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PL1.

ENHANCING ENVIRONMENTAL QUALITY AND PUBLIC HEALTH BY PROMOTING RESOURCE CIRCULATION USING WASTE CO-PROCESSING IN CEMENT PLANTS

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Abstract: *Since ages, countries throughout the world have been using landfill sites for dumping waste at minimum cost. Currently, an estimated 2 billion tonnes of municipal solid waste is generated globally, out of which almost 33% remain uncollected by municipalities (Waste Atlas 2018). Currently, the top three municipal solid waste-generating countries are the USA, i.e., 258 million metric tons, China, i.e., 220 million metric tons, and India, i.e., 169 million metric tons (Statista 2020).This daily accumulation of waste materials is increasing heavily on a daily basis with increase in population, causing scarcity of further land to be used for landfills. According to the World Bank, the generation of municipal solid waste is anticipated to rise to 3.4 billion tonnes by 2050 (The World Bank 2020a). These landfills are generally without any scientific treatment or segregation in developing countries including India. Treatment capacities are not sufficient causing local harm, release of greenhouse gases and other pollution. From the current world population of 7.6 billion (US Census Bureau 2020), nearly 3.5 billion people are deprived of basic waste management facilities (Waste Atlas 2018). As a result these landfill sites have become a breeding ground for contamination by flies, rodents, mosquitoes and causing diseases like dermatological, respiratory, genetic, and several other kind of infectious diseases. Among these wastes accumulated, various materials have been proven to be useful resources which can be used again as an input in various industries. A major portion of these wastes may be utilized and resources can be recirculating by various treatment and management processes by the implementation of 3Rs and circular economy concepts. Co-processing of wastes in cement plant is one of the options for this solution. This paper deals with enhancing the environmental quality and public health by promoting the process of co-processing of waste materials in cement plants thereby reducing the path of waste materials to the landfill sites. Co-processing is defined as the process where waste materials are used as a source of energy or raw materials. By applying this circular economy concept, usage of conventional fuel can also be greatly reduced. A case study has also been done to enquire whether co-processing is the best option to be implemented on cement plants. If the waste materials are co-processed in cement plants effectively, landfill sites will no longer overflow with waste and quality of health and environment can also be improved significantly. Moreover, it will help to obstruct the flow of waste materials to ocean, hence preventing marine littering and creating micro plastics too.*

Keywords: *Co-processing, Circular economy, GHGs. landfill, municipal solid waste, waste management.*

INTRODUCTION

Landfills have been extensively utilized for solid waste disposal throughout the globe. Developing countries in particular, such as China and Mexico, India treat landfills as the primary method for disposing solid waste in landfills due to several advantages, including economic efficiency and low technological barriers (Zacarias-Farah and Geyer-Allely, 2003; Rodrigo et al., 2016).
Presently, solid waste landfilling is considered to be one of the major environmental concerns due to its significant methane (CH_4) production. Although selecting landfill as a viable option for solid waste management should be given the last priority due to considerable greenhouse gas (GHG) emissions in comparison to other waste management technologies. (Majdinasab, A.; 2017)
The most significant environmental nuisance of the landfill approach is the landfill gas (LFG) production resulting in thousands of tons of the greenhouse gas (GHG) to be vented into the global atmosphere. The LFG is mainly composed of CH_4 (50–55%) and CO_2 (40–45%), which are generated during the anaerobic digestion of the solid waste through landfill sites (Ayalon et al., 2001; Scheutz et al., 2009a)

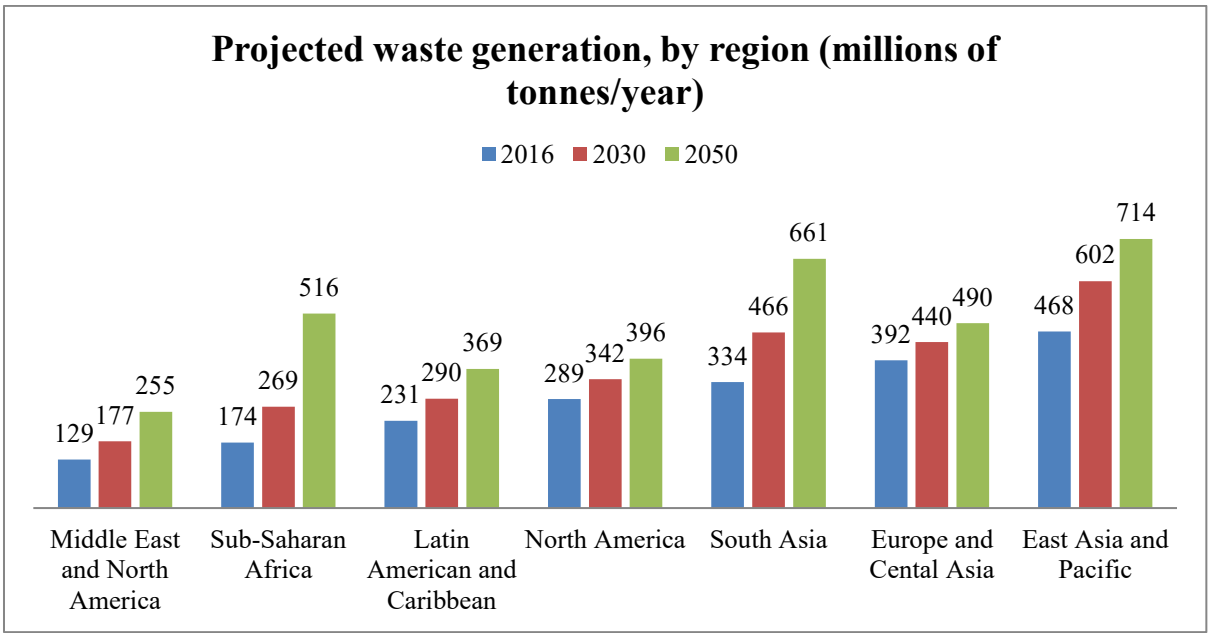

Figure (1): Projected Solid Waste Generation in different region of the world from 2016 to 2030 (The World Bank; 2021)

