

IPC Guidance Note

S2 3.01

Processes Subject to  
Integrated Pollution Control

Cement Manufacture,  
Lime Manufacture and  
Associated Process



ENVIRONMENT  
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## IPC Guidance Notes

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# **Processes Subject to Integrated Pollution Control**

IPC Guidance Note  
Series 2 (S2)  
Mineral Industry Sector

## **S2 3.01 Cement Manufacture, Lime Manufacture and Associated Processes**

Prepared by the Environment Agency

September 1996

**Environment Agency  
Information Centre  
Head Office**

ENVIRONMENT AGENCY



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## Executive Summary

**This IPC Guidance Note supersedes Her Majesty's Inspectorate of Pollution's Chief Inspector's Guidance Notes IPR 3/1 and IPR 3/2 published by HMSO in 1992** and is issued by the Environment Agency as one of a series of guidance notes for processes prescribed for Integrated Pollution Control (IPC) in Regulations<sup>(1)</sup> made under Section 2 of the Environmental Protection Act 1990 (EPA90). It is a guide on techniques and standards relevant to cement and lime manufacture and associated processes.

It will be used by Agency staff, in conjunction with other relevant guidance<sup>(2)</sup>, in assessing operators' proposals relating to their authorisations under EPA90. This Note should be used together with separate guidance on monitoring<sup>(3)</sup>, dispersion methodology<sup>(4)</sup>, and assessment principles for determining Best Available Techniques Not Entailing Excessive Cost (BATNEEC) and Best Practicable Environmental Option (BPEO)<sup>(5)</sup> to provide a framework for a consistent approach to the regulation of this class of IPC process.

This Note covers Part A processes described under "cement and lime manufacture and associated processes", Section 3.1 of the Regulations<sup>(1)</sup>. These processes are defined as:

- (a) Making cement clinker.
- (b) Grinding cement clinker.
- (c) Any of the following processes, where the process is related to a process described in paragraph (a) or (b), namely, blending cement; putting cement into silos for bulk storage; removing cement from silos in which it has been stored in bulk; and any process involving the use of cement in bulk, including the bagging of cement and cement mixtures, the batching of ready-mixed concrete and the manufacture of concrete blocks and other cement products.
- (d) The heating of calcium carbonate or calcium magnesium carbonate for the purpose of making lime where the process is likely to involve the heating in any 12 month period of 5,000 tonnes or more of either substance or, in aggregation, of both.
- (e) The slaking of lime for the purpose of making calcium hydroxide or calcium magnesium hydroxide where the process is related to a process described in paragraph (d) above.

# 1 Introduction

## Scope and status of Guidance Note

### 1.1 Scope and status of Guidance Note

This IPC Guidance Note supersedes Her Majesty's Inspectorate of Pollution's Chief Inspector's Guidance Notes IPR 3/1 and IPR 3/2 published by HMSO in 1992 and is issued by the Environment Agency as one of a series of guidance notes for processes prescribed for Integrated Pollution Control (IPC) in Regulations<sup>(1)</sup> made under Section 2 of the Environmental Protection Act 1990 (EPA90). It is a guide on techniques and standards relevant to the processes covered by the Note.

It will be used by Agency staff, in conjunction with other relevant guidance<sup>(2)</sup>, in assessing operators' proposals relating to their authorisations under EPA90. This Note should be used together with separate guidance on monitoring<sup>(3)</sup>, dispersion methodology<sup>(4)</sup>, and assessment principles for determining Best Available Techniques Not Entailing Excessive Cost (BATNEEC) and Best Practicable Environmental Option (BPEO)<sup>(5)</sup> to provide a framework for a consistent approach to the regulation of this class of IPC process.

This Note represents the state of understanding at the time of writing, and includes:

- description(s) of the principal processes covered by the Note;
- the prescribed substances and other substances that can cause harm and are most likely to be released from the processes;
- guidance on appropriate techniques for the control of releases;
- benchmark release levels;
- other environmental standards relevant to the process; and
- information on economic implications of pollution control.

An operator should keep up to date with the best available techniques relevant to the process. This Note may not therefore be cited in an attempt to delay the introduction of improved, available techniques, and, except where specifically stated to the contrary, nothing contained herein should be considered prescriptive.

The concepts of BATNEEC and BPEO expressed in the EPA90 and associated Regulations are site-specific. This Note cannot take into account such site-specific considerations. Thus, while operators' proposals should be judged against the benchmark release levels given in this Note, the benchmarks

should not be applied as uniform release limits. They are indicative, but not prescriptive, for new processes which are expected to use modern techniques for the prevention, minimisation and abatement of releases.

Where less stringent release levels are proposed for a specific case, comparing them and the benchmark release levels will indicate the degree of technical and economic justification required to be provided by the operator. Conditions in authorisations which relate to permitted releases should ensure that all factors, including those which are site-specific, have been taken into account, and that the legal requirements to use BATNEEC and BPEO are fully satisfied.

Compliance with statutory environmental quality standards or objectives, and with agreed international obligations relating to permitted releases or environmental standards, remains mandatory. No discretion is permitted without formal policy approval.

Figures are included in this Note for the purposes of illustration and clarification. The appearance of any item of plant in a figure does not imply any recommendation – reference must be made to the text.

### 1.2 Existing processes

Existing processes should be upgraded taking into account the criteria included in Articles 4, 12 and 13 of the European Community Directive on the combating of air pollution from industrial plants known as the Air Framework Directive (84/360/EEC)<sup>(6)</sup>. Article 13 requires the following points to be taken into account:

- the plant's technical characteristics;
- its rate of utilisation and remaining life;
- the nature and volume of polluting emissions from it; and
- the desirability of not entailing excessive costs for the plant concerned, having regard in particular to the economic situation of undertakings belonging to the category in question.

Whilst it may be possible to make improvements to existing processes using techniques described in Section 2 of this Note, the state of design of some existing plant may prevent operators from achieving the release levels given in this Note, even with improvements.

## Processes covered by this Note

Existing processes in this class have been authorised and site-specific improvement plans set where required. On reviewing an existing authorisation, or considering a variation, the above criteria should be applied to ensure the continuing application of BATNEEC/BPEO. This may require a timetable for improving or decommissioning the process. Improvement plans are a site-specific issue therefore no target dates are included in this Note.

### 1.3 Processes covered by this Note

This Note covers Part A processes described under "cement and lime manufacture and associated processes", Section 3.1 of the Regulations<sup>(1)</sup>. These processes are defined as:

- (a) Making cement clinker.
- (b) Grinding cement clinker.
- (c) Any of the following processes, where the process is related to a process described in paragraph (a) or (b), namely, blending cement; putting cement into silos for bulk storage; removing cement from silos in which it has been stored in bulk; and any process involving the use of cement in bulk, including the bagging of cement and cement mixtures, the batching of ready-mixed concrete and the manufacture of concrete blocks and other cement products.
- (d) The heating of calcium carbonate or calcium magnesium carbonate for the purpose of making lime where the process is likely to involve the heating in any 12 month period of 5,000 tonnes or more of either substance or, in aggregation, of both.
- (e) The slaking of lime for the purpose of making calcium hydroxide or calcium magnesium hydroxide where the process is related to a process described in paragraph (d) above.

Where other prescribed processes are carried on in conjunction with the primary process, reference should be made to the relevant Chief Inspector's Guidance Notes or IPC Guidance Notes and, where appropriate, the Secretary of State's Guidance for Local Authority Air Pollution Control on the ancillary processes insofar as they have potential for releases to the environment.

In the context of this Note 'process' is from receipt of raw materials via production of intermediates to dispatch of finished products.

## 1.4 Processes

### 1.4.1 Cement process overview

There are three broad categories of cement products: Portland cement, Portland cement with the addition of pfa or blast furnace slag and special cements. All but certain special cements are manufactured by using substantially the same process route which is discussed in this Note. Portland cement, which is manufactured to British Standard BS12:1991, is defined as an active hydraulic binder based on ground clinker formed from a predetermined homogeneous mixture of materials comprising lime ( $\text{CaO}$ ), silica ( $\text{SiO}_2$ ) and a small proportion of alumina ( $\text{Al}_2\text{O}_3$ ) and generally iron oxide ( $\text{Fe}_2\text{O}_3$ ).

