

ALTERNATIVE FUELS IN CEMENT MANUFACTURE

TECHNICAL
AND ENVIRONMENTAL REVIEW



CEMBUREAU PRESENTATION

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The Association acts as spokesman for the cement sector towards the European Union institutions and other authorities, and communicates the industry's views on all issues and policy developments likely to have an effect on the cement market in the technical, environmental, energy and promotion areas. Permanent dialogue is maintained with the European and international authorities and with other International Associations as appropriate.

Serviced by a multi-national staff in Brussels, Standing Committees and issue-related Project Groups, established as required, enable CEMBUREAU to keep abreast of all developments affecting the industry.

CEMBUREAU also plays a significant role in the world-wide promotion of cement and concrete in co-operation with member associations, and the ready-mix and precast concrete industries. The Association regularly co-hosts conferences on specific issues aimed at improving the image of concrete and promoting the use of cement and concrete products.

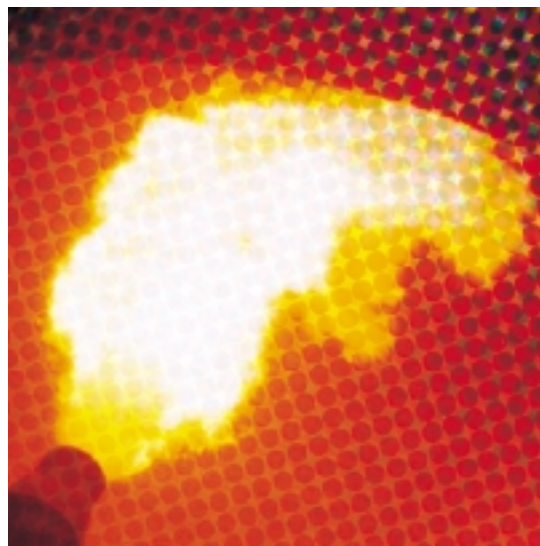
Since its foundation in 1947, CEMBUREAU has developed into the major centre for the dissemination of technical data, statistics and general information on the cement industry world-wide. Its publications serve as the principal source of information on the cement industry throughout the world. It is the editor of the "World Cement Directory" providing data on cement companies and works based in some 150 countries.



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**TECHNICAL
AND ENVIRONMENTAL REVIEW**



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EXECUTIVE SUMMARY

The use of cement has long been the basis for development of society and for the welfare of the people. For generations concrete, which is made from cement, has been the ultimate material for construction of harbours, roads, bridges, dams, houses, schools, hospitals.

The cement industry in the European Union produces about 170 million tonnes of cement each year. It contributes significantly to local and regional economies through more than 300 plants spread all over Europe and often in rural areas.

The cement industry recognises its responsibility to manage the environmental impact associated with the manufacture of its products. Over the past 20 years specific energy consumption has been reduced by about 30%, equivalent to approximately 11 million tonnes of coal per year. Dust emissions have been reduced by 90% as the industry has invested heavily in various emission abatement techniques.

Cement is produced in accordance with European and national legislation as well as internal procedures. Strict regulations are applied and plants are operated on the basis of permits from national authorities. Emissions are regularly checked by the authorities.

The cement industry is able to use waste as alternative fuels and raw materials to reinforce its competitiveness and at the same time contribute to solutions to some of society's waste problems in a way which valorises the waste and is beneficial to the environment. The use of alternative fuels today substitutes

approximately 2.5 million tonnes of coal every year.

The use of waste as alternative fuels in the cement industry has numerous environmental benefits such as:

- The use of waste as alternative fuels reduces the use of non-renewable fossil fuels such as coal as well as the environmental impacts associated with coal mining.
- The use of waste as alternative fuels also contributes towards a lowering of emissions such as greenhouse gases by replacing the use of fossil fuels with materials that would otherwise have to be incinerated with corresponding emissions and final residues.
- The use of alternative fuels in cement kilns maximises the recovery of energy from waste. All the energy is used directly in the kiln for clinker production. It also maximises the recovery of the non-combustible part of the waste and eliminates the need for disposal of slag or ash, as the inorganic part substitutes raw material in the cement.

The use of waste as alternative fuels is a safe way of valorising waste. The organic constituents are completely destroyed due to the high temperatures, long residence time and oxidising conditions in a cement kiln. The inorganic constituents combine with the raw materials in the kiln and leave the process as part of the cement. Heavy metals in the cement end up bound in the concrete. Concrete made from cement manufactured using alternative fuels has the same construction and environmental properties as concrete made from cement manufactured using fossil fuels.

INTRODUCTION

This publication was prepared by CEMBUREAU with the assistance of ERM (Environmental Resources Management) to provide information on the usage of selected waste materials in the European cement industry and in particular the usage of organic materials as substitutes for fossil fuels.

The primary objective of a cement company is to produce and sell high quality cement. Whilst respecting this purpose, the use of waste materials can

bring a number of benefits both to the cement industry and to society in general. This publication gives background information concerning the manufacture of cement and the regulatory framework, and describes the special characteristics of cement plants which provide for the safe and effective use of alternative fuels. Competitiveness can be reinforced and at the same time some of society's waste problems can be solved in a way which valorises the waste and is beneficial to the environment.

