# TECHNO-ECONOMICAL ASSESSMENT OF ALTERNATIVE FUELS IN CEMENT KILN

## (A SOLUTION TO NATURAL RESOURCE PRESERVATION, WASTE MANAGEMENT AND TOTAL EMISSION REDUCTION)

***Thesis submitted in partial fulfillment of the requirement for the award of degree of***

**Master of Technology**
**in**
**Environmental Sciences and Technology**

*Submitted By*

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## DECLARATION

This is to certify that the thesis entitled "Techno-Economical Assessment of Alternative Fuels in Cement Kiln", is an authentic record of my own work carried out as requirements for the award of degree of Master of Technology in Environmental Science & Technology from Thapar University, Patiala, during January to June 2012.

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## CERTIFICATE

Certified that this project report "*Techno-Economic Assessment Of Alternative Fuels In Cement Kiln*" is the bonafied work of "Leenu Narang", in partial fulfilment of the requirement for the award of the degree of master of technology in environmental science and technology submitted in department of biotechnology and environmental sciences, Thapar University, Patiala. This project was carried out under our supervision.

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**Leenu Narang**

# Executive summary


The objective of this project is to find replacements for the coal for Dalmia Cement Plant, Dalmiapuram, Tamil Nadu, which could benefit the plant economically and environmentally. This plant has two rotary kilns installed, one kiln with the capacity of 1.5 million ton and another with the capacity of 1 million tonne annually. The studies were done for the 1million tonne capacity kiln.

This requires evaluation of potential waste materials. The status of the wastes within the state has to be studied to select the wastes which are available in the state and which have potential for their use as alternative fuel.

In this report, three potential wastes namely tyres, oil sludge and paint sludge, are taken into account for their use as alternative fuel in the plant. The selected wastes should 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 evaluation is done on the basis of four parameters including heating value of the fuel, cost of the fuel, availability of the fuel and emissions (gaseous as well as heavy metal). CPCB norms restrict the emissions within the limit.

The use of alternative fuel reduces the use of fossil fuel requirement. Moreover, the emission of greenhouse gases also reduces to a considerable value. Furthermore, this will reduce the burden of waste disposal considerably.

The use of alternative fuels will help in reducing energy costs and providing a competitive edge for a cement plant.

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# INTRODUCTION

India, being the second largest cement producer in the world after China with a total capacity of 245.40 Million Tonnes (MT) as per on 31st March 2011 [1], has got a huge cement industry and produces about 7% of world's production. Right from laying concrete bricks of economy to waving fly over, cement industry has shown and shows a great future. With the government of India giving boost to various infrastructure projects, housing facilities and road networks, the cement industry in India is currently growing at an enviable pace. More growth in the Indian cement industry is expected in the coming years.

The Indian cement industry is confronted with disparate goals, which at a first sight seem to exclude each other. On the one hand, there is enormous pressure to increase profit and margins, while at the same time there is considerable public interest on a sustainable and environment friendly usage of natural resources.

In other words, plant owners find themselves in a situation where fast and optimal reaction to continuously changing conditions, while still meeting various and probably conflicting objectives, is crucial for survival. It follows that there is a need for tools that elevate the plants to their optimal economic performance as given by the degrees of freedom left by the technological, environmental and contractual constraints.

Cement production involves the heating, calcining and sintering of blended and ground materials to form clicker. As a result, cement manufacturing is the third largest cause of man-made $CO_2$ emissions due to the production of lime, the key ingredient in cement. Therefore, energy savings during cement production could lead to lower environmental impact

The cement production has experienced great changes during the history, passing from vertical wet-process kilns to short dry-process rotary kilns with cyclone towers, high-efficiency coolers and tertiary air to precalciners. One of the most important changes that can be identified at this moment is the use of **Alternative Fuels (AF).**

Cement plants in India have long been dependent on use of fossil fuels for clinker production. With the advent of stricter environmental regulations and the government's promotion of cleaner production in the industries, the government and the private sector are seeking environmentally acceptable solutions to improve production as well as cost efficiency in their daily operations.

Several cleaner production programs were implemented by the government, through grants/programs of international development agencies and funding institutions 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.

The cement industry has many opportunities to replace a portion of the virgin natural resources it uses with waste and by-products from other processes. These may be used as fuels, raw materials, or as constituents of cement, depending on their properties. Alternative fuels and raw materials must meet quality specifications in the same way as conventional fuels and raw materials.

Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications [2]. Sometimes they can only be used after pre-processing to provide 'tailor-made' fuels for the cement process. At other times they can be just used as they are delivered without further processing. In nearly all cases, fuel components are blended prior to use to ensure a homogenous mixture with near constant thermal properties.

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 [2]. 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 [3].

Recently, Central Pollution Control Board has come up with guidelines on use of Alternative fuel for Cement Industry. Further, 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 $CO_2$ emissions released into the atmosphere, since waste replaces other fossil fuels producing greater $CO_2$ levels [1].

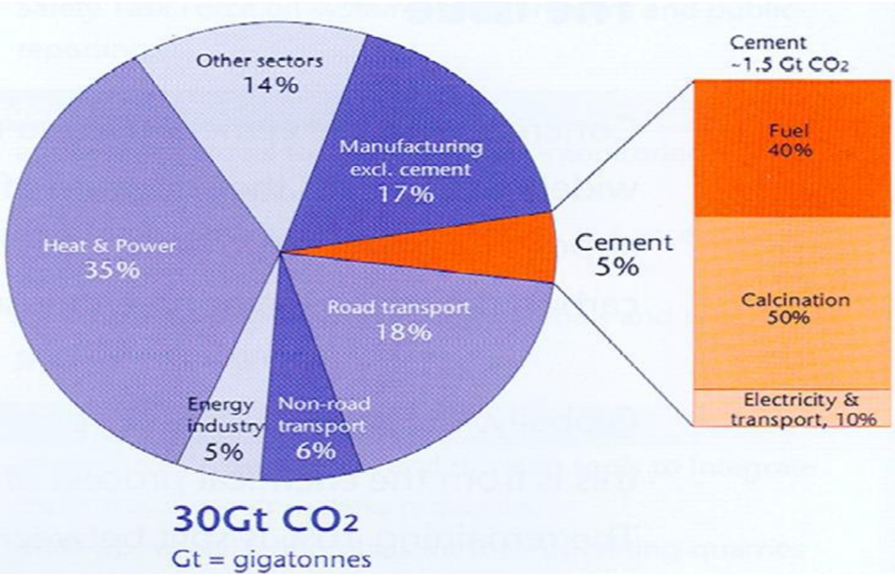


**Fig 1**: **Cement Industry Share in $CO_2$ Emissions**

***Source**: The Cement Sustainability Initiative Progress Report, June 2005*

Use of waste materials in the cement industry, also referred to as **co-processing**, contributes towards achieving its objectives of resource conservation and total emission reduction. Due to the characteristics of the production process, the cement industry is capable of co-processing:

- alternative fuels, which have a significant calorific value (e.g. waste oils);
- alternative raw materials, the mineral components of which mean they are suitable for the production of clinker or cement (e.g. contaminated soil)
- materials that have both a calorific value and provide mineral components (e.g. paper sludge, used tyres)

- Examples of Alternative Resources used primarily as **alternative raw material**: Aluminium hydroxide residues, catalysts, foundry sands, etc
- Examples of Alternative Resources used in the kiln for the production of clinker primarily as **alternative energy source**: Solvents, paint residues, hydrocarbon

residues, wood, paper, sludge from industrial waste water treatment, soils/plastics/textiles contaminated with hydrocarbons, pesticides, etc.

- Added to the clinker for the production of cement: Ground slag (steel), fly ash (power plants), alternative gypsum sources, etc.

Hazardous wastes disposal in cement kilns can play an integral role in hazardous waste management together with other disposal technologies. Using cement Kiln technology has economic and environmental benefits reported by many researchers [4, 5, 6, 7, 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, usually consisting of physical/chemical treatment, various incineration options and landfill.

The co-processing of waste has been recognized as a recovery operation under EU legislation.

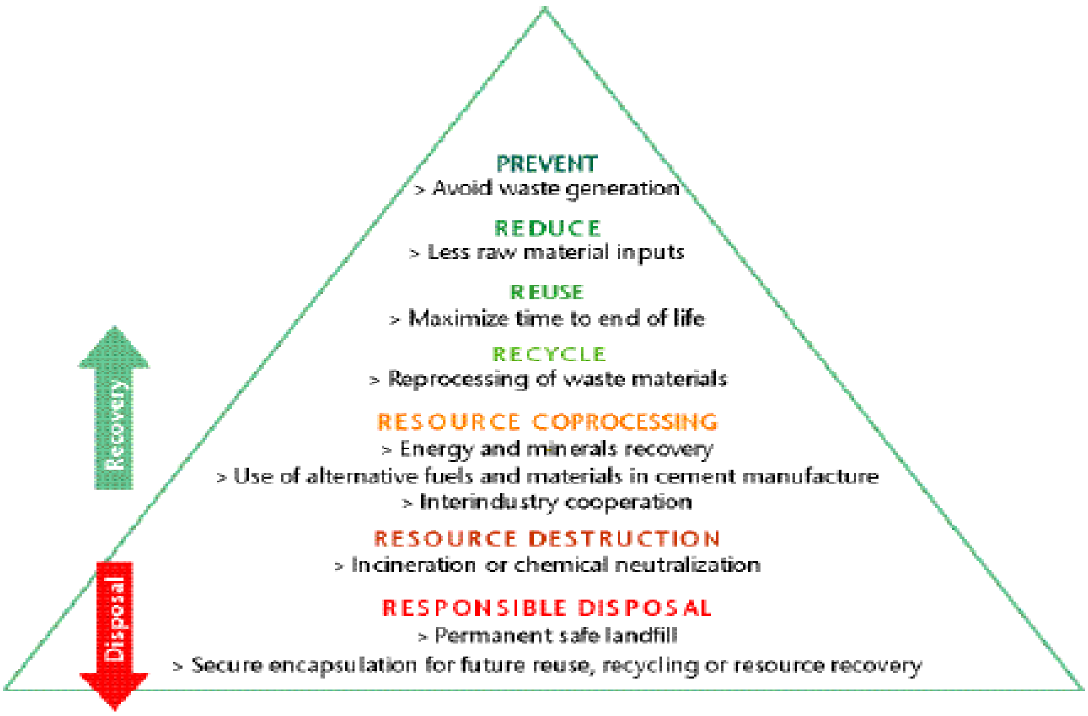


**Fig 2: Position of Co-Processing in Waste Management Hierarchy**
***Source: Anubhootiviewsnews BlogSpot***

Co-processing is a sustainable development concept based on the principles of industrial ecology [2, 9], a discipline that focuses on the potential role of industry in reducing environmental burdens throughout the product life-cycle.

In addition to energy recovery, there is also a corresponding saving relevant to $CO_2$ emissions released into the atmosphere, since waste replaces other fossil fuels producing greater $CO_2$ levels. But still the use of AF remains limited to minimal quantities and intermittent because of lack of infrastructure, low supply of AF and absence of environmental protocols/policy on use of AF. Recently, Central Pollution Control Board has come up with guidelines on use of Alternative fuel for Cement Industry. Further, it will not only solve the problem of waste management to significant level but also reduce use of fossil fuel.

Alternative fuels are the waste & by-products of other industries. The cement industry as an ecosystem is shown in the fig 3.

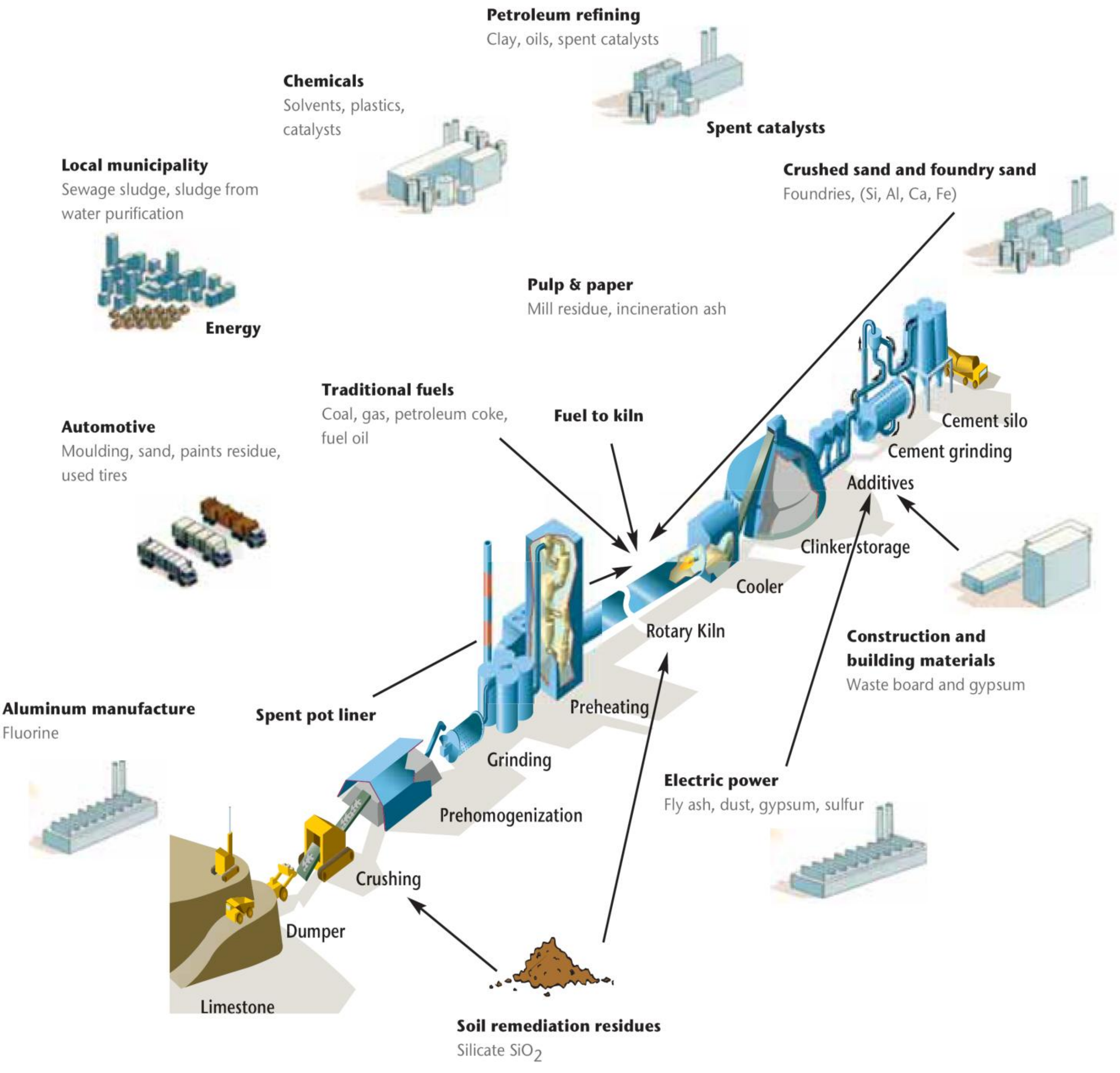


**Fig 3: Cement Industry Ecosystem**

# 1.1ALTERNATIVE FUELS

## 1.1.1 CLASSIFICATION OF ALTERNATIVE FUELS

Alternative fuels used in the cement industry are usually classified according to the concentration criterion into [10]:

- Gaseous (examples: landfill gas, pyrolysis gas),
- Liquid (examples: solvents, waste oils, greases),
- Solid (examples: animal powder, bark, paper, tyres, rubber wastes, plastics, fluff).

According to the classification by Cembureau, alternative fuels are divided into the following five classes:

Class 1: Gaseous alternative fuels (examples: refinery waste gas, landfill gas),

Class 2: Liquid alternative fuels (examples: low chlorine spent solvents, hydraulic oils),

Class 3: Pulverized, granulated or finely-crushed solid alternative fuels (examples: sawdust, dried sewage sludge, granulated plastic, animal flours, fine crushed tyres),

Class 4: Coarse-crushed solid alternative fuels (examples: crushed tyres, rubber/ plastic waste, wood waste, reagglomerated organic matter),

Class 5: Lump alternative fuels (examples: whole tyres, plastic bales).

**Solid alternative fuels may be divided into four groups**

**Group 1**: Solid, dry fuels of relative fine size, which do not adhere (dimensions:<2 mm, humidity: <10–15%); for example: wood dust, bark powder, rice husk,

**Group 2**: Solid, dry fuels of coarse size, which do not adhere (dimensions: <20 mm, humidity: <10–15%); for example: plastic waste, wood chips, waste wood,

**Group 3**: Solid, dry fuels which tend to stick (dimensions: <20 mm, humidity :< 10–15%); for example: animal powder, impregnated wood dust,

**Group 4**: Mixtures of different lumpy fuels (dimensions: <200 mm, humidity: <20%); for example: fluff, paper, cardboard.

There is also another classification of solid and liquid fuels used in the cement industry. Solid fuels are divided into three categories:

- Vegetable compounds or natural products (oil shale, peat, barks, sawdust, etc.),
- Synthetic products (used tyres, rubber waste, waste plastics, etc.),
- Others (parts of shredded cars, fuels derived from rejects, household garbage, etc.).

**Liquid fuels are divided into**

Liquid substitute fuels—

- Easily decomposed, slightly toxic (acid tar, oil residues, etc.),
- Stable toxic (polyaromatic hydrocarbons (PAH), polychlorinated biphenyl (PCB), etc.

## 1.1.2 ADAPTABLITY 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.

Following properties should be examined before the burning of alternative fuels is undertaken

- physical state of the fuel (solid, liquid, gaseous),
- content of circulating elements,
- toxicity (organic compounds, heavy metals),
- composition and content of ash,
- content volatiles,
- calorific value,
- physical properties (scrap size, density, homogeneity),
- grinding properties,
- humidity content,
- Proportioning technology.

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 BENEFITS OF USING ALTERNATIVE FUELS

Environmental benefits:

- Reduction of the use of non-renewable fossil fuels such as coal as well as the environmental impacts associated with coal mining
- Contribution towards a lowering of emissions such as greenhouse gases by replacing the use of fossil fuels with materials that would otherwise have to be incinerated with corresponding emissions and final residues.

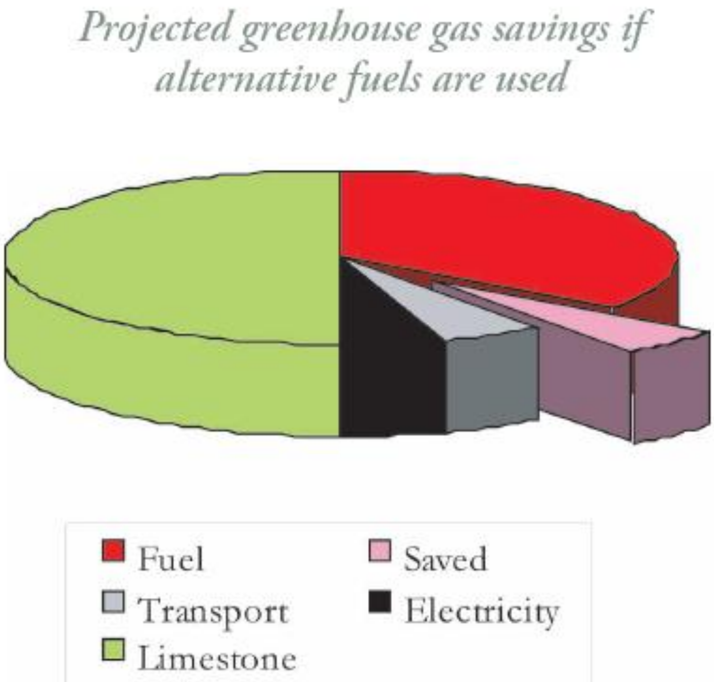


**Fig 4: GHG Savings While Using Alternative Fuels**
***Source: WBSCD Website***

- Maximisation of the recovery of energy from waste. All the energy is used directly in the kiln for clinker production.