A fundamental difference between cement manufacturing routes is whether the kiln process is wet or dry. However, all processes have the following stages in common:

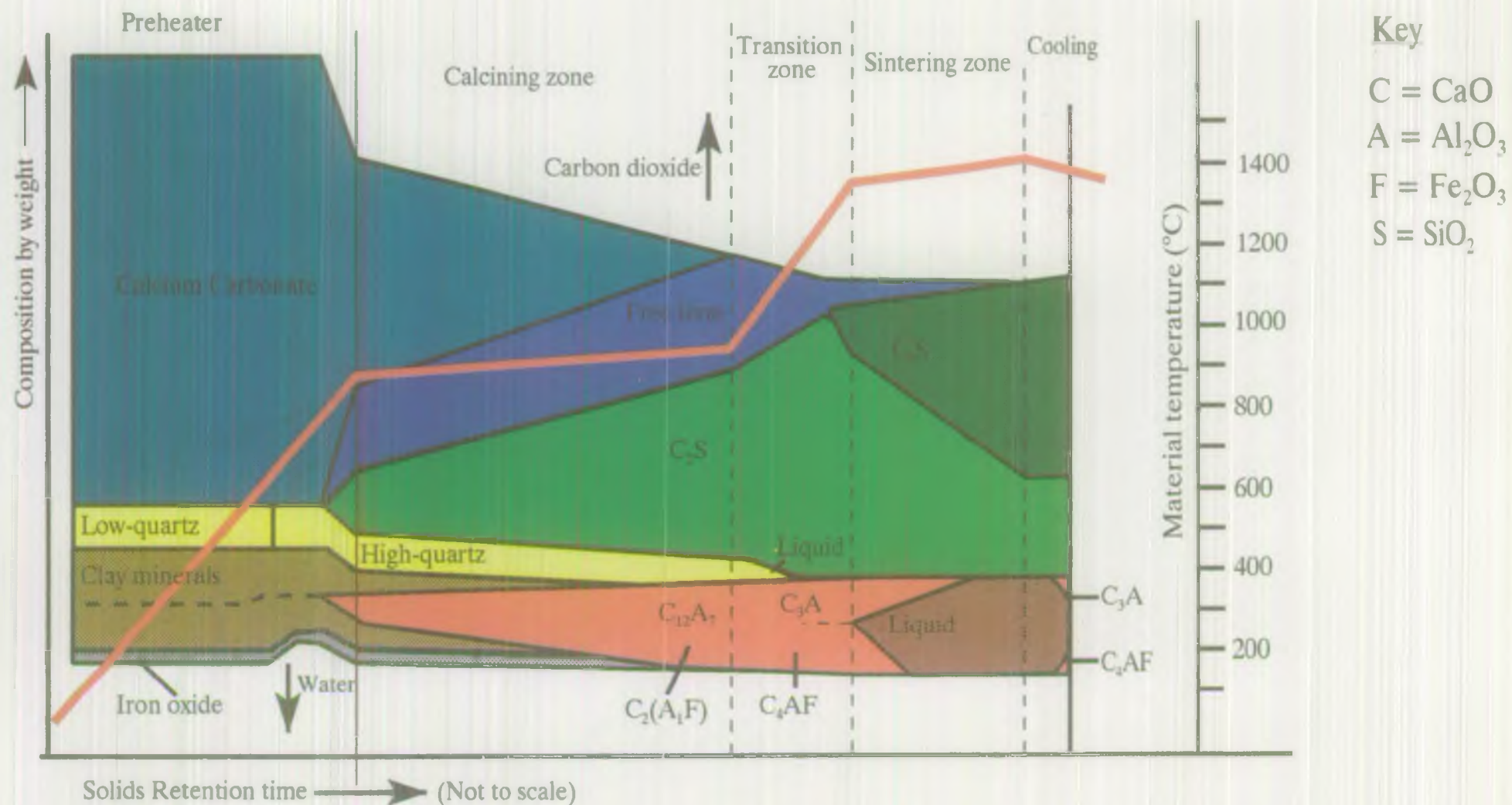
- raw material procurement (from on-site quarry or importing);
- raw material preparation (size reduction and blending to achieve a given homogeneous chemical specification);
- fuel handling (fuel grinding if solid fuels are used);
- kiln processing (where raw materials are chemically reacted by the application of heat in a kiln system to produce clinker);
- cement milling (clinker size reduction with additional materials); and
- cement packing and dispatch.

The major releases from the process are from the kiln system to air. However, significant releases of particulates can occur from all other parts of the process.

The primary raw materials used in cement manufacture are limestone or chalk and clay or shales. These materials provide the essential calcium carbonate, silica, alumina and ferric oxide which, when burned, produce cement clinker that consists mainly of calcium silicates and aluminates.

Raw materials contain varying proportions of the required constituents as well as impurities and moisture levels peculiar to the specific location from which they are quarried. The raw materials, therefore, are carefully blended in proportions suitable for a given cement production site to produce cement with the desired properties.





## Processes

Regardless of whether the process route is wet or dry, the heating of the raw materials follows certain stages:

- drying, with the removal of any moisture present;
- calcination at approximately 800–900°C, with the conversion of the limestone to free lime with the release of carbon dioxide;
- sintering at approximately 1450°C in a liquid state, where the free lime reacts with the other components to form calcium silicates, aluminates and aluminoferrite (the principal ingredients of Portland cement). This sintered product is known as cement clinker and this process stage is also referred to as 'burning' or 'clinkering'; and
- cooling where the temperature of the liquid is reduced from 1450 to 1100°C to form stable crystals within the kiln followed by cooling to about 250°C in a clinker cooler.

A typical preheater kiln processing diagram is given in Figure 1 showing the broad variation in chemical composition and temperature with time and position within the kiln system. The fate of sulphur and trace metals is not shown.

Dehydration and calcination are endothermic and clinkering is exothermic. However, cement manufacture is an energy intensive activity and the choice of fuels affects both the environmental releases and the economics of the process. Total energy cost can represent 65–75% of the variable costs of the process.

In order to control the setting time of the final cement product, 3–8% gypsum (calcium sulphate) is ground with the cement clinker to form Portland cement.

The finished cement is stored in silos and can be sold in bulk or bagged forms. Finished cement is not usually stored on site for more than a few days but clinker can be stored in silos or covered buildings if longer term storage is required.

### 1.4.2 Lime process overview

There are two basic products from the UK lime industry: quicklime ( $\text{CaO}$ ) and hydrated or slaked lime ( $\text{Ca(OH)}_2$ ) and to a smaller extent, their magnesia ( $\text{MgO}$ ) equivalents. In contrast to the cement industry, lime is used in a wide variety of different applications such as steel and non-ferrous metal production, liquid waste treatment, construction, flue gas desulphurisation, sugar refining, and agriculture. There are, therefore, various specifications for finished lime products

dependent on the end use. For instance, some uses of hydrated lime may require low levels of impurities such as iron oxide, silica, magnesium oxide, fluoride and a specified surface area. Steel making processes using quicklime require limits on such things as calcium carbonate and sulphur contents.

Lime specifications are controlled by raw material/fuel selection and the type of kiln process used.

Lime processes follow the following basic steps:

- limestone quarrying, usually from an on-site quarry;
- limestone size reduction;
- fuel handling (grinding if solid fuels are used);
- kiln processing (where limestone is heated to produce quicklime and drive off  $\text{CO}_2$ );
- quicklime size reduction;
- packing and dispatch of exported quicklime;
- quicklime hydration; and
- packing and dispatch of hydrated lime.

Major releases are generally from the kiln to air. However, significant releases of particulates can occur from any part of the process, notably the hydrator.

