Co-processing of waste-derived fuels

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One of the ways in which the global cement industry is looking to reduce CO_2 emissions is through the further substitution of conventional fossil fuels with non-fossil (gaseous, liquid, pulverised, coarse crushed) alternative (or secondary) fuels for resource efficiency and economic reasons. In fact, the industry has already increased its usage of alternative fuels nine-fold since 1990. Here we take a step-by-step look at best practice in the co-processing of waste-derived fuels.

Many regulations do not explicitly restrict the use of alternative waste-derived fuels (WDFs) to certain categories or concentration limits but focus on emission limits only. Other regulations specify an explicit list of acceptable WDFs with maximum and/or minimum concentrations for various parameters – heavy metals, chlorine, calorific value – known as a "positive" list. Some regulations specify a "negative" list with waste categories that are not allowed to be co-processed. Regardless of the approach chosen, the local raw material and fuel chemistry, the infrastructure and the cement production process, the availability of equipment for controlling, handling and feeding the waste materials, and site-specific health, safety and environmental issues will determine the waste categories to be accepted at a specific plant.

Input control – general rules

The supplier of the WDF as well as the waste's chemical and physical properties need to be established prior to use. Consistent long-term supply of appropriate waste is required to maintain stable conditions during operation. The content of sulphur, nitrogen, chlorine, fluorine, metals and volatile organic compounds (VOC) needs to be specified and carefully controlled. Limitations in terms of the product and/or the process should be established. Feeding of the WDF to the kiln must ensure exposure to sufficient temperature, sufficient retention time, sufficient mixing conditions and surplus oxygen (O_2) ensuring complete oxidation. The waste type and composition will determine the adequate feeding point, ie, the main or the secondary burner in the precalciner/preheater, and the kiln inlet will ensure temperatures > 900˚C. No waste should be fed as part of a raw mix feed if it contains organics, and no waste feed should be fed during start-up or shutdown. Handling and feeding systems should be appropriate to the waste used, and must ensure stable and controlled input to the kiln. The operator should assess risks from fugitive emissions, and equipment failure modes and appropriate safeguards should be incorporated into the design to prevent environmental pollution, health and safety problems. Automated monitors should be employed to alert operators in the event of a waste handling problem. Interlocks should be provided to stop the flow of waste automatically if either normal fuel or feed supply, or combustion airflow is interrupted (fans stopped or reduced), or if carbon monoxide (CO) levels indicate problems with combustion efficiency.

Selection of feed point

The use of WDFs should not detract from smooth and continuous kiln operation, product quality, or the site's normal environmental performance. Therefore, a constant quality and feed rate of the waste materials must be ensured. The feed point for wastes into the kiln should be selected according to the nature of the wastes used (see Figure XX.1).

Coarse crushed and lump fuels can be fed to the calciner, kiln inlet or to the mid-kiln valve only (with some exceptions). Organic hazardous wastes should be introduced in the high-temperature combustion zone of the kiln system, ie, the main burner, the precalciner burner, the secondary firing at the preheater, or the mid-kiln for long dry and wet kilns. It is important to bear in mind the following:

- Chlorinated organic compounds should be introduced at the main burner to ensure complete combustion due to the high combustion temperature and long retention time. Other feed points are appropriate only where tests have shown high destruction and removal efficiency rates.
- Alternative raw materials (ARM) with VOCs should not be introduced with other raw materials in the process, unless tests have shown that undesired emissions at the stack do not occur. Such raw materials can be fed through a double or triple flap arrangement into the kiln inlet.
- Mineral inorganic wastes free of organic compounds can be added to the raw meal or raw slurry preparation system. Mineral wastes containing significant quantities of organic components are introduced via the solid fuels handling system, ie, directly to the main burner, to the secondary firing or, rarely, to the calcining zone of long wet or dry kilns.
- Mineral additions such as granulated

Figure XX.1: feeding of liquid and pulverised waste through the main burner

Figure XX.2: feeding of waste-derived mineral additions to the cement mill

blastfurnace slag (GBS), fly ash from thermal power plants or industrial gypsum, can be fed to the cement mill (see Figure XX.2).