The landfill wastes include both organic and inorganic matter. The organic matter covers more than 50% of the total waste material. Due to improper management of landfill garbage, it causes serious risks to human health directly by the emission of toxic gasses. On the other hand, landfill sites are the natural habitat of several microbes and arthropods. Moreover, the population of insect vectors of various diseases, insect scavengers as well as pollinators is thriving in landfill sites. It shows that landfill sites and adjacent areas are hotspots for a wide variety of arthropods.
Landfill sites are also likely to generate other non-methane volatile organic compounds (VOCs) including hydro-chlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs) which are typically generated at low scales (Bogner et al., 2010).
Uncontrolled waste management degrades land, ground water and air quality, leading to health risks to humans, animals and the ecosystem. Presently, industrial waste in most cases is disposed to landfills after incineration, without utilizing the full potential of the wastes through recirculation. (Sadala; 2019)

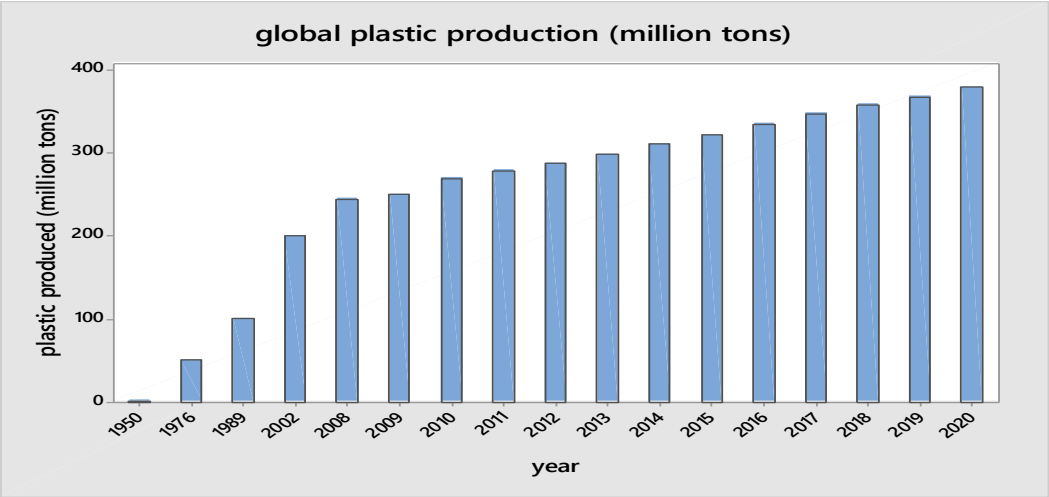

Figure (2): Production of plastics worldwide 1950-2019
(Statista; 2021)

In kolkata, a city of India, there is a dumpsite named Dhapa, whose area is around 21.1hectares where 3500 tons of solid wastes are accumulated on a daily basis, causing giant mountains of waste materials. Kolkata has an area of about 187.33 km^2 and a population of about 10 million (including floating population). Kolkata Municipal Corporation (KMC) comprises 15 "boroughs" and 141 electoral "wards"; each borough consisting of a cluster of wards. (WBPCB)
Garbage is repulsive and malodorous material attracting insects and eaten by different animals and scavengers (Jofre et al., 2011). Garbage destroys natural sights, produce a bad smell, provide a breeding site to insects, spread disease and pollute the environment, leading to problems for natural activities.
So it has become an evident warning that alternatives should be found out in order to reduce this huge heaves of waste material, piling up in landfill sites and causing scarcity of land.
Several alternative options have been implemented to manage accumulated solid waste to reduce the necessity of landfilling. However, recent investigations in the US show that over 50% of the MSW produced is currently decomposed through landfill sites. This clarifies that landfilling is the most common approach to solid waste management (USEPA, 2012; Weitz et al., 2002).
The proper management of landfill sites could reduce the population dynamics of various insect pests, and health risks could be decreased in low and middle-income countries. (Muhammad Qasim et al, 2020)
Co-processing of this waste for energy recovery and as an alternative raw material in cement kiln can be an effective management methodology for this waste stream. This is being practiced sustainably in number of countries but in India the process lacks proper implementation. The auxiliary technological requirement is less and the process is highly economical and effective. (S K Ghosh et al, 2016)
Indian cement industry is rated as one of the best performing industry across various industrial sectors in terms of energy efficiency, quality control, and environmental sustainability and adaptive in venturing into new technology. Indian cement industry is contributing to circular economy primarily by (i) Circular Supply Chain, (ii) Recovery and Recycling.
Waste from various industries is being utilized by the cement industry as alternative fuels and raw materials (AFR). As cement manufacturing process itself supports the environmentally sustainable waste utilization due to high temperature incineration without leaving any residue, hence it is acting as backbone for waste generating industries. (Kapil Kukreja et al, 2020)

LITERATURE REVIEW

Co-processing

Co-processing is defined as the process where wastes are utilized as a source of energy or raw material, or both to replace natural mineral resources and conventional fuels such as coal, petroleum

coke etc. in the manufacturing process. Basel and Stockholm Conventions highlighted the suitability of cement kiln for co-processing of hazardous and other wastes. Co-processing in cement kiln is scientific, sustainable, proven and established technology for disposing hazardous and non- recyclable waste in environmentally sound manner. This practice can be extremely attractive and cost-efficient, especially for emerging economies having insufficient waste treatment capacity, like India. (Saha et al, 2017). There are several benefits of co-processing when compared to other recycling processes. When waste is co-processed in a cement kiln, it leads to 100% energy and material recovery and does not leave behind any byproducts like ash, etc. Due to its economic, environmental and social benefits, it has been proved as one of the five important pillars for large scale reduction of CO2 emissions from Indian cement industry. The traditional linear extract-produce-use-dump material and energy flow model implemented so far in the modern economic system has been proved unsustainable at long term (Korhonen et al., 2018).

