

KEYWORDS : Alternative Fuel, Cement, Emission, Green cement.

INTRODUCTION –

Cement manufacture needs a considerable amount of energy (electricity and thermal) and raw materials. The production process is very complicated, requiring pyroprocessing processes, a huge quantity of raw materials (all with different characteristics), and numerous fuel sources. This technique uses 1.7 tons of raw materials (mostly limestone) and 3.3-6.4 GJ of energy every ton of clinker [1,2]. Because production of cement is highly energy consuming business, the cost of energy contributes for around 20-25 percent of the total cost [3]. A contemporary cement plant's normal electrical energy use is about 110-120 kWh per ton of cement. The burning process consumes the maximum thermal energy, but cement grinding consumes the most electrical energy[3].

The thermal energy necessary for the cement manufacturing is often provided by fossil fuels like coal, natural gas, and petroleum coke (petcoke). Several researchers experimented with several alternative coal-fired plant operating options because of environmental considerations. Different CO_2 collection technologies may be used to minimizeemission of CO_2 from coal-fired power plants. Oxy-fuel combustion is one of them, and it might be a feasible solution for the cement industry. NO_x emissions might be reduced by burning oxygen-rich fuels [4,5]. However, since the carbon concentration of the fly-ash may grow during this operation, it may cause issues with clinker quality. A rise in SO_2 levels in the flue gas has also been documented [4]. The ECO-Scrub method has been investigated for large-scale boilers, with comparable findings in terms of decreased NO_x emissions [6]. These CO_2 capture systems are only useful for reducing CO_2 and NO_x emissions; they do not guarantee clinker quality or the reduction of certain heavy metal emissions. The use of alternative fuels provides a better choice for cement manufacturers to cut emissions while also reducing their reliance on fossil fuels. The rising cost of fossil fuels is another motivation for cement makers to shift their focus to alternative fuels in order to attain the most cost-effective and environmentally benign fuel mix. The phrase "alternative fuels" in this context refers to all non-fossil fuels and waste from other sectors, such as biomass leftovers, sewage sludge, tyre-derived fuels, and other industrial and commercial wastes [7].

Scrap tires were originally employed as a supplementary source of energy in the cement industry in Germany in the onset of the 1950s [8]. During the two global economic recessions of 1980-1982 and 1990-1991, many cement manufacturers were forced to lower the operating costs. Because fuel costs made up such a large portion of manufacturing costs, alternative fuels were appealing as a means of obtaining cost savings. Several harmful waste fuels were burned in cement factories in the United States and Europe in the late 1980s and early 1990s. Non-poisonous waste fuels, like tires, have also become well-established and acknowledged as an alternative fuel in the manufacturing of cement over time [9]. Cement industry may use a variety of alternative fuel sources.

Because of the lengthy residence lengths at high temperatures, the inherent capacity of clinker to absorb and lock impurities like heavy metals into the clinker, and the kiln's alkaline atmosphere, the cement rotary kiln may burn a broad variety of materials. Alternative fuels for the cement industry are often supplied, including plastics, waste lubricants, sewage sludge (SS), and waste tyres. Meat and bone meal (MBM), which is made from slaughterhouse waste, is another viable alternative fuel for the manufacturing of cement [10]. Aside from that, alternative fuels for the cement industry have lately been discovered as industrial waste, spent pot linings, and agricultural biomass [11].

Aside from the economic benefits, the utilization of alternative fuels in manufacturing of cement sector may result in a decrease in waste disposal sites, which may be archived. The main difficulty with employing alternative fuels in the cement industry is pollution. The cement industry is responsible for 5-6 percent of all CO_2 produced by human activity, that contributes to around 4percent of global warming [12]. The cement industry's CO, NO_x, and SO_2 emissions lead to serious acid rain and greenhouse consequences [13]. Another environmental risk is heavy metal emissions from the cement sector, which must be addressed with suitable controls. Prior to the adaption and deployment of any alternative fuel, the environmental effect must be considered.