**Bernburg plant -
5000 t/day capacity**

The primary
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Valorisation
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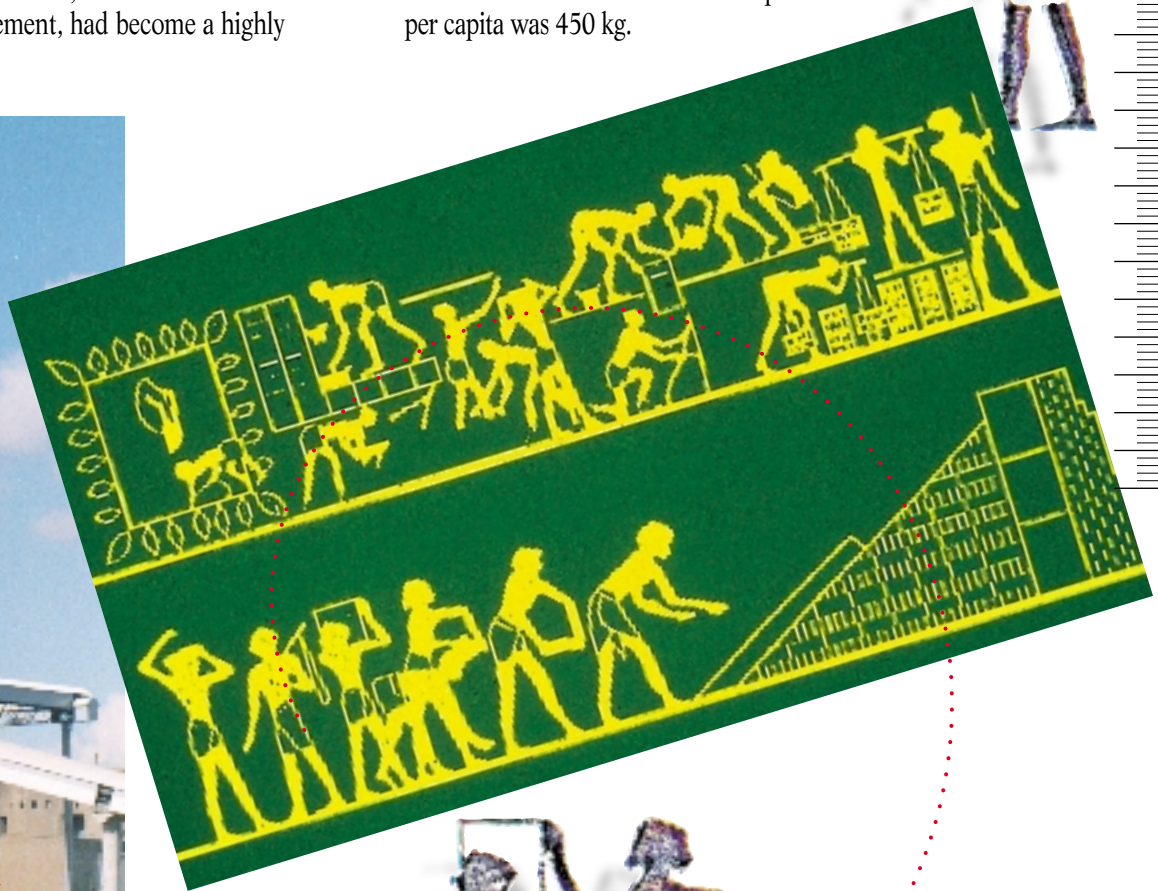
BACKGROUND

The European cement industry

Cement has played a key role as a construction material throughout the history of civilisation. In Europe the use of cement and concrete in large civic works can be traced from antiquity through modern times. Portland cement was patented in 1824 and by the end of the 19th century concrete, based on Portland cement, had become a highly

appreciated construction material throughout Europe.

Cement manufacturing is a major mineral commodity industry. In 1995 the world production of cement was 1420 million tonnes. In the European Union cement is produced in more than 300 plants. The total cement production in the European Union amounted to 172 million tonnes in 1995 and the consumption was 168 million tonnes. The cement consumption per capita was 450 kg.



The use of cement has contributed
to the welfare of society
for generations.

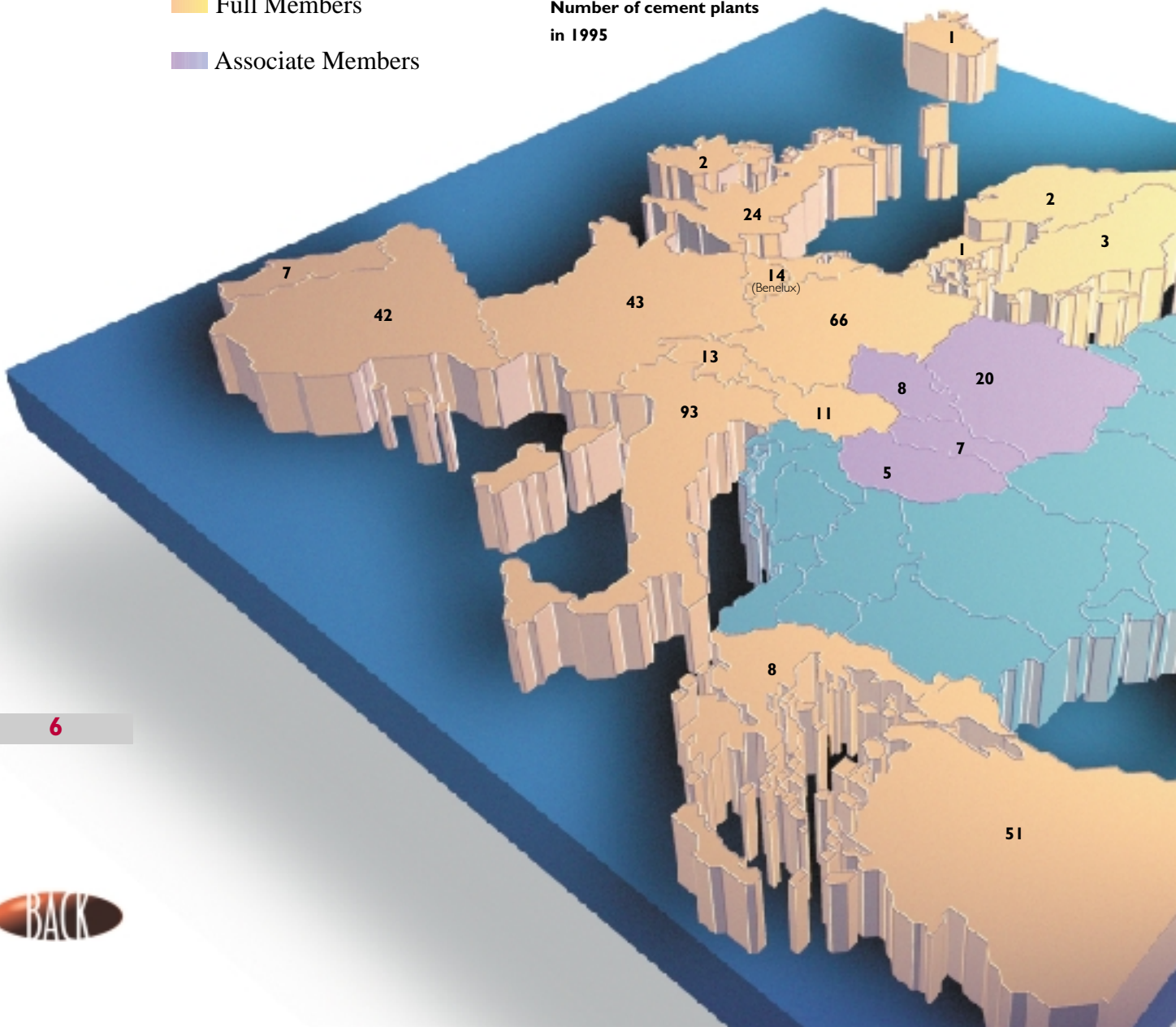
The cement industry
contributes significantly to local
and regional economies.