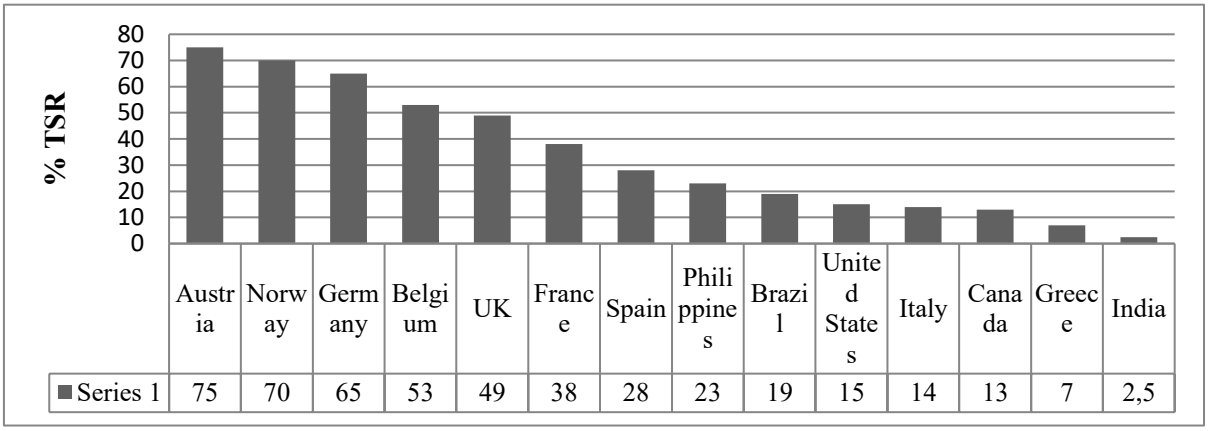

Figure (3): Countries and their Thermal Substitution Rates (TSR)
(Saha et al., 2017; Karstensen et al., 2018)

In contrast, the circular economy provides the economic system with an alternative that fosters to reduce negative environmental impacts and stimulate new business opportunities. In this line, most materials (including biomass and waste-derived fuels such as tires, sewage sludge (SS) and municipal solid waste (MSW), plastic waste, E wastes) contain some potential energies that can be utilized by cement industries in order to meet the requirements of the thermal energy, (Malinauskaite et al., 2017). Therefore, the use of those materials as a source of energy in cement plants contributes towards overcoming challenges such as climate change, waste management and fossil fueldepletion, while utilizing principles of circular economy (ECOFYS, 2016; Malinauskaite et al., 2017). On the other hand, unsuitable technical conditions in co-processing cement plants may lead to the emission of some of the most hazardous pollutants, such as heavy metals and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) (Mari et al., 2009). Consequently, a number of recent studies have been aimed at evaluating the environmental impact of co-processing cement plants (Georgiopoulou and Lyberatos, 2018; Mari et al., 2017; Richards and Agranovski, 2017; Rovira et al., 2014, 2015, 2016).

TYPES OF WASTE IN CO-PROCESSING

Use of MSW in cement kiln

In Vietnam, a study showed that utilizing cement kiln to dispose the municipal solid wastes is good way to choose. In Vietnam, there are more than 76 cement kilns, if it is assumed that each cement kiln could dispose 70 000 tons wastes per year (200 tons per day), the cement industry can dispose 5.3 million tons wastes per year, contributed for handling 23% of total MSW generation in Vietnam. The waste could turn into the components of cement and will not pollute again or leave any byproduct. The cement kiln can dispose different states wastes (Solid, Semi-solid or liquid). It is cheaper way of disposing MSW than building the incinerator plants (Lê Cao Chiến, 2016).

Use of AFR in cement kiln

The substitution of fossil fuels by alternative fuels (AF) in the production of cement clinker is ofgreat importance both for cement producers and for society because it conserves fossil fuels and, in the case of biogenic wastes, reduces greenhouse gas emissions. In addition, the use of alternative fuels can help to reduce the costs of cement production. Energy costs and environmental concerns have encouraged cement companies worldwide to evaluate to what extent conventional fuels can be replaced by waste materials, such as waste oils, mixtures of non-recycled plastics and paper, used tires, biomass wastes, and even wastewater sludge (D. Amsaveni et al, 2020).

Use of plastic waste in cement kiln

Various studies in a paper showed that there was no unfavorable impact on the environment, clinker and cement properties when plastic waste was used a fuel in cement production. Hence co-processing of plastic waste is one of the best alternatives for its disposal, saving of energy resource, in ecological sustainable and environmental friendly manner. The total cost saving per day was Rs. 9705 (Rs. 542,325 per annum) and 9 tons coal save per day. The co-processing of waste plastics reduces the overall CO2 emissions, after replacement of coal by plastic waste the total reduction of CO2 is17.81 tons/day or 6500 tons/annum. The cost of collection and treatment may limit the use of waste plastics‟ Interactions between coal and waste plastics can improve combustion efficiency (Ghosh, 2019).