Global Production And Environmental Impacts –

Cement manufacturing varies widely from nation to nation and is heavily influenced by raw material availability. According to a latest assessment, worldwide cement output passed 4 billion tons, with China accounting for majority of market, while average cement plant generating capacity remained in the range of 1.5–2.5 million tonnes yearly [14].

Cement output has risen dramatically in recent years, and the sector has expanded, particularly in emerging Asian nations such as China and India.

Energy needed for manufacture, mining of natural resources, direct and indirect greenhouse gas emissions during clinker production and transportation, and waste creation are all important environmental concerns associated with cement. Many extensive environmental studies on the effects of many primary processes engaged in cement manufacture have been done [15]. There are two primary sources of gas emissions in the Portland cement production process:
1. The calcination process, which accounts for almost half of all emissions.
2. The use of fuel combustion to heat raw materials.

Environmental challenges span from a local level, such as cement kiln dust (CKD), to a global one, like global warming (like CO_2-SO_2-NO_x emissions). PM10 refers to CKDs with a diameter of less than 10 m. Table 1 [16-23] summarizes the various gases released throughout the cement manufacturing process.

Table 1 Summery of gases emission durirng cement manufacturing process (g/kg* cement and g/kg** clinker) [16-23]

No.	CO_2	SO_2	NO_x	CKD/PM-10
1.	870 g/kg*	-	-	-
2.	810 g/kg*	-	-	-
3.	800 g/kg*	0.40-0.60 g/kg*	2.4 g/kg*	0.1-10 g/kg*
4.	820 g/kg*	-	-	-
5.	690 g/kg*	0.82 g/kg*	1.2 g/kg*	0.49 g/kg*
6.	810 g/kg*	0.58 g/kg*	1.5 g/kg**	0.04 g/kg**
7.	900 g/kg*	0.27 g/kg**	1-4 g/k**	200 g/kg**
8.	895 g/kg*	-	-	150-200
9.	-	0.54 g/kg**	-	-
10.	-	-	2.5 g/kg**	0.1-0.3 g/kg**
Mean	814 g/kg*	0.5 g/kg*	2.5 g/kg**	25 g/kg*

Emissions of CO_2 during calcination and energy-related CO_2 emission were differentiated by Gartner [23]. (energy bound CO_2). In terms of energy-bound emissions, the effectiveness of the rotary kiln is critical. Table 2 [24] illustrates the specific heat consumption in the cement clinker manufacturing process as a function of the technology utilized. An appropriate kiln type may decrease energy consumption to <2.9 GJ per ton clinker, while a conventional cement kiln uses 3.1 GJ per ton of energy and emits around 0.31 kg of carbon [24].

Emissions from raw materials are restricted. Partially substituting additional cementitious materials like fly ash or blast furnace slag for raw materials is one alternative. Replacement levels of up to 10% have been recorded [25]. In principle, CO_2emissions might be decreased by up to 25% by replacing 10% of the limestone [24].

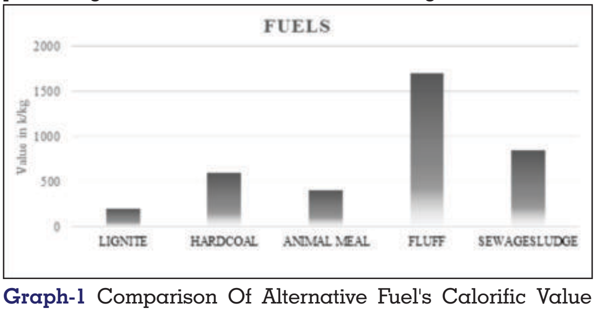
Table 2 Specific thermal energy consumption in a clinker manufacturing process [24]

Kiln Process	Themal Energy Consumption (Gj/Clinker)
Wet process	5.85-6.28
Long dry process	4.60
Shaft kiln	3.70-6.60
1-Stage cyclone preheater	4.18
2-Stage cyclone preheater	3.77
4-Stage cyclone preheater	3.55
4-Stage cyclone preheater plus calciner	3.14
6-Stage cyclone preheater plus calciner	<2.93

Alternative Fuel –

The utilization of alternative fuels for clinker manufacturing is critical not just for the cement industry, but also for theenvironment. Alternative fuels were first used in the mid-1980s. Starting in the calciner lines, up to nearly 100 percent alternative fuel burning in the precalciner stage was achieved in a relatively short time.Animal waste, tires,lumpy materials, waste oil, and sewage sludges are the most often utilized alternative fuels. Solid recovered fuels include those reclaimed from industrial waste streams, as well as, to an increasing degree, municipal sources. Plastics, shredded paper, textiles, foils,and rubber are among the waste-derived fuels.