Operations and process control

Operating requirements should be developed to specify the acceptable composition of the waste feed, including acceptable variations in the physical and/or chemical properties of the waste. For each waste, the operating requirements should specify acceptable operating limits for feed rates, temperatures, retention time, O_2, etc. For start-up, shutdown, or upset conditions of the kiln, written instructions should be issued, describing conditions of use of wastes. Kiln operators should know and understand these instructions.

The general principle of good operational control of the kiln system using conventional fuels and raw materials should be applied. All relevant process parameters should be measured, recorded and evaluated continuously and may cover free lime, O_2 concentration and CO concentration.

Kiln operation and feeding of wastes

The plant should characterise a good operation and use this as a basis to improve other operational performance. Having characterised a good and stable kiln, establish reference data by adding controlled doses of waste, and look at changes and required controls and practice to control emissions. The impact of wastes on the total input of circulating volatile elements, such as chlorine, sulphur or alkalis, must be assessed carefully prior to acceptance as they may cause operational problems in the kiln system.

The kiln process must be operated to achieve stable conditions, which may mean applying process control optimisation (including computer-based automatic control systems) and the use of modern, gravimetric solid fuel feed systems. Input limits and operational set points for these components should be set individually by the site based on the process type and on the specific site conditions. Procedures for stopping waste feed in the event of an equipment malfunction or other emergency must be implemented and the set points for each operating parameter that would activate feed cut-off must be specified. The waste feed must also be cut off when operating conditions deviate from limits established in the permit.

No organic hazardous waste burning should take place unless the cement kiln is operating at normal temperatures in the range of 1100-1600˚C and instrumentation must be provided to record continuously the rate of flow of these wastes. Feeding of organic hazardous wastes should not be permitted during periods of kiln start-up, shutdown, major upset or conventional (coal) fuel interruption. The kiln coating temperature should also be measured by a recording optical pyrometer and conventional (coal) fuel flow should be continuously measured and recorded.

System controls and set points should provide for the automatic shutdown of the introduction of wastes in the event of the following:

- Cement kiln temperatures fall below 1100˚C.
- Conventional raw meal and fuel flow is interrupted.
- Kiln speed decreases to below 60rph.
- Loss of draught occurs in the firing hood and main fan stoppage.
- The kiln should be always operated in an oxidising atmosphere. O_2 in the kiln exhaust gases must be maintained at a level of not less than 1.5 per cent and be continuously recorded.
- If the outside skin temperature of the kiln exceeds 500˚C, the feed of wastes should be stopped and shutdown should be initiated for repair of the refractory.
- Waste introduction into the kiln should cease in the event of kiln ring formation.
- WDFs must not be used during failure of the air pollution control devices. The kiln exhaust gases must be quickly conditioned and cooled to lower than 200˚C to avoid formation and release of dioxins and other persistent organic pollutants (POPs).
- Fugitive emissions must be prevented and controlled and the off-gas dust from the filters should be fed back into the kiln to the maximum extent practicable, to reduce issues related to treatment and emissions. Dust that cannot be recycled should be managed in a manner demonstrated to be safe.

Laboratory and quality control

The plant needs an adequate laboratory with sufficient infrastructure, including sampling, instrumentation and test equipment. Inter-laboratory tests should be carried out periodically to check and improve the performances and maintenance of the laboratory. Personnel must be competent and should be trained according to their specific needs and to the nature of the wastes used. Fuels, raw materials and any waste entering, being processed or produced at the site, should be controlled regularly. A plan should provide detailed instructions for personal assignment, sampling, frequency of sampling and analysis, laboratory protocols and standards, calibration procedures and maintenance, and recording and reporting protocol.

Initial waste evaluation

Cement kilns are normally heated and fired using pulverised mineral coal with a predefined particle size distribution and consistent heat, ash and water content. Any alternative fuels (AFs) used by a local cement plant should ideally resemble the same characteristics as coal, ie, be continuously available in large quantities with high and uniform quality, low water and ash content, a fineness appropriate for the desired feeding point, good flowability and metrability for low excess air combustion, and not cause any environmental or product damage.