Waste materials in cement production

it was found out that Various waste materials like Coating residues, aluminium recycling sludge, Industrial lime, Lime sludge, Fly ashes, Crushed sand, Roasted pyrite, Mechanical sludge, Red sludge contained compounds with cementious value and they could be also used as a raw material in production of cement. The goal was the ecologically beneficial and economically viable co-processing of high calorific waste materials as a contribution to the conservation of non-renewable primary energy resources. It is generally agreed that co-processing of waste in cement kilns can be a valid option for solving waste problems in developing and emerging countries, provided basic rules and principles are observed. (Dieter Mutz.2017)

CO-PROCESSING TECHNOLOGY

Co-processing is an industrial technique of using wastes as a substitute for raw materials and/or fuels, as a way to minimize the consumption of minerals and non-renewable fossil fuels (Stafford, 2015).Co-processing is a more environmentally friendly and sustainable method of waste disposal in comparison of land filling and incineration because of reduced emissions and no residue after the treatment (Geocycle). Wastes occur in different forms and qualities. The transformation of waste to AFR requires certain standards. Some types of waste cannot be used directly as AFR, but must undergo a preparation process. This step produces a waste product with defined characteristics that complies with the technical specifications of cement production and guarantees that environmental standards are met (GTZ, 2006).

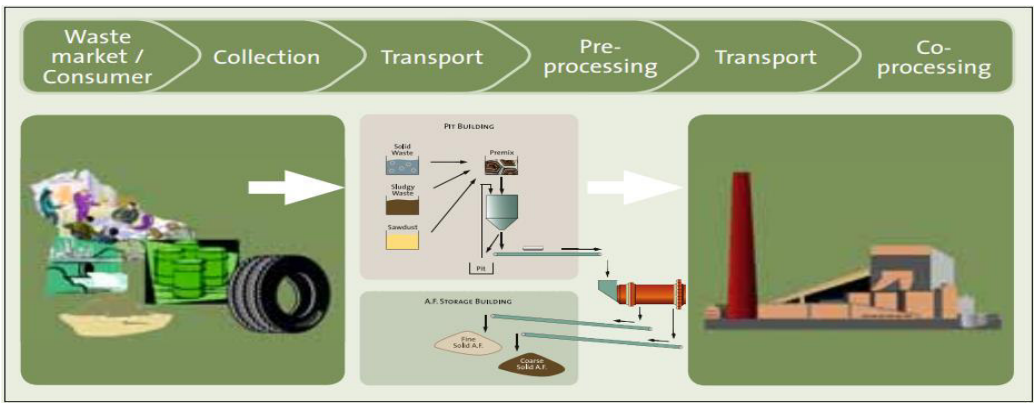

Figure (4): Pre-processing technology from waste to alternative fuel (GTZ, 2006)

Due to the high temperature (1450ºC) in cement kiln, different types of wastes can be successfully disposed without harmful emissions. As per the Basal Convention, wide variety of wastes including hazardous wastes, get disposed in an environmentally safe and sound manner through the technology of co-processing in cement kiln. Disposal of non-recyclable fraction of plastic wastes through co-processing is practiced in many countries as a regular method for their environmentally sound disposal. Different feed points can be used to insert AFR into the cement production process. The most common ones are:

- via the main burner at the rotary kiln outlet end
- via a feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel)
- via secondary burners to the riser duct
- via pre-calciner burners to the pre-calciner
- via a feed chute to the pre-calciner (for lump fuel)
- Via a mid-kiln valve in the case of long wet and dry kilns (for lump fuel) (GTZ, 2006).

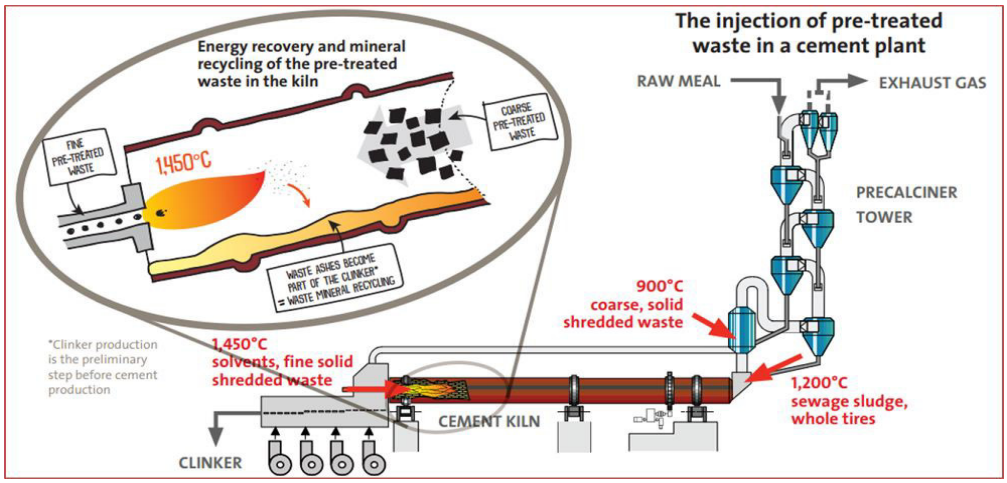

Figure (5): Co-processing technology in cement kiln (Geocycle)

EMISSION IN CO-PROCESSING

Carbon dioxide (CO_2) is the major oxide produced from the combustion of most fuels. Carbon monoxide (CO) is formed in the case of incomplete combustion as an intermediate product, and converted to CO_2 in the presence of oxygen. Potentially harmful acid gases, particulate matter and VOC are also associated with the combustion of fuels in cement kilns. A substantial amount of these emissions are due to the organic content of raw materials introduced into the kiln.

