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An Investigation on Process Optimization in Cement Industries through Co-processing of Plastic Waste

Dharmendra Singh Ghosh
M.Tech. Research Scholar
Energy Technology
Vindhya Institute of Technology & Science
Jabalpur, (M.P.) [INDIA]
Email: rskari88@gmail.com

Shoab Ahmed Ansari
Assistant Professor
Department of Mechanical Engineering
Vindhya Institute of Technology & Science
Jabalpur, (M.P.) [INDIA]
Email: shoabansari.hr@gmail.com

Abstract—*This work proposes the decomposition of plastic waste & energy recovery in cement factory. Cement industry ranks 2nd in energy consumption among the industries in India. It is one of the major emitter of CO_2, due to combustion of fossil fuel and calcinations process. The main objective of the research work is to assess the energy consumption and energy conservation of the Indian cement industry and to predict future trends in cement production and reduction of CO_2 emissions. In order to achieve this objective, a detailed energy and reduction of CO_2 emission analysis of a typical cement plant was carried out. The purpose of this study was a quantitative analysis of the energy, environmental and greenhouse gas effects of replacing fossil by plastic waste. The use of plastic waste was examined with a focus on this practice at ACC cement plant. The total cost saving per day is Rs. Rs. 9705 (Rs.3542, 325 per annum) and 9 tons coal save per day. The co-incineration of coal and waste plastics reduces the overall CO_2 emissions, after replacement of coal by plastic waste the total reduction of CO_2 is17.81 tons/day or 6500 tons/annum. The sensitivity analysis of the forecasting model was conducted and found satisfactory.*

Keywords:— *Plastic Waste, Co-processing, Cement Industry, Energy Recovery, Waste Recovery, CO_2 reduction.*

1. INTRODUCTION

India generates about 6.2 million tons of hazardous wastes annually, out of which around 3.09 million tones is recyclable, 0.41 million tones is incinerable and 2.73 million tones is land-fillable. The local administration, civic bodies and policy makers are posed with a serious concern of its effective & safe disposal. All developed nations globally have utilized cement kilns in their countries as an effective option for industrial, municipal and hazardous waste disposal. Spiraling fuel costs, uncertainty in fuel availability and goal to reduce CO_2 emissions has led few cement plants in India to use alternative fuels. Plastic create threat to the environment in the form of long lasting waste. It is not biodegradable and hence, remains in Environmental cycle with its ill effects for a long time. Thus, plastic waste management is a matter of concern for the environment regulatory agencies. Plastic carry bags made from the recycled plastic using substandard colors have been proven to be dangerous for the health.

1.1 Categories of plastics

- Recyclable Plastics (Thermoplastics)
- Non-Recyclable Plastics (Thermoset & others)

1.2 Options for Plastic Waste Management

- Primary recycling involves processing of a waste/scrap into a product with characteristics similar to those of original product.
- Secondary recycling involves processing of waste/scrap plastics into materials that have characteristics different from those of original plastics product.
- Tertiary recycling involves the production of basic chemicals and fuels from plastics waste/scrap as part of the municipal waste stream or as a segregated waste.
- Quaternary recycling retrieves the energy content of waste/scrap plastics by burning / incineration. This process is not in use in India.