While 100percent replacement rates have been reached in certain kilns, larger rates of alternative fuels are not possible in others due to local trash markets and permission restrictions. In any event, their use necessitates a change in the combustion process. Modern multi-channel burners developed for alternative fuels enable modification of the flame shape to improve the fuels' burning behavior as well as the clinker's burning conditions [26]. In a traditional preheater kiln, fuels may only be burned at substitution rates of up to 25%–30% in the kiln intake. This is not the case with precalciner kilns, where the calciner receives up to 65 percent of the total fuel energy input and the main kiln burner receives a minimum of 35 percent. As a result, using alternative fuels in the precalciner has no effect on the type of the fuels put in the kiln, and hence has no effect on kiln performance. Most operators begin by increasing the use of alternative fuels in the precalciner. Following that, they begin to increase the percentage of alternative fuels in the sintering zone.



Graph-1 Comparison Of Alternative Fuel's Calorific Value [26,37]

In reality, when alternative fuels are employed in the cement kiln, they are combined with the raw meal, which might affect the qualities of the clinker. A recent article examined the chemical effects of minor components introduced to clinker as a result of alternate fuel usage [27]. Sulphur and phosphorus, for example, have a significant influence on belite content and C 4 AF formation [28]. The burnability of uncooked food is affected by halogen and chloride [29].

A research looked at the future of alternative fuel consumption and found that in affluent nations, a ratio of 40 to 60 percent alternative fuel may be attained by 2050, but in underdeveloped nations, the ratio would be around 25 to 36 percent[30]. Much greater substitution rates are technically achievable. In several European nations, the average replacement rate for the cement sector is above 50%, with annual averages of up to 98 percent for specific cement plants. Alternative fuel utilization has the potential to reduce CO_2 emissions significantly, since fuel-related CO_2 emissions account for around 40% of total CO_2 emissions from cement manufacturing.

Although cement kilns might theoretically utilize up to 100percent alternative fuels, there are significant practical constraints. Most alternative fuels have drastically different physical and chemical qualities than traditional fuels. While some, likebone-and-meat meal, are simple to employ in the cement business, others pose technological difficulties. These are caused by factors such as a high moisture content, a low calorific value,or anincreased other trace ingredient or chlorine concentration. For example, volatile metals (such as Hg, thallium, and Cd) must be carefully regulated, and cement kiln dust must be properly removed from the system. As a result, pre-treatment is often required in order to get a more homogenous composition and optimal combustion. Higher replacement rates, on the other hand, face more political and legal obstacles than technological ones:

- Waste management regulation has a substantial influence on availability: increased fuel substitution occurs only when local or regional waste policy prohibits dedicated incineration or landfilling and allows for regulated waste collection and alternative fuel treatment.
- Local rubbish collection networks must be sufficient.
- With rising CO_2 prices, alternative fuel costs are anticipated to rise. The cement industry may therefore find it more difficult to get large volumes of biomass at reasonable pricing.
- The degree of societal acceptability of waste fuel co-processing in cement plants may have a significant impact on local adoption. Even if emissions from well-managed cement plants are reduced with alternative fuel utilization [31], people are frequently worried about hazardous emissions from co-processing. Furthermore, the employment of alternative fuels has the ability to improve thermal energy usage such as when pretreatment is necessary, as described above.

Alternative Fuels Classification –

Cement kilns employ a variety of energy sources to achieve the high temperatures required for clinker production. Fuel oil, coal, natural gas, and petroleum coke are the most frequent fuel sources for the cement industry [32].

