Sustainable Waste Management: A Case Study of Cement Industry

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ABSTRACT
Sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs, and Sustainable Waste Management is using waste produced efficiently so that use of amount of material resources get reduced. India, is the second amongst cement producers in the world with a total capacity of 245.40 Million Tonnes (MT), has a huge cement industry and produces about 7% of world’s total production. The Indian cement industry has on one hand, enormous pressure to increase profit and margins, while on other; there is considerable public interest on a sustainable and environment friendly usage of natural resources. The objective of this paper is to pursue sustainable waste management for a cement industry through replacement of coal with some alternative fuel, which actually belongs to the group of hazardous wastes and which could benefit the plant economically and environmentally, and improve sustainability of plant. The use of alternative fuels will help in reducing energy costs and providing a competitive edge for a cement plant. Furthermore, this will reduce the burden of waste disposal considerably. So, it also supports to fulfilling Sustainable Waste Management issues.

Key Words: Sustainability; Sustainable Waste management; Hazardous Waste; Alternative Fuels.

1. INTRODUCTION
In 1987 the World Commission on Environment and Development sought to address the problem of conflicts between environment and development goals by formulating a definition of sustainable development: “Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs.”(World Commission on Environment and Development, 1987). In the extensive discussion and use of the concept since then (see e.g. Holmberg, 1992; Reed, 1997; Harris et al., 2001), there has been a growing recognition of three essential aspects of sustainable development, which are Economic, Environmental, Social aspects [1].

Sustainable waste management: Definition: Using material resources efficiently to cut down on the amount of waste produced. And, where waste is generated, dealing with it in a way that
actively contributes to the economic, social and environmental goals of sustainable development. The different waste management options can be organized in an order known as the waste management hierarchy that reflects the relative sustainability of each.

Fig 1.1: The "three pillars" of sustainability bounded by the environment [2].

Fig 1.2: Waste Management Hierarchy [3].

India, is the second amongst cement producers in the world with a total capacity of 245.40 Million Tonnes (MT) as on 31st March 2011, has a huge cement industry and produces about 7% of world’s total production. Cement plants are an essential part of India’s industrial landscape and are increasingly important partners in innovative waste management solutions, called co-processing. Co-processing waste in this way consists of using both the calorific potential to heat the kiln and the material component from the fuel ash as a raw material, It also has a direct impact on lowering CO2 emissions, since it reduces the quantity of natural raw materials needed for clinker production [4]. Several cleaner production programs were implemented by the government, to build the capacity of industries in meeting new environmental policies. Some of the cement plants in the country had been authorized by CPCB for using biomass, waste oils, and rubber wastes (tires and mouldings) for use as alternative fuel (AF) for coal after successful trial runs.
A cement plant consumes 3,000 to 6,500 MJ of fuel per tonne of clinker produced, depending on the raw materials and the process used [5]. Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. As well as providing energy, some of these fuels burn to leave fuel ash containing silica and alumina compounds (and other trace elements). These combine with the raw materials in the kiln contributing to the structure of the clinker and form part of the final product. It has been reported that the costs associated with fuels in a cement plant can be as high as 30 to 40 percent of the total production costs [6]. Recently, Central Pollution Control Board has come up with guidelines on use of Alternative fuel for Cement Industry. It will not only solve the problem of waste management to significant level but also reduce use of fossil fuel. In addition to energy recovery, there is also a corresponding saving relevant to CO2 emissions released into the atmosphere, since waste replaces other fossil fuels producing greater CO2 levels [7].

![Image of Cement Industry Share in CO2 Emissions]

**Fig 1.3: Cement Industry Share in CO2 Emissions [8].**

Co-Combustion or Co-processing of alternative fuels and raw materials (AFRs) and hazardous wastes in cement kilns will usually constitute one tool in a complete toolbox, complementary with other treatment options. The co-processing of waste has been recognized as a recovery operation under EU legislation. Co-processing is a sustainable development concept based on the principles of industrial ecology [6,9].

### 1.1 ADAPTABILITY OF ALTERNATIVE FUELS

The burning of various types of wastes requires the detailed control and adaptation of technological processes to each type of waste. For this reason, alternative fuels are derived from wastes having similar composition and properties. As a mixture of various wastes, alternative fuels must be produced in conformity with certain rules:

- The chemical quality of the fuel must meet regulatory standards assuring environmental protection,

- The calorific value must be stable enough to allow the control of the energy supply to the kiln; the objective being to arrive at a fairly homogeneous composition, and