From water supply to waste water systems, from roads and bridges to air transport infrastructure and harbours, from residential houses to commercial and industrial structures, from schools to hospitals, concrete is the essential material in providing for development of man's activities.

The cement industry is a highly capital intensive industry, with yearly capital investments in CEMBUREAU member countries in the order of ECU 1 billion.

Full Members
Associate Members

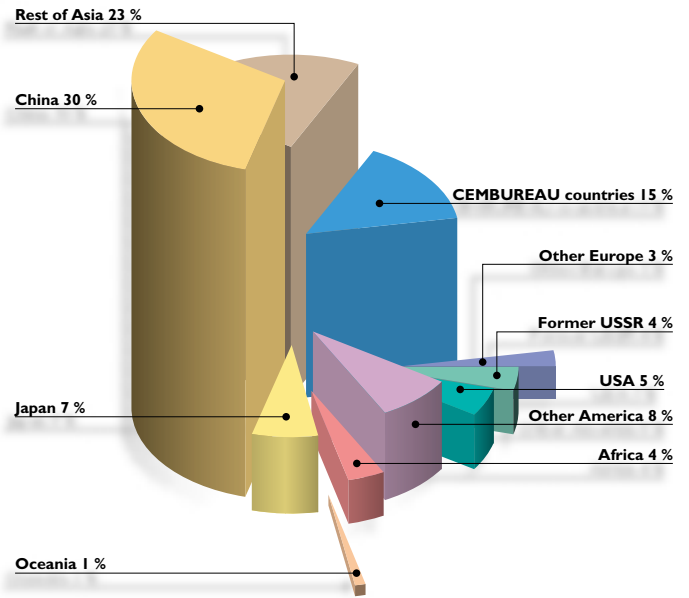
Number of cement plants in 1995



The huge investments and long pay-back periods for process modifications make the cement industry very careful in selecting and developing new technologies.

The use of cement has contributed to the welfare of society for generations. The cement industry significantly contributes to local and regional economies through the wide geographic spread of its plants which are mainly located in rural areas.

World cement production 1995



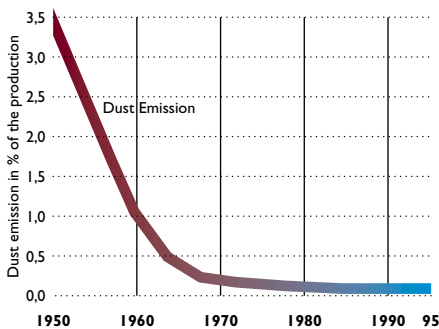
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Responsible environmental management by the cement industry

The cement industry recognises its responsibility to manage the environmental impact associated with the manufacture of its products. Over the past few decades the European cement industry has demonstrated an impressive record in continual environmental improvement within the context of the sustainable manufacture and use of cement. A few examples of these achievements and their resulting benefits to the wider environment are as follows:

- Dust emissions have been reduced by 90% over the last 20 years, as a result of refinements in the production process and substantial investment in modern product handling methods and air pollution control equipment.

Reduction of dust emission

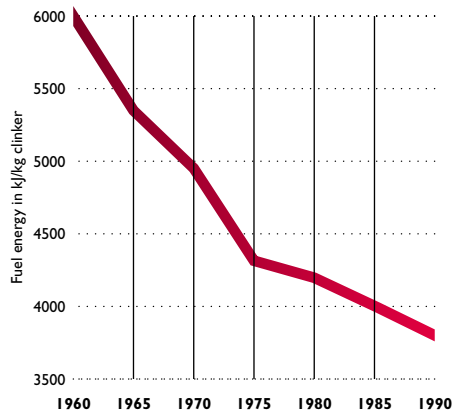


- The industry has been at the forefront of developing and applying quarry restoration methods to return depleted quarries to productive, scenic or recreational use.

- The specific energy consumption for the production of cement clinker has been reduced by approximately 30% since the 1970s. This reduction in primary energy requirements is equivalent to approximately 11 million tonnes of coal per year with corresponding benefits in reduction of CO₂ emissions.
- Research into improved cement products has resulted in increased

Reduction of specific energy

Development of the specific fuel energy consumption in CEMBUREAU countries since 1960



strength performance and more efficient use of cement.

- Conservation of natural non-renewable resources has been obtained through the valorisation of wastes as raw materials for clinker production and as alternative fuels. Through this valorisation the cement industry contributes to solving society's waste problems by reducing the amount of waste to be disposed

of (with additional benefits in emission of CO₂).

- The use of blended cements in which blastfurnace slag, power station fly ash, natural pozzolana or limestone is used together with cement clinker is contributing further to the conservation of primary natural mineral resources and fossil fuels, and to the reduction of atmospheric emissions, especially of CO₂.



**Old quarries
used for
recreational
leisure time**

REGULATORY FRAMEWORK

The cement industry, like other industrial sectors, is strictly regulated.

The cement industry, like other industrial sectors, is strictly regulated via national and international legislation regarding environmental protection, health and safety and quality of products.

The manufacture of cement is a mature industrial activity and the emission control regulations currently applied to the industry are the result of extensive review and refinement over a number of years. Legislation regarding emissions from cement plants exists in all EU countries and the cement plants measure emissions under the control of regulatory authorities. These national systems have proved effective in regulating the use of ordinary fuels as well as alternative fuels in cement kilns to the overall benefit of the environment.