- Maximisation of the recovery of the non-combustible part of the waste and elimination of the need for disposal of slag or ash, as the inorganic part, substitutes raw material in the cement.

Technological benefits:

- Flame temperature at 2000 ˚C and material temperature at around 1400˚C which together with residence time of 4 – 5 seconds in an oxygen rich atmosphere ensures destruction of organic components in any residues
- The neutralization of any acid gaseous formed during combustion by the alkaline nature of raw material and subsequent incorporation in the clinker.
- Interaction of flue gases and the raw material present in the kiln ensures that the non-combustible part, if any is reduced.
- On total life cycle concept, it is superior in comparison with the specialized incinerator or any other mode

Social and economical benefits:

- Implementation in rural area would contribute to overall development of the area and employment Opportunities for the rural people.
- Generates additional revenue for economically backward and frequent drought affected farmers of the region and aids rural upliftment & ameliorating their economic status.

## 1.3 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 metallics, 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.

Another problem with cement solidification is that certain wastes can cause problems 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.

# CHAPTER - 2

# THE CEMENT INDUSTRY

## 2.1 ENERGY REQUIREMENT

Indian cement industry is one of the core industries of the country consuming about 16 million tonnes of coal and 11 billion electric units annually. Cement industry is highly energy intensive, requiring on an average about 0.80 Mil.K.Cal of thermal energy per tonne of clinker production and about 100 kWh of electric energy per tonne of cement production. [11]

### 2.1.1 FUEL

The main energy inputs to the cement industry are coal and power. Coal is predominantly being used in the Indian cement industry. The quality of indigenous coal supplied is poor with high ash content (30 to 35%) which affects the efficiency of kiln apart from increasing the fuel consumption leading to higher specific Green House Gas emission. Deteriorating and inconsistent quality of coal has become a limiting factor in improving energy efficiency, productivity and clinker quality. The use of these coals results in a number of operational problems such as improper and inefficient burning and higher per unit consumption of coal as well as lower operational efficiencies which tend to further increase the emission of green house gases. The frequent variations in the quality of coal, inadequate supplies and transportation bottlenecks have rendered it imperative to import coal from countries like Africa, China, Indonesia etc. besides going for substitute fuels like lignite, rice-husk petroleum coke etc. However, import of coal is costly and a drain on our national exchequer even though it has helped cement industry getting quality coal.

Cement plants located in the south are using nearby available lignite. Cement plants located in Tamil Nadu are already using lignite along with coal. The opening of new lignite mine at Neyveli and exploitation of lignite in Gujarat and Rajasthan have further heightened the hopes of cement plants for using more and more lignite. Many cement plants are utilising lignite blended with coal to the extent possible. Pet coke, which has proved to be an excellent alternate fuel to coal, is a residual product from oil refinery with high calorific value and insignificant ash content but often with high sulphur content as compared to coal. A number of cement plants have attempted successfully using Alternate Fuel.

## 2.2 RAW MATERIAL REQUIREMENT

- Calcareous materials, CaO (such as limestone, chalk, marl, etc)
- Argillaceous material, $Al_2O_3$ and $SiO_2$ (such as clay, shale,
- slate, etc)
- Powdered coal or fuel oil.
- Gypsum($CaSO_4.2H_2O$)

Functions of the ingredients of content

- Lime is the principal constituent of cement. Its proportion must be properly regulated. However, excess of lime reduces the strength of cement, because it makes the cement to expand and disintegrate. On the other hand, presence of lesser amount of lime than required also reduces the strength of cement and makes it quick-setting.
- Silica imparts strength to cement
- Alumina makes cement quick-setting. Excess of alumina, however, weakens the cement.
- Calcium sulphate (gypsum) helps to retard the setting action of the cement. It actually enhances setting time of cement.
- Iron oxide provides colour, strength and hardness to the cement.
- Sulphur trioxide is desired in smaller proportions. Its excess reduces the soundness of cement.
- Alkalis, if present in excess, cause the cement efflorescent.

## 2.3 CEMENT MANUFACTURING PROCESS

Depending on how the raw material is handled before being fed to the kiln, basically three different types of processes can be distinguished:

- The dry,
- Semi-dry/semi-wet and
- Wet process.

In the dry process the feed material enters the kiln in a dry, powdered form. The kiln systems comprise a tower of heat exchange cyclones in which the dry feed is preheated ("preheater kiln") by the rotary kiln's hot exit gases prior to entering the actual kiln. The calcination process can almost be completed before the raw material enters the kiln if part of the fuel is added in a special combustion chamber ("precalciner kiln").

In the wet process, which is often used for raw materials with high moisture content, the feed material is made by wet grinding and the resulting slurry, which contains typically 30-40% water, is fed directly into the upper end of the inclined kiln.

In the semi-dry or semi-wet process 10-20% water is either added to the ground dry feed material or removed from a slurry for instance by filter presses resulting in a feed material containing about 15-20% moisture. Pellets of feed material are loaded onto a travelling grate where they are preheated by the rotary kiln's hot exit gases. By the time the feed material reaches the kiln entrance the water has evaporated and calcination has begun.

Presently, about 78% of cement production is from dry process kilns, a further 16% of production is accounted for by semi-dry and semi-wet process kilns, and about 6% of cement production now comes from wet process kilns due to lack of suitable raw materials for other processes. **Fig 5** describes the cement manufacturing process.

### 2.3.1RAWMILL

The dosed raw materials are dried and finely ground in the Raw Mill to form an intermediate product, called "raw meal". The grinding provides an increased surface area to enhance the heat exchange in the downstream heating process.

### 2.3.2 HOMOSILOS

The "raw meal" is then stored in a homogenizing silo in which the chemical variation is reduced. This homogenizing process is important to stabilize the downstream sintering process as well as to provide a uniform quality product. The "raw meal" is then transferred to the Preheater Tower.

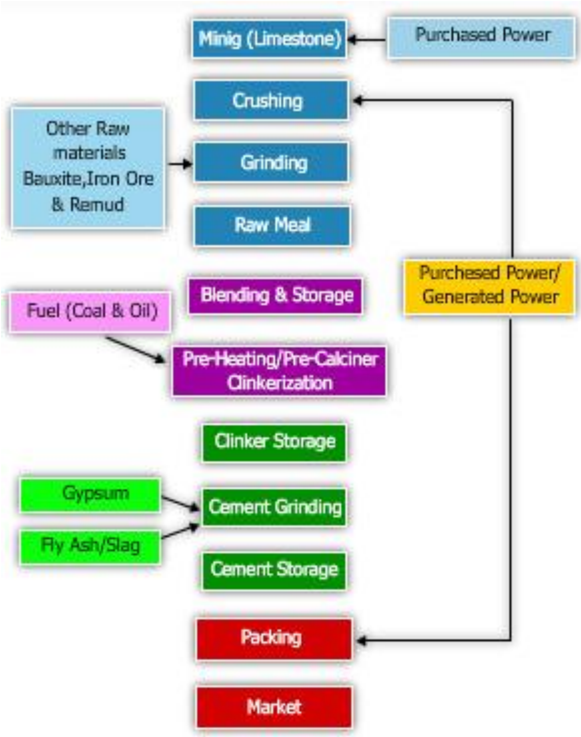


**Fig 5**: **Cement Manufacturing Process**

## 2.3.3 PREHEATER

In the Preheater, the raw meal undergoes a series of concurrent heat exchanges with the hot exhaust gas from the kiln system. The gas and material stream are separated by cyclones after each heat exchange process. The raw meal temperature increases from 80$^{o}$C to 1000$^{o}$C within 40 seconds. The first chemical reaction also takes place in the Precalciner of the Preheater, where limestone $CaCO_3$ is decomposed into lime (CaO).

## 2.3.4 KILN

The calcinated material entering the kiln, then undergoes a long heating process. The material temperature rises from 1000$^{o}$C to 1450$^{o}$C. Mineral matrixes of raw material are totally destroyed and cement minerals are formed at the sintering temperatures. A semi-product called “clinker” is formed.

Chemical reactions take place as the temperature rises:

- 70 to 110 °C - Free water is evaporated.
- 400 to 600 °C - clay-like minerals are decomposed to $SiO_2$ and $Al_2O_3$.

- 650 to 900 °C - calcium carbonate reacts with $SiO_2$ to form belite ($Ca_2SiO_4$).
- 900 to 1050 °C - the remaining calcium carbonate decomposes to calcium oxide and $CO_2$.
- 1300 to 1450 °C - partial (20–30%) melting takes place, and belite reacts with calcium oxide to form alite ($Ca_3O \cdot SiO_4$).

Coal and other alternative fuels are used as energy sources for the process. The ash from fuels is absorbed into the clinker matrix. The residual heat from the clinker leaving the kiln is recovered by a grate cooler to reduce the energy requirement.

### 2.3.5 CONDITIONING TOWER

The flue gas exiting the preheater is directed to the raw mill for drying. Before it enters the electrostatic precipitator ("EP") for its final dust removal process, its temperature and humidity is regulated in a conditioning tower. This process is essential as it affects the dust collecting efficiency of the electrostatic precipitator ("EP").

### 2.3.6 ELECTROSTATIC PRECIPITATOR

Electrostatic precipitator is commonly used as the final dust removal device for flue gases. It consists of chambers each of which contains a series of collection plates and an overhead framework of suspended rigid high-voltage electrodes. Particles in the gas stream are charged by a high-voltage, direct current field which is generated from the discharge electrodes, suspended between the collector plates. Current applied directly to the discharge electrodes manifests a highly active and visible glow in the electrode known as the "corona". In the strong electrical field region near the electrode-emitting surface, large numbers of both positive and negative ions are formed. As the discharge electrodes have a negative polarity, the positive ions are attracted to them. Both negative and positive ions are formed in equal amounts directly in the corona region near the discharge electrodes and over 99 percent of the gas space between the discharge electrodes and the collector plates contain only negative ions. As the particles entrained in the gas stream pass through the corona field, they are bombarded by negative ions and become charged in a fraction of a second. They are then attracted to the grounded collector plates where they are collected.

Particulate matter on the collecting plates and high voltage electrodes is removed by the impact of "rapper" mechanisms. Dislodged particles from the high voltage electrodes and collector plates fall into a hopper directly below each precipitator chamber.

### 2.3.7 ID FAN

Induced draft fans (ID fan) are installed in the process to drive the gas stream movements.

### 2.3.8 GRATE COOLER

The residual heat from the clinker leaving the kiln, is recovered by a grate cooler (consisting of rows of grates). Cooling air is injected from the bottom of the grate, and is forced into the clinker which is travelling slowly on the grate. The heated air is then recycled as secondary air for combustion in the kiln, or in the Precalciner.

### 2.3.9 FINISH MILL

The final process of cement making is called finish grinding. Clinker dosed with controlled amount of gypsum is fed into a finish mill. Typically, a finish mill is a horizontal steel tube filled with steel balls. As the tube rotates, the steel balls are lifted, tumble and crush the clinker into a super-fine powder. The particle size is controlled by a high efficiency air separator. Other additives may be added during the finish grinding process to produce specially formulated cement [12].

## 2.4 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 s) for the disposal of hazardous wastes.

Other advantages of a cement kiln are the following:

- Waste treatment does not require any additional source of heat and there is no increase in discharges to the atmosphere,
- It is much cheaper to adapt a cement kiln to waste incineration than build a new incineration plant

The use of WDF in the process of clinker production also has certain limitations, such as technological limitations related to the volume of waste-derived fuel. The waste volume depends on the effective incineration surface, i.e. the kiln's length and capacity. The use of WDF must not have a negative impact on the kiln running or clinker quality WDF should be used in accordance with strictly defined rules so as to ensure that incineration products do not have an adverse impact on the process of clinker production, that is do not affect cement quality or cause pollution of gases discharged to the atmosphere. [10]

# CHAPTER -3

# REVIEW OF LITERATURE

Ever since the first energy crises of 1974, world attention was drawn towards harnessing non-conventional energy sources to substitute costly and depleting fossil fuel. Since then mention of energy from the waste do find a place in all articles which try to present possible sources of cheap and renewable energy. [13].

The growth of chemical industries in developed and developing countries resulted in the release of huge quantities of hazardous waste into the environment in the form of solid, liquid and gas. Such type of wastes posed substantial hazard when improperly disposed. In India, detoxification, destruction and solidification of hazardous waste for safe and secured disposal is non-existent in most of the industrial units. Most of the highly hazardous industrial sectors dispose their waste in low-lying area because of the fact that economical aspects outweigh the environmental aspects [14, 15, 16, 17, 18, 19].

The control mechanisms for the treatment and safe disposal of hazardous wastes were through the regulations by the ministry. The Hazardous Waste (Management and Handling) Rules, 2008 comprise of the guidelines for guiding the local authorities in the management of Hazardous Waste. The guidelines are meant for guiding the local authorities in the management of hazardous wastes. The guidelines also provide necessary details for the occupier, generator, transporter and operator of the disposal facility [20, 21]. Out of many methods of disposal of hazardous waste, the disposal by incineration is one of the environmentally sound methods as compared to other methods of disposal practised in India. The main problem associated with the incineration of hazardous waste was generation of air pollution reported by many workers [22, 23, 24].

In hazardous wastes disposal cement kilns can play an integral role in hazardous waste management together with other disposal technologies. Using cement kiln technology has economic and environmental benefits reported by many researchers [17, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32].

It has been found that many countries like USA, UK, France, Australia, Norway, Italy, Sweden, Canada, and Singapore are using hazardous waste as fuel in cement kiln for cement manufacture. It has been found that 3 cement plants of Onoda Cement Co. Japan are using 26 types of industrial wastes delivered from 252 industries with annual consumption of 131000 tonnes of waste as fuel. As a result, 1,10,000 tonnes of coal was saved per year and accordingly the fuel cost was reduced by 6.9%. The investment in the equipment is about 73.6 million US dollars and the interest and depreciation expenses account for 130% of the reduced cost assuming that the invested money will be recovered in 10 years [33].

Kreft reported "The law governing wastes gives priority to avoiding waste before it is recycled or treated in some other way. This sets the objectives for a modern waste economy with the ultimate aim of causing the least possible emission when dumping and landfilling unavoidable residues.

When waste treatment is divided into the areas of combustion, landfilling of residuals and flue gas cleaning then the following differences becomes apparent: -

- Combustion in cement rotary kilns takes place at substantially higher temperatures than when burning in a refuse incineration plant, and the residence time of the flue gases is also significantly higher. This means that toxic compounds are destroyed more effectively in cement kilns than in a refuse incineration plant.
- The residuals produced in refuse incineration plants, such as slag and ash; do not occur when refuse is burnt in cement kilns because these mineral residuals become constituents of the cement. Their chemical compositions are similar to that of raw meal and do not affect the cement quality, while residuals from a refuse incineration plant have to be dumped and land filled.
- Flue gas cleaning in a cement works takes place in the process itself through contact between the flue gases and the raw meal, during which the acid gas constituents and heavy metals are deposited and to a great extent are retained in the cement. [34]

The flue gas cleaning systems installed are confined to dust removal, in which the dust which is removed also contains deposited residue components. The flue gas cleaning system installed in a refuse incineration plant is technically much more sophisticated, but also provides more effective separation. As a consequence it follows that symbiosis of the advantages of the two concepts is bound to produce a better scheme – combustion in a rotary cement kiln with the advantages of high temperatures and residence times while avoiding residuals, and integration of an extended flue gas cleaning system into the plant design for a cement kiln".

USEPA specified the limit of various parameters like heat content suspended solid water content, ash content, lead content, chromium content, etc of hazardous waste as fuels for cement kilns and also provide the type of hazardous waste, process requirement and environmental regulations [17].

It has been found that the most important aspect of combustion of hazardous waste in the cement kiln was the flame shape, which was directly linked to the formation, stability and characteristics of the coating in the kiln, clinker quality, clinker cooling and heating rate. Clemente Greco et.al. have reported that the injection of hazardous waste derived fuels was achieved through the parallel guns or through guns with a slight angle related to the main burner. This form of firing, however, did not give good results as the flame was deformed by the side injection, altering the sequence of ignition that take place along the flame. The only way of controlling the successive ignitions, insuring their continuity, resulting in high flexibility and controllable flame, was to inject fuels concentrically through the main burner. Water content, physical state (solid, liquid, gas) and physical properties ( aggregation state, particle dimension, viscosity); heating value; composition; turbulence level; flame intensity and shape were the parameters which were considered at the time using derived fuels for cement kilns. The maximum water content for firing was determined by the fuel net value [35]. It has also been reported that the degree of substitution to which liquid alternative fuels depends mainly on water content, solids in suspension as well as the size of the solid particles found in the liquid [35].

As the demand for hazardous waste derived fuel substitutes grew, it became apparent that many solid hazardous waste streams had good energy value but diverse chemical and physical characteristics. Cement kilns need blended mixtures with consistent energy content and uniform physical characteristics to ensure minimum disruption of cement manufacturing process. Many processes have been developed to condition waste into more suitable forms. Solid hazardous wastes were considered most difficult and expensive materials to process.

It has been reported that three methods have been developed to introduce these materials in the cement kilns as the fuel substitute. In the first method, solids were transported to the kiln with the liquid hazardous waste. This method was limited by the amount of liquid waste available and percentage of solids which were held in suspension. Most of the kiln in USA that were using liquid hazardous waste as a fuel substitutes already have a significant percentage of solid material content. The second method utilised was encapsulation of the solid wastes into the containers. These containers were introduced at an intermediate point of the cement manufacturing process, so that they would oxidise before entering the burning zone. Although this method was effective but it could not maintain the effective quality of the clinker and consistency of heat input. The third method involved the processing of diverse solid waste streams into homogeneous dry powders. These dry powders were then injected into burning zone with pneumatic transport system. Various solid Hazardous waste streams such as chemical process sludge, oil refinery separator sludge and distillation bottoms were brought to the treatment, storage and disposal facilities [28].

The manufacture of cement is an energy-intensive process. By burning waste fuels to recover their energy value, a typical cement kiln can burn 113-500 L of liquid waste per day, providing 20 to 25% of a kiln's daily heat requirement [3].

Regarding waste oil, 1 billion gallons are collected every year in the US; 75% is marketed directly as fuel oil, 14% is refined and 11% is distilled. In the EU, of the approximately 1.7 million tons of waste oil collected every year, 63% is used by cement kilns. About half of the waste oil used by cement kilns in the EU is treated prior to use, while the other half is used as a secondary fuel without treatment [45].

The use of tires by cement plants has increased dramatically over recent decades: in 1991 nine plants in the US were burning tires and by 2001, 39 plants were using discarded tires for fuel**.** By 2005, 58 million tires were burned in 47 cement facilities around the US (RMA 2006). Similar trends have evolved in the EU largely driven by policies banning whole tires in landfills as of 2003, and shredded tires as of 2006 The German Federal Environmental Office commissioned a study in 1999 to evaluate the trade-offs among different landfill alternatives for scrap tire and found that among thermal utilization processes, cement kilns are the optimal choice [46].

During the incineration of hazardous waste which contains toxic and heavy metals like Cd, Cr, Co, Pb, Cu, Zn, As, Ni, etc are trapped in clinker matrix which improve burn ability of raw mix, modified the mineralogical composition are generally changed the properties of the final cement manufactured was reported by many researchers [10, 21, 28, 29, 35, 47, 48,]. A detailed study on the effect of ZnO, BaO, $CaSO_4$ on formation rate of clinker and found the ZnO has the accelerating clinkering effect [38].

