Co-processing waste materials in cement production: experience from the past and future perspectives

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Abstract: The neglected, municipal solid waste management has become an important issue for national and local governments in developing countries in recent times, not only because of the tremendous rise of wastes but also of the resultant environmental degradation and rising public concern. Co-processing of waste in cement plants has been used as a treatment option for certain waste material in Europe, the USA and Japan, however, its application is not common in Asia. If properly applied, co-processing of waste material in cement kilns offers an environmentally sound and financially feasible option for an improved waste management. Within a public private partnership, the German Development Corporation (GIZ) and the cement company Holcim developed internationally recognised guidelines as a tool for promoting environmentally sound co-processing. These guidelines were recognised by the Secretary of the Basel Convention and have been applied in many countries worldwide, including India. Currently, the co-processing of non-recyclable left-overs from municipal solid waste in cement kilns in India is being explored. This paper details out the above.

Keywords: co-processing; cement kilns; municipal solid waste.

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1 Present situation of waste management in India

Waste management is a neglected public service in many cities of India. Very often waste is discharged in sewers, buried or burnt within the premises, illegally dumped at unsuitable locations, or taken to landfills that fail to meet requirements for the environmentally sound disposal of waste. This can cause contamination of soil, water resources, and the atmosphere, leading to deterioration of the living conditions and health of the adjacent populations. Toxic substances and persistent compounds escape into the environment, are spread through the air over large areas, and can enter the food chain, affecting human and animal health.

Several factors can cause these problems:

- Not many local urban bodies have an integrated waste management strategy and only a few can offer an appropriate technical infrastructure for disposing of waste in a controlled and environmentally sound manner.
- Although a law concerning the controlled handling of waste exists, it is often not properly enforced.
- Uncontrolled disposal is usually the cheapest way to get rid of the waste, and the waste generators tend to be unwilling to pay much for adequate disposal.
- Political decision makers rarely pay enough attention to the subject of waste management, and may know little about the consequences for human health or the high cost of the remediation of the damage caused by uncontrolled waste disposal.

There is general understanding that waste management has to be improved, and different solutions are being discussed. Waste avoidance, cleaner production, producer responsibility or sustainable use of natural resources is only a few of the strategies being promoted. In spite of technological progress and an increasing social and political awareness, the problem of growing waste streams persists.

Attempts to build state-of-the-art incineration plants could not be realised as expected by some waste managers and political decision makers due to the lack of adequate quantities of the required streams of input material of waste, financial resources for the high investment and operating costs, the absence of required qualified personnel and proper monitoring by the urban local bodies. The operation of sanitary landfills for the final disposal of hazardous wastes are today still the exception and in those cases were secure landfills are in operation for municipal waste, the financial sustainability is hardly ensured.

As a conclusion, the present practice of final waste disposal in India must be regarded as problematic. Some progress could be achieved with recycling and composting; refuse derived fuel (RDF) plants have also been installed in some cities but still the aspects of use of this RDF has not been explored and the final disposal of domestic and hazardous

waste at sanitary landfills and any operational activity linked to incineration remains largely unexplored.

2 Cement production and waste management

The cement industry consumes a significant amount of natural resources and energy. Cement consumption is increasing, especially in an emerging country like India. Worldwide cement production in 2007 was 2.77 billion tones, with a steady increase of an estimated 3.6% per year (Cembureau: World Cement Production, Evaluation 2004). In order to be competitive and to contribute to a sustainable development, the cement industry continuously tries to improve environmental performance by optimising the use of natural resources and reducing its energy consumption.

One way of doing this is to gradually replace fossil fuel and primary raw materials with waste-derived materials.

Table 1 Key figures on cement

Worldwide cement production, now and in future:	Tons per year:
2007	2.77 billion
2020	3.80 billion
2050	5.40 billion
Average thermal energy consumption for 1 ton of clinker	3,500 MJ = 120 kg coal
Electrical energy consumption for 1 ton of cement	190 MJ
Share of energy costs in the total production cost of cement	30% to 40%
Source of CO_2 emissions in cement production	60% calcination process, 40% fuel
Total CO_2 emitted each year by the cement industry worldwide	Approx. 1.6 billion tons per year or 4% of the total CO_2 emissions

Source: Cembureau: Sustainable Cement Production (2009) and IEA: Energy Efficiency and CO_2 Emissions from the Global Cement Industry (2006)

3 Combining improved waste management with sustainable cement production: an opportunity to create a win-win situation

Alternative fuels and raw materials (AFR) from waste can play an important role in contributing towards reducing fossil fuel use and costs while conserving natural resources, lowering global CO_2 emissions, improving waste management and reducing the need for landfills. The use of AFR in resource and energy intensive industries is called co-processing.