The types of AFs and their availability needs to be carefully considered prior to starting local co-processing activities. Therefore, sourcing and the need for pre-treatment/pre-processing of the AF are crucial first steps. The aim of the initial acceptance procedure is to set the outer boundaries and limits for the wastes that can be accepted by a particular kiln, and the conditions and requirements for their preparation and delivery specification. Any waste fed to a cement kiln should be homogenous, have stable heat and moisture content, stable chemical and physical composition, and a pre-specified distribution.

In real life, a cement plant operator usually receives wastes from various producers with various waste characteristics. To fulfil the requirements mentioned above, wastes must often be pre-processed prior to delivery to the cement plant. However, the cement plant operator must specify the requirements for waste acceptance with the waste owner and the pre-processing facility prior to any deliverables. It is also important to consider the compatibility of the non-combustible inorganic elements present in the waste and the ash, with the clinker mineral chemistry, and the tolerance for additional elements such as chlorine, fluorine, bromine, phosphorus, zinc, sulphur and heavy metals.

Waste acceptance

Wastes should only be accepted from trustworthy parties throughout the supply chain, with traceability ensured prior to reception by the facility and with unsuitable wastes refused. The pre-processing facility and cement plant operator must develop an evaluation and acceptance procedure that includes the following features:

- To evaluate possible impacts before delivering the waste to the cement plant or pre-processing facility, each waste supplier must prepare a representative sample. This must include a datasheet detailing the chemical and physical properties, information on relevant health, safety and environmental considerations during transport, handling and use of the material. It must also specify the source of the particular shipments being made.
- Test and check the sample's physical and chemical characteristics against specifications.

Assessment of possible impacts

When the cement plant operator and the pre-processing facility have received information about the waste, it is important to:

- Assess the potential impact of transporting, unloading, storing and using the material on the health and safety of employees, contractors and the community. Ensure that equipment or management practices required to address these impacts are in place.
- Assess what personal protective equipment (PPE) will be required for employees to safely handle the waste on site.
- Assess the compatibility of wastes –reactive or non-compatible wastes must not be mixed.
- Assess the effect the waste may have on the process operation. Chlorine, fluorine, sulphur and alkali content in wastes may build up in the kiln system, leading to accumulation, clogging and unstable operation. Excess chlorine or alkali may produce cement

Figure XX.3: inspection of drums with hydrocarbon sludge before pre-processing

Figure XX.4: sampling and analysis of alternative fuels at the pre-processing facility

kiln dust or bypass dust (and may require installation of a bypass) that must be removed, recycled or disposed of responsibly. The heat value is the key parameter for the energy provided to the process. Wastes with high water content may reduce the productivity and efficiency of the kiln system. The ash content affects the chemical composition of the cement and may require an adjustment of the composition of the raw materials mix.

- Assess the potential impact on process stability and quality of the final product.
- Assess the effect the waste may have on plant emissions and whether new equipment or procedures are needed to ensure that there is no negative impact on the environment.
- Determine what materials analysis data the waste supplier will be required to provide with each delivery, and whether each load needs to be tested prior to off-loading at the site.

Commonly-restricted wastes

Develop a uniform list of restricted wastes valid for the plant based on the previous impact assessment and the plant's raw material and fuel composition. Certain cement companies choose not to treat certain wastes and materials, including infectious and biological active medical waste, asbestos and radioactive waste. Individual companies may exclude additional materials depending on local circumstances and company policy. Shipments crossing international boundaries and classified as hazardous waste under the Basel Convention must meet with the requirements of the convention.

Risky wastes

When the waste composition cannot be described in detail, the cement plant operator and the pre-processing facility may agree with the waste producer on specific packaging requirements, ensuring that the waste will not react during transport or within containers. For example, risks may arise from waste with phosphides, cyanide with acids, and wastes with mercury and thallium.

Check list for acceptance control

Delivered wastes must generally undergo specific admission controls, whereby the previously received declaration by the waste producer provides the starting point. After comparison by visual and analytical investigations with the data contained in the declaration, the waste is either accepted and allocated to the appropriate pre-processing and/or storage area, or rejected in the case of significant deviations.