1.3 Plastic Waste Management in India

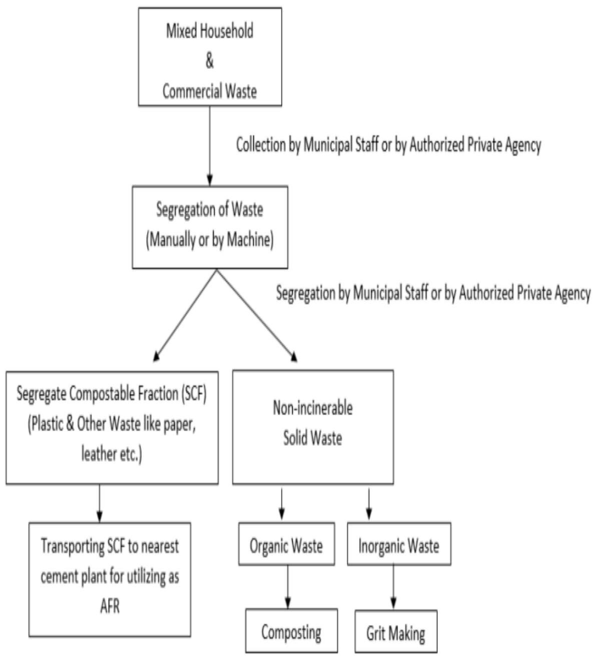

Figure 1: Plastic Waste Management in India

1.4 The main ill effects of plastic waste

- Plastic carry bags, plastic laminated pouches (including gutkha pouches) and other non-recyclable plastics littered throughout present ugly and unhygienic scenes and conditions.
- Littered plastics clog and disturb the drainage of towns at times causing flooding in urban area. This spread of plastic waste also reduces the rate and quantum of rain water percolation, resulting in lowering of already low water levels.
- Garbage containing plastics on burning causes air pollution and may emit hazardous gases.
- Garbage mixed with plastic interferes in waste processing facilities and create problem in landfill operations.
- Plastic waste creates problem in the collection of MSW. It being littered at places other than waste bins causes it to remain uncollected.
- Cattle and other animals sometimes ingest plastic waste mixed with eatables, resulting in fatalities.
- It is not biodegradable and hence, remains in environmental cycle with its ill effects for a long time.
- The soil fertility deteriorates as the plastic bags form part of manure remains in the soil for years.
- Plastic also reach the ocean through rivers and waterways. Fish and other marine species ingest plastic garbage as food items and die in the process.

1.5 Why Cement Kilns are suitable for burning wastes

Co-processing ranks higher in the waste processing hierarchy. High flame temperature (2000°C) ensures complete destruction of harmful pollutants. Total neutralization of acid gases, sulphur oxides and hydrogen chloride, by the active lime in the kiln load, in large excess to the stoichiometry. Kiln lines equipped with ESPs/Bag filters – ensures negligible particulate emission. Intense contact between solid and gas phases – ensures condensation of volatiles, absorbs SO_2 and neutralize acid gases. No production of by-products such as ash or liquid residue from gas cleaning.

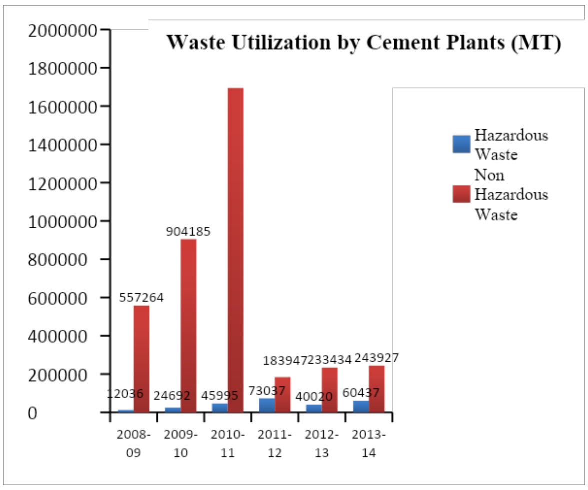

Figure 2: Waste Utilization by Cement Plant (MT)

1.6 Concept of Co-processing

Co-processing is a proven sustainable development concept that reduces demands on natural resources, reduces pollution and landfill space, thus contributing to reducing the environmental footprint. Co-processing is also based on the principles of industrial ecology, which considers the best features of the flow of information, materials, and energy of biological ecosystems, with the aim of improving the exchange of these essential resources in the industrial world. The co-processing of waste in the cement industry provides a maximum substitution of non-renewable materials.