The rules for national regulation of cement plants are laid down at European level in the European Community Directive on the combating of air pollution from industrial plants (84/360/EEC). These rules are being replaced by those in the new Directive on Integrated Pollution Prevention and Control (96/61/EC) – the “IPPC” Directive. This new important environmental legislation aims at achieving a high level of protection for the environment as a whole by means of measures “designed to prevent or, where that is not practicable, to reduce emissions” to air, water and land.

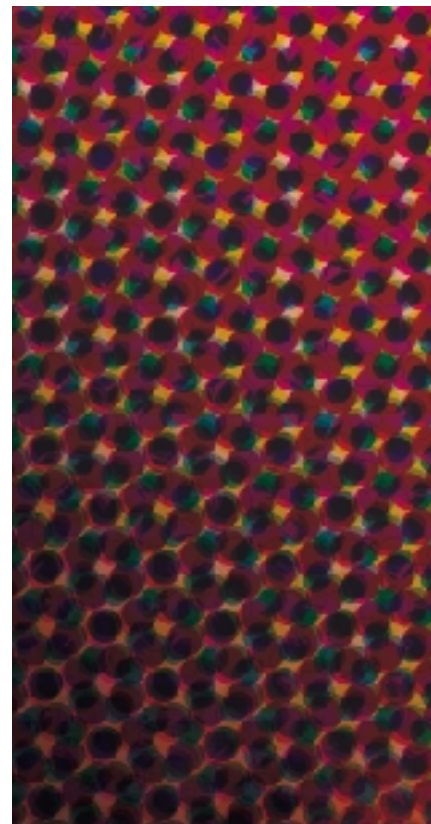
The use of hazardous waste as an alternative fuel in cement kilns is regulated at EU level by Directive

94/67/EC. While the Directive sets out rules for the burning of hazardous wastes in dedicated plants for incineration of waste, it also recognises and provides for the procedure of co-combustion or co-incineration, that is the burning of wastes in industrial furnaces (such as cement kilns) not exclusively designed for such purposes. The Directive also accepts the need to take account of emissions from raw materials and fuels other than hazardous fuels in setting emission controls on exhaust gases from cement kilns.

The same strict standards that are applied to dedicated hazardous waste incinerators are also applied in cement

IPPC Directive covers procedures for granting operation permits. Permits shall include emission limits for dust, SO_x, NO_x, heavy metals and organic compounds.

These limits shall be set by national Authorities based on “Best Available Techniques”.



National permit systems
effectively control the use of
ordinary fuels as well as
alternative fuels to the
benefit of the environment.

kilns to the emissions which result from the combustion of hazardous waste.

The European Commission, the Parliament and the Council have recently published their reviews of the Community Strategy for Waste Management originally established in

1989. All three documents have a certain flexibility regarding the application of the waste management hierarchy. The utilisation of alternative fuels in the cement industry is supported by the general principles of waste management at both European Union and national levels.

The wastes used as alternative fuels in cement kilns would alternatively either have been landfilled or destroyed in dedicated incinerators with additional emissions as a consequence. Their use in cement kilns replaces fossil fuels and maximises the recovery of energy.

Employing alternative fuels in cement plants is an important element of a sound waste management policy. This practice promotes a vigorous and thriving materials recovery and recycling industry, in line with the essential principles of the EU's waste management hierarchy.

Waste Management

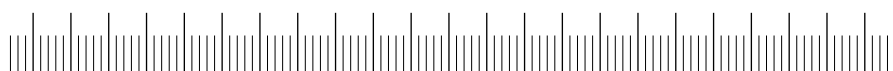
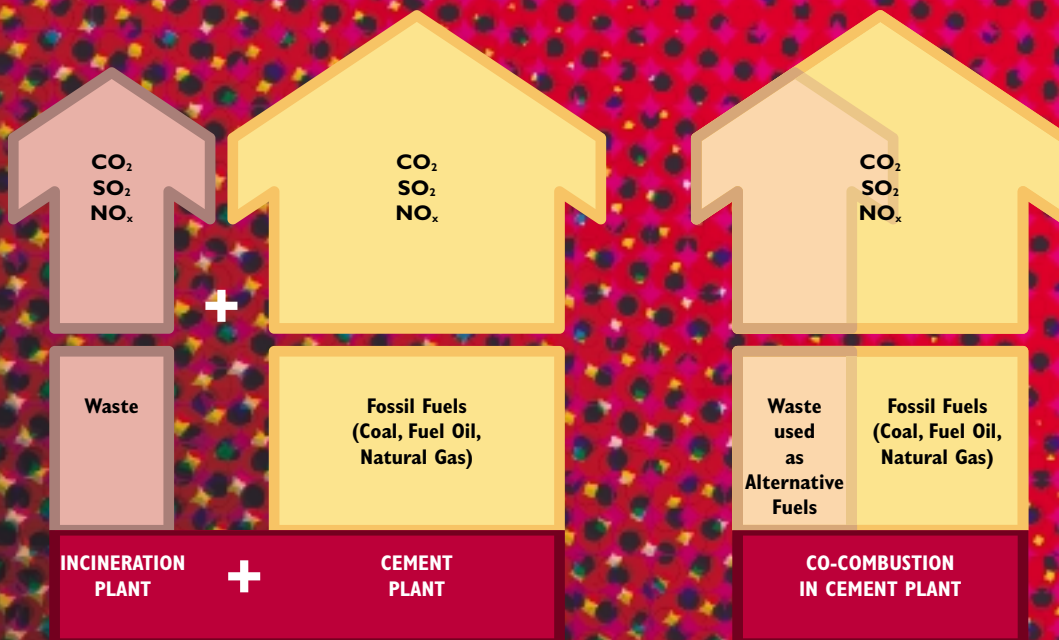
Hierarchy