The lime making process consists of the burning of calcium or magnesium carbonates at a temperature ranging between 900 and 1500°C, which is sufficiently high to liberate carbon dioxide, and to obtain the derived oxide. For some processes, significantly higher burning temperatures are necessary, for example dead-burnt dolomite.

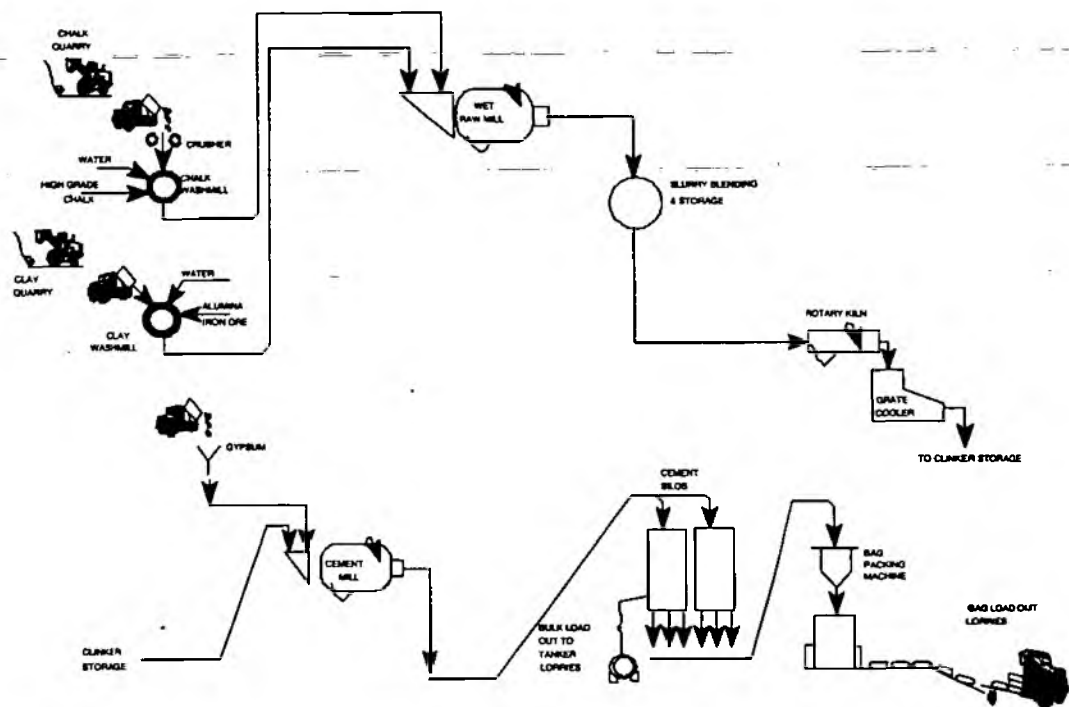
Calcium carbonate when heated produces 56% (by weight) calcium oxide and 44% carbon dioxide. Consequently, lime production produces a very large quantity of carbon dioxide.

Magnesium carbonate is processed in a similar way, the product being magnesia. Magnesium carbonate when heated produces 48% magnesia and 52% carbon dioxide. Dolomite and dolomitic limestone are mixtures of calcium carbonate and up to 44% magnesium carbonate, and are processed in a similar fashion to limestone.

High purity limestone (96–98% calcium carbonate) or dolomite is quarried, crushed and transported to the kiln. Within the kiln, carbon dioxide is liberated by the application of heat and exhausted to atmosphere. The calcium oxide product is transported from the kiln to silo storage. From the silo, the burnt lime is either taken to the end user

## Processes

Figure 2: Typical wet kiln process



## a. Wet process

Figure 2 gives a flow diagram of a typical wet kiln process. The wet process is now declining in use due to the cost penalty associated with driving off water from the wet slurry feed into the kiln.

Typical slurry moisture fed to the kiln is in the range 30% to 40%, depending upon the physical properties of the raw materials. Additives may be used to reduce moisture. Raw materials may contain considerable moisture (up to 22% in some cases) and may be ground together or separately with the addition of water to form a slurry in wash mills or drums. Polyelectrolytes may be used to minimise the amount of water which has to be added whilst still maintaining the pumpability of the slurry.

Oversize material is screened off for reprocessing and the finely divided liquid slurry is pumped to large blending and storage tanks in which further adjustments may be made to the composition.

From the slurry storage tanks the raw mix is pumped to the back end of the kiln where it is carefully metered before entering. The slurry gradually moves towards the flame at the burning end due to the rotational movement of the kiln and its slight downward inclination. The kiln performs all the thermal functions of the process: drying, calcining and sintering.

The length and diameter of wet kilns are large in relation to output and a higher induced draught

fan volume is required compared with other processing techniques because of the steam generated (by drying within the kiln) and higher volumes of products of combustion (from the higher fuel consumption).

Wet kilns are fitted with systems of chains to increase heat exchange with the hot combustion gases.

## b. Semi-wet process

The semi-wet process relies on mechanically removing the majority of the water content of the slurry prior to feeding to the kiln thus lower specific fuel consumptions can be achieved compared with the wet process. Figure 3 shows a typical semi-wet process flow diagram.

## Slurry preparation

Slurry preparation is identical to the wet process but followed by pressure filtration to reduce moisture content to 17–20%.

The filter cake is passed through an extrusion press where pellets are formed. The pellets are transferred to a moving grate preheater where, before entering the rotary kiln, they are dried and partly calcined by the hot kiln exit gases. Alternatively, the filter cake can be fed to a hammer crusher which acts as a dryer, again using hot kiln exhaust gases. A third option, which is less fuel efficient, is to feed the cake directly to the kiln equipped with chains as in the wet process.



for use in the form of quicklime, or transferred to a hydrating plant where it is reacted with water to produce hydrated or slaked lime.

Some kilns are located with other process plant. For instance, both quicklime and  $\text{CO}_2$  released during kiln processing are used in sugar refining.

The lime kiln process therefore differs from the cement process in that the only raw material used is limestone or dolomite and only drying and calcination occur within the kiln system. Wet processing is not used in the UK lime industry.

### 1.4.3 Raw materials and quarries

The primary raw materials are usually extracted from quarries that are near the cement or lime production plant. Quarry operations, such as size reduction, can fall under Part B of the Regulations<sup>(1)</sup>, but are generally part of the IPC process if they are related to and carried on as part of the process. Inspectors should agree with the local authority the status of any associated quarry operations.

Quarries associated with the production process are often used for the disposal of solid waste, particularly waste dust either from dust abatement plant or other parts of the process.

Raw materials such as limestone are quarried using hard rock techniques. The release of particulate matter can occur at any stage of the quarrying process. The process usually involves the drilling and blasting of stone followed by crushing and grinding. Lime kilns generally use much coarser and purer feed limestone than cement processes. Usually the fine grinding stages will be carried out at cement production sites rather than in the quarry.

Materials such as chalk and clay are quarried in a wet state and so the potential for dust release is much less than for hard rock quarrying.

For cement production other raw materials may be required to adjust chemical composition of the kiln feed including sand, iron oxide and bauxite. The storage and handling of these materials can result in the release of dust. Secondary raw materials such as pfa, blast furnace slag and other process residues may partially replace primary raw materials subject to their chemical suitability and the environmental releases associated with their use.

### 1.4.4 Kiln and associated processing – cement production

For cement manufacture, a rotary kiln is usually used for the sintering stage. There are a number of systems for drying and calcining, all of which are integral to the kiln. The main types are given below:

- wet process where the slurry feed is dried and calcined within the kiln;
- semi-wet process where the slurry is filter pressed and the resulting cake or nodules fed to the kiln directly or via a grate preheater or dryer-crusher;
- semi-dry process where dried ground material (raw meal) is nodulised with water, then dried and partly calcined in a grate preheater; and
- dry process where the raw meal is preheated in a series of cyclones (four or five stages), possibly incorporating a precalcining stage in which some of the fuel is burned.

In all systems the kiln feed moves counter-currently against a hot air stream. This counter-current flow regime affects pollutant releases which are discussed further below.