1.6.1 Benefits of Co-processing

- Reduction of CO_2- Emissions
- Preservation of resources
- Residue free combustion
- High thermal efficiency
- Fulfillment of substantial dump disposal
- Reduced dependence on primary markets

1.6.2 Impact of co-processing on kiln emissions

- Alternative fuels have no influence on total SO_2 emissions.
- Alternative fuels do not lead to higher NOx emissions
- There is no correlation between the use of alternative fuels and emissions levels.
- HCl emissions vary irrespective of the fuel used
- Emissions vary irrespective of the fuel used.

1.7 Waste Management Hierarchy

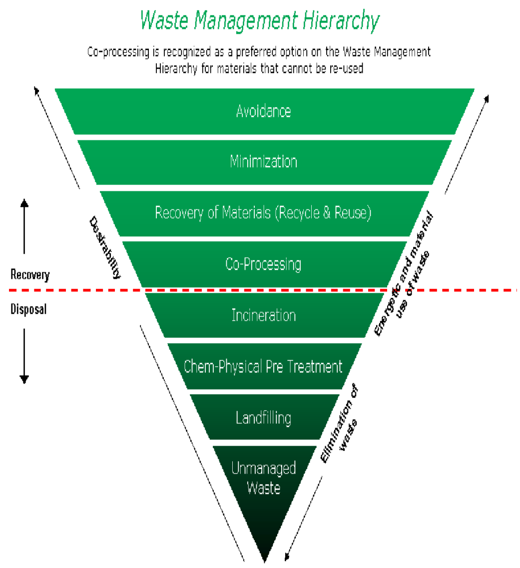

Figure 3: Waste Management Hierarchy

1.8 Co-processing of plastic waste in Cement kilns and power plants

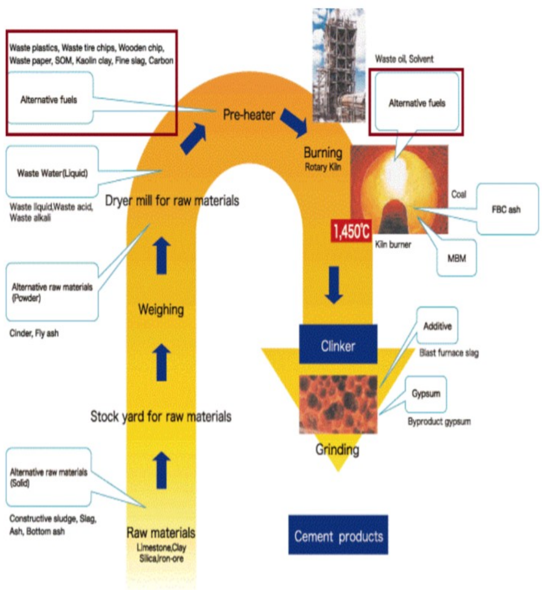

Figure 4: Co-processing of plastic waste in Cement kilns and power plants

2. REVIEW OF LITERATURE

D. Amsaveni et al (2019) investigated the possibility to produce plastic cement by mixing high density polyethylene waste with cement from which its production is optimized. Aim of this research is to add the plastic waste at the most level, for which dynamic programming has been used to select the company which will reduce the maximal level of plastics.

Fayza S. Hashem et al (2019) studied the possibility of using Rubber waste (RW) and plastic waste (PW) as sources of refused derived fuel in cement plant.

Ahmad K. Jassim (2017) in his research mixed high density polyethylene waste with Portland cement to investigate the possibility to produce plastic cement, and study the effect of replacing sand by fine polyethylene waste with different percentage on the properties of product.

Rahul Baidya et al (2016) 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 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.

Ying-Chu Chen et al (2016) evaluated the potential for energy recovery and GHG mitigation from municipal solid waste (MSW) with a waste-to-material (WTM) approach. Measures to reduce GHGs were also suggested in this study.

Hrvoje Mikulcic et al (2016) reviewed the current status of the cleaner cement manufacturing, the cement industry's shifting to alternative raw materials and alternative energy sources, and the modeling of the thermo-chemical processes inside the cement combustion units.