Emission of sulphur dioxide

Sulphur dioxide (SO_2) is generated from the combustion of fuels containing sulphur. Its formation and abundance are governed by the sulphur content of the fuel. Low sulphur coals have occasionally been blended with traditional coals to reduce SO_2 emissions. Several major utility providers and the U.S Department of Energy have also considered the co-firing of biomass with coal in boilers for the same purpose (Tillman.D.A, 2000). SO_2 can be removed, post-combustion, from the exhaust going through the kiln stack, by the use of scrubbers and adsorbents.

Emission of oxides of nitrogen

Formation of oxides of nitrogen (NO_x) increases exponentially with increasing temperature and excess air because air contains N_2 and O_2, which react to form thermal NO_x. NO_x formed by the oxidation of organo-nitrogen compounds found in the fuel is dependent on the reactivity of the fuel. Highly reactive fuels promote early release of nitrogen in the fuel mass. The nitrogen content in fuels is generally low; therefore, fuel derived NOx for cement kilns forms a small fraction of total NO_x expected after combustion in excess air (79% N_2) (Cembureau, 1999).

Emission of particulate matter

Particulate matter (PM) emissions are influenced by fuel composition and extent of combustion, especially PM with a median aerodynamic diameter ≤ 10 μm (PM10) or ≤ 2.5 μm (PM2.5) (Gibson, 2009). Total suspended particulates (TSP) which include all airborne PM (~ < 60 μm) are a function of the percentage of ash or mineral matter in the fuel, coupled with the unburned carbon resulting from incomplete combustion. It is also expected that a higher volatile content will reduce unburned carbon in the products of combustion leading to reduced TSP. Gases such as SO_2, NOx, and VOC's can also transform in the atmosphere to form secondary fine PM and ground-level ozone (O_3) by a number of chemical reactions (Tillman, 2012).

Emission of volatile organic compounds

The extent of thermal degradation of produced VOC's, such as benzene, xylene and toluene, is largely dependent on the prevailing temperature and residence time. At temperatures above 1000°C, and favorable retention time within this zone, the mixture of organic vapour from devolatilization of the solid fuel and air is oxidized to form CO, CO_2, NOx and H_2O, thereby removing harmful VOC's in emissions. Emissions of VOC's from the kiln stack are therefore more attributable to the release of the organic content of raw materials before reaching the high temperature zone of the kiln than to incomplete combustion of the fuel (Cembureau, 1999).

IMPROVEMENT OF ENVIRONMENTAL QUALITY BY USING ALTERNATIVE FUELS

The usage of Alternative fuels in cement manufacturing helps in reducing the emission, along with it plays role in significant ecological benefits of conserving non-renewable resources (Rahman, et al; 2013). The primary benefit of using alternative fuel is potential reduction in CO_2 emissions at plant level, as alternative fuels have lower carbon contents, on an energy basis, than fossil fuels. Co-processing in the European cement industry resulted in an approximately 18 percent reduction in conventional fuel (mostly coal) use, a reduction of about 8Mt of CO_2 emissions each year, and a savings of about 5Mt of coal (Cembureau, 2009). The CHG emissions can be reduced as for prevention of methane gas. Usage of alternative fuels also which will, reduce the environmental impacts of the extraction (mining or quarrying), transporting, and processing of fossil fuels by reducing of coal imports and conservation of fossil fuels (CII, 2016). Due to its advantages in terms of combustion of waste & no residual left over, hazardous wastes in alternative fuel can be disposed safely. Flame temperatures of up to 2000°C and high residence times provide good conditions for destruction of organic compounds also (Ghosh, et al; 2019). Considering the morphology of the waste used as alternative fuel, the environmental potential was analyzed not only for the waste sector but also for clinker production, which allows achieving the task – to estimate the environmental potential for co-processing of waste implementation (Kleshchov, et al; 2019).

IMPACT OF CO-PROCESSING ON PUBLIC HEALTH

Co-processing of alternative fuel in cement production can successfully convert the hazardous and other toxic materials into clinker, without producing any ash. Those hazardous and toxic materials dumped in the landfill site can cause various adverse effects on humans residing nearby the landfill sites. The various wastes in landfill sites generates foul smelling, which makes various contaminations, produces hygiene related issues and also spreads to the farming lands by leakage. The foul smelling of various toxic waste materials can also cause different health related problems for the people of near residence has been observed. An increased occurrence of health symptoms such as sleepiness, fatigue, headaches etc among residents near waste sites has consistently (Vrijheid; 2000). Leachate problem, forming from rain falling on top of the landfill or from groundwater addition, can also cause severe concern to the environment through producing toxins like Methane, Carbon Dioxide Organic Acids, Alcohols Aldehydes and many more and hence affecting public health . Water storage adjacent to the dump sites becomes contaminated due to dumping of solid hazardous wastes. Marine litter poses a major danger to charismatic species as Plastic bags and abandoned nets are a risk to

turtles, dolphins and seals. Plastic ingestion can guide to ulceration gastrointestinal blockages and internal perforation and death. About 15 % of the species affected through entanglement and ingestion are on the IUCN Red List (Ten Brink et al, 2016). Plastic debris such as discarded or lost fishing gears are threats to coral reefs. Similarly, sea grass beds are also at risk as plastic debris pile up on them. This is how plastic debits and marine litters become a real threat to the marine environment (Das et al; 2020) .This polluted water can be accumulated to the human body through Chemicals in the food chain leached from some plastics used in food/beverage storage are harmful to human health which may cause blood infection; and reduced oxidative stress, reproductive system abnormalities, even cancer (Padgelwar et al; 2019). Co-processing in cement kiln contributes helps in efficient eliminating plastic waste disposal in open landfills, hence promotes in reduction in dumping of water sources nearby, which creates marine littering problem (UNEP; 2019) .So, utilizing these waste materials as alternative fuels in co-processing process of cement manufacturing helps in reduction of waste accumulation in dumpsites subsequently helps in blockage the flow path to the ocean and other water storage nearby and can solve the marine littering problem (Intercement, 2019).