Prior to signing any commercial contract, the cement plant operator must ensure that:

- The waste generator, collector and pre-processing facility provide adequate information on the composition and risks of the material.
- They do not accept any substances, compounds or preparations that are not allowed or on the "negative" list.
- They prohibit blending of incompatible materials and perform compatibility tests if needed.
- They perform sampling on the site of the generator, collector or the pre-processing facility and analysis before acceptance of commercial contracts. Sampling and analysis can be carried out by own, or external, certified laboratories.
- They do not start transportation to plant site before completion of the acceptance process. This acceptance process does not replace sampling and analysis of waste deliveries at the plant sites.
- They communicate the inherent safety and health risks indicated by the waste generator, collector or pre-processor, or identified by the sample analysis to the downstream operations (transport, pre- and co-processing) to ensure that PPE and installations are adapted accordingly.
- They provide simple, clear and practical handling procedures, based on the material properties, to each person who will work with the waste.
- They provide commercial employees with adequate training in chemistry to allow them to enforce the waste acceptance criteria.

Waste reception and handling

Wastes received in drums at the pre-processing facility and cement plant must have been packed, labelled and loaded properly to ensure that it reaches the plant in good condition. The transport of packed waste, typically waste in drums, should present detailed instructions on the types of material. All wastes received at the plant should initially be treated as being unknown and hazardous until compliance with specifications has been positively verified (see Figure XX.3). Vehicles carrying wastes must stop upon arrival and make the necessary identifications. Such vehicles should be:

- Weighed in and out of the site and deliveries must be recorded.
- Documents relating to vehicles carrying hazardous waste must be checked and compliance with site acceptance specifications and regulations determined.
- Document checks should cover waste certificates, transport certificates, etc.
- Instructions for unloading, including safety and emergency instructions, should be provided in due time to vehicle drivers.
- A vehicle found not to comply should not be allowed to enter the site.

Management for non-compliant deliveries

Written instructions must describe what to do in the case of non-compliance with specifications and the waste producer must be informed about non-compliant deliveries. If non-compliance cannot be cleared with the producer, the shipment must be rejected and if required in the permit, authorities must be notified. Deliveries should be evaluated for each waste producer on a statistical basis to assess the performance and reliability of the producers, and contracts should accordingly be reviewed periodically.

Checking, sampling and testing incoming wastes – general considerations

Delivered wastes must undergo specific admission controls, whereby the previously received declaration by the waste producer provides the starting point. Vehicle loads should be sampled and analysed once on site (see Figure XX.4) according to the frequency and protocol defined in the site control plan, checking agreement with site specifications according to the plan of control. Accept wastes once their properties are confirmed to agree with specifications.

Assess incoming wastes

Apply a suitable regime for the assessment of incoming waste. Such assessment must reveal:

- that the wastes received are within the range suitable for the installation
- whether the wastes need special handling, storage, treatment and/or removal for off-site transfer
- whether the wastes are as described by the supplier (for contractual, operational or legal reasons).

Techniques for checking

Techniques for checking vary from simple visual assessment to full chemical analysis. The extent of the procedures adopted will depend upon:

- the nature and composition of the waste
- heterogeneity of the waste
- known difficulties with wastes (of a certain type or from a certain source)
- specific sensitivities of the installation concerned (eg, certain substances known to cause operational difficulties)
- whether the waste is of a known or unknown origin (the latter should be avoided)
- existence or absence of a quality-controlled specification for the waste
- whether the wastes have been dealt with before and the plant's experiences with it.

Waste pre-processing

The use of wastes must not detract from smooth and continuous cement kiln operation, product quality, or the site's normal environmental performance, implying that wastes used in cement kilns must be homogenous and have a stable chemical composition and heat content, and a pre-specified size distribution. Pre-processing and preparation with the objective of providing a more homogeneous feed and more stable combustion conditions may therefore be necessary. Such pre-processing can include drying, shredding, grinding or mixing, depending on the type of waste.