Azad Rahman et al (2015) presented recent development on the usage of alternative fuels in cement industry 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.

Jose-Luis Galvez-Martos et al (2014) reviewed use of Life cycle assessment (LCA) to assess waste co-incineration in cement kilns with a special attention to those key inventory results highly dependent on the initial assumptions made. The main focus of this paper is the life cycle inventory, LCI, of carbon emissions, primary energy and air emissions.

Cheng-Gang Chen et al (2013) explained the effects of the mechanical–chemical stabilization process for municipal solid waste incinerator fly ash on the chemical reactions in cement paste.

Wendell de Queiroz Lamas et al (2013) employed the technique of co-processing to reduce the costs of fossil fuel consumption (non-renewable source) for introducing alternative fuels as part of the manufacturing process. This technique provides a lower cost of production, introducing fuel waste from different industrial activities, besides contributing to the reduction of environmental liabilities; they generate waste when discarded in inappropriate places.

Azad Rahman et al (2013) summarize and reviews literatures on the usage of different types of alternative fuel and their impacts on the plant performance. Cement manufacturing is a high energy consuming and heavy polluting process.

Alfonso Aranda Uson et al (2013) provided a literature review of the approaches for proper use of alternative fuels and materials in the cement industry for the planning and promotion of different methods that can decrease the environmental impacts, lower the consumption of energy and material resources, and reduce the economic costs of this industry, based on previously published research studies.

Nabajyoti Saikia et al (2012) presents a review on the recycling plastic waste as aggregate in cement mortar and concrete productions. For better presentation, the paper is divided into four different sections. In the first section, types of plastics and types of methods used to prepare plastic aggregate as well as the methods of evaluation of various properties of aggregate and concrete were briefly discussed. In the next two sections, the properties of plastic aggregates and the various fresh and hardened concrete properties of cement mortar and concrete in presence of plastic aggregate are discussed. The fourth section focus on the practical implications of the use of plastic waste in concrete production and future research needs.

2.1 Problems Statement

Modern life style with its emphasis on consumption and disposal has brought in its wake the acute problem of solid waste management. Currently, however only between 5 to 25% of plastic waste is being recycled, but a lot of remaining percentage of plastic waste is being non-recycled. These non-recycled plastic wastes create threat to the environment in the form of long lasting waste. Thus, plastic waste management is a matter of concern for the environment regulatory agencies.

2.2 Objective of Research Work

The main objective of this project is to accelerate AFR (Renewable and alternative fuel) initiatives and increasing usage of AFR in the Indian Cement Industry through capacity building, data availability and facilitating exchange of waste by working closely with Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs), thereby reducing environmental impacts of waste generation and raw material usage.

2.3 Scope of work

- Management of Non-recyclable plastic waste in the Municipal solid waste.
- Disposal of plastic waste in nearest ACC cement factory.
- Reduction of CO2 emission by replacement of plastic waste in the place of coal.
- Different possible solutions which would be practically feasible to improve or make more effective Municipal Solid Waste Management.

3. METHODOLOGY

3.1 Requirements for co-processing of waste

- An approved national/local licenses, permits, authorizations and permissions.
- Suitable location, technical infrastructure, storage and processing equipment.
- Adequate air pollution control devices.
- Exit gas conditioning/cooling and low temperatures.
- Clear management and organizational structure.
- Qualified and skilled employees to manage wastes and health, safety and environmental issues.
- Adequate emergency and safety equipment and procedures, and regular training.
- Adequate facilities for plastic waste acceptance and feeding control.
- Independent audits, emission monitoring and reporting.
- Open disclosure of performance and

compliance verification reports on a regular basis.