- The physical form must allow easy handling of the material for transportation and a stable, adjustable flow of material in the cement plant.
1.2 THE EFFECTS OF HAZARDOUS WASTE ON CEMENT
The engineering performance of Portland cement is largely unaffected by small additional quantities of heavy metal or certain non-metals, e.g., phosphorous. There is an upper limit (in the 1% by weight of clinker range 10,000 ppm) above which these compounds start to affect the setting and hardening properties of cement. This particularly applies to lead, zinc, chromium and phosphorous compounds. Rather large quantities of the refractory metals (Ba, Cr, Ni, V), perhaps exceeding 1% can be accommodated in the clinker minerals without deleterious effect. However, these metals (Cd, Pb, Hg) can be stabilized as complex minerals in various aluminium silicate materials similar to some clays. Arsenic, being close in proximity to silicon (in the Periodic Table), is believed to replace silicon in the crystal lattices of cement minerals. Quite small amounts of lead and zinc may retard the setting and especially the hardening of cement if they are added in the mixing. The presence of oxides of lead, zinc and boron disturb the phenomenon of setting the cement. Also wastes can cause problem of cement solidification with the set, cure, and permanence of the cement, unless the wastes are pre-treated. The hazardous waste burning cement industry needs to stop accepting the hypothesis that significant levels of heavy metals from waste burning do not cause problems with the clinker since these metals must incorporate in the mineral structure of the clinker.

2. LITERATURE REVIEW
The key objectives of study are given below.

- To understand the utility of hazardous waste as alternative fuel in cement manufacturing.
- With the help of cost, availability and accessibility factors analyzing the sustainable waste.
- Finding Benefits of using alternative fuels for a cement plant.

2.1 KILN SUITABILITY FOR DESTRUCTION OF WASTES

The process of clinker burning in a rotary kiln creates favourable conditions for the use of waste materials as alternative fuels. These include:

- High temperature,
- Alkaline environment,
- Oxidizing atmosphere,
- The lack of incineration wastes as all metallic and non-metallic incineration products undergo a complete absorption,
- Large heat-exchange surface,
• Good mixture of gases and products, and

• Sufficient time (over 2 seconds) for the disposal of hazardous wastes.

2.2 WASTE CLASSIFICATION
Waste can be classified as:

Non-Hazardous waste: Some of the cement plants in the country had been testing fuels made from municipal waste, few industrial wastes, or their mixtures for use as alternative fuel (AF) for coal. Non-hazardous waste majorly contributes as alternative raw material, since calorific value of such waste is low.

Hazardous waste: As the alternative Fossil Fuels (Lignite and Pet coke) has limited availability, Hazardous Combustible Wastes can be looked as an option to co-process along with the primary fuel. The hazardous incinerable waste has vast potential to be used as a supplementary resource or for energy gradient recovery on Co-combustion. Their higher calorific value /constituents, which are ingredients of cement, evolve scope of its utilization as a supplementary resource material in the cement industry. USEPA defined the hazardous waste as “Wastes or combination of Wastes that pose a substantial presence or potential hazard to human health or living organism.” The classification is given below:

Table 2.1: Classification of Hazardous Wastes

<table>
<thead>
<tr>
<th>1) Solid hazardous wastes:</th>
<th>2) Semi-solid hazardous waste:</th>
<th>3) Liquid hazardous wastes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Paint residue</td>
<td>a) Tank bottom sludge</td>
<td>a) Cleaning agents like mineral turpentine</td>
</tr>
<tr>
<td>b) Spent carbon residue</td>
<td>b) Oily sludge</td>
<td>b) Waste oil</td>
</tr>
<tr>
<td>c) Distillation residue</td>
<td>c) Liquid slurry</td>
<td>c) Tarry waste</td>
</tr>
<tr>
<td>d) Phosphorus residue etc.</td>
<td>d) Tarry waste</td>
<td>d) Amines waste etc.</td>
</tr>
<tr>
<td></td>
<td>e) Filter aid sludge etc.</td>
<td></td>
</tr>
</tbody>
</table>

2.3 HAZARDOUS WASTE SITUATION IN INDIA
The category-wise classification of this quantity is as follows.

• Land Fillable HW – 27,28,326 MTA (Metric Tonnes/Annum)

• Incinerable HW - 4,15,794 MTA

• Recyclable HW - 30,88,387 MTA

It is obvious that the recyclable portion of HW is in the range of 49.55 % and is more than other two categories. The land disposable portion and incinerable portion are in the tune of 43.78 % and 6.67 % respectively.
3. RESEARCH METHODOLOGY

3.1: Steps in Research Methodology

After selecting a cement industry, oil sludge is selected as a waste to be used as alternative fuel in kiln then following data is collected for it:

- Proximate Analysis Data
- Ultimate Analysis Data
- Data for Heavy Metal Analysis of Fuel
- Data for Emissions by fuel

3.1 OPERATING CONDITIONS FOR USING WASTE IN KILN

a) Co-processing plants shall be designed, equipped, built and operated in such a way that the gas resulting from the co-processing is raised in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of 950°C for two seconds. For hazardous wastes with a content of more than 1% halogenated organic substances (expressed as chlorine), the temperature has to be raised to 1100°C.