Furthermore, it was found found that Zn-containing waste could effectively improve burn ability of raw mix, increase alite content highly enhance the early strength of cement [39]. The effect of large addition of Cd, Cr, Zn, Pb to the raw cement meal on the composition and properties of the clinker and the cement was studied by many workers [38, 39, 40, 41, 43]. It was found that matrices of calcium silicates and calcium aluminates were able to trap large quantity of Cd, Cr, Zn, Pb. [40]

The Portland cement clinker could accept Cd, Cr, Zn in its matrix with a modification of its hydration behaviour i.e. delayed setting time and lower strength for Cd and Zn and shorter setting and higher early strength for Cr [40]. Behaviour of transition metal oxides and their relative effectiveness at different temperatures have been reported. [41] The use of Ti-containing waste reduce the temperature of melt formation of the raw meal was reported by many researches [41, 42, 44]. It was reported that crystal size of $C_3S$ increase up to 1% only and higher concentration have deleterious effect on its formation. $TiO_2$ was incorporated upto 4.5% in $C_3S$ at 1450°C. It had been reported that alite containing $TiO_2$ has hydraulic activity than ordinary alite [44].

It was reported that properly managed cement kiln can accomplish with no significant increase in emission and environmental impact. It was reported that the burning of hazardous waste as a fuel in cement kiln is technically and environmentally viable method as all three provisions temperature, time and turbulence are definitely more than adequate. Even the most stable hazardous organic in the waste can be easily, safely and completely destructed to non-hazardous product [23]. Destruction and removal efficiency (DRE) of principal organic hazardous constituent was usually better than 99.99%, sometimes even 99.9995%. Besides the very high DRE in most of the cases there was no significant change in the emission either, more over some emissions were found to be reduced when hazardous waste co-firing was used. The same was found for emission of toxic heavy metals. The work on the efficiency of destruction of industrial waste, used in the co-incineration in rotary kilns of the cement industry, considering the principle of the chemistry equilibrium and the kinetic of the reactions was carried out. As an example, it has analyzed the burn of one hazardous waste which has in its composition toluene, xylene and dichloroethane. The temperatures of the transformation and the time of the reaction to the formation of sub-products which will originate $CO_2$, $H_2O$ and HCl, are evaluated and no additional emissions were noticed. Thus, the formation of the pollutants in the kiln is preliminary estimated and the different forms to control the emissions is also discussed.

A research was carried out in the Federal Republic of Germany, which used about 5,00,000 tons of waste oils containing polychlorinated biphenyls (PCB) as contaminants. Tests were carried out under industrial conditions with a view to ascertaining whether such waste oils can be harmlessly fired in cement kilns. In several series tests, in which up to 10 percent of the overall fuel energy requirement of the kiln is to be provided by waste oil with progressively increasing PCB content ranging from 50 to 1000 ppm, it is to be investigated up to what PCB content it is with certainty possible to achieve pollutant-free combustion. For this purpose comprehensive safety precautions have been taken to ensure reliable combustion. From the available results it can be inferred that, with adequate atomization of the oil in the gas steam, the PCB can be completely or very largely burnt in the cement kiln. [47]

Several reviews have been published on co-firing of hazardous waste in cement kiln [17, 22, 23, 24, 31]. Solid hazardous waste could be well used as alternative fuels in rotary cement kilns. Neither PCDD or PCDF traces were found over the detection level nor the total concentration of polycyclic aromatic hydrocarbons increased in the emissions.

It was reported that the burnable liquid hazardous wastes have been incinerated and safely disposed in cement kiln [31]. Some of them are easily destructed at relatively low temperatures and without the formation of toxic substances. Simple hydrocarbon oils, non-halogenated solvent, etc, belongs to this group.

# CHAPTER -4

# COMBUSTIBLE HAZARDOUS WASTE

## 4.1 WASTE MATERIALS

The cement industry provides a public or industrial service by disposing of wastes even those with little or no useful energy or mineral content. This may be done at the request of national governments or in response to local demand. It can be done because a cement kiln provides high temperatures, long residence time, and a carefully controlled facility capable of high destruction efficiency.

There are differences in temperature between different parts of the process, it is important that waste materials are introduced at the correct point in the process to ensure complete combustion or incorporation and to avoid unwanted emissions. For example, raw materials with volatile organic components may be introduced in the cement kiln at the main burner, in mid-kiln, in the riser duct, or at the precalciner. They should not be introduced with other raw materials except where tests demonstrate that this will have no effect on the off-gases.

## 4.2 WASTE CLASSIFICATION

Waste can be classified as:

- Hazardous waste
- Non-Hazardous waste

### 4.2.1 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.

### 4.2.2 HAZARDOUS WASTES:

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. Central Pollution Control Board under the Hazardous wastes (Management and Handling & Trans boundary movement) Rules, 2008 has been empowered to accord approval for utilization of hazardous wastes. About 6.2 Million tonnes of hazardous wastes including out of which 0.41 Million tonnes of Incinerable wastes is annually generated in India. The disposal of such waste in common and captive incinerators leads to the loss of vital resource besides having potential to cause severe environmental risks if not operated in an environmentally sound manner.

However, Co-combustion of hazardous wastes in cement kiln, wherever, characteristics so suggests, will eradicate such risks and harness the encapsulated energy, hence a priority area. In order to streamline the procedure of co-processing so as to give a thrust to such activity, the guidelines have been prepared by CPCB in India.

` National Waste Management Council defined the hazardous waste as follows:

"Any waste , other than radioactive waste, which by reasons of physical and /or chemical or reactive or toxic, explosive, corrosive or other characteristics causing damage or likely to cause danger to health or environment, whether alone or when coming in contact with other wastes or environment" [48]

This definition of hazardous waste is based upon two criteria:

a) Presence of specific chemicals, thought to be hazardous e.g. waste soluble chemicals of lead, copper, etc, mercury, arsenic, oil waste, pesticides, etc.

b) The quantity of specific chemicals in the waste. The waste is hazardous, if it contains some specific chemicals above the regulatory quantities in the waste.

Accordingly, categories, characteristics and the regulatory quantity of hazardous waste are given in **Annexure 2** [14, 20, 48]. On the basis of regulatory quantities of hazardous chemicals, all the hazardous waste generated by industrial activity are put under 18 categories. Out of 18 categories of hazardous waste, most of the hazardous wastes under the categories no. 5, 6, 7, 8, 9, 10, 11 and 15 have potential of being used as fuel in the cement industry because of their flammable characteristics. The list of the wastes generated from various processes is given in **Annexure 3.**

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 because:

1) Such waste are non degradable or persistent in nature,
2) They can be biologically magnified,
3) They can be lethal, or
4) They may or tend to cause detrimental cumulative effects."

USPEA has specified the following four characteristics:

1) Ignitability: Substances those are easily ignited and burnt vigorously and persistently. Examples includes volatile liquid, such as solvents whose vapour ignite at relative low temperature (i.e. flash point less than 60°C)
2) Corrosivity: Substances including liquid with pH less than 2.0 or greater than 12.5 and that are capable of corroding steel at a rate greater than 6.35mm per year at a temperature of 55°C.
3) Reactivity: Substances those are unstable under normal condition. They can cause explosions and/or liberate toxic fumes, gases, vapours when mixed with water. Cyanide or sulphide bearing wastes which when exposed to pH conditions between 2 and 2.5 can generate toxic gases, fumes or vapours in quantity sufficient to present a danger to human health or the environment.
4) Toxicity: Substances those are fatal or harmful when ingested or absorbed, toxicity is determined using a standard laboratory test.

## Classification of Hazardous Waste

In India, the hazardous waste (management and handling) Rules 1989 have been framed by the MOEF, Govt. Of India, under the provision of Environmental Protection Act, 1986. In the said rules hazardous wastes or combustible hazardous waste are classified on the basis of presence of specific hazardous chemicals and quantities of specific hazardous chemicals of flammable nature present in the waste. These specific hazardous chemicals are phenols, organic emulsion hydrocarbons (halogenated, non-halogenated), etc. [17, 22, 48]. In cement industry, injection systems for feeding the fuels in cement rotary kiln depend upon the physical state of the fuel. It is better to classify combustible hazardous waste on the basis of their physical state. The classification is given below:

1) Solid hazardous wastes:
   a) Paint residue
   b) Spent carbon residue
   c) Distillation residue
   d) Phosphorus residue
   e) Spent resin catalyst etc.
2) Semi-solid hazardous waste:
   a) Tank bottom sludge
   b) Oily sludge
   c) Liquid slurry
   d) Tarry waste
   e) Filter aid sludge etc
3) Liquid hazardous wastes
   a) Cleaning agents like mineral turpentine
   b) Waste oil
   c) Tarry waste
   d) Amines waste etc.[14, 35]

The combustible hazardous wastes generated in India are given below:

1) Paint residue and liquid waste from paint industry.
2) Spent carbon residue

3) Pesticide residue

4) Oily sludge

5) Pharmaceutical off specification products

6) Petrochemical halogenated and non halogenated waste.

7) Liquid slurry from vinyl chloride monomer industry.

8) Filter aid sludge from di-amine and polyamines industry

9) Phosphorus residue[15, 16, 18, 19, 21]

## 4.3 HAZARDOUS WASTE SITUATION IN INDIA

It is estimated that, in India, there are 36,165 nos. of hazardous waste generating industries, which are generating 62,32,507 Metric Tonnes of hazardous wastes every year. The recyclable portion of HW is in the range of 49.55 % and the land disposable portion and incinerable portion are in the tune of 43.78 % and 6.67 % respectively.

As per a recent report published by CPCB, Delhi in Feb.2009 [48], following are some of the salient findings of same:-

i. In India, there are 36,165 nos. of hazardous waste generating industries, generating 62,32,507 Metric Tonnes of hazardous wastes every year. 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.

ii. Gujarat, Maharashtra and Andhra Pradesh are the top three HW generating States. The relative contributions by these States are 28.76 %, 25.16 % and 8.93 %

respectively. Thereafter, Chhattisgarh (4.74 %), Rajasthan (4.38 %), West Bengal (4.17 %) and Tamil Nadu (4.15 %) are found as major generators of HW. These seven States are together generating 80.29 % of country's total HW.

iii. Maharashtra and Gujarat putting together are generating 62.87 % of country' total incinerable HW. Their individual contributions are 36.75 % and 26.12 % respectively. Other States generating significant quantities of incinerable HW are Andhra Pradesh (7.61 %), Rajasthan (5.54 %), Uttar Pradesh (3.78%), Punjab (3.57 %), West Bengal (3.03 %) and Tamil Nadu (2.68%) respectively. These eight States are generating 89.08 % of the country's total Incinerable HW.

iv. Common Treatment, Storage and Disposal Facilities (TSDF) are developed for the disposal of land disposable HW at 22 different places in 10 States only namely Gujarat (7 Nos.), Maharashtra (4 Nos.), Uttar Pradesh (3 Nos.), Andhra Pradesh (2 Nos.), Himachal Pradesh (1 No.), Madhya Pradesh (1 No.), Punjab (1 No.), Rajasthan (1 No.), Tamil Nadu (1 No.), and West Bengal (1 No.). Total waste handling capacities (disposal capacity) of these facilities, is 15,00,568 MTA which is much less than the present generation of 27,28,326 MTA of land-disposable HW. The deficit of TSDF capacity is 12,27,758 MTA. It is obvious that additional TSDFs with waste handling capacities to the tune of 15,00,000 MTA or so must be developed to accommodate the present and future quantities of land disposable HW.

v. Common TSDF located in Andhra Pradesh, Himachal Pradesh, Madhya Pradesh and Uttar Pradesh are having surplus capacities to handle the present quantities of land disposable waste generated in these respective States while the common TSDF located in Gujarat, Maharashtra, Punjab, Rajasthan, Tamil Nadu and West Bengal do not have adequate capacities to accommodate the present quantities of land disposable HW.

vi. In a similar way, for incineration of the incinerable HW, the details of the facilities available in the country are as follows-

| | |
|---|---|
| • Common Incinerators | 13 Nos. in 6 States |
| • Individual Incinerators | 127 Nos. in 12 States |
| • Total incineration capacity | 3,27,705 MTA |
| • Present generation of Incinerable waste in the country | 4,15,794 MTA |
| • Deficit of Incineration capacities | 88,089 MTA |

It is proposed by different States to install additional incinerators to provide additional incineration capacity of 2,56,710 MTA [5].

Andhra Pradesh, Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab, Pondicherry are having adequate incineration capacities (common & captive) to handle the incinerable wastes generated in the respective States. On the other hand Madhya Pradesh, Rajasthan, Uttar Pradesh, West Bengal and Daman, Diu & DNH need to augment the incineration facilities available with them to properly dispose-off the incinerable waste generated in their areas.

About 6.2 Million tonnes of hazardous wastes is annually generated in India, out of which around 3.09 Million tonnes is recyclable, 0.41 Million tonnes is incinerable and 2.73 Million tonnes is land-fillable [11]. This categorization of hazardous wastes into 3 classes is based on the hazard potential and its characteristics guiding its ultimate disposal, in accordance with the Hazardous wastes (Management and Handling & Transboundary Movement) Rules, 2008. Most of these wastes have characteristics suited to their utilization as resource material either for recovery of energy or materials like metals or their utility in construction, manufacture of low-grade articles or recovery of the product itself, which after processing can be utilized as a resource material. Hence a new mind- set treating the hazardous waste as a resource material rather than a difficult disposable material is the need of the hour.

The cost of providing incinerator would depend on its capacity ranging from ` 10 crore to ` 30 crore. Assuming disposal cost of incinerable hazardous waste is about ` 16,000/- per MT, it may roughly be estimated that additionally about ` 640 crore / annum would be incurred in incinerating hazardous waste in our country [11]. Besides, incinerator if not operated optimally may contribute to emissions including toxic Dioxins and Furans. This coupled with resource conservation (4) and reduced carbon emissions make a strong case for considering co-processing as a sound and better alternative for hazardous wastes disposal in general and incinerable waste in particular.

## 4.4 HAZARDOUS WASTE SITUATION IN THE STATE OF TAMIL NADU

Since the project was carried out for the Dalmia Cement Plant located in Dalmiapuram, Tamil Nadu, it was important to survey the status of waste available in that region of the country. Traditionally, Tamil Nadu has always been in forefront of industrialisation with a strong presence in manufacture of engineering and auto components, textiles, leather, sugar, drugs, etc. During the post legislation period, since 1991, private sector began to take over lead in the industrial development in the country. Tamil Nadu is currently ranked fifth largest economy among the states in India.

The policy of Tamil Nadu government has been "to maximize the welfare of the people of Tamil Nadu, by creating the gainful employment opportunities by achieving higher and sustainable economic growth with emphasis on balanced regional development through greater public and private investment in manufacture and infrastructure development".

This increasing industrialisation in the state is largely dependent on the use of fossil fuels as a source of energy. Also, everyday there is significant increase in the irreversible contamination of the natural resources (and, water, air).The use of fossil fuels can be substituted by the waste (co-processing). Coupling benefits like resource conservation and waste management, co-processing is surely the better and sound alternative.

The main sources of hazardous waste and cause of an adverse impact on the state's environment are industries like boil refineries, petrochemicals, sugar, dyeing, pulp and paper, tanneries, drugs, auto industries and other chemical industries.

The collection, transportation, storage, handling, treatment and disposal of hazardous waste are important issue since improper handling and disposal can cause serious damages to the environment

The Tamil Nadu Pollution Control Board (TNPCB) has a special monitoring cell at its head office, Chennai, to monitor the 17 categories of highly polluting industries, specified by the government of India.

There are 233 large and medium units identified in 17 categories of highly polluting industries and these are being closely monitored by the board. These 17 categories involve:

**Table 1: 17 Categories of Highly Polluting Industries**

| S.No. | Sectors | Number of Units |
|---|---|---|
| 1 | Aluminium Smelting | 1 |
| 2 | Drugs and Pharmacy | 27 |
| 3 | Chloro alkali | 3 |
| 4 | Cement | 19 |
| 5 | Copper Smelting | 1 |
| 6 | Dye and Dye Intermediate | 1 |
| 7 | Distillery | 17 |
| 8 | Fertilizer | 6 |
| 9 | Iron and Steel | 2 |
| 10 | Tannery | 55 |
| 11 | Oil Refinery | 3 |
| 12 | Pesticide | 1 |
| 13 | Pulp and Paper | 3 |
| 14 | Petrochemical | 12 |
| 15 | Sugar | 41 |
| 16 | Thermal power Pant | 41 |
| 17 | Zinc Smelting | 0 |

In order to generate an updated inventory for hazardous waste in the state, an exercise in different district was initiated by the state government.

Existing Hazardous Waste Management for combustible hazardous waste generated from these industries is as follows [**Table 2**] [20, 26]:

**Table 2: Waste management for combustible hazardous waste**

| S.No. | Type of waste | Collection | Treatment | Disposal |
|---|---|---|---|---|
| 1 | Paint residue & liquid waste | Manual | Nil | On land |
| 2 | Oily sludge | Pumping to centrifugal decanter | Centrifugal decanter | Landfill |
| 3 | Pigment waste | Hand driven trolley | Nil | Landfill |
| 4 | Tarry waste | Gravity from distillation still | Incineration | Landfill |
| 5 | Spent carbon residue | Manual tipping into drums | Incineration | Landfill |
| 6 | Halogenated HC(petrochemicals) | Pumping | Incineration | Landfill |
| 7 | Non halogenated HC | Pumping | Incineration | Landfill |
| 8 | NaCl waste with 1% amines | Manual shoveling into drums | Nil | Landfill |
| 9 | Filter aid with 70% diamines & poly amines | Manual shoveling into drums | Nil | Landfill |

The present information on total hazardous waste generated from industries in the state is given in the **Table 3**. At present around, 181,856,699 MT of hazardous waste are generated in the state of which nearly, 42,916,982MT are recyclable.128,984,214MT are disposable and 10,072,612MT is incinerable waste.[28]

**Table 3: Hazardous Waste generation in Tamil Nadu**

| S.No. | District | No. of units | Total Quantity of HW Generation in MTA | Quantity of HW (in MTA) | | |
|---|---|---|---|---|---|---|
| | | | | Landfillable | Recyclable | Incinerable |
| 1 | Chennai | 94 | 1644.412 | 187.817 | 1041.273 | 443.022 |
| 2 | Coimbatore | 368 | 23182.115 | 2261.478 | 822.481 | 98.156 |
| 3 | Cuddalore | 41 | 6541.246 | 4856.792 | 886.454 | 798 |
| 4 | Dharmapuri | 10 | 26.95 | | 26.95 | |

| S.No. | District | No. of units | Total Quantity of HW Generation in MTA | Quantity of HW (in MTA) | | |
|---|---|---|---|---|---|---|
| | | | | Landfillable | Recyclable | Incinerable |
| 5 | Dindigul | 46 | 6055.585 | 5370.3 | 659.685 | 22 |
| 6 | Erode | 341 | 6191.714 | 5923.2 | 268.514 | |
| 7 | Kancheepuram | 162 | 8913.883 | 6095.389 | 1750.418 | 1068.076 |
| 8 | Kaniyakumari | 19 | 133.687 | 0.108 | 123.219 | 10.36 |
| 9 | Karur | 60 | 6482.429 | 6324.52 | 157.909 | |
| 10 | Krishnagiri | 63 | 3324.168 | 1276.127 | 1481.016 | 567.025 |
| 11 | Madurai | 116 | 2007.506 | 964.064 | 564.23 | 479.212 |
| 12 | Nagapattinam | 17 | 652.337 | 296.28 | 290.587 | 65.47 |
| 13 | Nammakkal | 116 | 1664.31 | 1591.83 | 144.48 | |
| 14 | Nilgiri | 11 | 685.82 | 618 | 51.82 | 16 |
| 15 | Perambalur | 13 | 286.361 | 1.675 | 137.686 | 147 |
| 16 | Pudukkottai | 29 | 478.527 | 443.067 | 35.4 | 0.06 |
| 17 | Rammad | 10 | 9.194 | 0.096 | 9.09 | 0.008 |
| 18 | Salem | 118 | 13190.126 | 9474.828 | 794.816 | 2920.483 |
| 19 | Sivaganga | 20 | 223.508 | 162.02 | 60.788 | 0.7 |
| 20 | Thanjavur | 26 | 101.136 | 1.938 | 99.198 | |
| 21 | Theni | 11 | 1029.052 | 1000 | 29.052 | |
| 22 | Thiruvallur | 154 | 25011.549 | 5306.754 | 17960.48 | 1864.315 |
| 23 | Thiruvannamalai | 13 | 52.164 | | 52.164 | |
| 24 | Thiruvarur | 11 | 450.184 | 440 | 10.144 | 0.04 |
| 25 | Thoothukudi | 39 | 50026.929 | 39995.294 | 9958.434 | 73.21 |
| 26 | Tirunelveli | 38 | 1363.475 | 1171.582 | 126.501 | 65.392 |
| 27 | Trichy | 54 | 2906.545 | 990.104 | 972.721 | 943.72 |
| 28 | Vellore | 153 | 18308.324 | 13696.382 | 4264.254 | 347.688 |
| 29 | Villupuram | 17 | 483.631 | 445.18 | 28.436 | 10.015 |
| 30 | Virudhunagar | 40 | 429.831 | 161.389 | 135.782 | 132.66 |
| | **Total** | **2210** | **18,19,73,808** | **12,89,84,214** | **4,29,16,982** | **1,01,90,534** |

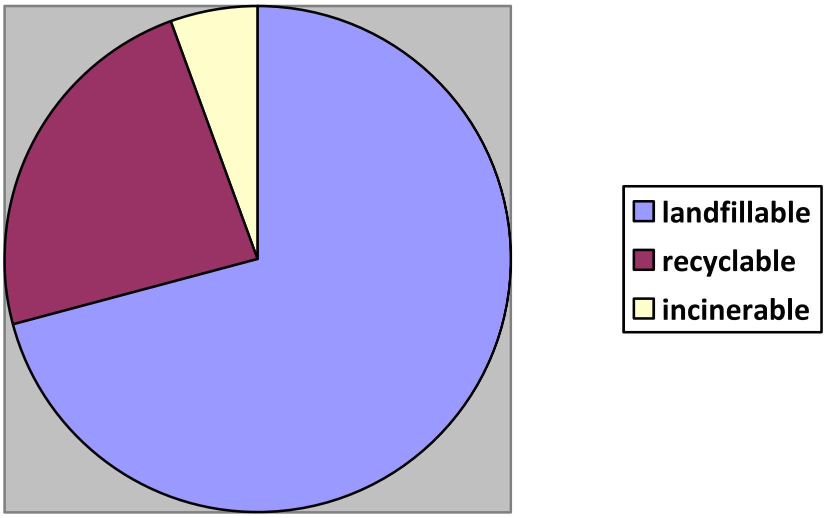


**Fig 6: Pie Chart Showing Classification of Hazardous Waste**

The amount of incinerable waste produced is 1,01,90,534 MTA, which is quite high. This waste can be diverted towards the cement kiln so as to reduce the emissions and providing energy efficiency to the kiln.