This is usually carried out in a purpose-built facility, which may be located outside or inside the cement plant. If the AF is prepared outside the cement plant, the fuels only need to be stored at the cement plant and then proportioned for feeding them to the cement kiln.

Figure XX.5: shredded tyres and rubber waste

Alternative fuels

AFs can be subdivided into five classes:

1. gaseous – eg, petcoke oven gases, refinery waste gas
2. liquid – eg, hydraulic oils, insulating oils. Some equipment can be sealed under a nitrogen blanket to reduce fire and explosion risks when handling liquids.
3. pulverised, granulated or fine crushed solids – eg, ground waste wood, granulated plastic.
4. coarse crushed solids – eg, crushed tyres, rubber/plastic waste (see Figure XX.5).
5. lumps – eg, whole tyres, plastic bales.

Mixing and homogenisation of wastes will generally improve feeding and combustion behaviour. Mixing of wastes can involve risks and should be carried out according to a prescribed recipe.

Pre-processing and mixing of AFs

Techniques used for waste pre-processing and mixing are wide ranging and may include:

- mixing and homogenising of liquid wastes to meet input requirements eg, viscosity, composition and/or heat content
- shredding, crushing and shearing of packaged wastes and bulky combustible wastes, eg, tyres
- mixing of wastes in a bunker using a grab or other machine (eg, sprelling machines for sewage sludge)
- production of refuse-derived fuel (RDF), usually produced from source separated waste and/or other non-hazardous waste.

Solid heterogeneous wastes can be mixed in a bunker or a pit prior to loading into transport or feed systems. In bunkers the mixing involves blending of wastes using cranes and the crane operators can identify potentially problematic loads (eg, baled wastes, discrete items that cannot be mixed or will cause loading/feeding problems) and ensure that these are removed, shredded or directly blended (as appropriate) with other wastes. Crane capacity must be sufficient to allow mixing and loading at a suitable rate.

Segregation of waste types for safe processing

Waste acceptance procedures and storage depend on the chemical and physical characteristics of the waste. Appropriate waste assessment is an essential element in the selection of storage and input operations and is strongly related to the checking, sampling and assessment of incoming wastes. The segregation techniques applied vary according to the type of wastes received at the plant. Segregation relates to maintaining separation of materials to avoid hazardous mixtures. Extensive procedures are required to separate chemically incompatible materials.

Proper labelling of the wastes (eg, in accordance with the European Waste Catalogue) that are delivered in containers, assists with their identification and traceability, and ensures:

- knowledge of waste content, which is required for the choice of handling/processing operations
- the operator's ability to trace sources of problems and then take steps to eliminate or control them
- the ability to demonstrate conformance with restrictions on waste types and quantities received/processed.

Bar code systems and scan readers can be used for packaged and liquid wastes. The costs of such systems are low in relation to the benefits.

General design considerations

Carefully consider the cement plant and the pre-processing facility layout to ensure access for day-to-day operations, emergency escape routes, and maintainability of the plant and equipment.

Apply recognised standards to the design of installations and equipment. Any modifications to installations and equipment should meet requirements set in the standards. Thoroughly evaluate existing equipment refitted for a different service from a safety and performance standpoint before resuming commercial production. Document any modifications to installations and equipment.

Assess operations for health and safety risks or concerns to ensure that equipment is safe and to minimise risks of endangering people or installations, or damaging the environment. Use appropriate procedures to assess risks or hazards for each stage of the design process. Only competent and qualified personnel should undertake or oversee such hazard and operability studies.

Design for reception and storage of hazardous wastes

Establish suitable and safe transfer systems from transportation to the storage area to avoid risks from spillages, fugitive emissions or vapours. Suitable vapour filtration and capture equipment should be in place to minimise impact to the reception point and surrounding areas from unloading activities. Transfer and storage areas must be designed to manage and contain accidental spills into rainwater or firewater, which may be contaminated by the materials. This requires appropriate design for isolation, containment and treatment as follows:

- All ground area within diced, storage areas must be sealed so that spills will not penetrate the ground.
- Sealed concrete surfaces with well controlled drainage are recommended.
- All leaks, spills, rainwater, etc, should be easily collected and saved for destruction.
- No run-off water from the waste chemical storage area should be discharged to sewers. Any such run-off should be redirected into storage tanks for subsequent high temperature destruction in the kiln.
- Leak-free design should be specified whenever possible.
- Methods to contain and recover piping leaks without environmental contamination should be provided.