The choice of process route can be influenced by two factors: the energy costs and the nature of the raw materials available. For instance, chalk naturally occurs in a wet state and so semi-wet processing may be the preferred route. Inspectors should note that the specific energy requirements of the different kiln systems generally decrease significantly from the wet to the dry process (typical figures are given in Table 1) as do the specific amounts of most pollutants released.

Kiln system	Specific fuel consumption (kcal/kg clinker)	Specific power consumption (kWh/tonne clinker)
Wet	1450	17.5
Semi-wet (grate preheater)	1150	variable
Semi-dry (grate preheater)	850	17.5
Dry (preheater)	800	22.5
Dry (preheater and calciner)	800	22.5
Theoretical heat of reaction	c 420	-

**Table 1:**  
Typical energy consumption of different kiln systems

Processes

Figure 3: Typical semi-wet process

Processes

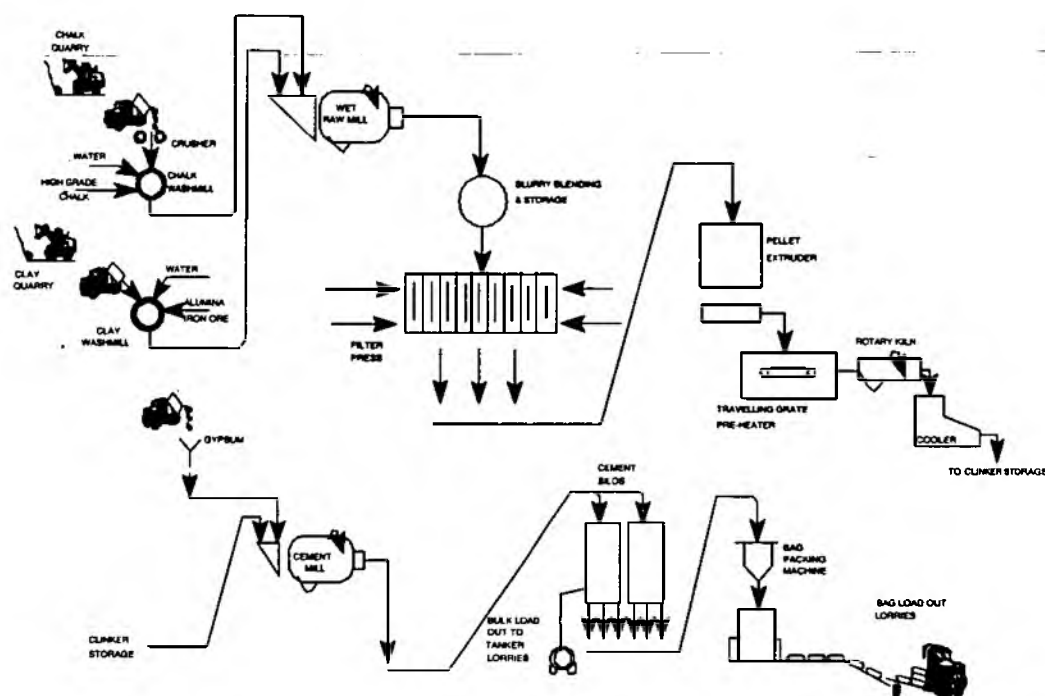
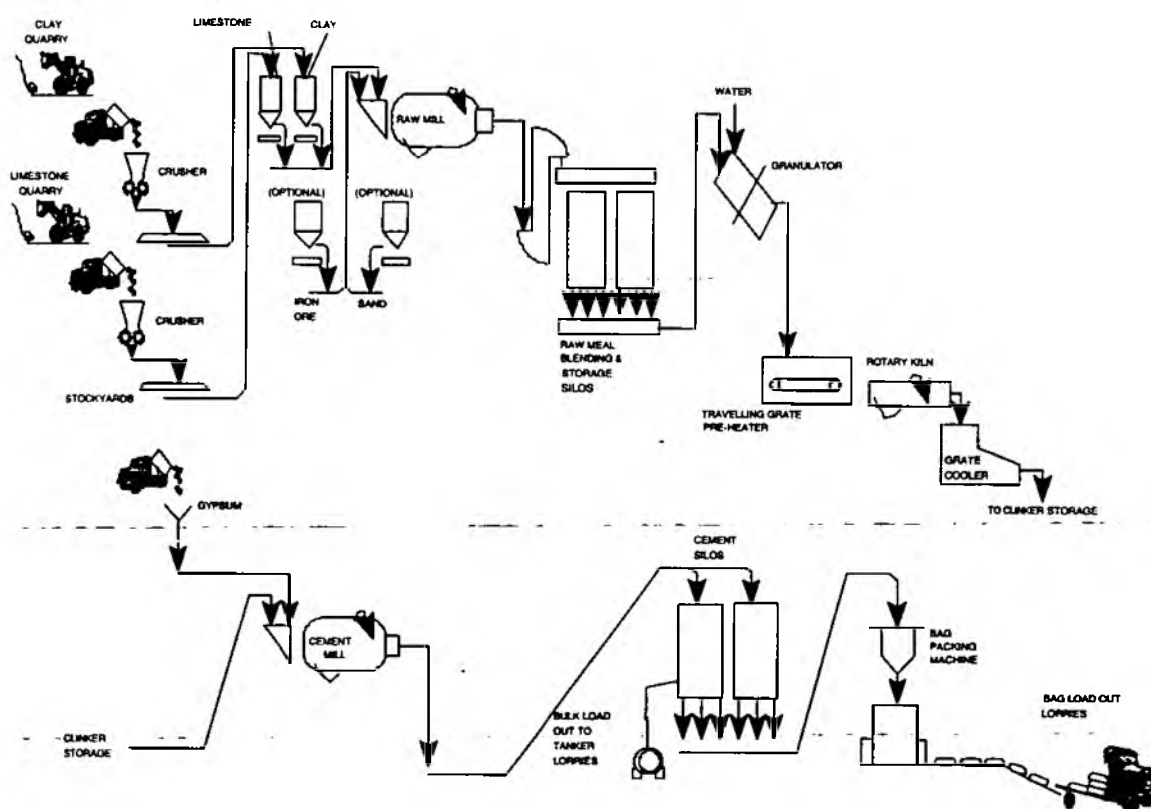


Figure 4: Typical semi-dry process



## Processes

### c. Semi-dry process

The raw meal preparation route for the semi-dry process is as for the dry process, the raw meal is then nodulised, using the minimum quantity of water necessary, and the nodules fed directly to a moving grate, double-pass, preheater similar to the semi-wet process. A typical semi-dry process diagram is given in Figure 4.

#### Clinker cooling

Clinker cooling is carried out after the kiln to allow the clinker to be handled and to recover some of its heat content. All coolers operate by passing air through the clinker and there are three main types:

- grate coolers;
- planetary coolers; and
- rotary coolers.

The grate cooler consists of perforated moving or reciprocating grates which slowly push the clinker from the hot to the cold end. Air passes through the perforations, cools the clinker and is itself preheated before passing into the kiln as secondary combustion air or used for solid fuel and/or raw material drying or passed to the precalciner as tertiary combustion air.

A planetary cooler consists of a series of 10 to 12 large diameter tubes fastened to the kiln shell and rotating with it. The clinker drops into these and by virtue of the inclination of the kiln, passes through the coolers tumbling across the incoming ambient air stream drawn in by the kiln induced draught fan.

The rotary cooler is a rotating cylinder, usually mounted beneath the kiln fitted with lifter and tumbling plates. Air flow is as for the planetary cooler.

#### Cement milling

The clinker is transferred to covered storage halls or clinker silos where it is held prior to milling. It is withdrawn from storage and fed to the cement mill by weigh proportioners with an addition of 3 to 8% of gypsum and possibly other additions. The resulting product is cement, which is then conveyed to cement silo storage. Gypsum is added to control the setting properties of finely ground clinker.