b) Co-processing plants shall have and operate an automatic system to prevent waste feed:
   I. at start up, until the temperature of 950°C or 1100°C as the case may be.
   II. Whenever the temperature of 950°C or 1100°C as the case may be is not maintained.
   III. Whenever emission monitoring show that any emission limits value is exceeded due to disturbances or failures of air pollution control devices.

c) Co-processing plants shall be designed, equipped, built and operated in such a way as to prevent emission into the air giving rise to significant ground level air pollution; in particular; exhaust gases shall be discharged in a controlled fashion and in conformity with ambient air quality standards by means of a stack, the height of which is calculated in such a way as to safeguard human health and
d) The management of the co-processing plant shall be in the hands of a skilled person, competent to manage the hazardous waste in an environmentally sound manner.

4. DATA COLLECTION & ANALYSIS

4.1 IMPLICATION IN CEMENT PLANT

The study was carried out for the plant that has two kilns installed, one with the capacity of 1.75 MT and another with 1MT capacity. The conclusions for kiln with 1 MT capacity were drawn. Presently, the plant is using imported coal as the fuel for the production of clinker. The purpose of the study was to find out replacements for the coal which could benefit the industry economically and environmentally. The wastes having potential for their use as alternative fuel and which were available in good quantity were selected. oil sludge was taken into account for use as alternative fuel. The selected wastes have to be characterised, on the basis of which the quantity of the alternative fuel that could be added to the rotary kiln can be evaluated. The suitable quantities are decided on the basis of the following factors:

1) The quality of clinker should not be affected. For this, the amount of heavy metals and other minerals entering the clinker should be known and it should not exceed the allowable limit.

2) The emissions should be within the limit.

3) The availability of the desired waste material, that is to be used as a fuel, also governs the quantity of fuel entering the kiln. The cost of waste being used as fuel should not exceed the cost of fossil fuels.

4.2 OIL SLUDGE

The processing of crude oil in refineries and petrochemical plants creates oil emulsive waste water. Processing this waste water means separating it into its main components of oil, water, and solids. The objective is to recover as much oil as possible and to dispose of the other components in an efficient way [10]. The first step in the process of disposing of the sludge is reclamation. In order to extract as much oil from the sludge as possible, a combination of chemicals and demulsifiers is used. The collection of the topmost layers of oil is conducted with the use of pumps and barges. The separation of the sludge is done with a centrifuge. The oil recovered is then delivered to a refinery or sold on the market. Hard particles, from which oil cannot be recovered, must then be disposed of. The best way of disposing of hard particles is using them as a heat source in the cement industry [11]. For using oil sludge as an alternative fuel it should be analysed for various parameters like the ultimate and proximate analysis are carried out. The elemental analysis was carried out to establish the suitability of liquid waste on the
quality of cement or manufacturing process. The results are given in Table 4.1:

Table 4.1: Heavy Metal Analysis

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>HEAVY METAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mercury</td>
<td>0.1000%</td>
</tr>
<tr>
<td>2.</td>
<td>Cadmium</td>
<td>0.10%</td>
</tr>
<tr>
<td>3.</td>
<td>Lead</td>
<td>0.10%</td>
</tr>
<tr>
<td>4.</td>
<td>Chromium</td>
<td>0.10%</td>
</tr>
<tr>
<td>5.</td>
<td>Zinc</td>
<td>5.14-34.81%</td>
</tr>
<tr>
<td>6.</td>
<td>Chlorine</td>
<td>0.03-0.09%</td>
</tr>
</tbody>
</table>

The various combinations of oil sludge (Alternative Fuel) and coal were evaluated for their calorific value, heavy metal analysis and emissions. The results were compared to standards established for disposal of hazardous waste in cement kiln. (Table 4.2) From the table below one could find that replacement of coal with oil sludge provides better calorific value to the fuel. The emissions of the greenhouse gases are also reduced. This contributes to the environmental benefits. It can be concluded from the table that maximum 15% of the coal can be replaced by the oil sludge. Above this percentage, the value of lead increases above the standard value i.e. 23% which affects the quality of the clinker.

The oil sludge as a fuel costs around Rs.1000 per tonne including the transportation cost where as coal costs around Rs. 5800. This brings economical benefits to the organisation. If we use 100% coal, we require 1,25,806 ton of coal per annum for producing 1 million ton of cement. The total cost of this amount of coal is around 73 crore. Availability of oil sludge was estimated around 20,000 metric tonne per annum .