CASE STUDY: Co-processing of NRPW in cement plant, Ariyalur, Tamil Nadu
[Visit date – Feb. 06 - 08, 2021]
A visit was organized as working under the project "OPTOCE", an initiative of Norwegian company SINTEF in collaboration with Jadavpur University, West Bengal to cement manufacturing plants at Ariyalur district, Tamil Nadu.
The project OPTOCE is about research on use of non-recyclable plastics as an alternative fuel in cement kilns results in reducing marine litter and landfills area. The objective of the visit was to provide us an insight knowledge regarding mainly the usage of AFR in the cement manufacturing process and its components, internal working of the company and opportunity to learn practically through interaction regarding the manufacturing, quality control, packaging in the plant, etc.

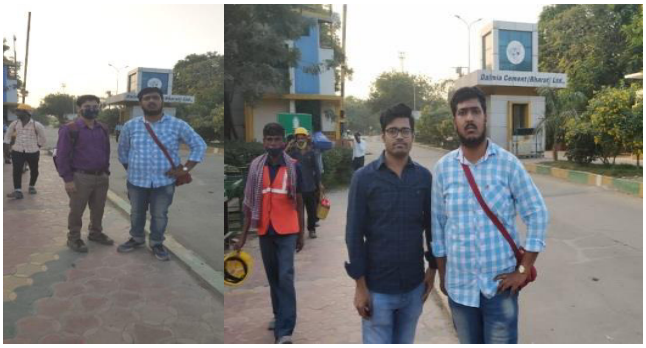

Figure (6): Picture captures at main entrance of cement plants in Ariyalur, Tamil Nadu.

Cement plants at Ariyalur in Tamilnadu take raw material (NRPW) from municipalities of Tiruchirappalli, Coimbatore, and Chennai. Private companies like Zigma segregate the plastic waste from dumpsites of mentioned places and send it to AFR plant of cement plants.
These private companies are handover the segregated waste to cement plants at zero cost and get subsidy from Government.
Cement plant take the responsibility for decomposition of these wastes without harming the environment. Dalmia also buy a huge amount of plastic waste from biscuit factories in Puducherry and paper mills near the plant. Plants receive the waste having size less than 500 mm and store it at the storage facility of AFR handling plant.
These wastes can't use directly for co-processing as an alternative fuel due to limitation of size and quality. For co-processing samples are taken from each vehicle and get tested. Dalmia cement plant has a separate lab for sampling and testing of the incoming waste from different location.

Table 1: Parameters and testing methods for sample of waste in cement plant

Sl. No.	Parameters	Unit	Test Method
1.	Ash content	%	Muffle Furnace (850^{0}C)
2.	Moisture content	%	Oven (188^{0}C)
3.	Gross calorific value (GCV)	Kcal/Kg	Bomb calorimeter
4.	Chlorine (Cl)	%	Volumetric analysis
5.	Sulphur (S)	%	Gravimetric analysis

After getting the test result, data matched with the government guidelines on co-processing of waste in cement kiln and allowed for co-processing or rejected to the respective supplier. Waste loaded to the conveyers attached with shredder and shredded up to size of 75 mm. these shredded waste passes through magnetic separator where all the ferrous part get removed. After magnetic separator it passes through a mechanical screen called screening of waster as per the required size. Screen segregates these wastes into more than 75 mm and less than 75 mm size. Waste having size of more than 75 mm get rejected and send again to the shredder through conveyors.

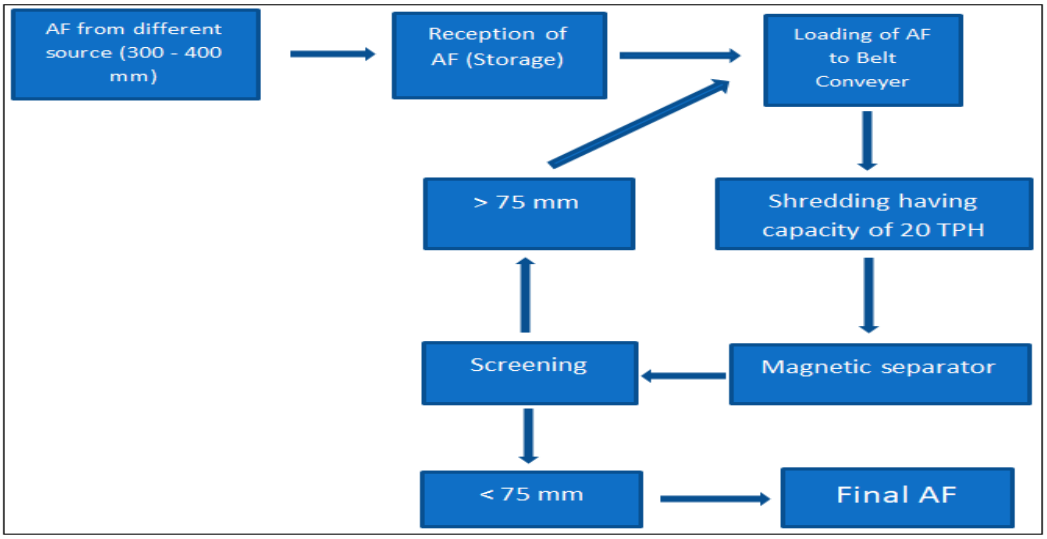

Figure (7): Flow chart for Pre-processing of Alternative Fuel in Cement plants

As per the data available in report of CPCB on plastic waste generation in 2018-19, total non-recyclable plastic waste co-processed in cement kiln is 1.38 million tons, which is around 4% of total plastic waste generated (3.36 million tons) and 38.4% of total plastic waste used for material and energy recovery in India (2018-19).