# CHAPTER -5

# GUIDELINES FOR COPROCESSING OF HAZARDOUS WASTE

The hazardous wastes for co-processing need to be handled in an environmentally safe manner avoiding the possibilities of contaminating the nearby environment and eliminate the chances of accidents leading to environmental catastrophe. The requirements of handling, including labelling, packaging, transport and storage applicable to the hazardous wastes have been described in following sub-sections, however, these will not be applicable to other substances like tyre chips, plastic waste and other high volume low effect wastes such as phosphogypsum, red mud, slag from pyro-metallurgical operations etc. (not covered under the purview of the Hazardous wastes) (Management and Handling & Transboundary movement) Rules, 2008 [37]:

## 5.1 PROCEDURE FOR HANDLING OF HAZARDOUS WASTE

### 5.1.1 RESPONSIBILITIES FOR OCCUPIER FOR HANDLING OF HAZARDOUS WASTES:

"Occupier" in relation to any factory or premises, means a person who has, control over the affairs of the factory or the premises and includes in relation to any hazardous waste the person in possession of the hazardous waste.

a) The occupier shall be responsible for safe and environmentally sound handling of hazardous wastes generated in his establishment.

b) The hazardous waste generated in the establishment of an occupier shall be sent or sold to a recycler or re-processor or re-user registered or authorized under these rules or shall be disposed of in an authorized disposal facility.

c) The hazardous waste is transported from an occupier's establishment to a recycler for recycling or reuse or reprocessing or to an authorised facility for disposal shall be transported in accordance with the provisions of these rules.

d) The occupier or any other person acting on his behalf, who intends to get his hazardous wastes treated and disposed of by the operator of a Treatment, Storage and

Disposal Facility shall give information to the operator of the facility, such information may be determined by SPCB.

e) The occupier shall take all adequate steps while handling hazardous wastes to:

(i) Contain contaminants and prevent accidents and limit their consequences on human beings and the environment; and

(ii) Provide persons working on the site with the training, equipment and information necessary to ensure their safety.

### 5.1.2 AUTHORIZATION:

(i) Every person who is engaged in processing, treatment, package, storage, transportation, use, collection, conversion, offering for sale, transfer or the like of hazardous waste shall require to obtain an authorization from the State Pollution Control Board.

(ii) The hazardous waste shall be collected, treated, recycled, re-processed, stored or disposed of only in facility authorized by the State Pollution Control Board/ Pollution Control Committee for the purpose.

(iii) Every person engaged in generation, processing, treatment, package, storage, transportation, use, collection, destruction, conversion, offering for sale, transfer or the like of the hazardous waste or the occupier of the facility shall make an application to SPCB for authorization.

(iv) On the receipt of the application complete in all respects for the authorization, the SPCB may grant an authorisation in a period of one hundred and twenty day , after inquiry as it considers it necessary and the satisfaction that the applicant possesses appropriate facilities, technical capabilities and equipment to handle hazardous waste safely. This authorization is valid for 5 years and shall be subjected to conditions laid down therein.

(v) The SPCB may after giving reasonable opportunity of being heard to the applicant may refuse to grant any authorization.

(vi) Every person authorized under these rules shall maintain the record of hazardous wastes handled by him and submit an annual return coming detail to SPCB on or before $30^{th}$ day of June following to the financial year to which that return relates.

(vii) An application for the renewal of an authorization shall be made before its expiry and the SPCB may renew the authorization after examining each case on merit subject to the condition that there has been no report of violation of the provisions of the Act or the rules made there under or conditions specific in the authorization.

(viii) The occupier or operator of the facility shall take all the steps, wherever required, for reduction and prevention of the waste generated or for recycling and reuse and comply with the condition specified in the authorization.

(ix) The SPCB shall maintain a register containing particulars of the condition imposed under these rules for management of hazardous waste, and it shall be open for inspection during office hours to any person interested or affected or a person authorized by him on his behalf.

## 5.1.3 POWER TO SUSPEND OR CANCEL AUTHORIZATION

(i) The SPCB may, if in its opinion the holder of the authorization has failed to comply with any of the conditions of the authorization or with any provisions of the Act or these rules or with any provision of the Act or these rules and after giving him a reasonable opportunity of being heard and after recording reasons thereof in writing cancel or suspended the authorization for such period as it considers necessity in the public interest.

(ii) Upon suspension or cancellation of the authorisation the SPCB may give directions to the person for safe storage of hazardous wastes, and such person shall comply with such direction.

## 5.1.4 STORAGE OF HAZARDOUS WASTE

The occupier, re-processor/re-user/co-processor of facility may store the hazardous wastes for a period not exceeding ninety days of the permitted quantity for reprocessing / reuse and shall maintain a record of sale, transfer, storage and reprocessing of such wastes and make these records available for inspection: Provided that the State Pollution Control Board may extend the said period in following cases, namely:-

(i) Small generators up to tones per annum.

(ii) Recyclers, re-processors and facility operators up to six months of their annual capacity (iii)Generators who do not have access to any Treatment, Storage, Disposal Facility in concerned State; or

(iv) The waste which needs to be specifically stored for development of a process for its recycling, reuse.

## 5.2 PROCEDURE FOR RECYCLING, REPROCESSING OR REUSE OF HAZARDOUS WASTE

### 5.2.1 PROCEDURE FOR GRANT OF REGISTRATION:

(1) Every person desirous of recycling or reprocessing the hazardous waste may make an application accompanied with a copy each of the following documents for the grant or renewal of the registration:-

(a) Consent to establish granted by the SPCB under Water (Prevention and Control of Pollution) Act, 1974 and the Air (Prevention and Control of Pollution) Act, 1981.

(b) Certificate of registration issued by the District Industries Centre or any other Government agency authorized in this regard.

(c) Proof of installed capacity of the plant and machinery issued by the District Industries Centre or any other government agency authorised in its behalf; and

(d) in case of renewal, certificate of compliance of effluent, emission standards and treatment and disposal of hazardous wastes, as applicable, from the SPCB.

(2) The CPCB on being satisfied that the applicant is utilizing environmentally sound technologies and possesses adequate technical capabilities, requisite facilities and equipment to recycle, reprocess or reuse hazardous waste, may grant registration to such applicants stipulating therein necessary conditions for carrying out safe operations in the authorized place only.

(3) The CPCB shall dispose of the application for registration within a period of 120 days from the date of receipt of such application complete in all respects.

(4) The registration shall be valid for a period of five years from the date of issue, unless the operation is discontinued by the unit or registration is suspended or cancelled by CPCB.

(5) The CPCB may cancel or suspend the registration granted under these rules if it has reasons to believe that the recycler or re-processor has failed to comply with any of the conditions of the registration, or with any provision of the Act or rules made thereunder.

(6) The CPCB may after giving a reasonable opportunity of being heard to the applicant, by order, refuse to grant or renew the registration.

(7) The recycler or re-processor shall maintain records of hazardous waste purchased and processed and shall file an annual return of its activities of previous year to SPCB on or before the $30^{th}$ day of the June of every year.

### 5.2.2 CONDITIONS FOR SALE OR TRANSFER OF HAZARDOUS WASTES FOR RECYCLING:

The occupier generating the hazardous wastes may sell it only to recycler having a valid registration from CPCB for recycling or recovery.

### 5.2.3 STANDARDS FOR RECYCLING:

The CPCB may issue the guidelines for standard s of performance for recycling processes from time to time.

### 5.2.4 UTILIZATION OF HAZARDOUS WASTE:

The utilization of the hazardous wastes as a supplementary resource or for energy recovery, or after processing shall be carried out by the units only after obtaining approval from the CPCB.

## 5.3 TREATMENT, STORAGE AND DISPOSAL FACILITY FOR HAZARDOUS WASTE

### 5.3.1 TREATMENT, STORAGE AND DISPOSAL FACILITY FOR HAZARDOUS WASTE:

(1) The state government, occupier, operator of a facility or any association of occupiers shall individually or jointly or severely be responsible for, and identify sites for establishing the facility for treatment, storage and disposal of Hazardous waste in the state.

(2) the operator of common facility or occupier of a captive facility shall design and setup the treatment, storage and disposal facility as per technical guidelines issued by SPCB in this regard from time to time and shall obtain approval from the SPCB for the design and layout in this regard from time to time.

(3) The SPCB shall monitor the setting up and operation of Treatment, Storage and Disposal Facilities regularly.

(4) The operator of the Treatment, Storage and Disposal Facility shall be responsible for environmentally sound operation of the treatment, storage and disposal facility and its closure and post closure phase, as per guidelines issued by CPCB from time to time.

## 5.4 PACKAGING, LABELING AND TRANSPORT OF HAZARDOUS WASTE

### 5.4.1 PACKAGING AND LABELLING:

(1) The occupier or operator of the treatment, storage and disposal facility or recycler shall ensure that the hazardous waste are packaged and labelled, based on the composition in the manner suitable for safe handling, storage and transport as per the guidelines issued CPCB from time to time.

(2) The labelling and packaging shall be easily visible and be able to withstand physical conditions and climatic factors.

### 5.4.2 TRANSPORTATION OF HAZARDOUS WASTE:

(1) The transport of the hazardous wastes shall be in accordance with the provisions of these rules and the rules made by the central government under the motor vehicles act 1988 and other guidelines issued from time to time in this regard.

(2) The occupier shall provide the transporter with the relevant information, regarding the hazardous nature of the waste and measure to be taken in case of an emergency and shall mark the hazardous waste container.

(3) In case of Hazardous waste for final disposal to a facility for treatment, storage and disposal existing in a state other than state where the hazardous waste is generated, the occupier shall obtain no objection certificate from the SPCB of both the states.

(4) In case of transportation of Hazardous waste through a state other than the state of origin or designation, the occupier shall intimate the concerned SPCB before it hands over the hazardous waste to the transporter.

## 5.5 MANIFEST SYSTEM

(1) The occupier shall prepare six copies of the manifest comprising of the colour code indicated below and all six copies shall be signed by the transporter:

| Copy number with colour code | Purpose |
|---|---|
| Copy 1 (White) | To be forwarded by the occupier to SPCB or committee |
| Copy 2 (Yellow) | To be carried by the occupier after taking signature on it from the transporter and rest of the four copies to be carried by the transporter. |
| Copy 3 (Pink) | To be retained by the operator of the facility after signature |
| Copy 4 (Orange) | To be returned to the transporter by the operator of the facility or recycler after accepting the waste |
| Copy 5 (Green) | To be returned by the operator of the facility to SPCB/Committee after treatment and disposal of waste. |
| Copy 6 (Blue) | To be returned by the operator of the facility to the occupier after treatment and disposal of Hazardous waste materials. |

(2) The occupier shall forward the copy 1(White) to SPCB, and in case hazardous wastes is likely to be transported through any transit state, the occupier shall prepare an additional copy for intimation to such State and forward the same to the concerned SPCB before he hands over the hazardous waste to the transporter.

(3) No transporter shall accept hazardous waste from an occupier for the transport unless it is accompanied by copies 3 to 6 of the manifest.

(4) The transporter shall submit the copies 3 to 6 of the manifest duly signed with date of the operator of the facility along with the waste management.

(5) Operator of the facility, upon completion of the treatment and disposal operations of the hazardous wastes, shall forward copy 5 (green) to SPCB and copy 6 (blue) to the occupier and the copy 3 (pink) shall be retained by the operator of the facility.

## 5.6 PROCEDURE FOR THE GRANT OF APPROVAL FOR UTILIZATION OF HAZARDOUS WASTE AS A SUPPLEMENTARY RESOURCE OR FOR ENERGY RECOVERY.

1. The applicant desirous to utilize the hazardous wastes after processing or for energy recovery or as supplementary resource shall submit the proposal to CPCB (online as well) along with the following enclosures:

   i) Information on proposed HW utilization as per the format given in ANNEXURE- 4 along with all the supporting technical details, process flow sheet, waste characteristics etc. as required.

   ii) Copy of valid consent to establish/operate under the Air Act and Water Act from the concerned SPCB/PCC.

2. Incomplete applications will be communicated to the applicant an in case of no response within 30 days, the application should be returned with approval of the technical expert committee.

3. Complete applications shall be placed before technical expert committee constituted by CPCB to evaluate environmentally soundness of the proposal. The proponents should make technical presentation before the committee. For all new waste categories trial runs should be conducted.

4. After approval of the recommendations of the technical expert committee by Chairman, CPCB, the individual cases should be processed accordingly.

5. CPCB shall issue letter to the unit permitting procurement of desired quantity of HW as raw material after obtaining permission from concerned SPCB/PCC.

6. After receipt of permission and procurement of HW, the unit shall inform about the preparedness of carrying out trial runs. Trial run should be carried out by the unit in presence of CPCB/SPCB officials and monitoring conducted by an EPA recognized NABL accredited laboratory.

7. The concerned Zonal Office shall submit the report on the trial run within the 30 days.

8. After the receipt of the report of the trial run from the Zonal Office , the matter shall be placed before the technical committee. The recommendations of the committee shall be approved by the Chairman, CPCB.

9. The units, which do not respond to CPCB’s request for clarifications/document/trial run may be asked finally to respond within 30 days and in case of no response within 30 days, in case no response is received within 30 days, the case shall be deemed to be withdrawn by the applicant and same shall be communicated to the unit and concerned SPCB.

10. The technical expert committee shall meet when atleast 05 cases have been accumulated or at every two months, whichever is earlier

11. Rule 11 of HWM Rules, 2008, does not stipulate validity of the approval to be accorded by the CBCP but the same may be permitted initially for one year with random checks/sampling by SPCB/CPCB twice a year. Based on satisfactory results regular permission with 5 years validity limit shall be permitted.

12. The application for renewal of approval granted for 1 year shall be submitted to CPCB at least 2 months in advance of the expiry. The application shall be submitted along with the self declared compliance report w.r.t. conditions stipulated by the CPCB in the approval letter. The application shall be forwarded to respective Zonal Office of CPCB for verification of the same. The inspection, report as received from the Zonal Office along with the recommendations, shall be placed before committee for making the appropriate recommendations.

**Other guidelines for co-processing of Hazardous Waste in cement kiln as per Hazardous Waste (Management and Handling & Transboundary movement) Rules, 1989 [20].**

## 5.7 FEEDING OF MATERIALS FOR CO-PROCESSING:

Different feed points can be used to insert the co-processing materials into the cement production process. The most common ones are:

- The main burner at the rotary kiln outlet end
- The rotary kiln inlet end
- The pre-calciner
- The mid kiln (for long dry and wet kilns)

Appropriate feed points have to be selected according to the physical, chemical and toxicological characteristics of the substances, if relevant, used. Wastes of high calorific value have to be always fed into the high temperature combustion zones of the kiln system. Such wastes containing stable toxic components should be fed to the main burner to ensure complete combustion in the high temperature and long retention time. Alternative raw materials containing components that can be volatilized at low temperatures (for example, hydrocarbons) have to be fed into the high temperature zones of the kiln system. Feeding of alternative raw materials containing volatile (organic and inorganic) components to the kiln via the normal raw meal supply should be avoided unless it has been demonstrated by trial runs in the kiln that there is no undesired emission from the stack.

## 5.8 SUITABILITY OF SUBSTANCES FOR CO-PROCESSING:

1. The decision on what type of substances can be used is based on the clinker production processes, the raw material and fuel compositions , the feeding points, the air pollution control devices and the given waste management problems. Categories of Hazardous wastes/substances for which regular permission has been granted by CPCB for co-processing in Cement Industries

**A. Hazardous Wastes**

1. Paint Sludge from automobile sector
2. Petroleum Refining sludge
3. Tar waste
4. ETP sludge.

**B. Other Wastes**

1. Plastic Wastes
2. Tyre chips

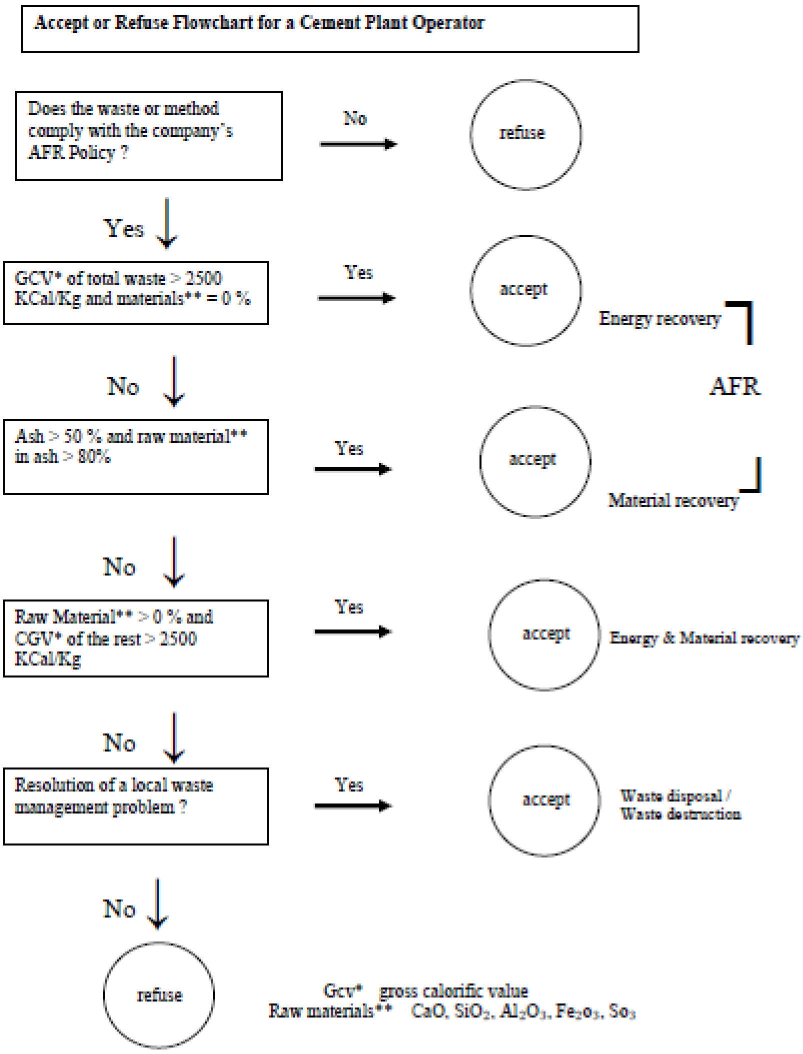


**Fig 7: Accept-Refuse Chart for Deciding the Suitability of Waste Material**

2. As a basic rule, waste accepted must give an added – value for the cement kiln:

- Calorific value from the organic part

- Material value from the mineral part

Many substances, particularly those of low calorific value, contain a significant proportion of incombustible substance(s), while inorganic substances are used as a combination of high and low calorific value raw material.