- Adequate alarms for abnormal conditions should be provided.

Monitoring systems capable of detecting volatile organic vapours should be placed at key process locations to signal accidental waste fuel leaks. Periodic monitoring for VOC emissions should be provided. All volatile organic emissions from waste storage and pre-processing facilities could be exhausted to the cement kiln for complete destruction. Alternatively, a closed vapour line between the storage tank vents and the tank trucks should be provided to return the displaced volatile organic vapours from the storage tanks to the tank truck, when loading the tanks. A back-up carbon adsorption vapour control system could be provided to control VOC storage tank breathing emissions. Explosion proof safety valves should be used.

Housekeeping

General tidiness and cleanliness contribute to an enhanced working environment and can allow potential operational problems to be identified in advance. The main elements of good housekeeping are:

- the use of systems to identify and locate/store wastes received according to their risks
- the prevention of dust emissions from operating equipment
- effective waste water management
- effective preventive maintenance.

Waste storage

Limit waste volumes in storage and waste storage time to a minimum. Maximum allowed waste storage should be determined on the installed fire protection systems, which should include early warning sensors like temperature and smoke detectors. Define limits for waste and processed waste storage time per type of material in the permit, taking into consideration the corresponding health and safety risks (toxicity, reactivity, flammability/explosion potential, and storage conditions) and local regulations.

Ensure that storage facilities are fit for purpose. In general, the storage of wastes needs to consider the unknown nature and composition of wastes, as this gives rise to additional risks and uncertainties. In many cases, this uncertainty means that higher specification storage systems are applied for wastes than for well-characterised raw materials.

A common practice is to ensure, as far as possible, that hazardous wastes are stored in the same containers (drums) that are used for transport, thus avoiding the need for additional handling and transfer. Good communication between the waste producer and the waste manager helps to ensure wastes are stored and transferred, etc, so that risks all along the chain are well managed. It is also important that only well characterised and compatible wastes are stored in tanks or bunkers.

Best available techniques (BAT) and best environmental practice (BEP)

Advancements in the cement industry will concentrate on the further development of new technology and on the utilisation of secondary materials and other supplementary cementitious materials (SCMs). In recent years improvements in cement production lines with precalcining systems include homogenisation technology, new preheating and precalcining systems with the capacity of up to 10,000tpd of cement, various new types of crushing and grinding systems, new operation and management systems, and new environmental protection measures such as the use of new bag dust collectors and low NO_x burners. The utilisation of secondary materials and SCMs may save huge amounts of natural resources.

BAT/BEP for cement production

Dry preheater/precalciner kilns are regarded to be the best available techniques and to constitute the best environmental practice. These technologies are also the most economically feasible option, which constitutes a competitive advantage and thereby contributes to the gradual phasing out of older, polluting and less competitive technologies. For new plants and major upgrades, the best available techniques for the production of cement clinker is a dry process kiln with multi-stage preheating and precalcination. A smooth and stable kiln process, operating close to the process parameter set points, is beneficial for all kiln emissions as well as energy use. This can be obtained by applying:

- process control optimisation, including computer-based automatic control systems
- the use of modern fuel feed systems
- minimising fuel energy use by means of preheating and precalcination to the greatest extent possible, considering the existing kiln system configuration.

Careful selection and control of substances entering the kiln can reduce emissions and when practicable, homogenous raw materials and fuels with low contents of sulphur, nitrogen, chlorine, metals and VOC should be selected.