- prevention

- recovery

- disposal

Waste recovery by the cement industry reduces emissions

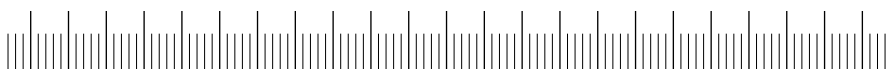
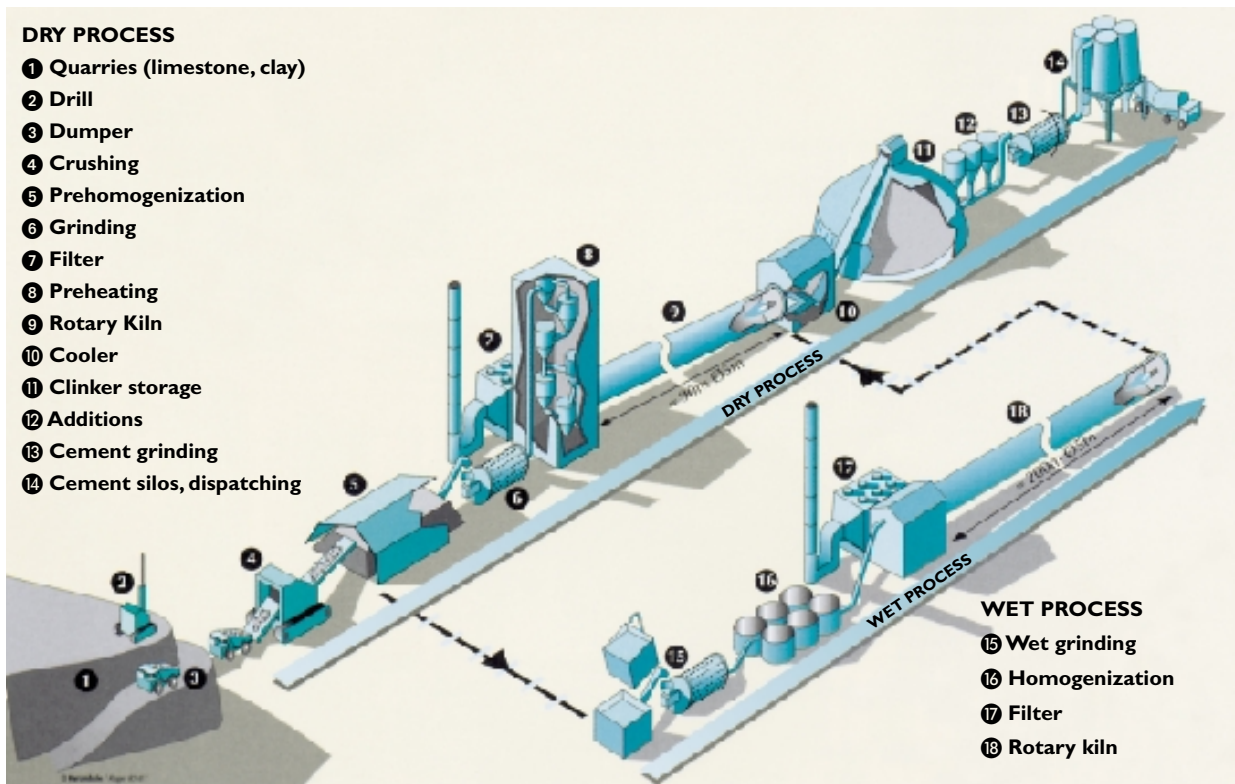
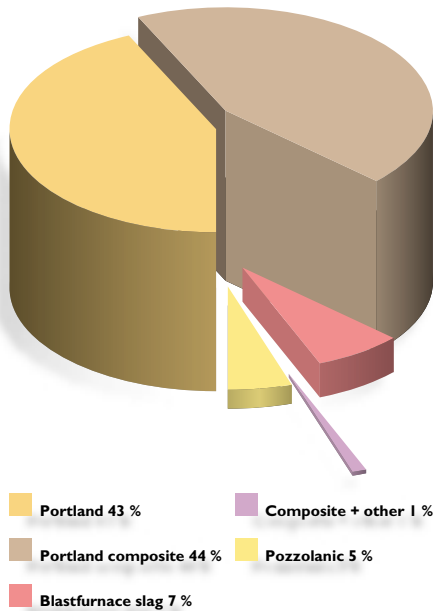


HOW CEMENT IS MADE

The process

Cement production involves the heating, calcining and sintering of blended and ground raw materials, typically limestone and clay or shale and other materials to form clinker. This clinker burning takes place at a material temperature of 1450 °C in kilns, which are inclined rotating cylinders lined with heat-resistant bricks. Afterwards, the clinker is ground with a small amount of gypsum to give Portland cement, which is the most common variety of cement manufactured in Europe. In addition, blended cements are produced by intergrinding cement clinker, small amounts of gypsum as well as materials like fly ash, granulated blast furnace slag, limestone, natural or artificial pozzolanas.

Deliveries of cement types in EU and EFTA



Large cement plants produce of the order of 4,000 tonnes of cement per day.

Depending on how the raw material is handled before being fed to the kiln, basically three different types of processes can be distinguished: the dry, semi-dry/semi-wet and wet process. The technology applied depends on the origin of the raw materials. The origin/type of limestone/clay and the water content (ranging from 3% for hard limestone to above 20% for chalk), are particularly important.

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

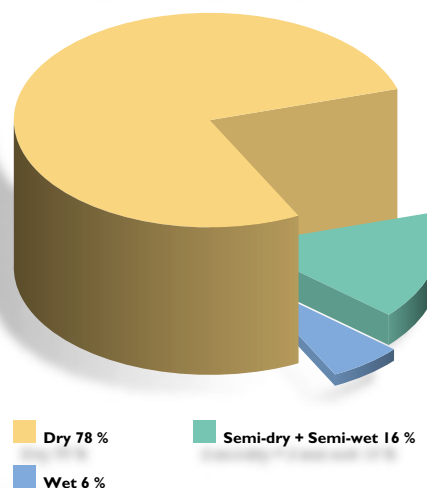
In the wet process, which is often used for raw materials with a high moisture content, the feed material is made by wet grinding and the resulting slurry, which contains typically 30-40% water, is fed directly into the upper end of the inclined kiln.

In the semi-dry or semi-wet process 10-20% water is either added to the ground dry feed material or removed from a slurry for instance by filter presses resulting in a feed material containing about 15-20% moisture. Pellets of feed material are loaded onto a travelling grate where they are

preheated by the rotary kiln’s hot exit gases. By the time the feed material reaches the kiln entrance the water has evaporated and calcination has begun.

Over the past few decades the European cement industry has invested heavily in a planned move from the wet process to the more energy-efficient dry process, where the raw materials allow. Presently, about 78% of Europe’s cement production is from dry process kilns, a further 16% of production is accounted for by semi-dry and semi-wet process kilns, and about 6% of European production now comes from wet process kilns due to lack of suitable raw materials for other processes.

