Environmental Impacts of Utilization of Industrial Wastes as Raw Materials for Co-Processing in Cement Plant

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Abstract— Industrial wastes are normally characterized with its toxic and hazardous nature. Proper disposal of huge quantity of industrial wastes into environmentally safe manner is troublesome for waste generators as well as authorities of the country. Proper disposal needs energy, expertise in its handling and manifold economical cost. Further, land disposal of industrial wastes leads to liability of its supervision for decades and cost of cleanup in case of failure of landfill. The cement industry is an intensive consumer of natural material resources, energy and also having great potential of greenhouse gas emission. Some of the industrial wastes are having lesser hazardous characteristics and potential for its reuse/ reutilization. Chemical gypsum, Iron Sludge, ETP sludge from textile effluent, dust from foundry or metallurgical activities, marble waste, fly ash etc are having Cementious properties or Pozzolana properties can be utilized for manufacturing of blended cement. Proper use of wastes as alternate raw materials can decrease the environmental impacts lowering the consumption of natural materials & embodied energy with associated waste management activities. Further, utilization of wastes as AFR reduces economical cost of its proper incineration or secured disposal at landfills and also reduces economical costs towards fresh materials consumption & energy requirements at cement industry.

Key words: Waste, Co-Processing, Utilization, Cement, Alternate Fuel and Raw Materials (AFR)

I. INTRODUCTION

Since industrial revolution began, the producer as well as regulatory authorities struggling with the problems associated with resulting wastes. Ever growing population, rate of increasing in urbanization, stress of providing basic need and giving better living standards to people of the country resulted in increase in industrialization manifolds. Manufacturing of products and waste generation are parallel activities. Indiscriminate disposal of hazardous wastes poses serious environmental problems. Thus adequate handling and disposal of industrial wastes are serious concern for the waste generator as well as regulatory authorities.

The industrial wastes having hazardous characteristics from various industries like Dyes and Dyes intermediates, chemical, textile, pesticides, pharmaceuticals, metallurgical etc creates great concern to the environment. Since the pollutants in the wastes lead to problems of ground water pollution, extreme change in soil condition, adverse effects on plants and poor productivity of soil. Waste disposal practices like controlled manner incineration or secured land filling at developed "Treatment, stabilization, disposal facility (TSDF)" are widely used but consumes a lots of energy, resources and increasing in economical burden in land cost and other associated activities. Necessity was felt It is necessary to develop a suitable technology for utilization of wastes into Eco-friendly and useful materials.

Cement/ Concrete is the most widely used construction material in all type of civil engineering works and cement is the main constituent of the concrete which act as a binder between fine and coarse aggregates. There are two types of cement that is ordinary Portland cement and Portland Pozzolana cement (blended cement). Pozzolana that is commonly used in concrete includes fly ash, silica fume and variety of natural pozzolans such as calcinied clay and volcanic ash. Blended cement is manufactured with addition of supplementary materials. Blending of other supplementary Cementious or siliceous material when used in conjunction with Portland cement, contributes to the properties of hardened concrete through hydraulic and pozzolanic activity or both.

The industrial wastes that have to be disposed at TSDF can be kept to use in some manner after testing its characteristics and hazardous nature. Possessing cementations nature of wastes can be utilized as binder properties in cement concrete. Huge demand and then production of cement leads to massive consumption and mining of exhaustible natural resources and energy demand besides emission of many harm full gases into the atmosphere.

Hence, the researchers are currently focused on waste material having cementing properties, which can be added as partial replacement of cement which reduces cement clinker production leading to limiting consumption of resources, energy, emission of pollutants and balancing with sustainable development. Some of the mineral admixtures like fly ash, Silica fume, Rice Husk ash, gypsum, ground granulated blast furnaces slag (GGBS) are used as cementations materials.

II. CRITICAL LITERATURE REVIEW

A. Dipali Tank (2019)[1]

The experimental study concluded that locally available industrial wastes show very promising characteristics for Alternate Cementious materials in place of natural mined raw materials. There is no adverse effect on cement quality if wastes are added into clinker in a controlled manner. Co-processing industrial waste has multifold environmental and financial benefits to waste generator as saving on waste transportation and disposal cost.

B. J. Viguri1, a. Andre âs (2001)[2]

Selected metal hydroxide cakes from the `on site' waste water treatment of nickel and chromium electroplating activities and the anodizing of aluminum materials were treated with

Portland cement and mixed with clay, offering two possibilities of solidification/ stabilization prior to land filling, and reutilization in ceramic products. The environmental impact assessment of both kinds of product based on criteria of eco-toxicity of acidic leachate leads to the conclusion that waste/cement ratios in the range of 3/1 to 1/ 2, and waste/clay between 1% and 3% are able to fulfill Spanish eco-toxicity limits.