3. In some cases kilns can be used for the safe disposal of hazardous waste such as obsolete pesticides, PCB or out-dated pharmaceutical products, which may not have appropriate material or energy value but can be disposed in cement kiln without impacting the product quality. However, for this type of treatment, regulatory authorities and cement plant operators

must come to individual agreements and standards on case - by - case basis in consultation with CPCB.

4. A wide range of hazardous waste materials may be co-processed such as; ETP sludge, paint sludge, refinery sludge and TDI tar. There are liquid hazardous wastes such as used oil, solvents or end - of - line products from the transport sector, which may also be used as Alternate Fuel and Raw Material (AFR). Some materials can be delivered as single batches directly to the cement plant, while other may be pre-processed to meet the required conditions. Regular quality control of the collected and delivered substances will help to ensure a smooth use of the AFR in kiln.

5. The quality of what goes in determines the quality of what comes out. Therefore, attention must be paid to the selection of raw materials and fuels.

6. Process requirement, product quality target or emission regulations all have a bearing on the choice of the physical and chemical parameters of the potential waste material considered for use. In selecting and using the substances, the aims are:

- To ensure that the waste used undergoes its most compatible treatment compared to other possible technologies.
- To restrain damaging effects to the products or the production process complying with the Hazardous Waste M,H & T M Rules, 2008.

7. The maximum concentration of various toxic parameters of waste, which may be considered for co-processing, is termed as Acceptance criteria and appended as Annexure-5. This is evolved based on the following criteria.

- Emission standards.
- Pollutants in traditional raw materials.
- Treatment alternatives for the available waste.
- Trial run conducted in India.

8. The waste can be sourced either from TSDF or from the waste generator directly. In case of former, the waste for co-processing needs to be homogenized for smooth operation of cement kiln as it could be composed of different characteristics of wastes.

9. All the waste cannot be used for co-processing, keeping in view the environment, health, safety and operational concern. The wastes listed below are normally not recommended for co-processing till otherwise proved/evidenced for.

- Biomedical waste
- Asbestos containing waste.
- Electronic scrap.
- Entire batteries.
- Explosives.
- Corrosives.
- Mineral acid wastes.
- Radioactive Wastes.
- Unsorted municipal garbage.

## 5.9 OPERATING CONDITIONS:

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 the environment.

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.

## 5.10 AIR POLLUTION CONTROL REQUIREMENTS:

The dust emission is the main pollutant as far as pollution from cement industry is concerned. The dust emission is unlikely to change when cement plant is processing hazardous and other substances. Generally cement kilns are equipped with Electro Static Precipitator or Bag House to control the particulate matter emission. Any acid gases formed during co-processing are likely to be scrubbed by the raw material being of an alkaline nature and are incorporated into the cement clinker. However, cement industry has to ensure that they meet the particulate matter emission standards during co-processing as prescribed under the consent order issued by SPCB/PCC. For other pollutants i.e. HCl, SO2, CO, TOC, HF, NOx, total dioxins and furans, Cd + Tl + their compounds, Hg and its compounds, Sb + As + Pb + Co + Cr + Cu + Mn + Ni + V + their compounds, the emission during co-processing should not exceed the base line emissions i.e.; during pre co-processing phase of trial run.

## 5.11 EMISSION STANDARDS:

The emission standards for particulate matter prescribed for cement kiln by the concerned State Pollution Control Board shall be applicable during co-processing in cement kiln also. For other pollutants i.e. HCl, SO2, CO, TOC, HF, NOx, total dioxins and furans, Cd + Tl + their compounds, Hg and its compounds, Sb + As + Pb + Co + Cr + Cu + Mn + Ni + V + their compounds, the emission during co-processing should not exceed the base line emissions i.e.; during pre co-processing phase of trial run.

## 5.12 MONITORING REQUIREMENTS:

The continuous measurement of particulate matter emission shall be carried out at co processing plant and the emission data shall be submitted to CPCB and the concerned SPCB/PCC. As per direction of CPCB, monitoring of dioxins and furans including other parameters will be done by the cement plant.

# CHAPTER -6

# CASE STUDY OF IMPLICATION IN DALMIA CEMENT PLANT, TAMIL NADU

The study was carried out for Dalmia Cement Plant, Dalmiapuram, Tamil Nadu. The plant has two kilns installed, one with the capacity of 1.5 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.

For this, the status of the waste within the state was studied. The wastes having potential for their use as alternative fuel and which were available in good quantity within the state were selected. Three different wastes namely tyres, oil sludge and sludge from paint industry, were taken into account for their 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 [Annexure-4]. 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.

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

On this basis, the best combination of wastes and coal is made which makes the cement plant more energy and economically efficient.

The ultimate and proximate analysis of the coal and as follows:

**Table-4: Proximate Analysis**

| S.No. | Characteristics | Coal |
|---|---|---|
| 1 | Moisture | 11% |
| 2 | Fixed carbon | 49% |
| 3 | Ash | 12% |
| 4 | Volatile matter | 28% |
| 5 | Calorific value | 6,200Kcal/Kg |

**Table 5: Ultimate Analysis**

| S.No. | Characteristics | Coal |
|---|---|---|
| 1 | Carbon | 53.29% |
| 2 | Hydrogen | 1.77% |
| 3 | Nitrogen | 1.04% |
| 4 | Sulphur | .5% |
| 5 | Oxygen | 43.21% |

The quality of the cement is affected by the amount of heavy metals present in it. These heavy metals are contributed by the raw material and the fuel used. The quantity of these heavy metals should below the limit.

**Table 6: Limit of Heavy Metals**

| S.No. | Name of metal | Limit |
|---|---|---|
| 1 | Mercury | <.0010% |
| 2 | Cadmium | <.04% |
| 3 | Lead | <.29% |
| 4 | Chromium | <.75% |
| 5 | Zinc | <9% |

**Table 7: Heavy Metal Analysis of Coal**

| Heavy Metal | % |
|---|---|
| Mercury | .001 |
| Cadmium | .0001 |
| Lead | .001 |
| Chromium | .01 |
| Zinc | .01 |

**Table 8: Emissions While Using Imported Coal**

| $CO_2$ (mg/Nm3)* | $SO_2$ (mg/Nm3)** | $N_2$ (mg/Nm3)*** |
|---|---|---|
| 62.48481034 | 0.579703133 | 188.130864 |

Using 2500$Nm^3$/ton of air, emissions can be calculated as [**Table 8**]:

* $CO_2$ *(lb/ton of clinker) from fuel- 0.0367*%carbon*(lb fuel/ton of clinker)*

* *$SO_2$ *(lb/ton of clinker) from fuel- 0.02%sulphur*(lb fuel/ton of clinker)*

* **$NO_2$ *(lb/ton of clinker) from fuel- [(%nitrogen/100)] + [3.3478 (0.0267 * %carbon + 0.01*sulphur% + 0.08*% hydrogen – 0.01% oxygen]*(lb fuel/ton of clinker)*

# 6.1 TYRE DERIVED FUEL

Cement kilns are well suited for waste-combustion because of their high process temperature and clinker product and limestone feedstock act as gas cleaning agents. The addition of scrap tyre as fuel can put cement industry and environment in a better position for sustainable development of infrastructure. 1Bilion tyres are produced worldwide each year.

Most of the worldwide generated tyres (65.5%) are simply dumped in the open or in the landfill. Land filling is very common these days but number of waste tyres is increasing faster every year. The massive stockpiles posses fire and health hazard. Uncontrolled fires are dangerous as they produce large amount of toxic pollutants containing zinc oxides, dioxins, volatile organic compounds, PAH, depending on the combustion condition.

Tyres are made up of more than 100 different compounds. The main components are rubber (50 wt %), filters like silica gel or carbon black (25 wt %), steel (10 wt %), sulphur (1 wt %), zinc oxide (1 wt %) and many other additives like processing oil, plasticizer or vulcanisation accelerators.

Polymers cannot be degraded by themselves in general, thus, they cannot be returned to the environment through natural biological degradation/decomposition like biological materials. It is well known that scrap tyres possess high volatile and low ash content, with a high heat value than coal or biomass. The calorific value of tyres is between some 6450kCal/kg and 8000kCal/kg. To substitute 1 ton of coal (some 6100kCal/kg) around 0.76 - 0.95 ton of scrap tyres is needed. The net CO2 emission factor is approximately 59t of CO2/TJ for tyres and incineration of coal has emission factor of 96t CO2/TJ. Based on the ultimate and proximate analysis it can be said that tyre is a feasible option to be used in cement kilns, while paying attention to heavy metal concentration. Performance of OPC is largely unaffected by small additional quantities of heavy metal or certain non metallics. 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. Both shredded and whole tyres could be used in kilns.

## CHEMICAL CHARACTERISTICS

- Tyres are hydrocarbon based material derived from oil and gas.
- Tyres have heat content of 6000-8000 Kcal/Kg, depending upon the type of tyre and degree of wire removal.

A comparison of the proximate analysis indicates that tyres offer efficiency advantages in comparison to coal.

On the basis of proximate analysis tyres [Table 9] have following characteristics:

a) Tyres have lower moisture content. Since the energy required to heat and vaporize inherent water is generally non-recoverable in the energy conversion process, lower moisture content can translate into higher energy utilization efficiency.

b) Tyres have low ash content.

c) Tyre have higher volatile to fixed carbon ratio enhances its ability to combust rapidly and completely.

**Table 9: Proximate Analysis of Tyres**

| S. No. | Characteristics | TDF |
|---|---|---|
| 1 | Moisture | 0.75% |
| 2 | Fixed carbon | 21.85% |
| 3 | Ash | 23.19% |
| 4 | Volatile matter | 54.23% |
| 5 | Calorific value | 7,500Kcal/Kg |

On the basis of ultimate analysis, [Table 10] tyres offer some additional advantages:

a) Tyres have lower sulphur content. It offers additional advantages of decreasing Sulphur oxides emissions compared to coal.

b) Tyres have lower carbon to hydrogen ratio. It theoretically reduces carbon dioxide generation and hydrogen converts to water.

c) Tyres have lower nitrogen content. It can marginally decreases nitrogen oxide emissions.

d) Tyres have higher chlorine content.

**Table 10: Ultimate Analysis of Tyres**

| S.No. | Characteristics | TDF |
|---|---|---|
| 1 | Carbon | 67%33 |
| 2 | Hydrogen | 5.81% |
| 3 | Nitrogen | .25% |
| 4 | Sulphur | 1.6% |
| 5 | Oxygen | 1.64% |

**Table 11: Emissions from 2500Nm$^3$/ton of Air**

| CO2 (mg/Nm3)* | SO2 (mg/Nm3)** | N2 (mg/Nm3)*** |
|---|---|---|
| 62.48481034 | 0.579703133 | 188.130864 |

** $CO_2$ (lb/ton of clinker) from fuel- 0.0367*%carbon*(lb fuel/ton of clinker)*

** *$SO_2$ (lb/ton of clinker) from fuel- 0.02%sulphur*(lb fuel/ton of clinker)*

**** $N_2$ (lb/ton of clinker) from fuel- [(%nitrogen/100)] + [3.3478 (0.0267 * %carbon + 0.01*sulphur% + 0.08*% hydrogen – 0.01% oxygen]*(lb fuel/ton of clinker)*

**Table 12: The Heavy Metal Analysis of The Tyre Derived Fuel (TDF)**

| Result of Heavy Metal Analysis of TDF (%) | | | | |
|---|---|---|---|---|
| **Mercury** | **Cadmium** | **Lead** | **Chromium** | **Zinc** |
| 0.001 | 0.010 | 0.10 | 0.0070 | 34.81 |

**ADVANTAGE OF SCRAP TYRE OVER COAL:**

a) Used tyres have high energy content than coal, which makes them ideal for cement manufacturing i.e. tyre produces 25% more energy than coal.

b) The rubber and fabric element of the tyres are completely consumed without any of black smoke and smells normally associated with burning tyres.

c) Steel reinforcing oxidises and replaces a portion the iron i.e. otherwise added to the raw material mix used in the cement manufacturing.

d) There are no residues if tyre fuel is used in cement kiln.

e) Scrap tyres can be completely destroyed in cement kiln, the combination of extremely high temperatures, a positive oxygen atmosphere and long residence time, assured complete combustion of scrap tyre, the complete precludes products of incomplete combustion.

f) The quality of cement, while using whole or shredded tyres (TDF) and regardless of point of entry is as good as the quality produced while using coal and petroleum coke mixture.

g) The ash residue from TDF may contain lower heavy metals content than coal.

h) If coal is stored improperly on stockpiles, it can self ignite creating a serious fire hazard while in case of scrap tyre storage is not a problem [62].

The various combinations of tyre derived fuel (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-13)**

## TABLE- 13: Check for Suitability of Combination of Coal And TDF.

| Fuel Mix | | Calorific Value | Elemental Analysis (%) | | | | | Emissions( mg/Nm3) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| % coal | %TDF | (Kcal/Kg) | Hg | Cd | Pb | Cr | Zn | $CO_2$ | $SO_2$ | $N_2$ |
| 100% | 0% | 6200 | 0.001 | 0.0001 | 0.001 | 0.0100 | 0.01 | 64.22 | 0.4539 | 125.18 |
| 95% | 5% | 6265 | 0.001 | 0.0006 | 0.006 | 0.0099 | 1.75 | 64.1332 | 0.460155 | 128.3275 |
| 90% | 10% | 6330 | 0.001 | 0.0011 | 0.011 | 0.0097 | 3.49 | 64.0464 | 0.46641 | 131.475 |
| 85% | 15% | 6395 | 0.001 | 0.0016 | 0.016 | 0.0096 | 5.23 | 63.9596 | 0.472665 | 134.6225 |
| 80% | 20% | 6460 | 0.001 | 0.0021 | 0.021 | 0.0094 | 6.97 | 63.8728 | 0.47892 | 137.77 |
| 75% | 25% | 6525 | 0.001 | 0.0026 | 0.026 | 0.0093 | 8.71 | 63.786 | 0.485175 | 140.9175 |
| 70% | 30% | 6590 | 0.001 | 0.0031 | 0.031 | 0.0091 | 10.45 | 63.6992 | 0.49143 | 144.065 |
| 65% | 35% | 6655 | 0.001 | 0.0036 | 0.036 | 0.0090 | 12.19 | 63.6124 | 0.497685 | 147.2125 |
| 60% | 40% | 6720 | 0.001 | 0.0041 | 0.041 | 0.0088 | 13.93 | 63.5256 | 0.50394 | 150.36 |
| 55% | 45% | 6785 | 0.001 | 0.0046 | 0.046 | 0.0087 | 15.67 | 63.4388 | 0.510195 | 153.5075 |
| 50% | 50% | 6850 | 0.001 | 0.0051 | 0.051 | 0.0085 | 17.41 | 63.352 | 0.51645 | 156.655 |
| 45% | 55% | 6915 | 0.001 | 0.0055 | 0.055 | 0.0084 | 19.15 | 63.2652 | 0.522705 | 159.8025 |
| 40% | 60% | 6980 | 0.001 | 0.0060 | 0.060 | 0.0082 | 20.89 | 63.1784 | 0.52896 | 162.95 |
| 35% | 65% | 7045 | 0.001 | 0.0065 | 0.065 | 0.0081 | 22.63 | 63.0916 | 0.535215 | 166.0975 |
| 30% | 70% | 7110 | 0.001 | 0.0070 | 0.070 | 0.0079 | 24.37 | 63.0048 | 0.54147 | 169.245 |
| 25% | 75% | 7175 | 0.001 | 0.0075 | 0.075 | 0.0078 | 26.11 | 62.918 | 0.547725 | 172.3925 |
| 20% | 80% | 7240 | 0.001 | 0.0080 | 0.080 | 0.0076 | 27.85 | 62.8312 | 0.55398 | 175.54 |
| 15% | 85% | 7305 | 0.001 | 0.0085 | 0.085 | 0.0075 | 29.59 | 62.7444 | 0.560235 | 178.6875 |
| 10% | 90% | 7370 | 0.001 | 0.0090 | 0.090 | 0.0073 | 31.33 | 62.6576 | 0.56649 | 181.835 |
| 5% | 95% | 7435 | 0.001 | 0.0095 | 0.095 | 0.0072 | 33.07 | 62.5708 | 0.572745 | 184.9825 |
| 0% | 100% | 7500 | 0.0010 | 0.0100 | 0.100 | 0.0070 | 34.81 | 62.484 | 0.579 | 188.13 |

Replacement of coal with TDF 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 25% of the coal can be replaced by the tyre derived fuel (TDF). Above this percentage, the value of zinc increases above the standard value i.e. 9% which affects the quality of the clinker. Further, the utilization of TDF as alternative fuel will depend on the cost and availability factor.