> Co-processing is the use of waste as raw materials, or as a source of energy, or both, to replace natural mineral resources and fossil fuels such as coal, petroleum and gas in industrial processes.

A process is classified as co-processing if the waste contains a high calorific value (at least 8 MJ/kg), or a substantial raw material value (at least 50% ash or 80% raw material

in ash), or a combination of both. Co-processing fully respects the waste hierarchy and must be seen as an option to lower the industry's environmental footprint. Although co-processing proved to be successful mainly in the cement industry, it can be stated that the concept is applicable for any other resource and energy intensive industry.

In a few cases, specific types of hazardous waste, such as PCBs and obsolete or banned pesticides, are treated in cement plants. This is a disposal process that aims to ensure safe, affordable and environmentally sound treatment of highly hazardous wastes. However, certain categories of wastes like- the bio-medical wastes, asbestos containing waste, electronic scrap, batteries, explosives, corrosives, mineral acid wastes and radioactive wastes are not utilised for co-processing.

Since the co-processing approach can only be succeeded if clear legal provisions are in place and capacity building options are available. Holcim entered into a successful cooperation in the form of a public-private partnership (PPP) with GIZ – the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH. The PPP, which received funding from the German Ministry for Economic Cooperation and Development (BMZ), was launched in 2003 and had a time horizon of six years.

PPP aims at greater development-policy impact through cooperation between development organisations and private-sector businesses (GTZ, 2001).

Figure 1 Development synergies between public and private sector (see online version for colours)

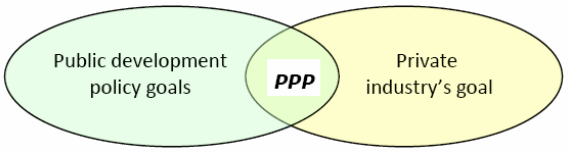


Table 2 Overview of waste and its sources for material recovery

Compounds	*Waste material*	*Industrial sources*
Clay mineral Al_2O_3	• Coating residues	• Foundries
	• Aluminium recycling sludge	• Aluminium industry
Limestone $CaCO_3$	• Industrial lime	• Neutralisation process
	• Lime sludge	• Sewage treatment
Silicates SiO_2	• Foundry sand	• Foundries
	• Contaminated soil	• Soil remediation
Iron-oxide Fe_2O_3	• Roasted pyrite	• Metal surface treatment
	• Mechanical sludge	• Metal industry
	• Red sludge	• Industrial waste water treatment
Si-Al-Ca-Fe	• Fly ashes	• Incinerator
	• Crushed sand	• Foundries
Sulphur S	• Gypsum from gas desulphurisation	• Incineration
	• Chemical gypsum	• Neutralisation process
Fluorine	• CaF_2 filter sludge	• Aluminium industry

Within that context, Holcim, one of the world's leading suppliers of cement has adopted a cement production strategy based on the gradual substitution of fossil fuels and additives

by AFR that are already in use. 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. But as it can be seen in Table 2, it also provides an overview of waste and its sources used for material recovery (Schneider, 2003).

4 Guidelines on co-processing waste material in cement plants

The main objective of the GIZ-Holcim cooperation was to develop "internationally recognised guidelines governing the co-processing of waste materials in cement production and their model application in selected countries". The idea behind those guidelines was to formulate international standards for co-processing to be applied in a sustainable and responsible way. Those standards would be valid for industrialised and developing countries alike.

The content of the guidelines (*Holcim-GIZ Guidelines on Co-processing Waste Material in Cement Production*, 2006) is based on experience from industrialised and developing countries, as well as from the public and private sectors. The guidelines take into consideration international conventions such as the Basel (SBC, 2004) and the Stockholm Conventions and the UN Framework Convention on Climate Change. They are considering initiatives of bilateral or multilateral organisations to improve waste management at national and local levels, as well as attempts by the cement industry to reduce the negative environmental impacts of cement production. The work of the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD), which looks at options for improving environmental performance and increasing corporate social responsibility was also considered.