3.2 Step by Step Process for Co-Processing of Cement Plants

- Availability of information on waste: There are many types of wastes that are successfully co-processed in several cement plants across the world without any specific environmental concerns. The data on these types of wastes should be compiled by organizations like Cement Manufacturers" Association (CMA) and Confederation of Indian Industry (CII) for the benefit of waste generators and cement plants.
- Suitability of Substance for Co-Processing: Material depending on the characteristics can be utilized directly from generator or after pre-processing. Any material which used in the process should give either calorific value from the organic part or material value from the mineral part. Waste material which satisfies any one of the following can be used in cement plant for co processing-
  - If GCV of the material should be > 2500 Kcal/kg and raw material = 0%
  - If ash content > 50% and raw materials in ash > 80%
  - If raw material > 0% and GCV of the balance > 2500 Kcal/kg
  - Solve the local waste management problem
- This is the list of material which has undergone trial run successfully and 22 cement manufacturing units in various states, already started co processing of these few categories of waste with approval of CPCB.
  - Plastic waste
  - Paint Sludge from automobile sector
  - Petroleum refining sludge
  - TDI tar waste
  - ETP sludge from M/s BASF India Ltd
  - Other Wastes
  - Plastic Wastes
  - Tyre chips
- For using the waste material in cement kiln, it should possess some characteristics listed below:
  - Operating Condition
  - Identification of Cement Factory
  - Air Pollution Control requirements
  - Emission standards
  - Monitoring requirements
  - Trial Run
  - Regular Usage
  - Collection of Plastic waste
  - Segregation & Pre-processing of plastic waste
  - Costs for disposal of plastic waste
  - Transport
  - Handling wastes with different chemical compositions
  - Monitoring for feeding plastic waste (PW) in cement kilns
  - Setting –up of laboratory for plastic waste analysis
  - Monitoring of emission by cement industry/SPCB
  - Forwarding progress report to CPCB
  - Technology used for treatment of plastic waste
  - Co-processing

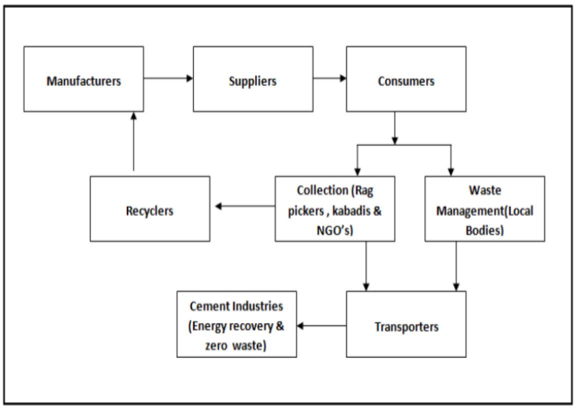

Figure 5: Process diagram of plastic waste to incineration

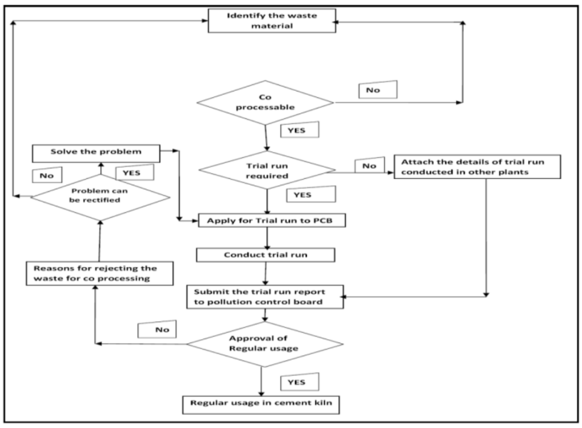

Figure 6: Flowchart for Co Processing Approval

4. RESULTS AND DISCUSSION

4.1 Energy Recovery and cost saving

The average consumption of coal at the plant is 2,500 tons/day.