Cement milling is typically performed by tube mills but the use of roll presses may offer energy saving. Tube mills operate in open or closed circuit with air classifiers or separators to improve efficiency. Milling generates considerable heat and internal air

cooling plus internal or external water sprays are necessary. Cement milling also produces particulate laden exhaust streams that require abatement.

#### Product handling and storage

Cement is transferred from the silos either direct into bulk road or rail tankers, or to a bag packing station. Potential particulate releases from this part of the process are significant.

#### Composite cement manufacture

In the manufacturing of composite (or interground) cements, granulated blast furnace slag, pulverised fly ash, pozzolana and/or fillers are added and ground with the clinker and gypsum, or milled separately and blended with the cement after the grinding stage.

### d. Dry processes

Dry kilns have three basic variants: long dry kilns, preheater kilns and precalciner kilns. A typical precalciner dry process flow diagram is given in Figure 5.

#### Raw materials preparation

Raw materials, usually with a moisture content of less than 12%, are fed at controlled ratios into a raw milling system where they are dried and ground to the required fineness (typically 10% retention on a 90 micron sieve). Several types of mill can be used such as air swept ball mills, closed circuit tube mills or roller mills. Drying is achieved by using hot exhaust from the preheater cyclones or the cooler but if additional drying capacity is required then an auxiliary furnace can be used.

The raw meal is transferred to the homogenising silos where it is pneumatically fluidised and mixed.

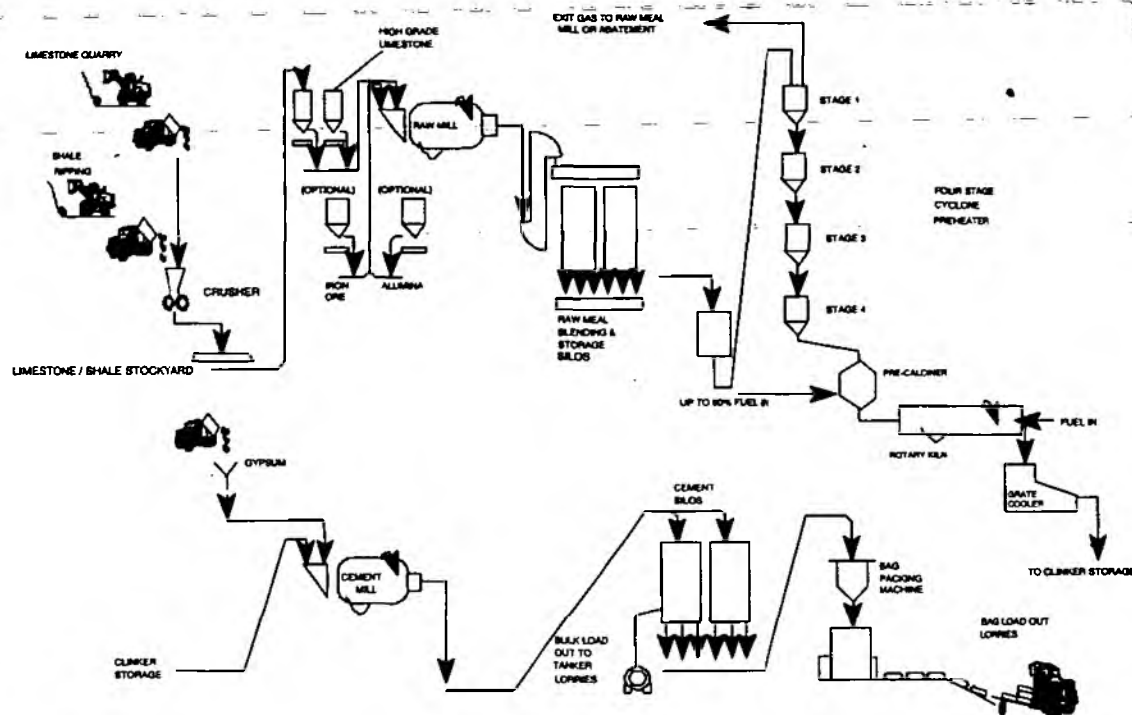
After homogenisation, the raw meal is stored in silos prior to use.

#### Cyclone preheaters

To improve the efficiency of the heat exchange process between the hot gases and the raw meal, cyclone preheater systems have been developed that carry out the preheating process outside the rotary kiln.

The preheater may consist of a riser pipe and up to six stages of cyclone preheaters. After the preheater, the hot meal enters a rotary kiln for the calcining and burning stage.

**Figure 5: Typical precalciner dry process**



The principle of all the cyclone preheaters is the same: raw meal is introduced and moves counter to the upward flowing hot gases leaving the kiln. The meal is swept up in the gas stream, separated out in the cyclone and passed down to the next stage where the procedure is repeated until the raw meal has passed through all stages, rising rapidly in temperature as it does so.

Heat transfer within cyclones is very efficient when compared to the kiln. The contact area with the finely divided raw meal is much greater than with a bed of material lying in the kiln with a limited surface contact area exposed to the hot gases. For example, a four stage cyclone preheater will raise the temperature of the raw meal to more than 800°C in 25 seconds, and the gas temperature will fall from 950–1000°C at the exit from the kiln to 370–380°C at the exit from the top or first stage cyclone. Material entering the kiln is up to 20% calcined.

## Precalciner

A further development is to carry out most of the calcination stage outside the rotary kiln in a separate calciner vessel. This vessel is positioned between the last preheater stage cyclone and the kiln and arranged to receive the output from the preheater. Up to 60% of the total fuel requirement is added at this stage, thereby ensuring that 80-90% of the calcination of the raw meal takes place. Thus, when the meal enters the kiln only final calcination and clinkering is required.

The precalciner takes its combustion air largely from the clinker cooler at the hot end of the kiln. This hot air may be transferred through the kiln itself or, more commonly, by a tertiary hot air duct parallel to the kiln.

The hot air from the grate cooler arrives at the precalciner at approximately 800°C, the kiln exit gases enter it at about 1000°C and calcination takes place at 850 to 900°C.

### Long dry process kilns

Dry process kilns have less thermal duty than wet process plant kilns. A long dry kiln performs the functions of final drying, ie driving off the final 0.5 to 1% moisture in the raw meal, calcining the raw meal and sintering in the burning zone.

#### 1.4.5 Kiln and associated processing – lime processes

There are four basic designs of kiln in use: shaft, rotary, rotary hearth and fluidised bed. All are designed to dry and calcine the limestone feed and cool the product quicklime. Table 2 compares the various types of kiln technology.

The quality of the lime produced depends on the quantity of impurities introduced with the raw materials and the fuels used. The temperature at which the limestone is calcined affects the reactivity to water of the resultant quicklime. Higher temperatures produce harder quicklime with lower

## Processes

**Table 2:**  
**Comparison**  
**of different**  
**lime kiln**  
**types**

Kiln type	Feed size range (mm)	Fuel consumption (kcal/kg quicklime)	Power consumption (kWh/quicklime tonne)
<b>Shaft</b>			
Simple	50-250	1100-1700	4-15
Mixed feed	90-200	950-1050	4-15
Double inclined	25-55	1000-1150	22-29
Annular shaft	20-150	950-1150	25-30
Parallel flow regenerative	20-200	850-950	15-34
<b>Rotary</b>			
Long	10-65	1500-2000	14-24
Short with grate preheater	10-50	1200-1450	20-25
Short with shaft preheater	10-60	1150-1450	17-45
Short with cyclone preheater	0-2	1100-1300	23-37
<b>Rotary hearth</b>	8-75	1400-1500	29-36
<b>Fluidised bed</b>	0-2	1100-1300	20-25

reactivity. The calcination temperature is in turn affected by the choice of kiln system.

All kiln systems are characterised by the counter-current flow of solids and gases as in cement production which has implications for the resulting pollutant releases discussed below.