The guidelines are aimed at government organisations and public institutions, local communities, non-governmental organisations, the cement industry and their associations as well as waste generators and waste companies. They can provide those target groups with relevant information on:

1 technical and legal conditions

2 environmental and safety standards

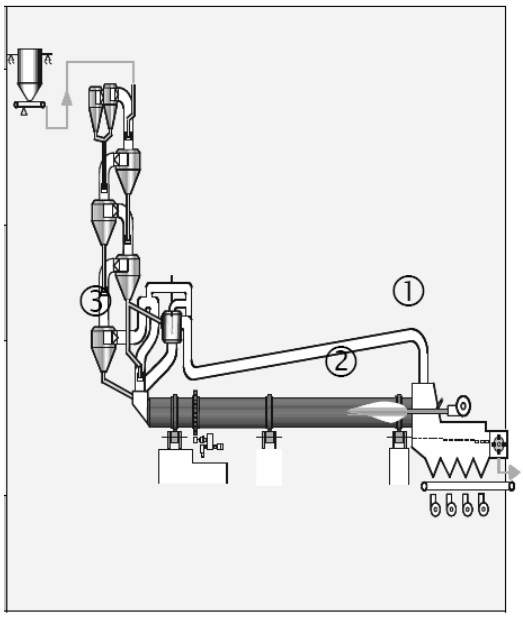
3 professional requirements needed to ensure that co-processing of waste does not have negative environmental or human health impacts.

The guidelines offer an overview of strategies for communication and stakeholder engagement and give recommendations for the permitting process as well as for control and enforcement procedures. The document also provide links to organisations, institutions, and companies active in the field of co-processing and propose ways and means for capacity building at all levels to ensure sound application of the technology.

The guidelines cover aspects for the preparation of AFR (pre-processing) and for feeding them in the kiln itself (co-processing). Aspects such as storage, transport, and environmental awareness are also dealt with.

Figure 2 Temperature and residence time during cement production

Characteristics	*Temperature and time*
Temperature at main burner ① of the rotary kiln ②	> 1,450°C: material > 1,800°C: flame temperature.
Residence time at main burner	> 12–15 sec > 1,200°C > 5–6 sec > 1,800°C
Temperature at precalciner ③	> 850°C: material > 1,000°C: flame temperature
Residence time at precalciner	> 2–6 sec > 800°C



Source: *Holcim-GIZ Guidelines on Co-processing Waste Material in Cement Production* (2006)

The basic concept of the guidelines is built on technical features and specific characteristics of the cement production process which makes it attractive for co-processing of waste:

- flame temperature in the main burning zone reaches 1,800 to 2,000°C
- high gas temperature and retention time guarantees the total and reliable destruction of all kinds of organic compounds
- sintering of all solid materials takes place at temperature of about 1,450°C in the rotary kiln
- lime acts as gas cleaner and neutralises acidic emissions
- there are uniform burnout conditions regardless of load variations due to the high thermal capacity of the rotary kiln
- high retention capacity for particle-borne heavy metals
- complete utilisation of fuels ashes as clinker components and hence simultaneous material recycling and energy recovery
- no generation of production-specific wastes due to complete material utilisation
- chemical-mineralogical trace elements are incorporated into the clinker matrix
- optimum energy recovery of more than 95% can be achieved.

5 Results achieved

GIZ along with Holcim has been active in the past in many countries with the objective to improve waste management systems and to close gaps in legislation. The work paved the way for the transfer of technological expertise and provides an example of how to disseminate integrated waste management systems. The main results achieved include:

- Implementation of the guidelines in more than 20 countries, combined with the provision of training and advisory services to interested parties from the public and private sector (including NGOs)
- Translation of the guidelines into seven languages
- Ensuring Holcim Group companies co-process waste in compliance with both company policy and GIZ-Holcim Guidelines
- Accreditation of most of the Holcim plants for quality and environmental management systems and implementation of an occupational health and safety system
- Undertaking trial burns for environmental impact assessments to prove stable product quality and controlled emissions.

Besides these direct results, the PPP has contributed to converting elements of the ambitious UN Millennium Goals into reality by implementing innovative concepts and new forms of cooperation. Cement companies have improved their efficiency and reduced their ecological footprint. GIZ has enabled partner governments in developing countries to manage waste more effectively and use resources in a sustainable manner.