Introduction of metal hydroxides cakes in the manufacture of ceramic products is an immobilization strategy of these wastes providing a non-eco-toxic material and leachate, which can be controlled in low concentrations of pollutants in water.

C. Sukhdev Vashist (2015) [3]

The objective of the study is to investigate different replacement levels of ordinary Portland cement by Waste marble powder and natural coarse aggregates with recycled coarse aggregates.

When marble powder is substituted as binder with cement and crushed tile aggregate is substituted as filler with coarse aggregate, the compressive strength was found to increase at lower replacements. Compressive strength of concrete increased up to 10% of partial replacement of Cement with waste marble powder and up to 30 % of partial replacement of coarse aggregates with recycled coarse aggregates. There is a decrease in the compressive strength of concrete if the replacement level increased from 10% to 15% for waste marble powder and 30% to 45% of recycled coarse aggregates. conserves natural resources.

D. Nafeth A. Abdelhadi (1995) [4]

Huge amounts of phosphogypsum (PG) are produced as by-products of phosphoric acid manufacture process. Heated PG2 showed an imperfect setting time, consistency and compressive strength over colder PG. The addition of 10% pozzolana showed a negative impact because of its large mixing ratio. Experimental results recommend the use of raw PG without treatment (heating) in cement production. This will eliminate a serious environmental source of pollution; besides, it will decrease the cost of cement production.

III. METHODOLOGY

Therefore some experimental trials to find out suitability of utilization of locally available industrial wastes as replacement of mineral gypsum were carried out in laboratory.

There are a number of types and grades of cement and the different tests done conforming to certain codes practiced. The tests also depend on the use of cement for a particular type of work. India follows the codes formed by the BIS body. Some of the codes that the cements should conform to are as follows: IS 269: 1989 – Specification for ordinary Portland cement, 33 grade; IS 8112: 1989 – Specification for ordinary Portland cement, 43 grade; IS 12269: 1987- Specification for ordinary Portland cement, 53 grade; IS 455: 1989 Specification for Portland slag cement; IS 1489 (Part 1): 1991 Specification for Portland Pozzolana cement: Fly ash based; IS 1489 (Part 2): 1991 Specification for Portland-Pozzolana cement: Calcinied clay based and IS 3466:1988 Specification for masonry cement.

Physical Properties	Chemical Properties
Finess Soundness Consistency Strength Settling time Heat of hydration Density Specific gravity	Loss of Ignition Sulphur Trioxide Free lime Alumina Magnesia Chloride etc

Table 1: Properties of Cement

Properties of cement mainly divided in to physical properties and chemical properties. as summarized in table 1. Considering the major focused area on more eco-friendly and cost effective disposal of wastes than conventional TSDF, the compressive test and Loss on Ignition were found relevant quality tests and were chosen for the experiments.

IV. EXPERIMENTAL PROCEDURE

Industrial solid wastes were collected from selected industrial plants considering its nature similarity with natural materials being used in blended cement and waste characterization as per prevailing Hazardous Waste and Other Wastes (Management and Transboundary Movement) Rules'2016. Laboratory tests i.e Compressive strength & Loss of Ignition were carried out for selected industrial wastes and results were analyzed in terms of blended cement quality as per IS standards.

Following industrial wastes have been selected in experiment as substitute of naturally occurring materials:

[1] Chemical Gypsums from Common Spent Acid Treatment and Disposal facilities (type-1) and a Dye & Dye intermediate industry (type-3) categorised as hazardous waste have been selected as a substitute to mineral Gypsum as it plays major role in retardant and strength of the cement.

[2] ETP sludge from physico-chemical treatment of effluent from metal finishing industry (type-2) as substitute of gypsum and iron oxide, it impacts colour, hardness and strength to the cement.

[3] Marble waste (type-4) is selected as substitute of silica-sand; it impacts strength to the cement.

V. RESULTS & DISCUSSION

Experiments were carried out for the different proportion of wastes with cement clinker and after curing in days as 1d, 3d, 7d and 28 day. Results are mentioned in the graphs no. 1 to 3.