Controlling emissions of polychlorinated dibenzodioxins (PCDD) and dibenzofurans (PCDF)

PCDD/PCDF control in cement production becomes a simultaneous effort to reduce the precursor and/or organic concentrations, preferably by finding a combination of optimum production rate and optimum gas temperatures and O_2 level at the raw material feed end of the kiln and reducing the air pollution control device (APCD) temperature. Feeding of ARMs as part of the raw material mix should be avoided if it includes elevated concentrations of organics and no AFs should be fed during start-up and shut down. The most important measure to avoid PCDD/PCDF formation in wet kilns seems to be quick cooling of the kiln exhaust gases to lower than 200˚C.

Modern preheater and precalciner kilns already inherently have this feature in the process design and have APCD temperatures less than 150˚C. Operating practices, such as minimising the build-up particulate matter on surfaces, can assist in maintaining low PCDD/PCDF emissions.

Conventional fuels

Three different types of conventional or fossil fuels are used in cement kiln firing in decreasing order of importance – pulverised coal and petcoke, fuel oil (heavy) and natural gas. To keep heat losses at a minimum, cement kilns are operated at the lowest reasonable excess O_2 factors. This requires highly uniform and reliable fuel metering as well as the fuel being present in a form which allows for easy and complete combustion (fuel preparation process and fuel storage). These conditions are fulfilled by all pulverised, liquid and gaseous fuels, be it conventional or AFs. Therefore, the main fuel input (65-85 per cent) has to be of this type whereas the remaining 15-35 per cent may be fed in coarse crushed or lumpy form. Fuel feed points to the cement kiln system are via the:

- main burner at the rotary kiln outlet end
- feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel)
- fuel burners to the riser duct
- precalciner burners to the precalciner
- feed chute to the precalciner (for lump fuel)
- mid-kiln valve to long wet and dry kilns (for lump fuel).

The fuel introduced via the main burner to the hot zone of the rotary kiln produces the main flame with temperatures of around 2000˚C. For process optimisation reasons the flame must be adjustable within limits. The flame is shaped and adjusted by the so-called primary air (10-15 per cent of total combustion air) through interaction of the outer axial air ring channel as well as of the conical inner air ring channel of the (main) burner.

Cement quality

The cement plant must carry out chemical and physical analysis for all relevant parameters concerning cement quality and potential clinker contamination on a routine basis and all data must be recorded. Co-processing of AFs will not affect the cement quality and this must be documented. The operator must be aware that fluorine, phosphate and zinc influences setting time and strength development of the cement, that chlorine, sulphur and alkalis affect overall product quality, and that chromium may cause allergic reactions in sensitive users.

The classification of cements in terms of their strength-giving properties has been practised for many years. It is impractical for cement producers to test the cements they make with all the many different sands and aggregates and in the wide range of mix proportions they are likely to meet in practice. Therefore, standard test procedures have been developed to enable manufacturers to control their production. The strength-giving characteristics of cements can take the form of assessments at early (2-3 days) or late (28 days) ages or both. The European ENV 197-1 places primary emphasis upon the 28-day strength and for this purpose introduces three classes – 32.5, 42.5 and 52.5 – representing the minimum characteristic strength in N/mm^2, which the cement is required to achieve at 28 days from tests made in accordance with the test method described in European Standard EN 196-1.

Co-processing wastes in cement kilns – a summary

There are several benefits of using WDFs in cement kilns, such as:

- Facilities and infrastructure are already in place – and operate 24/7.
- Circular economy, ie, recovers energy and saves fossil fuel and raw materials.
- Usually cost-efficient, compared to other alternatives.
- Energy efficiency approaches 90-100 per cent.
- The industry usually bears the investment and operation costs.
- Inherent features, eg, time and temperatures, are excellent for waste destruction.
- Usually there are no residues to dispose of.
- Emissions will normally be unaffected if properly operated.
- Reduces CO_2 emissions compared to incineration and landfilling.