(CV of coal = 4500 kcal/ kg)

6 T of Plastic waste from Jabalpur City & 1 T of Plastic waste from Katni

Of this, on an average 7 tons/day of plastic (CV of plastic =6000 kcal/ kg)

Total quantity of Non-recyclable plastic waste = 7 T/day

1 million tone = 1,000,000 tonne

1 tonne = 1000kg

The average consumption of coal at the plant is = 2,500 tons/day=1000x2500

= 25, 00,000 kg /day

(CV of coal = 4500 kcal/ kg)

1 kg of coal = 4500 kcal

25, 00,000 kg of coal= 1125 x 10^7 Kcal

(Cost of coal with transportation Rs. 0.81/ 1000 kcal)

Cost of 1000 Kcal coal = Rs. 0.81

Cost of 1125 x10^7 kcal of coal = Rs.9112500 actual per day coal consumption cost.

Cost of 1 kg of coal = Cost of 4500 Kcal coal = 0.81 X 4.5 = Rs. 3.645

On an average 7 tons/day of plastic waste = 7 x 1000 = 7000 kg

(CV of plastic =6000 kcal/kg)

1 kg of plastic waste = 6000 kcal

7000 kg of plastic waste = 6000 x 7000 = 42 x 10^6 kcal

(Cost of plastic waste with transportation = Rs.0.55 /1000 kcal)

Cost of 1000 Kcal of plastic waste = Rs. 0.55

Cost of 42 x 10^6 kcal (7T) of plastic waste = Rs. 23100

Cost of 1T of coal = 3.645 X 1000 = 3645

In terms of cost 7T of Plastic waste = 23100/3645 = 6.34T of coal

If 7 tons / day plastic waste replacement

= 9 tons/day coal

= 9 x1000= 9000 kg

= 9000 x 4500 =405 x 10^5

= 405 x 10^5 kcal

Cost of 1000 Kcal of coal

= Rs. 0.81

Cost of 9 tons of coal = 405 x 10^2 x 0.81 = Rs. 32,805

Total saving per day = 32805 - 23100 = Rs. 9705 = Rs.3542325 per annum

Total coal saving per day = Rs. 9705

4.2 CO_2 emission reduction per year

For every tonne of coal burned, approximately 2.5 tons of CO_{2e} are produced.

CO_2 emissions from combustion of 1 t Coal is 2.5 tons

CO_2 emissions from combustion of 2500 t of coal = 2500x 2.5= 6250 tons /day

Actual CO_2 emission in cement factory =6250 x 365=2, 28,125tons /annum

CO_2 emissions from combustion of 1 t Coal is 2.5 tons

CO_2 emissions from combustion of 9 t Coal = 9 X 2.5 = 22.5 tons

CO_2 emissions from combustion of 1 t plastic waste is 0.67 tons

CO_2 emissions from combustion of 7 t plastic waste = 7 X 0.67 = 4.69 tons

After replacement of coal by plastic waste the total reduction of CO_2

= 22.5 – 4.69 = 17.81 tons/day = 6500 tons/annum

5. CONCLUSIONS

The co-incineration result shows that there is no unfavorable impact on the environment, clinker and cement properties. Hence co- incineration of plastic waste is one of the best alternatives for its disposal, saving of energy resource, in ecological sustainable and environmental friendly manner. The total cost saving per day is Rs. Rs. 9705 (Rs.3542, 325 per annum) and 9 tons coal save per day. The co-incineration of coal and waste plastics reduces the overall CO_2 emissions, after replacement of coal by plastic waste the total reduction of CO_2 is17.81 tons/day or 6500 tons/annum. The cost of collection and treatment may limit the use of waste plastics" Interactions between coal and waste plastics can improve combustion efficiency.

5.1 Recommendations

- SPCBs should give permission to industries as soon as trial run completes without any delay at least for the large & corporate companies for co-incineration of plastic waste.
- All the units should provide proper Storage facilities and feeding systems for the plastic waste in the plant and avoid manual handling of plastic waste.
- Taking interstate transportation permission from SPCBs for transporting the plastic waste from one state to other state may be made further simpler.
- Awareness should be created among the users for using the different types of wastes to fill up the gap of insufficient quantity of plastic wastes where adequate quantity of wastes are not available for smooth co-incineration of plastic waste.
- The industries should be equipped for monitoring of environmental parameters as per the protocol during co incineration of plastic waste.

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