## COST:

The TDF as a fuel costs around Rs.3000 per tonne including the transportation cost where as coal costs around Rs. 5800. This brings economical benefits to the organisation. [**Annexure-4**]

## 6.2 PAINT SLUDGE

Out of the 18 categories of Hazardous Wastes framed by MOEF in Hazardous Waste (Handling and Management) Rules 1986, both solid and liquid waste from paint industry falling under category no. 7 have been taken up for detailed investigation for its potential utilization as fuel in cement industry. The waste generated at various steps of paint manufacturing is shown in the **Fig 8.**

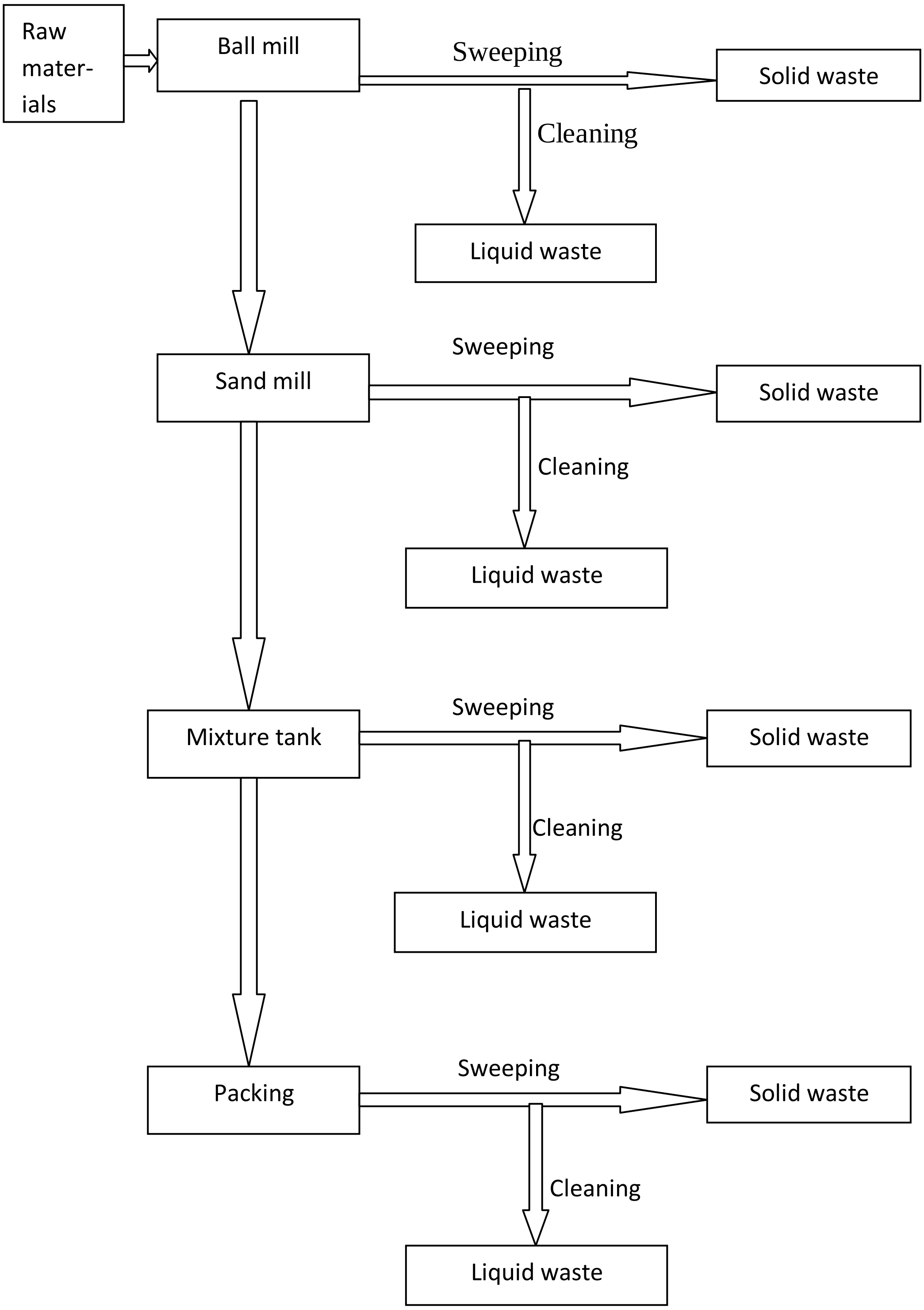


**Fig 8: The Waste Generated at Various Steps of Paint Manufacturing**

## CHARACTERISTICS OF LIQUID WASTE:

In paint manufacturing process, generation of liquid waste is from cleaning operation of ball mill, sand mill and mixture tank. In the cleaning operation, mineral turpentine oil has been used as cleaning agent, which in turn is contaminated by raw materials (binder, pigment, solvent, drier, etc).

The presence of turpentine oil and resin are the main source of acidic nature and pungent smell of liquid waste. The quantity of water content in the liquid waste comes from the presence of water as an impurity in raw materials and cleaning agent. Liquid waste is contaminated by suspended solids, which is main source of ash content and mineral content in liquid waste.

The main source of fuel value of liquid waste is mainly due to presence of 98% of petroleum based cleaning agents (mineral turpentine oil) and raw materials (binder, organic pigments, solvent, etc.)

## PHYSICO- CHEMICAL CHARACTERISTICS:

The liquid waste had a dark grey appearance with a pungent smell. This type of waste has significant amount of suspension solids. The pH value of the liquid waste was found to be 6.17 showing its slightly acidic nature. The sample had insignificant amount of water in liquid waste i.e. about 0.6% of wt. It does not contain iron pieces, stone pieces, etc.

## SUSPENSION SOLIDS:

**Table 14: Centrifugal Analysis of Paint Sludge**

| S.No. | Parameters | (%) |
|---|---|---|
| 1 | Suspension solids | 5.46% |
| 2 | Liquid content | 94.54% |

## ULTIMATE ANALYSIS:

The basic elemental analysis involved the determination of amount of carbon, hydrogen, nitrogen, sulphur, oxygen.

**Table 15: Ultimate Analysis of Paint Sludge**

| S.No. | Characteristics | Paint Sludge |
|---|---|---|
| 1 | Carbon | 72.25% |
| 2 | Hydrogen | 6.75% |
| 3 | Nitrogen | .36% |
| 4 | Sulphur | 1.23% |
| 5 | Oxygen | 9.67% |

## PROXIMATE ANALYSIS:

a) Suspension solid in the paint residues have lower moisture content. Since the energy required to heat and vaporize inherent water is generally non-recoverable in the energy conversion process, lower moisture content can translate into higher energy utilization efficiency.

b) Paint sludge has high ash content.

c) Paint Sludge have higher volatile to fixed carbon ratio enhances its ability to combust rapidly and completely.

**Table 16: Proximate Analysis of Paint Sludge**

| S.No. | Characteristics | Paint sludge |
|---|---|---|
| 1 | Moisture | 1.02% |
| 2 | Fixed carbon | 22.93% |
| 3 | Ash | 9% |
| 4 | Volatile matter | 67% |
| 5 | Calorific value | 7,500Kcal/Kg |

## HEAVY METAL ANALYSIS:

The elemental is important to establish the suitability of liquid waste on the quality of cement or manufacturing process.

**Table 17: Heavy Metals Analysis**

| Mercury% | Cadmium% | Lead% | Chromium% | Zinc% | Chlorine% |
|---|---|---|---|---|---|
| .1000% | 0.10% | 0.10% | 0.10% | 5.14%-34.81% | 0.03%-0.09% |

**Table 18: Emissions by Using 2500Nm$^3$/ton of Air**

| $CO_2$ (mg/Nm3)* | $SO_2$ (mg/Nm3)** | $N_2$ (mg/Nm3)*** |
|---|---|---|
| 62.48481034 | 0.579703133 | 188.130864 |

** $CO_2$ (lb/ton of clinker) from fuel- 0.0367*%carbon*(lb fuel/ton of clinker)*

** *$SO_2$ (lb/ton of clinker) from fuel- 0.02%sulphur*(lb fuel/ton of clinker)*

****$N_2$ (lb/ton of clinker) from fuel- [(%nitrogen/100)] + [3.3478 (0.0267 * %carbon + 0.01*sulphur% + 0.08*% hydrogen – 0.01% oxygen] * (lb fuel/ton of clinker).*

The various combinations of paint 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-19)**

**TABLE-19: Check for Suitability of Combination of Coal and Paint Sludge**

| Fuel Mix | | Calorific Value | Elemental Analysis (%) | | | | | Emissions( mg/Nm$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| % coal | % paint sludge | (Kcal/Kg) | Hg | Cd | Pb | Cr | Zn | $CO_2$ | $SO_2$ | $N_2$ |
| 100% | 0% | 6500 | 0.001 | 0.0001 | 0.001 | 0.010 | 0.010 | 64.22 | 0.4539 | 125.18 |
| 95% | 5% | 6620.95 | 0.001 | 0.0006 | 0.005 | 0.010 | 0.013 | 64.1332 | 0.435055 | 128.195 |
| 90% | 10% | 6741.9 | 0.001 | 0.0011 | 0.009 | 0.011 | 0.016 | 64.0464 | 0.41621 | 131.21 |
| 85% | 15% | 6862.85 | 0.001 | 0.0016 | 0.013 | 0.011 | 0.019 | 63.9596 | 0.397365 | 134.225 |
| 80% | 20% | 6983.8 | 0.001 | 0.0021 | 0.017 | 0.011 | 0.022 | 63.8728 | 0.37852 | 137.24 |
| 75% | 25% | 7104.75 | 0.001 | 0.0026 | 0.021 | 0.011 | 0.025 | 63.786 | 0.359675 | 140.255 |
| 70% | 30% | 7225.7 | 0.001 | 0.0031 | 0.025 | 0.012 | 0.028 | 63.6992 | 0.34083 | 143.27 |
| 65% | 35% | 7346.65 | 0.001 | 0.0036 | 0.029 | 0.012 | 0.031 | 63.6124 | 0.321985 | 146.285 |
| 60% | 40% | 7467.6 | 0.001 | 0.0041 | 0.033 | 0.012 | 0.034 | 63.5256 | 0.30314 | 149.3 |
| 55% | 45% | 7588.55 | 0.001 | 0.0046 | 0.037 | 0.012 | 0.037 | 63.4388 | 0.284295 | 152.315 |
| 50% | 50% | 7709.5 | 0.001 | 0.0051 | 0.041 | 0.013 | 0.040 | 63.352 | 0.26545 | 155.33 |
| 45% | 55% | 7830.45 | 0.001 | 0.0055 | 0.044 | 0.013 | 0.043 | 63.2652 | 0.246605 | 158.345 |
| 40% | 60% | 7951.4 | 0.001 | 0.0060 | 0.048 | 0.013 | 0.046 | 63.1784 | 0.22776 | 161.36 |
| 35% | 65% | 8072.35 | 0.001 | 0.0065 | 0.052 | 0.013 | 0.049 | 63.0916 | 0.208915 | 164.375 |
| 30% | 70% | 8193.3 | 0.001 | 0.0070 | 0.056 | 0.014 | 0.052 | 63.0048 | 0.19007 | 167.39 |
| 25% | 75% | 8314.25 | 0.001 | 0.0075 | 0.060 | 0.014 | 0.055 | 62.918 | 0.171225 | 170.405 |
| 20% | 80% | 8435.2 | 0.001 | 0.0080 | 0.064 | 0.014 | 0.058 | 62.8312 | 0.15238 | 173.42 |
| 15% | 85% | 8556.15 | 0.001 | 0.0085 | 0.068 | 0.014 | 0.061 | 62.7444 | 0.133535 | 176.435 |
| 10% | 90% | 8677.1 | 0.001 | 0.0090 | 0.072 | 0.015 | 0.064 | 62.6576 | 0.11469 | 179.45 |
| 5% | 95% | 8798.05 | 0.001 | 0.0095 | 0.076 | 0.015 | 0.067 | 62.5708 | 0.095845 | 182.465 |
| 0% | 100% | 8919 | 0.001 | 0.0100 | 0.080 | 0.015 | 0.070 | 52.67 | 0.077 | 185.48 |

Replacement of coal with paint 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 theoretically concluded from the table, that paint sludge can replace coal by 100% but ideally this is not possible as the flame intensity and other heating properties of the kiln are altered. Moreover, the utilization of paint sludge as alternative fuel will depend on the cost and availability factor. The availability of the paint sludge in Tamil Nadu is estimated to be around 100 ton per annum.

## COST:

The paint sludge costs around Rs.500 per tonne including the transportation cost where as coal costs around Rs. 5800. This brings high economical benefits to the organisation. [Annexure-4]

## 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. [62]

The activities of oil producing companies affect the environment and the health of the people living within the immediate vicinity of the crude oil processing plant. The hazards may trigger processes that may have adverse effects on the ecosystem of such areas. Water used (wastewater) during extraction of crude oil are contaminated and may contain varying quantities of organic matter, heavy metals, volatile hydrocarbons (such as benzene, xylene, and toluene) and many other potentially toxic compounds. This wastewater contains sludge, which are disposed off in an environmentally unfriendly manner. Because of the dramatic increase in the volumes of wastewater treated, large volumes of sludge need to be disposed off in an environmentally safe manner. Therefore, there is need to effect proper treatment of sludge before disposal or reuse. [63]

Three to five percent of all crude oil produced is ultimately unusable, when it is transported in ships or stored in tanks and sludge settles to the bottom of the vessels and containers. It cannot be drained from the tanks and must be removed and hauled away at considerable expense. That expense is, in part, the cost of hiring crews to remove the sludge from the tanks. A greater part of the expense is the disposal fee associated with the environmentally-unfriendly material. Large volumes of sludge are also formed at refineries and oil extraction sites. Accidents in the transportation of oil and petroleum products also add to environmental contamination.

The regulatory status of oil and oil sludge wastes removed from old tanks will depend upon whether the oil is used or unused, the source of the oil, and whether the oil sludge meets the definition of a hazardous waste. If the oil is unused, then the generator must make a hazardous waste determination based on testing or knowledge of the waste. Nonhazardous liquid oil may be mixed with an absorbent and disposed of in a municipal landfill. If the oil waste is hazardous, the waste must be managed in accordance with state and federal regulations.

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. [64]

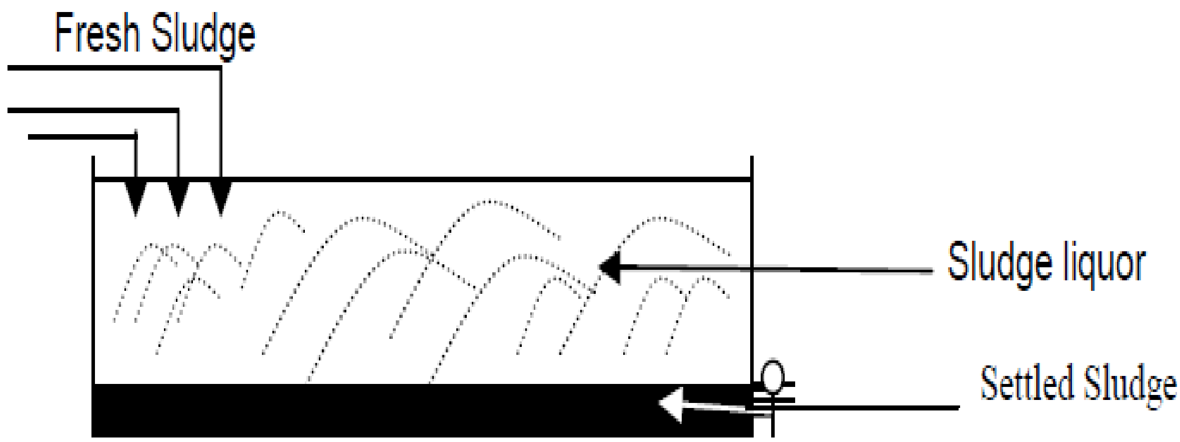


**Fig 9: Schematic Diagram of Sludge Sedimentation**

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 results are tabulated in TABLE-20 & TABLE- 21 respectively

**Table 20: Ultimate Analysis**

| S.No. | Characteristics | Oil Sludge |
|---|---|---|
| 1 | carbon | 28.90% |
| 2 | Hydrogen | 4.80% |
| 3 | Nitrogen | .17% |
| 4 | Sulphur | 6.48% |
| 5 | Oxygen | 25.34% |

**Table 21: Proximate Analysis**

| S.No. | Characteristics | Oil Sludge |
|---|---|---|
| 1 | Moisture | 13.20% |
| 2 | Fixed carbon | 15.20% |
| 3 | Ash | 41.60% |
| 4 | Volatile matter | 30% |
| 5 | Calorific value | 3,700Kcal/Kg |

## EMISSIONS:

Using 2500Nm3/ton of air, emissions can be calculated as: (Table 22)

**Table 22: Emissions by Using 2500Nm$^3$/ton of Air**

| CO2 (mg/Nm3)* | SO2 (mg/Nm3)** | N2 (mg/Nm3)*** |
|---|---|---|
| 62.48481034 | 0.579703133 | 188.130864 |

** $CO_2$ (lb/ton of clinker) from fuel- 0.0367*%carbon*(lb fuel/ton of clinker)*

** *$SO_2$ (lb/ton of clinker) from fuel- 0.02%sulphur*(lb fuel/ton of clinker)*

** $NO_2$ (lb/ton of clinker) from fuel- [(%nitrogen/100)] + [3.3478 (0.0267 * %carbon + 0.01*sulphur% + 0.08*% hydrogen – 0.01% oxygen]*(lb fuel/ton of clinker)*

## HEAVY METAL ANALYSIS:

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 23:

**Table 23: Heavy Metal Analysis**

| Mercury% | Cadmium% | Lead% | Chromium% | Zinc% | Chlorine% |
|---|---|---|---|---|---|
| .1000% | 0.10% | 0.10% | 0.10% | 5.14%-34.81% | 0.03%-0.09% |

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- 24)**

## Table-24: Check for Suitability of Combination of Coal and Oil Sludge

| Fuel Mix | | Calorific Value | Elemental Analysis (%) | | | | | Emissions(mg/Nm$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| % coal | %oil sludge | (Kcal/Kg) | Hg | Cd | Pb | Cr | Zn | $CO_2$ | $SO_2$ | $N_2$ |
| 100% | 0% | 6200 | 0.001 | 0.0001 | 0.001 | 0.0100 | 0.010 | 64.22 | 0.4539 | 125.18 |
| 95% | 5% | 6075 | 0.001 | 0.0001 | 0.074 | 0.0117 | 0.031 | 63.441 | 0.463705 | 127.4125 |
| 90% | 10% | 5950 | 0.001 | 0.0001 | 0.147 | 0.0133 | 0.051 | 62.662 | 0.47351 | 129.645 |
| 85% | 15% | 5825 | 0.001 | 0.0002 | 0.220 | 0.0150 | 0.072 | 61.883 | 0.483315 | 131.8775 |
| 80% | 20% | 5700 | 0.001 | 0.0002 | 0.293 | 0.0166 | 0.092 | 61.104 | 0.49312 | 134.11 |
| 75% | 25% | 5575 | 0.002 | 0.0002 | 0.366 | 0.0183 | 0.113 | 60.325 | 0.502925 | 136.3425 |
| 70% | 30% | 5450 | 0.002 | 0.0002 | 0.439 | 0.0199 | 0.133 | 59.546 | 0.51273 | 138.575 |
| 65% | 35% | 5325 | 0.002 | 0.0002 | 0.512 | 0.0216 | 0.154 | 58.767 | 0.522535 | 140.8075 |
| 60% | 40% | 5200 | 0.002 | 0.0003 | 0.585 | 0.0232 | 0.174 | 57.988 | 0.53234 | 143.04 |
| 55% | 45% | 5075 | 0.002 | 0.0003 | 0.658 | 0.0249 | 0.195 | 57.209 | 0.542145 | 145.2725 |
| 50% | 50% | 4950 | 0.002 | 0.0003 | 0.731 | 0.0265 | 0.215 | 56.43 | 0.55195 | 147.505 |
| 45% | 55% | 4825 | 0.002 | 0.0003 | 0.803 | 0.0282 | 0.236 | 55.651 | 0.561755 | 149.7375 |
| 40% | 60% | 4700 | 0.002 | 0.0003 | 0.876 | 0.0298 | 0.256 | 54.872 | 0.57156 | 151.97 |
| 35% | 65% | 4575 | 0.002 | 0.0004 | 0.949 | 0.0315 | 0.277 | 54.093 | 0.581365 | 154.2025 |
| 30% | 70% | 4450 | 0.002 | 0.0004 | 1.022 | 0.0331 | 0.297 | 53.314 | 0.59117 | 156.435 |
| 25% | 75% | 4325 | 0.003 | 0.0004 | 1.095 | 0.0348 | 0.318 | 52.535 | 0.600975 | 158.6675 |
| 20% | 80% | 4200 | 0.003 | 0.0004 | 1.168 | 0.0364 | 0.338 | 51.756 | 0.61078 | 160.9 |
| 15% | 85% | 4075 | 0.003 | 0.0004 | 1.241 | 0.0381 | 0.359 | 50.977 | 0.620585 | 163.1325 |
| 10% | 90% | 3950 | 0.003 | 0.0005 | 1.314 | 0.0397 | 0.379 | 50.198 | 0.63039 | 165.365 |
| 5% | 95% | 3825 | 0.003 | 0.0005 | 1.387 | 0.0414 | 0.400 | 49.419 | 0.640195 | 167.5975 |
| 0% | 100% | 3700 | 0.003 | 0.0005 | 1.460 | 0.0430 | 0.420 | 48.64 | 0.65 | 169.83 |

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.