Cement is produced by three processes



ENVIRONMENTAL ASPECTS OF CEMENT MANUFACTURE

Raw materials

In the cement kiln new minerals are formed giving cement its specific properties. The main components are the oxides of calcium, silicon, aluminium and iron.

Natural raw materials and coal ash used to produce cement contain a wide range of trace elements in addition to calcium, silicon, aluminium and iron.

Calcium is provided mainly by raw materials such as limestone, marl or chalk. The silicon, aluminium and iron components as well as other elements are provided by clay, shale and other materials. All the natural materials mentioned also contain a wide variety of other elements in small quantities.

Significant quantities of limestone, clay and other primary raw materials are quarried to service the demand for cement. In line with its commitment to sustainable development, the European cement industry has increasingly sourced alternative materials to substitute for the traditional natural raw materials. The industry currently uses large quantities of blast furnace slag, power station fly ash, silica fume, natural pozzolanas and limestone fines, mainly to substitute for clinker in cement. Some of these are also used as raw materials in the clinker production process.

The use of these alternative materials has significant positive environmental benefits. The need for quarrying of primary raw materials is reduced, energy consumption in producing cement is reduced and overall reductions in emissions of dust, CO₂ and acid gases are attained. In some applications, the performance of concrete can be

enhanced when Portland cement clinker is complemented by these materials.

Energy

Depending on the raw materials and the process, a cement plant consumes fuel amounting to about 3200 to 5500 MJ/t clinker. Electrical energy consumption is about 90 to 120 kWh/t cement.

Historically, the primary fuel used is coal. A wide range of other primary fuels are also used, including petroleum coke, natural gas and oil. The average European energy requirement to produce one tonne of cement is equivalent to the combustion of approximately 120 kg of coal.

The main constituents of fuel ash are silica and alumina compounds which combine with the raw materials to become part of the clinker. Like other natural products fuel ashes contain a wide range of trace elements which are also incorporated in the cement clinker.

With energy typically accounting for 30-40% of the production cost of cement, the cement industry throughout Europe has successfully concentrated significant efforts on improving energy efficiency in recent decades. In 1993 a study by the European Commission estimated that the real remaining potential energy saving in the cement manufacturing process was approximately 2.2% for the entire sector in the European Union.

Emissions

Releases from the cement kiln come from the physical and chemical reactions of the raw materials and from the combustion of fuels.

The main constituents of the exit gases from a cement kiln are nitrogen from the combustion air, CO₂ from calcination and combustion, water from the combustion process and the raw materials, and excess oxygen.

**Emissions
are controlled**

The exit gases also contain small quantities of dust, chlorides, fluorides,

sulphur dioxide, NO_x, carbon monoxide, and still smaller quantities of organic compounds and heavy metals.

Composition of exhaust gases

	%
N ₂	45-66
CO ₂	11-29
H ₂ O	10-39
O ₂ (stack)	3-10
Remainder	< 1

The exit gases from cement kilns are dedusted in filters (normally electrostatic precipitators) and the dust is normally returned to the process.

Cement plants are usually liquid effluent-free, since any water used in the process is evaporated within the kiln. If the air pollution control device uses a wet cleaning system, then the resulting effluent is generally returned to the start of the production process for use as makeup water, while the sludge is also returned to the kiln as feed material.



THE USE OF ALTERNATIVE FUELS

The benefits of using alternative fuels

Annually, the energy equivalent of about 25 million tonnes of coal is required by CEMBUREAU Members to service the demand for cement in Europe. This is a significant use of non-renewable primary fossil fuel, and therefore the industry is committed to seeking out more energy efficient ways of producing cement as well as alternative, more sustainable energy sources.

The use of alternative fuels is a well proven and well established technology in most of the European cement industry and this has been the case for more than 10 years. In 1995 about 10% of the thermal energy consumption in the European cement industry originated from alternative fuels. This is equivalent to 2.5 million tonnes of coal. The proportion is gradually increasing and figures above 50% are already achieved in certain regions.

Waste materials which the cement industry has utilised as alternative fuels include used tyres, rubber, paper waste, waste oils, waste wood, paper sludge, sewage sludge, plastics and spent solvents.

The use of waste as alternative fuels in the cement industry has numerous environmental benefits such as:

- Reduction of the use of non-renewable fossil fuels such as coal as well as the environmental impacts associated with coal mining.
- Contribution towards a lowering of emissions such as greenhouse gases

by replacing the use of fossil fuels with materials that would otherwise have to be incinerated with corresponding emissions and final residues.

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

Use of waste as fuels in cement kilns saves fossil fuels, reduces emissions to air and eliminates the need for disposal of slag and ash.



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

Safe valorisation in cement kilns

The use of waste as alternative fuels is technically sound as the organic part is destroyed and the inorganic part, including heavy metals, is trapped and combined in the product. Cement kilns

have a number of characteristics which make them ideal installations in which alternative fuels can be valorised and burnt in safety, such as:

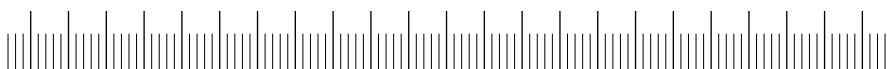
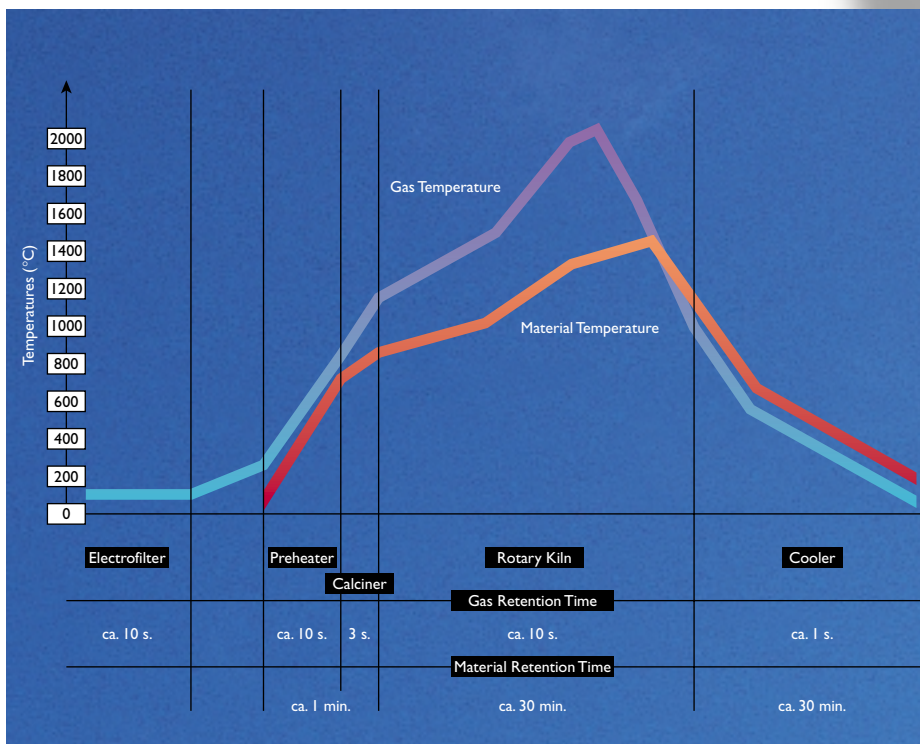
- High temperatures
- Long residence time
- Oxidising atmosphere
- High thermal inertia
- Alkaline environment
- Ash retention in clinker
- Continuous fuel supply



Two characteristics in particular are of importance for the use of waste as alternative fuel in cement kilns: burning conditions (high temperature with long residence time and oxidising atmosphere) and a natural alkaline environment.

Organic constituents
 Normal operation of cement kilns provides combustion conditions which are more than adequate for the destruction of even the most difficult-to-destroy organic substances. This is primarily due to the very high temperatures of the kiln gases (2000 °C in the combustion gas from the main burners and 1100 °C in the gas from the burners in the precalciner). The gas residence time at high temperature in the rotary kiln is of the order of 5-10 seconds and in the precalciner more than 3 seconds.

Because a cement kiln is a large manufacturing unit operating as a continuous process and with a high heat capacity and thermal inertia, a

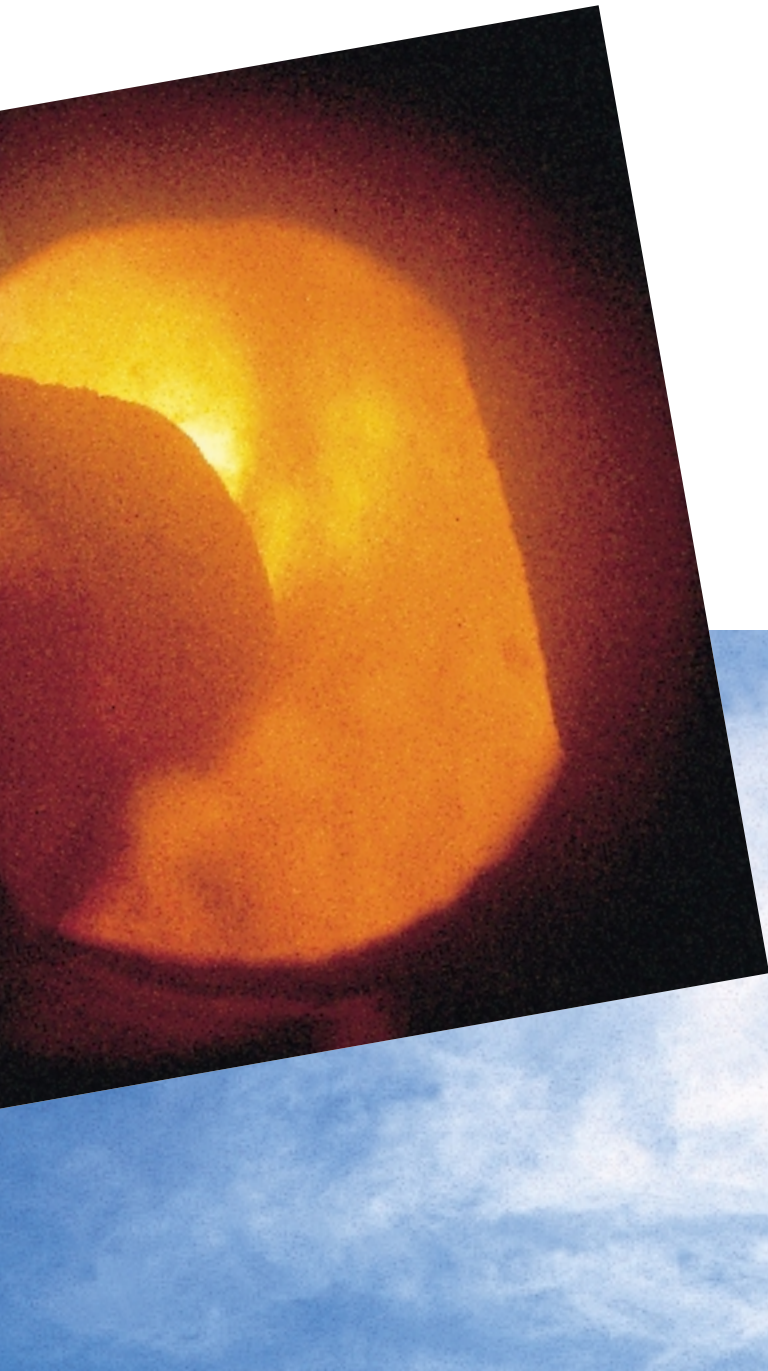


significant change in kiln temperature in a brief period of time is not possible. The cement kiln can readily switch back to conventional

fuel. The cement kiln therefore offers an intrinsically safe thermal environment for the use of alternative fuels.

Complete combustion of an organic compound composed only of carbon and hydrogen produces CO₂ and water. Additionally, if the organic compound (conventional fuel or alternative fuel) contains chlorine or sulphur, then acid gases such as hydrogen chloride and sulphur dioxide are also produced. These gases are absorbed and neutralised by the freshly formed lime and other alkaline materials within the kiln.