Table 2: Non-recycled plastic waste co-processed in cement kiln in India

Sl.	States & Uts	Amount of non-recycled plastic waste co-processed in cement kiln (Tons)
1.	Goa	6057.62
2.	Gujarat	86553.62
3.	Karnataka	25500
4.	Madhya Pradesh	18283
5.	Puducherry	272
6.	Telangana	1500
7.	Uttar Pradesh	21.37
Total		**1,38,188 tons**

Source: CPCB, 2019

DISCUSSION

Daily accumulation of waste materials is increasing heavily on a daily basis with increase in population, which are filling up landfill sites. We are presently running out of further land to be used as landfill sites. These waste materials are piling up, and causing heavy damage to our environment. So there is an immediate need to address this concern. Co-processing is one of the way to solve this problem. It can use up the waste materials and stop them from piling up in the landfill sites. Co-processing of alternative fuel in cement production can successfully convert the hazardous and other toxic materials into clinker, without producing any ash. Those hazardous and toxic materials dumped in the landfill site can cause various adverse effects on humans residing nearby the landfill sites which include reproductive system abnormalities, impaired brain, neurological functions, cancer, cardiovascular system damage and other sever issues. Not only, has human health, marine littering problem has impacts on marine life, it effects on Toxicology, Impacts on Inaction on Shipping and Tourism, and many more.
But further research and technology should be made in order to implement it successfully. Also, it should be economical. Standards on quality, environment, health of workers are also some concerns which needs to be addressed. It can be also analysed that if waste materials are used as fuel, amount of conventional fuel consumed daily, can also be readily reduced.

CONCLUSION

1) From the literatures and the case study on wastes from the various landfill sites, utilising as alternative fuels and raw materials (AFR), it can be evident that, alternative fuels not only minimise the overall cost of cement production and enhance the production efficiency, but also it helps to reduce the emission and upgrade the environmental quality around the cement plant.
2) Moreover the co-processing also promotes resource circularity by sustainable disposal of wastes from various landfill sites without formation any residual left over. Utilising waste as AFR also helps waste reduction in landfill sites, which will further promote waste reduction in landfill sites and helps in reduction of marine littering. In both ways
3) co-processing can help to cut down age old problem of land scarcity, as well as it will take a step forward to enhance the environmental quality to the surroundings of land filling site and the sea or river water nearby.
4) Reducing landfill volume, wastes can be collected directly from the source, like household or and market; where fresh waste are generated. So the waste quality will be enhanced as they can be collected separately and its pure form and also, cost for the waste dumping in dumpsites will be minimise.
5) So, encouraging co-processing of AFR can enhance the Thermal Substitution Rate (TSR) in Indian cement and which can help economically as well as environmental point of view.

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REFERENCES

[1] Ghosh, D.S., Ansari, S. A. (2019), An Investigation on Process Optimization in Cement Industries through Co-processing of Plastic Waste.

[2] Kleshchov, A., Hugi, C. J., Terentiev, O., Safiants, A.; Environmental potential analysis of co-processing waste in cement kilns; Eastern-European Journal of Enterprise Technologies 4/10(100):13-21
[3] Rahman, A., Rasul, M.G., Khan, M.M.K., Sharma, S. (2013): Impact of Alternative Fuels on the Cement Manufacturing Plant Performance: An Overview; Procedia Engineering 56: 393 – 400
[4] Cembureau, Sustainable Cement Production (2009): Co-Processing of Alternative Fuels and Raw Materials in the European Cement Industry.
[5] Confederation of Indian Industry; Promoting Alternative Fuel & Raw Material Usage in India Cement Industry; 2016
[6] Vrijheid, M.; Health Effects of Residence Near Hazardous Waste Landfill Sites (2000).: A Review of Epidemiologic Literature; Environ Health Perspect 108(suppl1):101-112.
[7] Intercemen; Co-processing: environmental, economic and public health gains (2019)
[8] Waste-Derived Fuels for Co-Processing In Rotary Cement Kilns by Ebenezer Afram Asamany, 2016.
[9] Tillman D.A. (2000): Co-firing benefits for coal and biomass, Biomass and Bioenergy. 19
[10] Cembureau (1999): "Best Alternative Techniques" for the cement industry.
[11] Gibson M.D., Heal M.R., Bache D.H., Hursthouse A.S., Beverland I.J., Craig S.E., Clark C.F., Jackson M.H., Guernsey J.R., Jones C. (2009): Using Mass Reconstruction along a Four-Site Transect as a method to interpret PM10 in West-Central Scotland, United Kingdom, Journal of the Air and Waste Management Association, 59.
[12] D.A. Tillman, D.N.B. Duong, N.S. Harding, Solid Fuel Blending - Principles, Practices, and Problems, in, Elsevier, 2012.
[13] M.D. Brace, E. Stevens, S. Taylor, S. Butt, Z. Sun, L. Hu, M. Borden, N. Khanna, J. Kuchta, J. Trites, R. Hart, M.D. Gibson, `The air that we breathe inverted question mark: assessment of laser and electrosurgical dissection devices on operating theater air quality, J Otolaryngol Head Neck Surg (2014).
[14] M.A. Bari, R.L.T. Curran, W.B. Kindzierski, Field performance evaluation of Maxxampassive samplers for regional monitoring of ambient SO_2, NO_2 and O_3 concentrations in Alberta, Canada, Atmospheric Environment, 114 (2015)
[15] L. Narang, Techno-economical assessment of alternative fuels in cement kiln, in: Department of Biotechnology and Environmental Sciences, Thapar University, Patiala, 2012.
[16] N. Themelis, M. Castaldi, Use of Alternative Fuels in Cement Production in, 2014.
[17] F. N. Stafford, M. D. Viquez, J. Labrincha, D. Hotza Advances and challenges for the co-processing in Latin American cement industry. International Congress of Science and Technology of Metallurgy and Materials. SAM – CONAMET, 2014.
[18] Holcim Group Support Ltd and Deutsche GesellschaftfürTechnischeZusammenarbeit (GTZ), 2006; Guidelines on co-processing Waste Materials in Cement Production, The GTZ-Holcim Public Private Partnership. Co-processing: a unique waste treatment solution, Geocycle
[19] D. Amsaveni, "Optimizing the usage of plastic waste in cement industry using discrete dynamic programming", Materials Today: Proceedings 21 (2020) 257–262,
{20] Sadhan Kumar Ghosh, "Co-processing of industrial waste in cement kiln – a robust system for material and energy recovery", Environmental Sciences 31 (2016) 309 – 317
[21] Abul Salam, "Environmental and Health Impact of Solid Waste Disposal At Mangwaneni Dumpsite In Manzini: Swaziland", Journal of Sustainable Development in Africa (Volume 12, No.7, 2010)
[22] Shobhit Maheshwari, "Role of Waste Management at Landfills in Sustainable Waste Management", *International Journal on Emerging Technologies* **8**(1): 324-328(2017
[23] H. D. Robinson, P. J. Maris, "The Treatment of Leachates from Domestic Waste in Landfill Sites", Journal (Water Pollution Control Federation), Jan., 1985, Vol. 57, No. 1 (Jan., 1985), pp. 30-38
[24] Xu Ya, Xue Xiangshan, Dong Lu, Nai Changxin , Liu Yuqiang , Huang Qifei, "Long-term dynamics of leachate production, leakage from hazardous waste landfill sites and the impact on groundwater quality and human health", Waste Management 82 (2018) 156–166