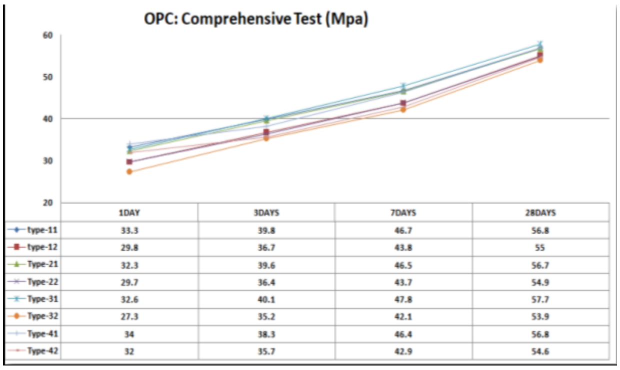
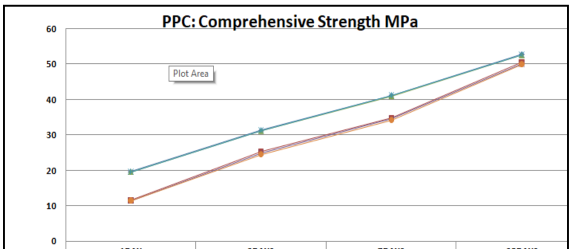


Fig. 1: Sample compared with OPC grade



	1DAY	3DAYS	7DAYS	28DAYS
type-13	19.7	31.3	41.2	52.8
type-14	11.6	25.4	34.8	50.6
Type-23	19.5	31.1	41	52.6
Type-24	11.5	25	34.6	50.1
Type-33	19.5	31.2	41.2	52.7
Type-34	11.5	24.6	34.3	50

Fig. 2: Sample compared with PPC grade

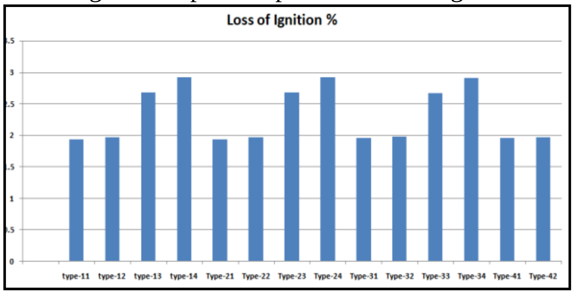


Fig. 3: Loss on Ignition test

Results of mixing of various wastes with cement clinker as shown in graphs 1 to 3 show following main output:

1) With mixing of Gypsum, earlier comprehensive strength shows reduction than mixer without gypsum which later on increases at desired level.
2) Mixers were made by replacing 5% cement with marble powder shows good result in -terms of compressive strength.
3) With maximum 05 percentages mixing of chemical gypsum or ETP sludge there is increase of comprehensive strength. As expected, the strength increases as the curing time of concrete increases.

In all three cases the comprehensive strength and Loss of Ignition percentages shows results allowable as per the Indian standards IS 12269 : 2013 and IS 1489 (Part 1) : 1991 for OPC and PPC cement respectively.

The laboratory and operational trial indicated that locally available industrial wastes into proper percentages does not deteriorate the comprehensive strength and Loss ignition properties of OPC/ PPC cement quality.

VI. ENVIRONMENTAL IMPACT BENEFIT ANALYSIS

Environmental benefits associated with utilization of industrial wastes can be classified in to:

1) Benefits towards activities associated with waste disposal i.e. waste handling & management activities like collection, onsite storage, treatment, transportation, and temporary storage at TSDF, disposal, daily covering, leachate management, post disposal measures & securing TSDF etc.
2) Benefits towards activities associated with supplementary reuse of wastes i.e. mining/ harvesting natural resources, its purification/ production, transportation, utilization process, end- wastes management & handling.

Since the point of generation of industrial wastes environmental impacts become significant and hose includes health & safety of workers engaged in handling & disposal, spillages from in-house or off-site storages and leachate causing surface as well as ground water pollution, emission of air pollutants like dust and toxic gases from wastes, emission of air pollutants during transportation, accidental release of wastes into environment or failure of landfill may cause catastrophic environmental episodes.

The environmental impacts of utilization of industrial gypsum are principally attributed to the collection of waste from disperse locations and the associated environmental impacts of road transportation only e.g. emissions of carbon dioxide, nitrous oxides, and particulates only. There are no further impacts associated with its post utilization or future liability.

There are many environmental issues associated with sourcing of raw materials like gypsum and coal/ lignite through conventional methods, i.e. mined and synthetic gypsum, and through recycling, has environmental impacts. Conventional raw materials are sourced through mining, either open cast or underground mining or synthetic generation. This method of raw materials production is a key contributor to physical resource depletion, global warming potential resulting from energy use, photochemical oxidation and acidification. The principle environmental impacts of mined raw materials arise from exhaustible nature resource depletion and energy usage in their production.