Table 4.2: Check for Suitability of Combination of Coal and Oil Sludge

<table>
<thead>
<tr>
<th>Fuel Mix</th>
<th>Cal. Val. (Kcal/Kg)</th>
<th>Elemental Analysis (%)</th>
<th>Emissions (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hg</td>
<td>Cd</td>
<td>Pb</td>
</tr>
<tr>
<td>100% 0%</td>
<td>6200</td>
<td>0.001</td>
<td>0.0001</td>
</tr>
<tr>
<td>95% 5%</td>
<td>6075</td>
<td>0.001</td>
<td>0.0001</td>
</tr>
<tr>
<td>90% 10%</td>
<td>5950</td>
<td>0.001</td>
<td>0.0001</td>
</tr>
<tr>
<td>85% 15%</td>
<td>5825</td>
<td>0.001</td>
<td>0.0002</td>
</tr>
<tr>
<td>80% 20%</td>
<td>5700</td>
<td>0.001</td>
<td>0.0002</td>
</tr>
<tr>
<td>75% 25%</td>
<td>5575</td>
<td>0.002</td>
<td>0.0002</td>
</tr>
<tr>
<td>70% 30%</td>
<td>5450</td>
<td>0.002</td>
<td>0.0002</td>
</tr>
<tr>
<td>65% 35%</td>
<td>5325</td>
<td>0.002</td>
<td>0.0002</td>
</tr>
<tr>
<td>60% 40%</td>
<td>5200</td>
<td>0.002</td>
<td>0.0003</td>
</tr>
<tr>
<td>55% 45%</td>
<td>5075</td>
<td>0.002</td>
<td>0.0003</td>
</tr>
<tr>
<td>50% 50%</td>
<td>4950</td>
<td>0.002</td>
<td>0.0003</td>
</tr>
<tr>
<td>45% 55%</td>
<td>4825</td>
<td>0.002</td>
<td>0.0003</td>
</tr>
<tr>
<td>40% 60%</td>
<td>4700</td>
<td>0.002</td>
<td>0.0003</td>
</tr>
<tr>
<td>35% 65%</td>
<td>4575</td>
<td>0.002</td>
<td>0.0004</td>
</tr>
<tr>
<td>30% 70%</td>
<td>4450</td>
<td>0.002</td>
<td>0.0004</td>
</tr>
<tr>
<td>25% 75%</td>
<td>4325</td>
<td>0.003</td>
<td>0.0004</td>
</tr>
<tr>
<td>20% 80%</td>
<td>4200</td>
<td>0.003</td>
<td>0.0004</td>
</tr>
<tr>
<td>15% 85%</td>
<td>4075</td>
<td>0.003</td>
<td>0.0004</td>
</tr>
<tr>
<td>10% 90%</td>
<td>3950</td>
<td>0.003</td>
<td>0.0005</td>
</tr>
<tr>
<td>5% 95%</td>
<td>3825</td>
<td>0.003</td>
<td>0.0005</td>
</tr>
<tr>
<td>0% 100%</td>
<td>3700</td>
<td>0.003</td>
<td>0.0005</td>
</tr>
</tbody>
</table>
5. CONCLUSION

Co-processing in the cement industry is the optimum way of recovering energy and material from waste. It offers a safe and sound solution for society, the environment and the cement industry, by substituting non-renewable resources with societal waste under strictly controlled conditions. The purpose of the study was to find out replacements for the coal for A Cement Plant which could benefit the plant economically and environmentally. For this, the wastes having potential for their use as alternative fuel and which were available in good quantity within the state were selected. Oil sludge was taken into account for its use as alternative fuel. The selected wastes have been characterised, on the basis of which the quantity of the alternative fuel that could be added to the rotary kiln has been evaluated. It was found that:

1) Oil Sludge can replace 15% of the coal. Beyond this percentage lead value increases above the limit.

2) Up to this level of replacement the emissions were found to be within the limit.

3) The desired waste material, to be used as a fuel, is available within the state.

4) The cost of waste being used as fuel does not exceed the cost of fossil fuels.

Thus the Co-processing of hazardous substances in cement industry is much beneficial option, whereby hazardous wastes are not only destroyed at a higher temperature of around 14000C and longer residence time but its inorganic content gets fixed with the clinker apart from using the energy content of the wastes. Apart from this, no residues are left, which in case of incineration still requires being land filled as incinerator ash. Further the acidic gases, if any generated during Co-combustion gets neutralized, since the raw material is alkaline in nature. Such phenomenon also reduces resource requirement such as coal and lime stone. Thus utilization of Hazardous wastes for Co-combustion makes a win –win situation.

6. REFERENCES

1. Jonathan M. Harris; 2003; *Sustainability and Sustainable development*; International Society for Ecological Economics; Internet Encyclopaedia of Ecological Economics.


8 June 2005; The Cement Sustainability Initiative Progress Report; World Business Council For Sustainable Development.