Preventing and reducing risks

The following requirements and prerequisites should be in place to prevent and reduce risks to the greatest extent possible prior to using WDFs in cement kilns on a routine basis:

1. an approved environmental impact assessment (EIA) and all necessary national/local licences
2. compliance with all relevant national and local regulations
3. BAT/BEP performance and compliance with the Basel and the Stockholm Convention
4. approved location, technical infrastructure, and processing equipment
5. reliable and adequate power and water supply
6. adequate air pollution control devices and continuous emission monitoring ensuring compliance with regulation and permits; needs to be verified through regular baseline monitoring
7. exit gas conditioning/cooling and low temperatures (<200˚C) in the air pollution control device to prevent dioxin formation
8. clear management and organisational structure with unambiguous responsibilities, reporting lines and feedback mechanism
9. an error reporting system for employees
10. qualified and skilled employees to manage hazardous wastes and health, safety and environmental issues
11. adequate emergency and safety equipment and procedures, and regular training
12. authorised and licensed collection, transport and handling of wastes
13. safe and sound receiving, storage, preparation and feeding of wastes
14. adequate laboratory facilities and equipment for hazardous waste acceptance and feeding control
15. demonstration of hazardous waste destruction performance through test burns
16. adequate record keeping of wastes and emissions
17. adequate product quality control routines
18. an environmental management and continuous improvement system certified according to ISO 14001, EMAS or similar
19. regular independent audits, emission monitoring and reporting
20. regular stakeholder dialogues with local community and authorities, and for responding to comments and complaints
21. disclosure of performance reports on a regular basis.

Emission monitoring

Emission monitoring is obligatory to demonstrate compliance with existing laws, regulations and agreements. Emission monitoring is also needed to control the input of conventional materials and their potential impacts. Sulphides in raw materials may result in the release of sulphur dioxide (SO_2) and organic carbon in raw materials will result in CO, CO_2 and VOC emissions. Heavy metals in fuel and raw material, especially volatile heavy metals, which are not completely captured in the clinker, must be assessed, monitored and controlled.

Figure XX.6: emission monitoring is obligatory to comply with laws, regulations and agreements

Continuous emission measurements

To monitor the process and accurately quantify the emissions, continuous emission measurements are recommended for the following parameters – exhaust volume, humidity, temperatures, particulate matter, O_2, NO_x, SO_2, CO, VOCs, hydrogen chloride (HCl) and pressure. Periodic monitoring should be conducted for the following substances on a regular basis – metals and their compounds, total organic carbon, hydrogen fluoride (HF), ammonia (NH_3), PCDD/PCDF, and chlorobenzenes, HCB and PCBs including coplanar congeners and chloronaphthalenes. Measurements of the following substances may be required occasionally under special operating conditions, such as demonstration or the destruction and removal efficiency (DRE) and the destruction efficiency (DE) – benzene, toluene and xylene; polycyclic aromatic hydrocarbons; other organic pollutants. It is especially important to measure metals when wastes with higher metal content are used as raw materials or fuels.

Additional measures for exit gas cleaning

Activated carbon filters have high removal efficiencies for trace pollutants (> 90 per cent). Pollutants such as SO_2, organic compounds, metals, NH_3, ammonium (NH_4^+) compounds, HCl, HF and residual dust may also be removed from the exhaust gases by adsorption on activated carbon. Selective catalytic reduction can be applied for NO_x control. The process reduces NO and NO_2 to N_2 with the help of NH_3 and a catalyst at a temperature range of about 300-400˚C, which imply heating of the exhaust gases.

Test burn and performance verification

Test burns are recommended for the demonstration of the DRE and the DE of certain principal organic hazardous compounds (POHC) in a cement kiln. The DRE is calculated on the basis of mass of the POHC content fed to the kiln, minus the mass of the remaining POHC content in the stack emissions, divided by the mass of the POHC content within the feed. The DRE considers emissions to air only. The DE considers all out-streams (liquid and solids) in addition to the air emissions and is the most comprehensive way of verifying the performance. Test burns with hazardous compounds require professional supervision and independent verification. Test burns with non-hazardous hazardous waste are usually not a regulatory requirement but are sometimes done to evaluate the behaviour of the process and the influence on main gaseous emissions and the cement clinker quality when feeding waste to the kiln. Such simplified tests are usually conducted by process engineers at the cement plant using already installed on-line monitoring equipment and process operational data.

More information

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