In addition to these direct results, a considerable number of other impacts can be cited:

- The project made a concrete contribution towards more ecological and economical management of waste materials in the selected countries
- Co-processing waste materials in cement kilns is accepted as an alternative form of waste treatment that sensibly supplements – instead of competing with – the principle of ‘prevention – recycling – disposal’. Co-processing is an integrated part of local and national waste management concepts and strategies
- Adopting a win–win strategy, the project promoted a dialogue between public authorities and private enterprises, which is essential for successful waste management
- Taking co-processing of waste materials in cement kilns as an example, the project raised awareness and built up technical know-how. This can have positive developmental impacts across the entire waste management sector
- Dialogue with international and national NGOs, local communities and political decision-makers took place on the basis of recognised scientific criteria, leading to better acceptance and enabling people with divergent positions to engage in a different form of debate

- Pressures on increasingly scarce fossil energy resources are being reduced and countries are able to reduce the levels of foreign currency they spend on costly fossil fuel and raw materials
- The replacement of primary fuels such as coal and oil by high-energy waste materials helps to protect the climate.

Table 3 General principles for pre- and co-processing waste materials in cement production

Principle I	Co-processing respects the waste hierarchy: • Co-processing does not hamper waste reduction efforts, and waste shall not be used in cement kilns if ecologically and economically better ways of recovery are available. • Co-processing shall be regarded as an integrated part of modern waste management, as it provides an environmentally sound resource recovery option for the management of wastes. • Co-processing is in line with relevant international environmental agreements, namely the Basel and Stockholm Conventions.
Principle II	Additional emissions and negative impacts on human health must be avoided: • To prevent or keep to an absolute minimum the negative effects of pollution on the environment as well as risks to human health. • On a statistical basis, emissions into the air shall not be higher than those from cement production with traditional fuel.
Principle III	The quality of the cement product remains unchanged: • The product (clinker, cement, concrete) shall not be abused as a sink for heavy metals. • The product should not have any negative impact on the environment as e.g. demonstrated with leaching tests. • The quality of cement shall allow end-of-life recovery.
Principle IV	Companies engaged in co-processing must be qualified: • Have good environmental and safety compliance track records and to provide relevant information to the public and the appropriate authorities. • Have in place personnel, processes, and systems demonstrating commitment to the protection of the environment, health, and safety. • Assure that all requirements comply with applicable laws, rules and regulations. • Be capable of controlling inputs and process parameters required for the effective co-processing of waste materials. • Ensure good relations with the public and other actors in local, national and international waste management schemes.
Principle V	Implementation of co-processing has to consider national circumstances: • Country specific requirements and needs must be reflected in regulations and procedures. • A stepwise implementation allows for the build-up of required capacity and the setup of institutional arrangements. • Introduction of co-processing goes along with other change processes in the waste management sector of a country.

6 Conclusions

Contamination of water and soil, toxic residues, the inefficient use of non-renewable fossil fuels and global warming are in the forefront of ecological concerns and public discussions. Cost competitiveness, global competition and profitability are the concerns of business. The challenge facing today's society is to balance environmental protection and economic interest. Co-processing is an ideal example how to link business activities with providing a service for environmental protection. It also demonstrates the commitment of the private sector for its corporate social and environmental responsibility and the attempt of public authorities to assure impact oriented cooperation.

Co-processing waste materials in cement production offers plainly apparent advantages, if basic rules and principles are observed. Experiences over the past years revealed that there is a worldwide need for information, capacity building and for technical expertise on co-processing.

The development of the guidelines represents a highly successful policy network process. The guidelines themselves and the approach advocated therein have been met with considerable interest beyond the initial four pilot countries (Chile, Mexico, Morocco, and Philippines). Additional requests from authorities and organisations from more than 20 countries confirmed that there is a strong interest in getting more information about co-processing as a practical option for solving the 'burning' waste management problems in their respective countries.

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. There is a common understanding that high environmental standards must be set and their enforcement ensured. Special attention must always be given to the following components:

- Changes in or adaptations of laws and regulations so that co-processing acquires legal status and is considered in national waste management plans
- Use of a decision tree for co-processing as an integrated part of a waste management system. This will help to document the path of decisions that lead to co-processing and make them transparent.
- Skills and knowledge of personnel and government regulators/inspectors on waste incineration, including toxic/hazardous waste.
- Proper enforcement of the legal framework for all waste management activities, combined with monitoring by the authorities and strict enforcement of regulations
- Sound knowledge of established disposal paths in order to identify potentially improper disposal at an early stage.
- Prevention of rival disposal paths that are less viable both environmentally and economically.
- Establishment of local emergency preparedness and response programmes, in addition to any national programmes.
- Assuring transparency in information and communication schemes.

Strong partners, shared visions and a clear commitment have proved to be key success factors in the strategic alliance between the private and public sector. Compared to 'traditional' development cooperation, a PPP has a more practical approach: resources can be accessed more easily and quickly and may potentially be used in a more sustainable way, as the 'private' part of the work continues after the partnership has ended.

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