### Vertical shaft kiln

Figure 6 gives a schematic diagram of a simple vertical shaft kiln. The vertical shaft kiln receives lump limestone which is charged at the top of the unit through an airlock where it is preheated to 800°C by combustion gases. Burners are arranged so that they fire into the combustion chamber in a full range of directions to maximise the contact of hot gases with the stone. The injected fuel does not normally penetrate more than about 1 metre into the packed kiln which is therefore limited, in many designs, to 2 metres diameter (or width). The burners are located about a third of the way up the kiln from the base in the lower region of the calcination zone.

Obtaining even heat distribution across the limestone charge is inherently difficult in shaft kilns. Some kilns utilise beams which span across the kiln shaft and contain burner-nozzles which inject fuel more evenly across the limestone charge. Other kilns attempt to achieve the required temperature consistency by injecting fuel through vertical burner lances placed evenly across the charge. The use of a closely graded limestone feed to vertical shaft kilns encourages an even spread of heat in the burning zone.

At the bottom of the kiln there is an air lock and a discharge system. The speed of operation of the discharge mechanism determines the speed of descent of the limestone into the burning zone and through the kiln.

Cooling air is drawn into the kiln by the induced draught fan, and is preheated as it passes through the hot burnt lime leaving the burning zone. Additional air may be injected into the burning zone, from which the hot gases pass up the kiln preheating the slowly descending limestone and cooling the exit gases at the same time.

Inspectors should note that many older and smaller vertical shaft kilns operate with natural draught using a batch processing technique. Many will not fall under the Regulations<sup>(1)</sup> due to the small throughputs associated with these kilns.

### Mixed feed shaft kiln

A variation of the simple shaft kiln which uses mixed limestone and coke feed to obtain even heat distribution is known as a mixed feed shaft kiln. The process produces kiln gases with a high CO<sub>2</sub> content so it is suited to processes that use both quicklime and CO<sub>2</sub>, such as sugar refining and precipitated calcium carbonate production plants.

### Double inclined shaft kiln

Figure 7 shows a section through a double inclined shaft kiln in which the feed moves down through two shafts inclined at 60° each equipped with burners.



Figure 6: Simple vertical shaft kiln

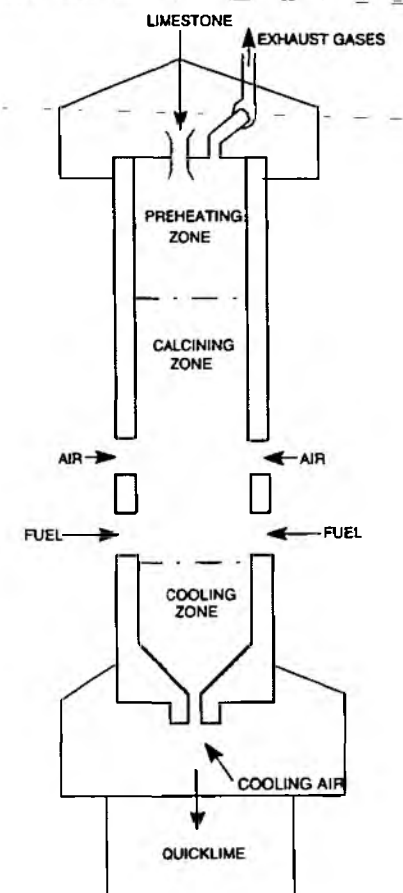
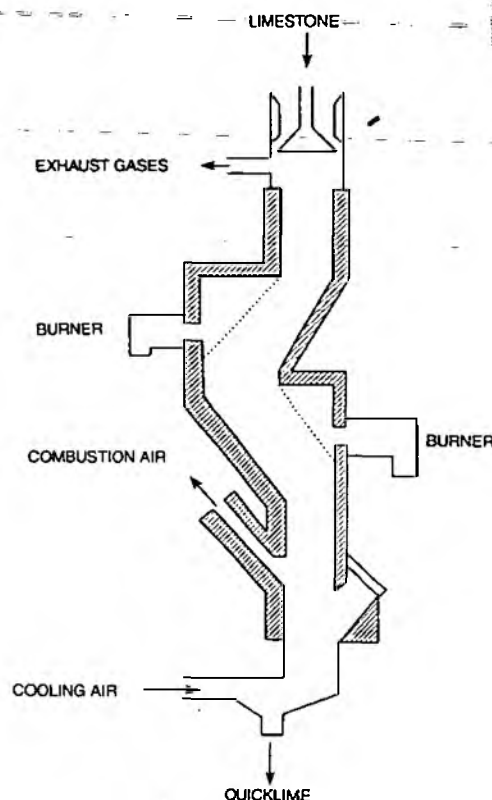


Figure 7: Section of double inclined shaft kiln



Processes

### Annular shaft kiln

Annular shaft kilns have a central cylinder which restricts the width of the kiln and ensures good heat distribution. Recycle of combustion gases back into the lower burner chamber moderates calcination temperatures thus producing high reactivity quicklime. A diagram is given in Figure 8.

### Parallel flow regenerative kilns

The parallel flow regenerative kiln (or Maerz kiln) has improved fuel consumption compared with other shaft kiln designs. A diagram of the kiln is given in Figure 9. The kiln utilises two (or three) interconnected shafts in order to use the limestone as a regenerative heat exchange medium to transfer surplus heat in the exit gas to the combustion air. The burning and charging cycles switch about every 12 minutes between the shafts.

In the Maerz type kiln, it is possible to preheat the combustion air to 800°C and thus the net heat input requirement is lower than in other kilns.

The limestone undergoes its final stages of calcination at moderate temperatures of about 1100°C and so high reactivity quicklime is produced.

### Rotary kilns

Modern versions of the rotary kiln incorporate a stone preheater in which hot kiln gases are used to heat the feed limestone. Figure 10 shows a diagram of a rotary kiln.

The rotary kiln is set at a slight angle (1 to 2 degrees) from the horizontal, sloping toward the hot end where fuel is introduced. The rotary action of the kiln coupled with the slope causes the limestone to move gradually towards the flame where it is calcined. Having passed the burning zone, the quicklime begins to cool and descends from the kiln into a cooler.

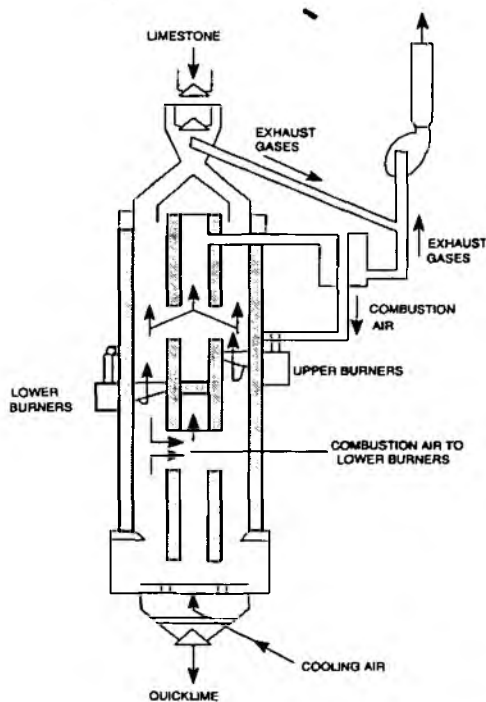
The cooler consists of a chamber in which ambient air is drawn through the quicklime by the kiln induced draught fan. This preheats the combustion air and allows the cooled quicklime to be handled. A series of double flap valves in the bottom of the cooler allow the quicklime to pass out to storage silos.