Further, the utilization of oil sludge as alternative fuel will depend on the cost and availability factor. The availability of oil sludge was estimated nearly around 20,000 ton per annum in Tamil Nadu.

## COST:

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 [Annexure-4].

Combinations of all three alternative fuels i.e. paint sludge, tyre derived fuel, oil sludge along with the coal were also analysed to find the most appropriate fuel mix [Annexure-4] for the cement plant (Table-25).

**Table-25: Check for Suitability of Combination of Coal & All 3 Alternative Fuels**

| Fuel Mix | | | | Calorific Value | Elemental Analysis (%) | | | | | Emissions(mg/Nm$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % coal | %TDF | %OS | %PS | (Kcal/Kg) | Hg | Cd | Pb | Cr | Zn | $CO_2$ | $SO_2$ | $N_2$ |
| 80.00% | 10.00% | 10.00% | 0.00% | 6080 | 0.001 | 0.0011 | 0.157 | 0.0130 | 3.53 | 59.30 | 0.43 | 124.07 |
| 80.00% | 10.00% | 0.00% | 10.00% | 6601.9 | 0.001 | 0.0021 | 0.019 | 0.0102 | 3.50 | 62.89 | 0.63 | 137.51 |
| 80.00% | 0.00% | 10.00% | 10.00% | 6221.9 | 0.001 | 0.0011 | 0.155 | 0.0138 | 0.06 | 58.32 | 0.58 | 123.80 |
| 70.00% | 20.00% | 10.00% | 0.00% | 6210 | 0.001 | 0.0021 | 0.167 | 0.0127 | 7.01 | 59.12 | 0.44 | 130.36 |
| 70.00% | 20.00% | 0.00% | 10.00% | 6731.9 | 0.001 | 0.0031 | 0.029 | 0.0099 | 6.98 | 62.72 | 0.64 | 143.80 |
| 70.00% | 10.00% | 20.00% | 0.00% | 5830 | 0.001 | 0.0012 | 0.303 | 0.0163 | 3.57 | 54.55 | 0.39 | 116.66 |
| 70.00% | 10.00% | 0.00% | 20.00% | 6873.8 | 0.001 | 0.0031 | 0.027 | 0.0107 | 3.50 | 61.74 | 0.78 | 143.54 |
| 70.00% | 0.00% | 20.00% | 10.00% | 5971.9 | 0.001 | 0.0012 | 0.301 | 0.0171 | 0.10 | 53.57 | 0.54 | 116.40 |
| 70.00% | 10.00% | 10.00% | 10.00% | 6351.9 | 0.001 | 0.0021 | 0.165 | 0.0135 | 3.54 | 58.14 | 0.59 | 130.10 |
| 70.00% | 0.00% | 10.00% | 20.00% | 6493.8 | 0.001 | 0.0021 | 0.163 | 0.0143 | 0.06 | 57.16 | 0.73 | 129.83 |
| 60.00% | 10.00% | 20.00% | 10.00% | 6101.9 | 0.001 | 0.0022 | 0.311 | 0.0168 | 3.58 | 53.40 | 0.55 | 122.69 |
| 60.00% | 30.00% | 10.00% | 0.00% | 6340 | 0.001 | 0.0031 | 0.177 | 0.0124 | 10.49 | 58.95 | 0.45 | 136.66 |
| 60.00% | 30.00% | 0.00% | 10.00% | 6861.9 | 0.001 | 0.0041 | 0.039 | 0.0096 | 10.46 | 62.54 | 0.65 | 150.10 |
| 60.00% | 0.00% | 30.00% | 10.00% | 5721.9 | 0.002 | 0.0012 | 0.447 | 0.0204 | 0.14 | 48.82 | 0.50 | 108.99 |
| 60.00% | 0.00% | 10.00% | 30.00% | 6765.7 | 0.001 | 0.0031 | 0.171 | 0.0148 | 0.07 | 56.01 | 0.89 | 135.86 |
| 60.00% | 10.00% | 0.00% | 30.00% | 7145.7 | 0.001 | 0.0041 | 0.035 | 0.0112 | 3.51 | 60.58 | 0.94 | 149.57 |
| 60.00% | 10.00% | 30.00% | 0.00% | 5580 | 0.002 | 0.0012 | 0.449 | 0.0196 | 3.61 | 49.80 | 0.35 | 109.26 |
| 60.00% | 20.00% | 10.00% | 10.00% | 6481.9 | 0.001 | 0.0031 | 0.175 | 0.0132 | 7.02 | 57.97 | 0.60 | 136.39 |
| 60.00% | 10.00% | 20.00% | 10.00% | 6101.9 | 0.001 | 0.0022 | 0.311 | 0.0168 | 3.58 | 53.40 | 0.55 | 122.69 |
| 60.00% | 10.00% | 10.00% | 20.00% | 6623.8 | 0.001 | 0.0031 | 0.173 | 0.0140 | 3.54 | 56.99 | 0.75 | 136.13 |
| 50.00% | 30.00% | 20.00% | 0.00% | 6090 | 0.001 | 0.0032 | 0.323 | 0.0157 | 10.53 | 54.20 | 0.42 | 129.25 |
| 50.00% | 30.00% | 0.00% | 20.00% | 7133.8 | 0.001 | 0.0051 | 0.047 | 0.0101 | 10.46 | 61.39 | 0.81 | 156.13 |
| 50.00% | 30.00% | 10.00% | 10.00% | 6611.9 | 0.001 | 0.0041 | 0.185 | 0.0129 | 10.50 | 57.80 | 0.61 | 142.69 |
| 50.00% | 20.00% | 20.00% | 10.00% | 6231.9 | 0.001 | 0.0032 | 0.321 | 0.0165 | 7.06 | 53.22 | 0.56 | 128.99 |
| 50.00% | 20.00% | 10.00% | 20.00% | 6753.8 | 0.001 | 0.0041 | 0.183 | 0.0137 | 7.02 | 56.81 | 0.76 | 142.42 |
| 50.00% | 20.00% | 0.00% | 30.00% | 7275.7 | 0.001 | 0.0051 | 0.045 | 0.0109 | 6.99 | 60.41 | 0.96 | 155.86 |
| 50.00% | 20.00% | 30.00% | 0.00% | 5710 | 0.002 | 0.0022 | 0.459 | 0.0193 | 7.09 | 49.63 | 0.37 | 115.55 |
| 50.00% | 10.00% | 20.00% | 20.00% | 6373.8 | 0.001 | 0.0032 | 0.319 | 0.0173 | 3.58 | 52.24 | 0.71 | 128.72 |
| 50.00% | 10.00% | 30.00% | 10.00% | 5851.9 | 0.002 | 0.0022 | 0.457 | 0.0201 | 3.62 | 48.65 | 0.51 | 115.29 |
| 50.00% | 10.00% | 10.00% | 30.00% | 6895.7 | 0.001 | 0.0041 | 0.181 | 0.0145 | 3.55 | 55.83 | 0.91 | 142.16 |
| 50.00% | 0.00% | 30.00% | 20.00% | 5993.8 | 0.002 | 0.0022 | 0.455 | 0.0209 | 0.15 | 47.67 | 0.66 | 115.02 |
| 50.00% | 0.00% | 30.00% | 20.00% | 5993.8 | 0.002 | 0.0022 | 0.455 | 0.0209 | 0.15 | 47.67 | 0.66 | 115.02 |
| 50.00% | 0.00% | 20.00% | 30.00% | 6515.7 | 0.001 | 0.0032 | 0.317 | 0.0181 | 0.11 | 51.26 | 0.86 | 128.46 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80.00% | 10.00% | 9.00% | 1.00% | 6132.19 | 0.001 | 0.0012 | 0.143 | 0.0127 | 3.53 | 59.66 | 0.45 | 125.41 |
| 80.00% | 9.00% | 10.00% | 1.00% | 6094.19 | 0.001 | 0.0011 | 0.157 | 0.0131 | 3.18 | 59.20 | 0.44 | 124.04 |
| 80.00% | 19.00% | 0.00% | 1.00% | 6474.19 | 0.001 | 0.0021 | 0.021 | 0.0095 | 6.62 | 63.77 | 0.49 | 137.74 |
| 80.00% | 0.00% | 19.00% | 1.00% | 5752.19 | 0.001 | 0.0003 | 0.279 | 0.0163 | 0.09 | 55.08 | 0.40 | 111.71 |
| 70.00% | 20.00% | 9.00% | 1.00% | 6262.19 | 0.001 | 0.0022 | 0.153 | 0.0124 | 7.01 | 59.48 | 0.46 | 131.71 |
| 70.00% | 9.00% | 20.00% | 1.00% | 5844.19 | 0.001 | 0.0012 | 0.303 | 0.0164 | 3.22 | 54.45 | 0.41 | 116.64 |
| 60.00% | 30.00% | 9.00% | 1.00% | 6392.19 | 0.001 | 0.0032 | 0.163 | 0.0121 | 10.49 | 59.31 | 0.47 | 138.00 |
| 60.00% | 9.00% | 30.00% | 1.00% | 5594.19 | 0.002 | 0.0012 | 0.448 | 0.0197 | 3.27 | 49.70 | 0.37 | 109.23 |
| 60.00% | 20.00% | 19.00% | 1.00% | 6012.19 | 0.001 | 0.0023 | 0.299 | 0.0157 | 7.05 | 54.74 | 0.42 | 124.30 |
| 60.00% | 19.00% | 20.00% | 1.00% | 5974.19 | 0.001 | 0.0022 | 0.312 | 0.0161 | 6.70 | 54.28 | 0.42 | 122.93 |
| 50.00% | 30.00% | 19.00% | 1.00% | 6142.19 | 0.001 | 0.0032 | 0.309 | 0.0154 | 10.53 | 54.56 | 0.44 | 130.60 |
| 50.00% | 19.00% | 30.00% | 1.00% | 5724.19 | 0.002 | 0.0022 | 0.458 | 0.0194 | 6.75 | 49.53 | 0.38 | 115.52 |
| 50.00% | 20.00% | 29.00% | 1.00% | 5762.19 | 0.002 | 0.0023 | 0.445 | 0.0190 | 7.09 | 49.99 | 0.39 | 116.89 |
| 50.00% | 29.00% | 20.00% | 1.00% | 6104.19 | 0.001 | 0.0032 | 0.322 | 0.0158 | 10.18 | 54.11 | 0.43 | 129.23 |
| 70.00% | 20.00% | 8.50% | 1.50% | 6288.285 | 0.001 | 0.0023 | 0.146 | 0.0123 | 7.01 | 59.66 | 0.47 | 132.38 |

Dalmia Cement plant, Dalmiapuram has two rotary kilns installed, one kiln with the capacity of 1.5 million ton and another with the capacity of 1 million ton annually. The calculations were done for the 1million ton capacity kiln.

Various combinations of the four fuels were quantified for heavy metals, emission level and calorific value. The yellow marked combinations were found suitable. Further these selected combinations were subjected to cost and availability parameter that finally affected the selection of the most appropriate fuel mix. [Table-26]

### Table-26: Selection of the Most Suitable Combination of Coal and AF

| Fuel Mix | | | | Calorific Value | Tons/Annum of Fuel Required | | | | Cost (In Crore) Per Ton | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % coal | %TDF | %oil sludge | % paint sludge | (Kcal/Kg) | Coal | TDF | OS | PS | fuel cost | T. cost | total cost |
| 80.00% | 10.00% | 10.00% | 0.00% | 6080 | 100645 | 10400 | 21081 | 0 | 53.98 | 9.626 | 63.6 |
| 80.00% | 10.00% | 0.00% | 10.00% | 6601.9 | 100645 | 10400 | 0 | 8745 | 52.92 | 9.009 | 61.9 |
| 80.00% | 0.00% | 10.00% | 10.00% | 6221.9 | 100645 | 0 | 21081 | 8745 | 51.38 | 9.543 | 60.9 |
| 70.00% | 20.00% | 10.00% | 0.00% | 6210 | 88065 | 20800 | 21081 | 0 | 50.29 | 9.139 | 59.4 |
| 70.00% | 20.00% | 0.00% | 10.00% | 6731.9 | 88065 | 20800 | 0 | 8745 | 49.23 | 8.522 | 57.8 |
| 70.00% | 10.00% | 0.00% | 20.00% | 6873.8 | 88065 | 10400 | 0 | 17491 | 46.63 | 8.440 | 55.1 |
| 70.00% | 10.00% | 10.00% | 10.00% | 6351.9 | 88065 | 10400 | 21081 | 8745 | 47.69 | 9.056 | 56.7 |
| 70.00% | 0.00% | 10.00% | 20.00% | 6493.8 | 88065 | 0 | 21081 | 17491 | 45.09 | 8.974 | 54.1 |
| 60.00% | 0.00% | 10.00% | 30.00% | 6765.7 | 75484 | 0 | 21081 | 26236 | 38.80 | 8.405 | 47.2 |
| 60.00% | 10.00% | 0.00% | 30.00% | 7145.7 | 75484 | 10400 | 0 | 26236 | 40.34 | 7.871 | 48.2 |
| 60.00% | 20.00% | 10.00% | 10.00% | 6481.9 | 75484 | 20800 | 21081 | 8745 | 44.00 | 8.570 | 52.6 |
| 60.00% | 10.00% | 10.00% | 20.00% | 6623.8 | 75484 | 10400 | 21081 | 17491 | 41.40 | 8.487 | 49.9 |
| 50.00% | 20.00% | 10.00% | 20.00% | 6753.8 | 62903 | 20800 | 21081 | 17491 | 37.71 | 8.001 | 45.7 |
| 50.00% | 20.00% | 0.00% | 30.00% | 7275.7 | 62903 | 20800 | 0 | 26236 | 36.65 | 7.384 | 44.0 |
| 50.00% | 10.00% | 10.00% | 30.00% | 6895.7 | 62903 | 10400 | 21081 | 26236 | 35.11 | 7.918 | 43.0 |
| 80.00% | 10.00% | 9.00% | 1.00% | 6132.19 | 100645 | 10400 | 18973 | 875 | 53.87 | 9.564 | 63.4 |
| 80.00% | 9.00% | 10.00% | 1.00% | 6094.19 | 100645 | 9360 | 21081 | 875 | 53.72 | 9.617 | 63.3 |
| 80.00% | 0.00% | 19.00% | 1.00% | 5752.19 | 100645 | 0 | 40054 | 875 | 52.33 | 10.098 | 62.4 |
| 80.00% | 19.00% | 0.00% | 1.00% | 6474.19 | 100645 | 19760 | 0 | 875 | 55.26 | 9.083 | 64.3 |
| 70.00% | 20.00% | 9.00% | 1.00% | 6262.19 | 88065 | 20800 | 18973 | 875 | 50.18 | 9.078 | 59.3 |
| 70.00% | 20.00% | 8.50% | 1.50% | 6288.285 | 88065 | 20800 | 17919 | 1312 | 50.13 | 9.047 | 59.2 |
| 100.00% | 0.00% | 0.00% | 0.00% | 6200 | 125806 | 0 | 0 | 0 | 62.90 | 10.065 | 73.0 |

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 paint sludge was estimated around 1000 metric tonne per annum, oil sludge was estimated around 20,000 metric tonne per annum and that of TDF was estimated around 20,000 metric tonnes per annum. On this basis three combinations were selected (highlighted with pink). [Annexure-4]

It can be concluded that maximum 30% replacement of the coal is possible without affecting the quality of the cement. This brings economical and environmental benefits to the industry.

The total cost of the Alternative Fuel formed from the combination of these fuels was calculated. The reduction in the cost of the fuel was found to be around 8% per annum, thus bringing large economical benefits to the plant.

The Co-processing of alternative fuels provides a solution in terms of reducing fossil fuel dependency as well as a contribution towards the lowering of emissions. The use of alternative materials in the cement industry lowers global $CO_2$ emissions and does not have a negative impact on production process emissions, or on the environmental and technical quality of the final product. Furthermore, co-processing in the cement industry is carried out in a safe and sound manner, thus not affecting the health & safety of its workers or neighbourhood.

# 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 [5]

The purpose of the study was to find out replacements for the coal for Dalmia Cement Plant, Dalmiapuram, Tamil Nadu, which could benefit the plant economically and environmentally.

For this, the status of the wastes within the state has been studied. The wastes having potential for their use as alternative fuel and which were available in good quantity within the state were selected. Three potential wastes namely tyres, oil sludge and sludge from paint industry, were taken into account for their 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) TDF can replace coal by 25% without affecting the quality of clinker. Beyond this percentage zinc increases above the standard limit i.e. 9%, affecting the settling properties of the cement.

2) Paint sludge if used as fuel does not alter the properties of cement, but the burning characteristics of the kiln are altered.

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

4) Maximum 30% replacement of the coal with the alternative fuels is possible without affecting the quality of the cement.

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

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

7) The cost of waste being used as fuel does not exceed the cost of fossil fuels. The reduction in the cost of the fuel was found to be around 8% per annum, thus bringing large economical benefits to the plant.

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 $1400^0$C 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.

# Annexure 1

**List of Other Units granted permission under Rule 11 of Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008, for utilization of hazardous waste in Cement Plant**

| Sl. No. | Name of the Cement Plant | Name of the Waste |
|---|---|---|
| 1. | ACC Ltd.,<br>Bargarh Cement Ltd.<br>Cement Nagar<br>PO Bardol<br>Distt. Bargarh (Orissa)<br>768 038 | ETP Bio solid (Soft drink Industry), Spent Carbon (Soft drink Industry |
| | | Chemical sludge (Automobile industry), Grinding muck (Textile machine manufacturing industry), Phosphate Sludge (Automobile industry),Oily Rags (Automobile industry), Chemical ETP Sludge (Automobile industry), Grinding dust (Rolling bearing & seal industry), WTP Sludge (Soft drink industry) |
| 2. | ACC Ltd.,<br>Chaibasa Cement Works,<br>P.O. Jhinkpani<br>Distt. West Singhbhum<br>(Jharkhand) 833 215 | Phosphate sludge (Automobiles Industry), WTP Sludge (Soft drink Industry), Spent Carbon (Soft drink Industry), Grinding muck (Textile Machine Manufacturing Industry) |
| | | Oily rags (Automobile industry), ETP Bio Solid (Soft drink industry), Chemical ETP Sludge (Automobile industry), Chemical Sludge (Automobile industry), Grinding dust (Automobile industry) |
| | | Spent catalyst from IOCL, Barauni Refinery |
| 3. | ACC Ltd.,<br>Chanda Cement Works<br>P.O. Cement Nagar<br>Distt. Chandrapur<br>(Maharashtra) 442 502 | Chemical ETP sludge (Automobiles Industry), ETP Bio solid (Soft drink Industry), Grinding Muck (Textile Machine manufacturing Industry),<br>Expired consumer products (Shampoo), Phosphate Sludge (Automobile Industry),<br>Spent carbon (Soft drink Industry), WTP Sludge (Soft drink Industry) |
| | | Oily rags (Automobile industry), Grinding dust (Automobile industry) |
| 4. | ACC Ltd.,<br>Jamul Cement Works,<br>Distt. Durg (Chhattisgarh)<br>490 024 | ETP Bio solid (Soft drink Industry) and Spent Carbon (Soft drink Industry) |
| | | Chemical Sludge (Automobile industry), Phosphate Sludge (Automobile industry), Grinding muck (Textile machine manufacturing), Oily Rags (Automobile industry), Chemical ETP Sludge (Automobile industry), Grinding dust (M/s SKF India Ltd, Bangalore), WTP Sludge (Soft drink industry) |
| 5. | ACC Ltd.,<br>Kymore Cement Works,<br>P.O. Kymore | Phosphate Sludge (Automobiles Industry), Grinding Muck (Textile Machine Manufacturing Industry), Chemical ETP sludge (Automobiles Industry) |