A desktop attempt is made to evaluate environmental impacts associated with disposal of industrial wastes to landfill site and for utilization at cement grinding unit for co-processing as alternate raw materials:

A. Matrix Representation

The parameters discussed are presented in the form of a matrix. The impact matrix relating to the,

1) Activities during illegal dumping or failure of secured landfill site
2) Activities during transportation and disposal of wastes to adequate secured landfill site
3) Activities during transportation and utilization of wastes by Cement Mill are presented.

Potential impact is given in the form of tables. The impact analysis has been carried out based on matrix method for mainly THREE alternatives:

1) Weighted Environmental Impacts disposal of wastes to adequate secured landfill site
2) Weighted Environmental Impacts utilization of wastes by Cement Mill.
3) Weighted Environmental Impacts disposal of wastes to illegal land-filling.

B. Criteria for Rating the Impacts

Following criteria has been considered for rating of the impacts. For each impact area, the magnitude of impact has been rated on the scale of 1 to 5

Score	Severity criteria
1	Very Less Impact
2	Less Impact
3	Moderate Impact
4	High Impact
5	Very High Impact

For each impact area, importance of the impact has been rated on the scale of 1 to3

Score	Severity criteria
1	Less Important
2	Moderately Important
3	Very Important

C. Ranking Criteria

Total nine impact areas are considered for ranking in this matrix. The criteria for overall ranking of the secured landfill facility are developed as follows.

1) The facility is having very high adverse impact If, total Score is above 300
2) The facility is having moderate adverse impact If, total Score is between 200 – 300
3) The facility is having less adverse impact If, total Score is below 100
4) The facility is having very less adverse impact If, total Score is below 100

Based on the criteria for rating the impacts, the weighted impacts are given as shown in tables. In this weighted impact matrix table the entries are presented in the form x, y, and T where ‘‘X’’ denotes the magnitude of the impact and ‘‘Y’’ denotes the importance of the impact, while “T” denotes the impact rating. “*” denotes not relevant impact to a particular activity.

Sr. No.	Potential Impact Area	Construction Phase Activity						Operation Phase Activity												Closure/ Post Closure Activity			Total
		Preparation of Site			Setting up of Integrated Waste Management Facility			Transportation of Wastes to facility from member industries			Waste material handling and in boundary transport			Processing Units (D.G set, waste compacting, layering, leachate mngt)			Land filling			Post closure			
		X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	Gross T
1.	Air Quality	4	3	12	4	2	8	4	3	12	4	3	12	3	3	9	5	3	15	3	2	6	74
2.	Infrastructure	2	2	4	1	1	1	2	2	4	2	1	2	1	1	1	5	3	15	1	1	1	28
3.	Water Quality	4	2	8	3	2	6	2	2	4	3	2	6	3	3	9	3	3	9	2	2	4	46
4.	Env. Hazards	1	1	1	2	2	4	3	3	9	3	3	9	1	1	1	3	3	9	3	3	9	42
5.	Land	5	3	15	4	3	12	4	3	12	4	3	12	2	2	4	5	3	15	3	2	6	76
6.	Noise & Odor	4	3	12	3	2	6	3	2	6	4	2	8	3	2	6	3	3	9	1	2	2	49
7.	Fauna	2	1	2	2	1	2	1	1	1	2	2	4	1	2	2	2	2	4	2	2	4	19
8.	Flora	2	2	4	2	1	2	1	1	1	3	2	6	1	2	2	3	3	9	3	2	6	30
TOTAL				58			41			49			59			34			85			38	364

Table: 2 Environmental Effect Matrix with Disposal of Wastes to Secured Landfill Site (Here, Environmental impacts of landfill construction stage & closure/ post closure phase are not considered)

Sr. No.	Potential Impact Area	Construction Phase Activity						Operation Phase Activity												Closure/ Post Closure Activity			Gross Total
		Preparation of site			Setting up of utilization facility			Transportation of Wastes to facility from member industries			Waste material handling and Transport			Processing Units (D.G set, pretreatment, drying)			Co-Processing			Post Co-processing			
		X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	
1.	Air Quality	*	*	*	*	*	*	4	3	12	3	3	9	1	1	1	1	1	1	*	*	*	24
2.	Infrastructure	*	*	*	*	*	*	2	2	4	2	1	2	1	1	1	1	1	1	*	*	*	8
3.	Water Quality	*	*	*	*	*	*	2	2	4	2	2	4	*	*	*	*	*	*	*	*	*	8