A number of studies evaluating organic emissions from combustion installations have focused on the family of chemicals known as “dioxins”. Directive 94/67/EC on the incineration of hazardous waste stipulates an emission limit of 0.1 nanogram of dioxins per cubic metre of gas emitted, the dioxins being measured in units of “toxic equivalents”. Cement kilns fired with conventional fossil fuel or with alternative fuels of all types can meet this emission limit.



Inorganic constituents

Alternative fuel ash can provide important constituents which contribute towards building the clinker phases in the same way as coal ash does. Used tyres, for instance, provide iron which is required as a clinker constituent as well as energy. If this iron is not provided by tyres, it has to be added to the process using other materials.

Metals, like any other elements, are not destroyed in an industrial furnace. Metals introduced into the cement kiln through the raw materials or the fuel will be present in either the releases or in the clinker. Extensive studies investigating the behaviour of metals in cement kilns have shown that the vast majority are retained in the clinker. For example, studies on antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, selenium, vanadium and zinc have established that near 100% of these metals are retained in the solids. Extremely volatile metals such as mercury and thallium are not incorporated into the clinker to the same degree and these metals are, therefore, carefully controlled in the alternative fuel.

Specifications and control procedures

The European cement industry is subject to strict controls on every aspect of its activities, from quarrying to cement production and product quality. All cement manufacturing plants have installed appropriate abatement techniques and control and management systems which are subject to regular audit and review. As a result of this, and the inherent suitability of

cement plants to handle organic and inorganic constituents of alternative fuels, the industry is in a position to ensure that there is no net increase in emissions when alternative fuels are used. Monitoring of kiln operations and of the quality of stack discharges is becoming increasingly sophisticated. Equipment has become automated as sites continue to invest in modern, upgraded systems.

The cement process is fully controlled

Control room - Bernburg plant





Alternative fuels
are regularly
analysed

ENVIRONMENTAL PERFORMANCE OF CONCRETE

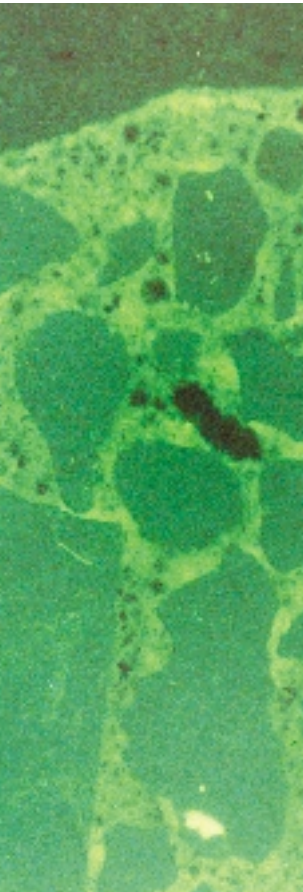
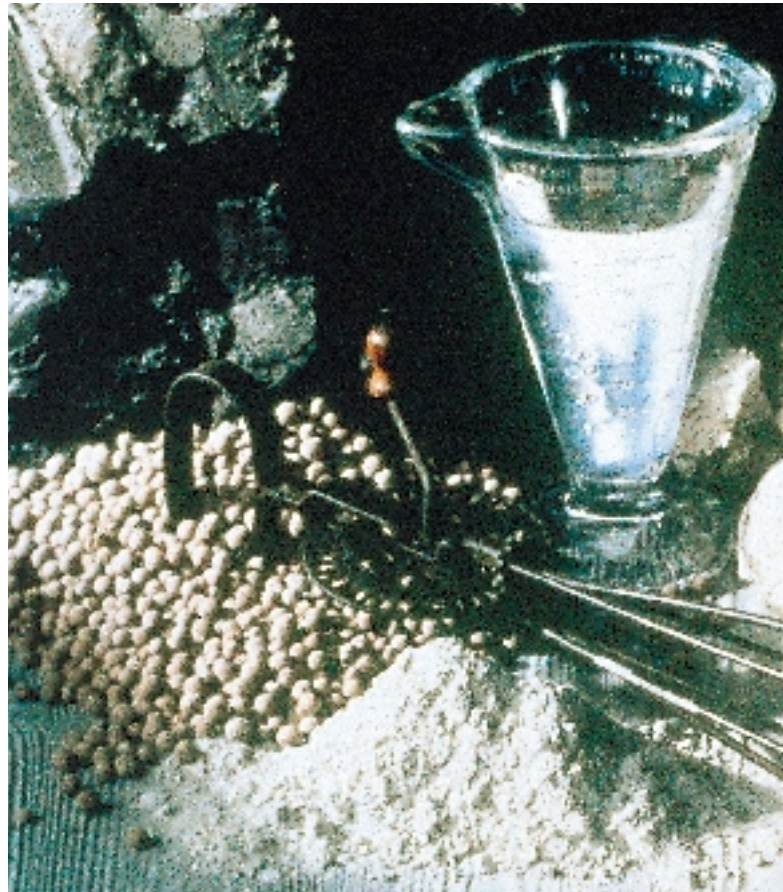
Cement is used to produce concrete. Concrete is an artificial stone made of cement, aggregates, sand and water.

Concrete is known for its high environmental performance. This performance is not impaired when alternative fuels are used for cement production. Concrete made from cement manufactured using alternative fuels has the same properties as concrete made from cement manufactured using fossil fuels.

One aspect of the environmental performance of concrete is the behaviour of heavy metals in concrete. These trace elements are found in various concentrations in the materials used for cement and concrete production, and ultimately determine the respective concentration in the concrete.

Inorganic constituents of alternative fuels like heavy metals are combined in the cement clinker. The use of alternative fuels for cement production may result in higher or lower concentrations of heavy metals in concrete as compared to when ordinary fuels are used. However, in practice the heavy metal concentrations in concrete are not significantly changed by the use of alternative fuels for cement production.

The heavy metals in the cement are bound in the clinker components, and they are chemically bound in the alkaline reaction products formed when cement reacts with water to give the concrete its strength. This fixation as well as the high denseness and low permeability of concrete result in a very



Concrete looked at through a microscope - it is a dense material





low potential for heavy metals to be released.

The leaching of heavy metals from concrete has been examined in a number of investigations. They all show that the release is very low, independently of the kind of fuels used for cement clinker production. The leached quantities have always been found to be either not measurable or significantly below levels allowed for drinking water.



Concrete is used for water storage constructions as there is no harmful leaching from concrete

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