### Rotating hearth kiln

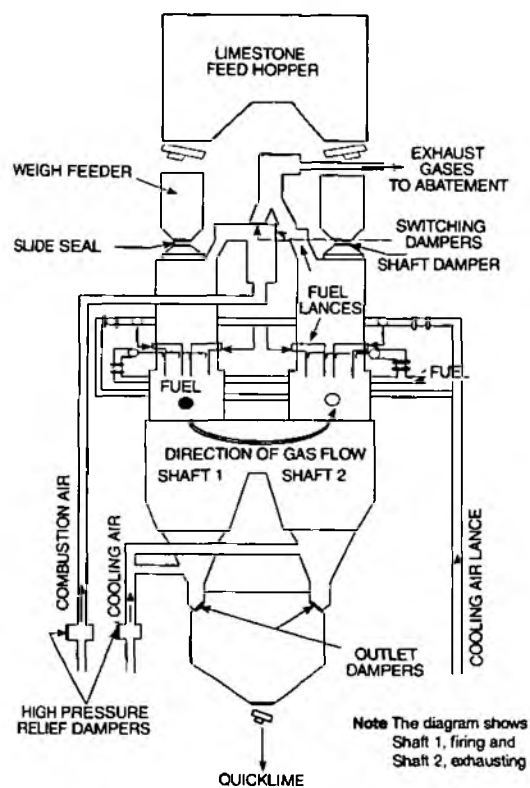
This type of kiln, now almost out of use, consists of an annular travelling hearth carrying the limestone charge. Multiple burners heat the limestone as it travels around the circuit. Use is

## Processes

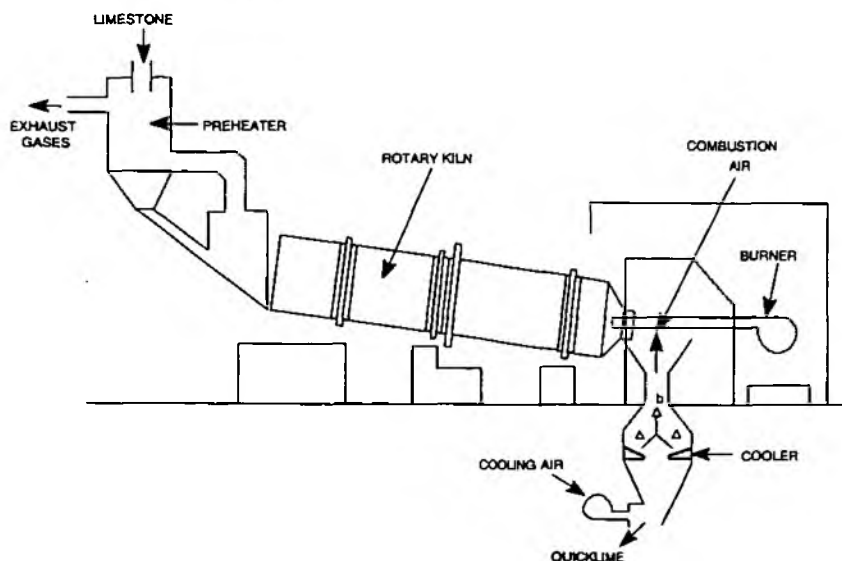
**Figure 8: Annular shaft kiln**

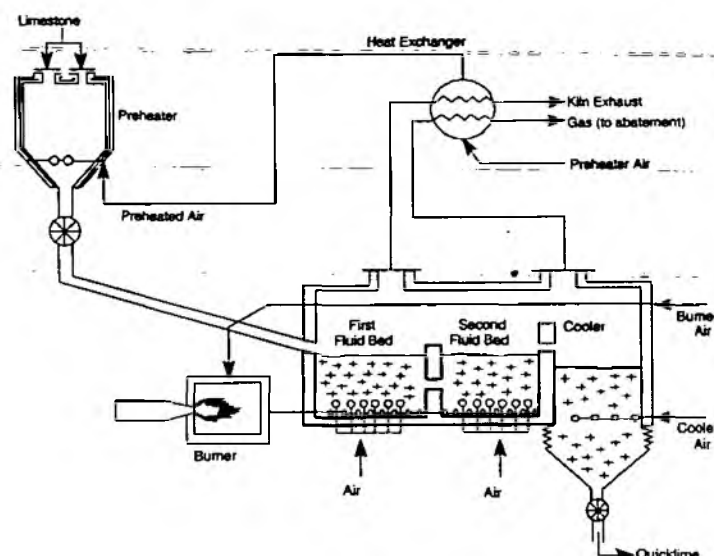


**Figure 9: Parallel flow regenerative kiln**



**Figure 10: Rotary kiln**



**Figure 11: Fluidised bed kiln**

Processes

made of preheating combustion air by using it to cool the product quicklime.

Due to the reduced abrasion compared with rotary and shaft kilns, rotating hearth kilns are used to maximise the production of pebble lime.

### Fluidised bed kiln

Figure 11 shows a diagram of a fluidised bed kiln. Fine limestone is fed to a preheater vessel using air heated via a heat exchanger on the kiln exhaust gases.

The preheated limestone then enters the first fluidised bed vessel where the temperature is increased and limestone starts to be calcined. As the limestone is calcined, the lighter quicklime flows over the weir wall into the next fluidised bed vessel where calcination is completed. The quicklime then passes through the cooler where ambient air is used as the cooling medium.

Although fluidised bed technology may offer lower pollutant releases and better heat usage than other lime kiln technologies, it is not well proven and is not generally applicable to the production of all types of lime.

### Product handling and storage

Various grades of quicklime can be produced: for example screened grades which are 6-40mm in size, and ground grades with 30-99% <75µm. Screen grades are crushed and screened before being stored in a silo. Screened grades may also be milled to produce various grades of ground quicklime which again are transferred to silos for storage. Alternatively, the screened grades may be crushed further before conversion to hydrated lime.

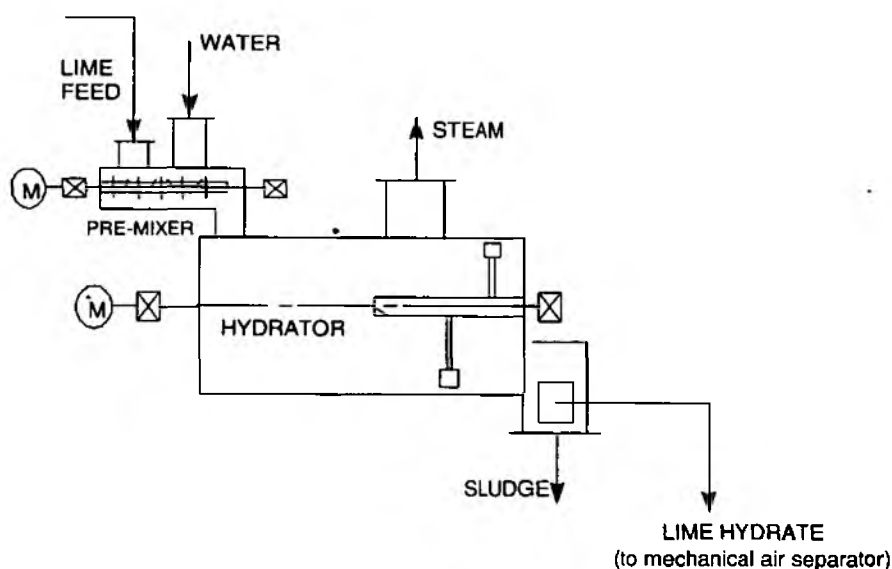
### Lime hydration and slaking

The hydration of lime is achieved by the controlled addition of water to the burnt lime in a lime hydrator to produce dry hydrated lime. Slaked lime is also produced which is a wet product with varying water contents.

For hydrated lime production, the quantity of water is about twice the stoichiometric amount required for the hydration reaction. The excess water is added to moderate the temperature generated by the heat of reaction by conversion to steam. The steam, which is laden with particulates, passes through abatement prior to discharge to atmosphere.

There are many designs of equipment but typically the hydrator consists of pairs of contra-rotating screw paddles which vigorously agitate the lime in the presence of water. A lime hydrator is shown in Figure 12. A strongly exothermic reaction takes place generating 272 kcal/kg of CaO. The average residence time of the solids in the main reactor is about 15 minutes. The heat release causes a vigorous boiling action which creates a partially fluidised bed. Dust is entrained in the steam which is evolved during the process. If this dust is collected in a wet scrubber a milk of lime suspension is produced, which is normally returned to the hydrator. The amount of water which can be added is limited to the process requirement of the hydrator.