Cement manufacturers all around the globe employ alternative fuels as a source of energy. These fuels are often made from a combination of industrial, municipal, and hazardous waste [33]. Solid or liquid alternative fuels are employed in the cement industry. Based on the kind of component and its organic composition, they must have an adequate chemical content. Solid alternative fuels are divided into four categories [34].

Such fuels usually include following compounds:

· Non-agricultural biomass residues
· Chemical and hazardous wastes
· Miscellaneous wastes
· Petroleum based wastes
· Agricultural biomass residues

The clinker and calciner forming kiln account for the majority of fuel use and, as a result, CO_2 production. When low-carbon fuels with a high hydrogen-to-carbon (H/C) ratio are used instead of traditional fossil fuels, the rate of carbon-dioxide emission is dramatically reduced. Alternative fuels have been demonstrated to enhance refractory life as well as minimize pressure loss in preheater towers [35], in addition to emitting less CO_2.

Several forms of alternative fuels may be utilized in a cement production if the appropriate equipment is provided. The utilization of alternative fuels in cement factories also helps to minimize landfill emissions [36]. As a result, it has been anticipated that the use of this form of fuel will grow at a pace of 1percent per year globally [35,37].

Advantages Of Alternative Fuels –

Ecological Advantages –

Many years of experience using waste as alternative fuels in the cement industry has shown that their usage is both economically and environmentally justifiable. To begin, there is a decrease in the usage of nonrenewable fossil fuels like coal, and also the environmental consequences of coal mining. Furthermore, by substituting substances that would otherwise have to be burnt with related emissions and ultimate wastes for fossil fuels, a contribution to decreasing emissions like greenhouse gases is made. All of the energy is utilized directly in the kiln to produce clinker [38].

The utilisation of alternative energy sources in cement furnaces is also defined by the broad term "environmental protection," because it saves not only primary sources of energy, but also waste that would otherwise have to be discarded of on waste disposal sites or burned in specially designed incineration plants. The use of alternative fuels derived from trash might decrease the quantity of garbage that has to be disposed of by up to 50 percent. Both incineration facilities and garbage disposal facilities have the potential to have considerable detrimental effects on environmental components. It is important to remember that obtaining primary energy sources has a negative impact on the environment [33,38].

Technological Benefits –

With a flame temperature of 2000°C and a material temperature of roughly 1400°C, and a residence duration of 4–5 seconds in an oxygen-rich environment, all organic components in any leftovers are destroyed. The alkaline composition of the raw material neutralizes any acid gases generated during burning, and it is then incorporated into the clinker. The interaction of flue gases with the raw material in the kiln guarantees that the non-combustible component of the kiln, if existent, is minimized. It outperforms a specialist incinerator or any other option in terms of entire life cycle cost. There are several social advantages, including the fact that implementation in rural areas would help to the area's general development and employment. Additionally, it produces extra cash for the region's poor and often drought-affected farmers, assisting rural uplift and improving their economic standing [33,38].

Economic Benefits –

The cement industry's usage of alternative fuels is linked to the energy-intensive clinker manufacturing process. The energy needed to produce one tonne of cement is around 3.3 GJ, which is equivalent to around 120 kg of coal. Energy expenses account for about 30–40percent of overall cement manufacturing costs. As a result of the use of alternative fuels, manufacturing costs will be reduced. The utilization of waste-derived fuels in cement factories not only helps the business financially, but also helps society. Smaller amounts of trash will be disposed of in or diverted to incineration facilities as a result of such waste management. This will result in fewer new disposal sites, a restriction on the growth of current sites, and the avoidance of the need to construct incineration facilities [33,38].

CONCLUSION –

Cement manufacturing expenses will be reduced by using alternative fuels. The use of alternative fuels instead of fossil fuels will lower energy costs, giving a cement factory that uses this form of energy a competitive advantage. Additionally, less garbage will need to be discarded or burned, resulting in fewer disposal sites. As a result, cement mills will benefit the environment by using waste-derived alternative fuels. Apart from waste recovery systems, this will most likely not be done. Furthermore, if cement factories have preheaters and the waste supply chain is coordinated, a rise in alternative fuel utilization has a lot of promise. Clinker replacement may help to reduce the environmental effect of cement manufacture even further.

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