| | | |
|---|---|---|
| | Distt. Katni (MP)<br>483 880 | Poly residue (Distillation residue) of M/s SRF India Ltd. |
| | | Spent Carbon (Soft drink industry), Oily Rags (Automobile industry), ETP Bio-solid (Soft drink industry), Grinding dust (Rolling bearing & seal industry),<br>WTP Sludge (Soft drink industry) |
| 6. | ACC Ltd.,<br>Lakheri Cement Works,<br>P.O. Lakheri<br>Distt. Bundi (Rajashan)<br>323 603 | Chemical ETP Sludge (Automobile industry),<br>ETP Sludge (CETP, Pali),<br>Phosphate Sludge (Automobiles Industry) , Grinding Muck (Textile Machine Manufacturing Industry) |
| | | Spent Carbon (Soft drink industry), Oily Rags (Automobile industry), WTP Sludge (Soft drink industry), ETP Bio-solid (Soft drink industry), Grinding dust (Rolling bearing & sealing industry) |
| 7. | ACC Ltd.,<br>Madukkarai Cement Works,<br>P.O. Madukkarai<br>Distt. Coimbatore (Tamil Nadu)<br>641 105 | Chemical ETP sludge (Automobiles Industry), ETP Bio-solids (Soft drink Industry), Grinding Muck (Textile Machine Manufacturing Industry) , Oily rags (Automobiles Industry), Phosphate Sludge (Automobiles Industry), Plastic & Laminates (Consumer goods), Spent Carbon (Soft drink Industry), WTP Sludge (Soft drink Industry) |
| | | Green mesh with resin (M/s Suzlon Energy Ltd.), Poly residue (M/s SRF India Ltd.) |
| | | Grinding dust (Rolling bearing & seal industry) |
| 8. | ACC Ltd.,<br>Wadi Cement Works<br>P.O. Wadi<br>Distt. Gulbarga (Karnataka)<br>585 225 | Grinding Muck (Textile Machine Manufacturing Industry), ETP Bio Solids (Soft drink Industry), Chemical ETP sludge (Automobiles Industry), Phosphate Sludge (Automobiles Industry), Spent Carbon (Soft drink Industry) and WTP Sludge (Soft drink Industry) |
| | | Solar Evaporation Pond Sludge (M/s Jubilant Organosys Ltd.), N Butanol salt (M/s Jubilant Organosys Ltd.), Green mesh with Resin (M/s Suzlon Energy Ltd.) and Grinding dust (M/s SKF India Ltd.) |
| | | Oily rags (Automobile industry) & Grinding dust (Automobile industry) |
| 9. | ACC Ltd.,<br>Gagal Cement Works<br>P.O. Barmana<br>Distt. Bilaspur (HP)<br>174 013 | Phosphate Sludge (Automobile Industry), Chemical ETP Sludge (Automobile Industry),<br>Grinding Muck (Textile Machine Manufacturing Industry) |
| | | Spent Carbon (Soft drink industry), Oily Rags (Automobile industry), ETP Bio-solid (Soft drink industry), Grinding dust (Rolling bearing & seal industry), |

| | | |
|---|---|---|
| | | WTP Sludge (Soft drink industry)<br><br>Veporub process waste (pharma industry) |
| 10. | Ultra Tech Cement Ltd.,<br>Aditya Cement,<br>Adityapuram, PO Sawa<br>Distt. Chittorgarh<br>(Rajasthan)<br>312 612 | ETP Sludge (Textile Ind) Lead Zinc Slag (Hindustan Zinc Ltd.)<br>Phosphate sludge & ETP Sludge (Automobile Industry) |
| 11. | Ultra Tech Cement Ltd.<br>P.O. Reddipalayam,<br>Ariyalur<br>Distt. Perambalur (Tamil Nadu)<br>621 704 | ETP Sludge (BASF I. Ltd.), Tyre Chips, Paint sludge, Refinery sludge and plastic waste |
| 12. | Ultra Tech Cement Ltd.,<br>Gujarat Cement Works,<br>P.O. Kovaya, Taluka Rajula,<br>Distt. Amreli (Gujarat)<br>365 541 | Waste mix solid & waste mix liquid (GEPIL, Surat) |
| | Ultra Tech Cement Ltd.,<br>Narmada Cement – Jafrabad Works,<br>Babarkot, Taluka Jafrabad,<br>Distt. Amreli (Gujarat)<br>365 540 | Waste liquid blend and waste solid blend ( M/s Colourtex Industries Ltd. (Unit 2)) |
| 13. | Ultra Tech Cement Ltd.,<br>Andhra Pradesh Cement Works,<br>Bhogasamudram,<br>PO: Chukkalur<br>Mandal:Tadipatri<br>Distt. Anantapur (AP) 515 415 | Solid and liquid organic spent solvent |
| 14. | M/s Ultra tech Cement<br>P.O. Mohanpura,<br>Tehsil Kotputli, Distt. Jaipur,<br>Rajasthan 303 108 | Paint sludge; phosphate sludge; chemical ETP sludge(automobile industries) and liquid organic solvents (pharma industries) |
| 15. | Lafarge India Ltd.,<br>Sonadih Cement Plant(**Line-I**), | Wastes mix solid & wastes mix liquid (GEPIL, Surat) |

| | | |
|---|---|---|
| | PO Reseda, Via Baloda Bazar<br>Distt. Raipur (Chhattisgarh) | |
| | Lafarge India Ltd.,<br>Sonadih Cement Plant (**Line-II**),<br>PO Reseda, Via Baloda Bazar<br>Distt. Raipur (Chhattisgarh) | Wastes mix solid & wastes mix liquid (GEPIL, Surat) |
| 16. | Lafarge Indn (P). Ltd.,<br>Arasmata Cement plant<br>PO Gopal Nagar<br>Janjgir, Champa<br>Chhattisgarh | Waste mix solid, waste mix liquid from GEPIL |
| 17. | 1. Ambuja Cements Ltd.,<br>P.O. Ambuja Nagar,<br>Kodinar<br>(Gujarat)<br>362 715 | TDI Tar<br><br>Waste mix liquid (M/s Lupin Ltd., Ankleshwar) |
| | 2. Gaj. Ambuja Cement Plant<br>P.O. – Ambuja nagar, Taluk -Kodinar<br>Distt. Junagarh,<br>Gujarat-362 715 | Waste mix liquid (M/s Gujarat Enviro Protection and Infrastructure Ltd., Surat) |
| 18. | Ambuja Cements Ltd., P.O. Rabriyawas,<br>Teh. Jaitaran<br>Distt. Pali (Rajasthan) | Paint sludge |
| 19. | Ambuja Cements Ltd., Suli,<br>P.O. Darlaghat<br>Distt. Solan (HP) | Paint sludge |
| 20. | Shree Cement Ltd.,<br>Bangur Nagar, Beawar<br>PO Box No. 33<br>Distt. Ajmer (Rajasthan)<br>305 901 | ETP Sludge from Textile Industries |
| | | Paint sludge (process waste residue of automobile ind.) |
| 21. | M/s Shree Cement Ltd.,<br>Village-RAS, Tehsil-Jaitaran,<br>Distt.-Pali, Rajasthan. | Paint sludge (automobile industry) |
| | | ETP sludge (Textile industry) |

| | | |
|---|---|---|
| 22. | Vasavadatta Cement<br>Post &Tq- Sedam<br>Distt. Gulbarga<br>Karnataka<br>585 222 | Tyre derived Fuel and Plastic wastes |
| 23. | M/s Trinetra Cement Ltd.,<br>Mahi Cement Works, P.O.<br>Walwana,<br>Banswara – 327 025,<br>Rajasthan. | Waste mix liquid & solid from GEPIL, Surat. |

# Annexure 2

## Categories of hazardous waste

| Waste Categories | Type of wastes | Regulatory Quantities |
|---|---|---|
| 1 | 2 | 3 |
| Waste Category No.1 | Cynide Wastes | 1 kilogrammes per year calculated as cynide. |
| Waste Category No.2 | Metal Finishing Wastes | 10 kilogrammes per year the sum of the specified substance calculated as pure metal. |
| Waste Category No.3 | Waste containing water soluble chemical compounds of lead, copper, zinc, chromium and antimony. | 10 kilogrammes per year the sum of the specified substance calculated as pure metal. |
| Waste Category No.4 | Mercury, Arsenic, Thallium and Cadmium bearing wastes. | 5 kilogrammes per year the sum of the specified substance calculated as pure metal. |
| Waste Category No.5 | Non-halogenated hydrocarbons including solvents | 200 kilogrammes per year calculated as non-halogenated hydrocarbons |
| Waste Category No.6 | Halogenated hydro-carbon including solvents | 50 kilograms per year calculated as helogenated hydrocarbons. |
| Waste Category No.7 | Wastes from paints, pigments, glue, varnish and printing ink. | 250 kilogrammes per year calculated as oil or oil emulsions. |
| Waste Category No.8 | Wastes from Dyes and Dye intermediate containing inorganic chemical compounds. | 200 kilogrammes per year calculated as inorganic chemicals. |
| Waste Category No.9 | Wastes from Dyes and Dye intermediate containing organic chemical compounds. | 50 kilogrammes per year calculated as organic chemicals. |
| Waste Category No.10 | Waste oil and oil emulsions. | 1000 kilogrammes per year calculated as oil and oil emulsions. |

| | | |
|---|---|---|
| Waste Category No.11 | Tarry wastes from refining and tar residues from distillation or prolytic treatment. | 200 kilogrammes per year calculated as tar. |
| Waste Category No.12 | Sludgesarising from treatment of waste containing heavy metals, toxic organics, oils emulsions and spend chemical and inceneration ash. | irrespective of any quantity. |
| Waste Category No.13 | Phenols. | 5 kilogrammes per year calculated as phenols. |
| Waste Category No.14 | Asbestos. | 200 kilogrammes per year calculated asbestos. |
| Waste Category No.15 | Wastes from manufacturing of pesticides and herbicides and residues from pesticides and herbicides formulation units. | 5 kilogrammes per year calculated as pesticides and their intermediate products. |
| Waste Category No.16 | Acid/Alkaline/Slurry | 200 kilogrammes per year calculated as Acids/ Alkalies. |
| Waste Category No.17 | Off-specification and discarded products | Irrespective of any quantity. |
| Waste Category No.18 | Discarded containers and Containers linears of hazardous and toxic wastes. | Irrespective of any quantity. |

# Annexure 3

**List of Hazardous Wastes**

| S.No. | Processes | Hazardous Wastes |
|---|---|---|
| | | |
| 1. | Petrochemical processes and pyrolytic operations | 1.1 Furnace/reactor residue and debris<br>1.2 Tarry residues<br>1.3 Oily sludge emulsion<br>1.4 Organic residues<br>1.5 Residues from alkali wash of fuels<br>1.6 Still bottoms from distillation process<br>1.7 Spent catalyst and molecular sieves<br>1.8 Slop oil from wastewater<br>1.9 ETP sludge containing hazardous constituents |
| 2. | Drilling operation for oil and gas production | 2.1 Drill cuttings containing oil<br>2.2 Sludge containing oil<br>2.3 Drilling mud and other drilling wastes |
| 3. | Cleaning, emptying and maintenance of petroleum oil storage tanks including ships | 3.1 Oil-containing cargo residue, washing water and sludge<br>3.2 Chemical-containing cargo residue and sludge<br>3.3 Sludge and filters contaminated with oil<br>3.4 Ballast water containing oil from ships. |
| 4. | Petroleum refining/re-refining of used oil/recycling of waste oil | 4.1 Oily sludge/emulsion<br>4.2 Spent catalyst<br>4.3 Slop oil<br>4.4 Organic residues from process<br>4.5 Chemical sludge from waste water treatment<br>4.6 Spent clay containing oil |
| 5. | Industrial operations using mineral/synthetic oil as lubricant in hydraulic systems or other applications | 5.1 Used/spent oil<br>5.2 Wastes/residues containing oil |

.

| S.No. | Processes | Hazardous Wastes |
|---|---|---|
| | | |
| 6. | Secondary production and/or use of zinc | 6.1 Sludge and filter press cake arising out of zinc sulphate production<br>6.2 Zinc fines/dust/ash/skimmings (dispersible form)<br>6.3 Other residues from processing of zinc ash/skimmings<br>6.4 Flue gas dust and other particulates |
| 7. | Primary production of zinc/lead/copper and other non-ferrous metals except aluminium | 7.1 Flue gas dust from roasting<br>7.2 Process residues<br>7.2 Arsenic-bearing sludge<br>7.3 Metal bearing sludge and residue including jarosite<br>7.4 Sludge from ETP and scrubbers |
| 8. | Secondary production of copper | 8.1 Spent electrolytic solutions<br>8.2 Sludges and filter cakes<br>8.3 Flue gas dust and other particulates |
| 9. | Secondary production of lead | 9.1 Lead slag/Lead bearing residues<br>9.2 Lead ash/particulate from flue gas |
| 10. | Production and/or use of cadmium and arsenic and their compounds | 10.1 Residues containing cadmium and arsenic |
| 11. | Production of primary and secondary aluminium | 11.1 Sludges from gas treatment<br>11.2 Cathode residues including pot lining wastes<br>11.3 Tar containing wastes<br>11.4 Flue gas dust and other particulates<br>11.5 Wastes from treatment of salt slags and black drosses |
| 12. | Metal surface treatment, such as etching, staining, polishing, galvanising, cleaning, degreasing, plating, etc. | 12.1 Acid residues<br>12.2 Alkali residues<br>12.3 Spent bath/sludge containing sulphide, cyanide and toxic metals<br>12.4 Sludge from bath containing organic solvents<br>12.5 Phosphate sludge<br>12.6 Sludge from staining bath<br>12.7 Copper etching residues<br>12.8 Plating metal sludge<br>12.9 Chemical sludge from waste water treatment |

| S.No. | Processes | Hazardous Wastes |
|---|---|---|
| | | |
| 13. | Production of iron and steel including other ferrous alloys (electric furnaces; steel rolling and finishing mills; Coke oven and by product plant) | 13.1 Process dust<br>13.2 Sludge from acid recovery unit<br>13.3 Benzol acid sludge<br>13.4 Decanter tank tar sludge<br>13.5 Tar storage tank residue |
| 14. | Hardening of steel | 14.1 Cyanide-, nitrate-, or nitrite-containing sludge<br>14.2 Spent hardening salt |
| 15. | Production of asbestos or asbestos-containing materials | 15.1 Asbestos-containing residues<br>15.2 Discarded asbestos<br>15.3 Dust/particulates from exhaust gas treatment. |
| 16. | Production of caustic soda and chlorine | 16.1Mercury bearing sludge<br>16.2 Residue/sludges and filter cakes<br>16.3 Brine sludge containing mercury |
| 17. | Production of acids | 17.1 Residues, dusts or filter cakes<br>17.2 Spent catalyst |
| 18. | Production of nitrogenous and complex fertilizers | 18.1 Spent catalyst<br>18.2 Spent carbon<br>18.3 Sludge/residue containing arsenic<br>18.4 Chromium sludge from water cooling tower<br>18.5 Chemical sludge from waste waster treatment |
| 19. | Production of phenol | 19.1 Residue/sludge containing phenol |
| 20. | Production and/or industrial use of solvents | 20.1 Contaminated aromatic, aliphatic or napthenic solvents not fit for originally intended use<br>20.2 Spent solvents<br>20.3 Distillation residues |

| S.No. | Processes | Hazardous Wastes |
|---|---|---|
| | | |
| 21. | Production and/or industrial use of paints, pigments, lacquers, varnishes, plastics and inks | 21.1 Wastes and residues<br>21.2 Fillers residues |
| 22. | Production of plastic raw materials | 22.1 Residues of additives used in plastics manufacture like dyestuffs, stabilizers, flame retardants, etc.<br>22.2 Residues of platicisers<br>22.3 Residues from vinylchloride monomer production<br>22.4 Residues from acrylonitrile production<br>22.5 Non-polymerised residues |
| 23. | Production and/or industrial use of glues, cements, adhesive and resins | 23.1 Wastes/residues (not made with vegetable or animal materials) |
| 24. | Production of canvas and textiles | 24.1 Textile chemical residues<br>24.2 Chemical sludge from waste water treatment |
| 25. | Industrial production and formulation of wood preservatives | 25.1Chemical residues<br>25.2Residues from wood alkali bath |
| 26. | Production or industrial use of synthetic dyes, dye-intermediates and pigments | 26.1 Process waste sludge/residues containing acid or other toxic metals or organic complexes<br>26.2 Chemical sludge from waste water treatment<br>26.3 Dust from air filtration system |
| 27. | Production or industrial use of materials made with organo-silicone compounds | 27.1 Silicone-containing residues<br>27.2 Silicone oil residues |
| 28. | Production/formulation of drugs/ pharmaceuticals | 28.1 Residues and wastes<br>28.2 Spent catalyst / spent carbon<br>28.2Off specification products<br>28.3Date-expired, discarded and off-specification drugs/ medicines<br>28.4Spent mother liquor<br>28.5Spent organic solvents |
| 29. | Production, use and formulation of pesticides including stock-piles | 29.1 Wastes/residues containing pesticides<br>29.2 Chemical sludge from waste water treatment<br>29.3 Date-expired and off-specification pesticides |

| | | |
|---|---|---|
| 30. | Leather tanneries | 30.1 Chromium bearing residue and sludge<br>30.2 Chemical sludge from waste water treatment |
| 31. | Electronic Industry | 31.1 Residues and wastes<br>31.2 Spent etching chemicals and solvents |
| 32. | Pulp & Paper Industry | 32.1 Spent chemicals<br>32.2 Corrosive wastes arising from use of strong acid and bases<br>32.3 Sludge containing adsorbable organic halides |
| 33. | Disposal of barrels / containers used for handling of hazardous wastes / chemicals | 33.1 Chemical-containing residue from decontamination and disposal<br>33.2 Sludge from treatment of waste water arising out of cleaning / disposal of barrels / containers<br>33.3 Discarded containers / barrels / liners used for hazardous wastes/chemicals |
| 34. | Purification processes for air and water | 34.1 Flue gas cleaning residue<br>34.2 Toxic metal-containing residue from used-ion exchange material in water purification<br>34.3 Chemical sludge from waste water treatment<br>34.4 Chemical sludge, oil and grease skimming residues from common industrial effluent treatment plants (CETPs) and industry-specific effluent treatment plants (ETPs)<br>34.5 Chromium sludge from cooling water treatment |
| 35. | Purification process for organic compounds/solvents | 35.1 Filters and filter material which have organic liquids in them, e.g. mineral oil, synthetic oil and organic chlorine compounds<br>35.2 Spent catalyst<br>35.3 Spent carbon |
| 36. | Waste treatment processes, e.g. incineration, distillation, separation and concentration techniques | 36.1 Sludge from wet scrubbers<br>36.2 Ash from incineration of hazardous waste, flue gas cleaning residues<br>36.3 Spent acid from batteries<br>36.4 Distillation residues from contaminated organic solvents |

# Annexure-4

- Feasibility of use of alternative fuel in cement industry is known worldwide.
- Alternative fuels such as tyre derived fuel, ETP sludge, paint sludge oil sludge, agricultural waste, municipal solid waste, etc, are known to be used in cement industry.
- We have assumed that these fuels are available in India.
- Dalmia Cement Plant is approved to use these wastes as a fuel in cement manufacturing process.
- At present Dalmia Cement Plant is using Imported/Indian coal as a fuel.
- I have identified Tyre Derived Fuel, paint sludge and oil sludge as potential waste materials to be used as fuel in the plant.
- Identified fuel's analysis was obtained from the company.
- Cost of the coal was obtained from the company.
- The cost of the identified alternative fuels is worked out on the basis of:

  a) It is available from disposing company at zero cost.

  b) Collection of the waste, loading of the waste is also at the cost of the producing company.

  c) Transporting cost and unloading cost is included in the cost of fuel used.

  d) Availability of the waste is ensured from the producing company.
- Norm of the emission as specified by CPCB has been used to restrict the emission within the limit.
- Quantity of the waste to be used is determined based on the

  a) Heating value

  b) Emissions (gaseous as well as heavy metals)

  c) Cost

  d) Availability

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