4.	Env. Hazards	*	*	*	*	*	*	3	3	9	3	3	9	*	*	*	1	2	2	*	*	*	20
5.	Land	*	*	*	*	*	*	4	3	12	3	3	9	*	*	*	*	*	*	*	*	*	21
6.	Noise & Odor	*	*	*	*	*	*	3	2	6	3	2	6	*	*	*	*	*	*	*	*	*	12
7.	Fauna	*	*	*	*	*	*	1	1	1	1	1	1	*	*	*	*	*	*	*	*	*	2
8.	Flora	*	*	*	*	*	*	1	1	1	1	1	1	*	*	*	*	*	*	*	*	*	2
TOTAL				*			*			49			41			2			4			*	96

Table 3: Environmental Effect Matrix with utilization of Wastes by Cement Mill

Sr. No.	Potential Impact Area	Construction Phase Activity						Operation Phase Activity												Closure/ Post Closure Activity			Total
		Preparation of Site			Setting up of TSDF			Transportation of Wastes to facility from member industries			Waste material handling and transport			Processing Units i.e. D.G set, waste compaction, leachate management			Landfilling			Post closure			
		X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	X	Y	T	Gross total
1.	Air Quality	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
2.	Infrastructure	*	*	*	*	*	*	2	2	4	2	2	4	*	*	*	5	3	15	5	3	15	38
3.	Water Quality	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
4.	Env. Hazards	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
5.	Land	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
6.	Noise & Odor	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
7.	Fauna	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
8.	Flora	*	*	*	*	*	*	5	3	15	5	3	15	*	*	*	5	3	15	5	3	15	60
TOTAL										109			109						120			120	458

Table 4: Environmental Effect Matrix with Disposal of Wastes to Illegal Landfilling

VII. RESULTS ANALYSIS

Weighted Environmental Impacts disposal of wastes to adequate secured landfill site are figured out at 364 points, Weighted Environmental Impacts utilization of wastes by Cement Mill are at 096 points and Weighted Environmental Impacts disposal of wastes to illegal land-filling are at 458 points.

Here, Cement grinding unit itself is a major source of particulate matter emission. Since last few decades, the increasingly strict controls on emissions from cement plants have considerably reduced the potential for public exposure to and environmental impacts of hazardous emissions.

Hence adequate control measures are mandatory to cement plant, no requirement of additional major investment in control measures.

If industrial chemical gypsum waste is co-processed correctly and according to stringent environmental and emissions standards and regulations, there are no additional health and environmental risks compared to those that result when mineral gypsum is used as raw material.

So, it can be concluded that, It clearly shows that co-processing of industrial wastes in cement plants will have considerable lesser adverse Environmental impact on the surrounding environment.

VIII. SOCIO ECONOMIC BENEFITS

Cement industry is itself highly job intensive industry. Further addition of waste based production, use of supplementary cementitious materials, ecofriendly products, lessen greenhouse gas emission increase carbon foot print can generates number of job opportunity directly and indirectly. Associated job may include handling and management of waste products from industries to cement plant, its pre-treatment etc.

Employing industrial waste materials as supplementary cementitious materials also attracts “Circular Economy” concept as these waste materials are being utilized instead of disposal at landfill and generates energy value and strength to the building materials.

Further, availability of supplementary materials without cost of mining and long distance transportation and security of availability throughout life span reduces procurement and operational cost of cement plant than mineral fresh raw materials. It improves supply side efficiency.

Cement plant can increase their Life Cycle optimization by utilizing waste materials and also reducing emission by increasing waste to clinker ratio.

IX. CONCLUSION

The experimental study concluded that locally available industrial wastes shows very promising characteristics for supplementary raw materials in cement production.. There is no adverse effect on cement quality if wastes are added in to clinker in controlled manner. Co-processing industrial waste has multifold environmental and social benefits besides financial cost reduction and savings. It reduces demands and depletion of exhaustible natural resources, reduces the environmental impacts of the extraction (mining or quarrying), transporting and processing of raw materials, reduces emission of Green House Gases & other pollutants at cement plant side. Co-processing also saves on cost on developing, operating and monitoring TSDF, reduces space required for Landfill as wastes are diverted to utilization leaving no residues for disposal. Further, developed TSDF may be utilized for more needy wastes having no reuse/ utilization potential.

Thus, Co-processing of industrial solid wastes as alternate raw materials in co-processing is a Win- Win situation for Waste generator, Cement Plant and also TSDF operator.

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