[25] Alireza Majdinasab, Qiuyan Yuan, "Performance of the biotic systems for reducing methane emissions from landfill sites: A review", Ecological Engineering 104 (2017) 116–130
[26] Muhammad Qasima, Huamei Xiao, Kang He, Ali Noman, Feiling Liua, Meng-Yao Chena, Dilbar Hussaind, Zakia A. Jamale, Fei Li, "Impact of landfill garbage on insect ecology and human health", ActaTropica 211 (2020) 105630
[27] Angela J. Nagle, Emma L. Delaney, Lawrence C. Bank, Paul G. Leahy, "A Comparative Life Cycle Assessment between landfilling and Co-Processing of waste from decommissioned Irish wind turbine blades", Journal of Cleaner Production 277 (2020) 123321
[28] Rahul Baidya, Sadhan Kumar Ghosh, Ulhas V. Parlikar, "Co-processing of industrial waste in cement kiln – a robust system for material and energy recovery", Environmental Sciences 31 (2016) 309 – 317
[29] Palash Kumar Saha, KåreHelge Karstensen, "*Co-processing of Alternative Fuels & Resources in Indian Cement Industry Baseline and Potential*", 2017, *International Society of Waste Management, Air and Water,* Global Waste Management 2017.
[30] Wendell de Queiroz Lamas, Jose Carlos Fortes Palau, Jose Rubensde Camargo, "*Waste materials co-processing in cement industry: Ecological efficiency of waste reuse*", 2013, Renewable and Sustainable Energy Reviews 19 (2013) 200–207
[31] Andrew Forrest, Luca Giacovazzi, Sarah Dunlop, Julia Reisser, David Tickler,Alan Jamieson, Jessica J. Meeuwig, "*Eliminating Plastic Pollution: How a Voluntary Contribution From Industry Will Drive the Circular Plastics Economy*", 2019, Frontiers in Marine Science, September 2019 | Volume 6 | Article 627
[32] Maria Luiza GrilloRenó, Larissa Ferrini Ferrari Alves, José Carlos Escobar Palacio, Lidiane La Picirelli de Souza, Felipe Orlando Centeno González, Pedro Jessid Pacheco Torres, "*Environmental analyze of cement production with application of wastes*", 2017, ENGEVISTA, V. 19, n.4, p. 916-930, Outubro 2017
[33] Williams, A, Buitrago, N. R., "*Marine Litter: Solutions for a Major Environmental Problem"* (2019); Journal of Coastal Research 35(3):648-663
[34] Das S; Jha P; Chatterjee A; "*Assessing Marine Plastic Pollution in India"*; (2020); IEG Working Paper No. 389 ;https://www.researchgate.net/publication/340862782 (accessed on 14.05.21)
[35] UNEP; "*Strategies to Reduce Marine Plastic Pollution from Land-based Sources in Low and Middle - Income Countries*"(2019)
[36] CPCB; "*Guidelines on Co-processing in Cement/Power/Steel Industry"* (2010)
[37] Padgelwar, S, Nandan, A Mishra, A. K.; "Plastic waste management and current scenario in India: a review"; International Journal of Environmental & Analytical Chemistry (2019)
[38] Ten Brink, P.; Schweitzer, J.-P.; Watkins, E.; Howe, M. (2016); "*Plastics Marine Litter and the Circular Economy"*- A briefing by IEEP for the MAVA Foundation