After hydration the product is transferred to an air-swept classifier where the coarse and fine fractions are separated using a recycling air stream. Part or all of the coarse fractions may be ground and recycled. The fine fraction is conveyed to storage silos. From here it is either discharged to bulk transport or transferred to a packing plant where it is packed in sacks or intermediate bulk containers.

**Figure 12: A lime hydrator**

## 1.5 Standards and obligations

### 1.5.1 Air quality standards

Statutory Instrument 1989 No.317, Clean Air, The Air Quality Standards Regulations 1989<sup>(7)</sup> gives limit values in air for the following substances:

- sulphur dioxide,
- suspended particulates,
- lead,
- nitrogen dioxide.

Inspectors are reminded that, at the time of writing, the Expert Panel on Air Quality Standards (EPAQS) has made recommendations with regard to possible implementation of air quality standards for five further substances, namely:

- benzene,
- 1,3-butadiene,
- carbon monoxide,
- ozone,
- suspended particulate matter less than 10 micrometre (PM<sub>10</sub>'s).

EPAQS have also made a recommendation for a new short term air quality standard for sulphur dioxide. EPAQS will be carrying out similar studies for oxides of nitrogen in the near future.

Any emission from the process should not result in a breach of the appropriate air quality standard beyond the site boundary.

### 1.5.2 Environmental quality standards

Statutory Instrument 1989 No. 2286<sup>(8)</sup>, The Surface Waters (Dangerous Substances Classification) Regulations gives the annual mean

concentration limit values for certain substances including cadmium and mercury.

## 1.6 Release routes

### 1.6.1 Releases from the kiln system

The main releases from the production of cement are from the kiln stage to air and will occur from the kiln exhaust gases, the clinker cooler exhaust and any bypass gases. There may also be significant release of kiln dust to land depending on the alkali content of the raw materials used. Polluting releases result from the particular chemical composition of the raw materials and fuels used. Similar releases can occur from lime production.

The production of cement clinker in kiln systems is characterised by cycles of components such as dust, chlorides, sulphur compounds and alkalis. These cycles may be internal to the system or partially induced by the recycling of kiln dust back into the system from abatement equipment. These cycles have a large effect on the inherent releases from any kiln processing system. The cycles result from the variation in the capacity of the material within the kiln system to absorb or release substances. The absorptive capacity of material varies with its physical and chemical state which in turn depends on its position within the kiln system. For instance, material leaving the calcination stage of the kiln process has a high free lime content and therefore has a high absorptive capacity for acid species such as SO<sub>2</sub>. However, when this same material passes to the sintering stage some of the absorbed sulphur will be released back to the gas phase. This variation, combined with the counter-current nature of the air and solids flow through the system, results in the capture into the clinker of

many of the pollutants that would otherwise potentially be released to air.

Lime kilns are similar to cement kilns in that pollutants are captured by the lime product and tend to leave with this stream but, as there is no sintering zone, the opportunity of internal kiln cycles is limited. The counter-current air flow will tend to release any volatile impurities contained in the raw material limestone into the exit kiln gases but with the generally large feed sizes compared with cement production, this effect will be smaller.

The type of kiln processing system also has a marked effect on the magnitude of releases to air. The preheater section on a dry cement kiln is a very efficient absorber of volatile or acid species such as sulphur oxides. This is due to the high gas-solid contact with the raw meal within the cyclone array, which acts as a dry scrubbing system.

The wet end (back end) of a wet cement kiln also acts as a pollutant absorber but it is not so efficient as a preheater kiln. Wet cement kilns also tend to release greater masses of some pollutants per tonne of clinker production compared with dry kilns due to their increased fuel requirements and larger gas flows.

### Kiln dust, alkalis and kiln bypasses

In the cement industry levels of alkalis and chlorides in the product clinker are controlled to achieve the required quality of the product cement. UK construction contracts often impose an alkali specification of 3 kg/m<sup>3</sup> of concrete because of the risk of alkali-aggregate reactions and thus the alkali content of the cement is limited. Alkalis in particular can also be a problem in the kiln system, as high levels can cause blockages in preheater cyclones.

The cement industry has several options to control clinker alkali content. The careful control of the alkali content of raw materials can be used but the practicality of this depends on the availability of low alkali raw materials.

In wet cement kilns, some of the alkalis evaporate in the sintering section but condense in the drying zone on the fine particulate matter. Hence, if an EP is used for arrestment, the finer proportion of the cement kiln dust (CKD) containing the highest concentration of alkali can be discarded whilst the remaining dust is recycled (by selecting the correct fields in the EP). The recycle can be achieved by introducing CKD into the rotary kiln by using specially designed scoops in the cylindrical walls of the kiln or, more frequently by injecting CKD into the burning zone of the kiln. In dry process kilns,

CKD is often blended into the raw feed for reintroduction. Typically an EP collects the equivalent of 10% of clinker production and up to 50% of the CKD may have to be discarded due to alkali content.

The inherent absorption capacity of preheater dry cement kilns can cause problems with blockages in the cyclone systems caused mainly by build up of alkalis. One option to curtail alkali levels is by bypassing part of the particulate laden gas stream out of the kiln back end away from the cyclone system and condensing the alkalis by cooling. Bypasses of up to 100% of the kiln gas flow may be necessary although this level would be extreme with 30% being more typical. This bypass stream can be high in pollutants (particulates and sulphur oxides) and must be separately treated (see below). The particulates removed from the bypass stream are high in alkalis and cannot be recycled into the process, again leading to CKD disposal outside the process.

In the lime industry, material collected in the kiln particulate abatement equipment is high in CaCO<sub>3</sub> but also contains ash and quicklime and is very fine, making it unsuitable for direct recycle.

### Nitrogen oxides

There are two principal mechanisms acting in any combustion process to form NO<sub>x</sub>: the oxidation of molecular nitrogen in the combustion air (known as thermal NO<sub>x</sub>) and the oxidation of nitrogen compounds in the fuel (fuel NO<sub>x</sub>). In the production of cement and lime, thermal NO<sub>x</sub> is a significant formation route.

Thermal NO<sub>x</sub> formation is strongly dependent on the combustion temperature, with a marked increase in formation above 1400°C.

In cement production, as the flame temperature in a kiln is around 2000°C, it is in the sintering zone where most of the thermal NO<sub>x</sub> is formed. In the calcination stage, temperatures are about 800–900°C which is not high enough to form significant thermal NO<sub>x</sub> compared with fuel NO<sub>x</sub>. As, in precalciner kilns, up to 60% of the fuel is burnt in the calciner stage, the amount of NO<sub>x</sub> produced is less than in wet process kilns, where all the fuel is burnt in the sintering zone. However, some studies have shown that in comparing precalciner and preheater dry kilns, the reduction in thermal NO<sub>x</sub> generation can be offset by an increase in fuel NO<sub>x</sub> production in precalciners.

In lime kilns, flame temperatures can be less than in cement production and so the contribution of thermal NO<sub>x</sub> can be lower.

## Release routes

$\text{NO}_x$  formation is also dependent on the amount of excess air present in the flame, with higher oxygen contents enhancing formation.

Different raw material characteristics can influence the amount of  $\text{NO}_x$  produced. For instance, some limestones require far less burning than others to produce cement clinker and consequently less thermal and fuel  $\text{NO}_x$  are produced per tonne of clinker made. In the production of dead burned dolomite, higher kiln temperatures are required thus producing higher levels of  $\text{NO}_x$ .

In addition, some raw materials contain chemically bound nitrogen which can convert to  $\text{NO}_x$  at temperatures between 300–800°C. However, this source of  $\text{NO}_x$  is usually insignificant for cement and lime processes.

### Sulphur oxides

The release of sulphur oxides from cement and lime production can occur from the kiln exhaust. The release is mainly in the form of  $\text{SO}_2$  (99%) although some  $\text{SO}_3$  is produced and, under reducing conditions,  $\text{H}_2\text{S}$  could be evolved.

Sulphur oxides arise due to the sulphur content of the fuel and raw materials. Raw materials, such as limestone, can contain sulphur in the form of sulphates, sulphides and organic compounds.

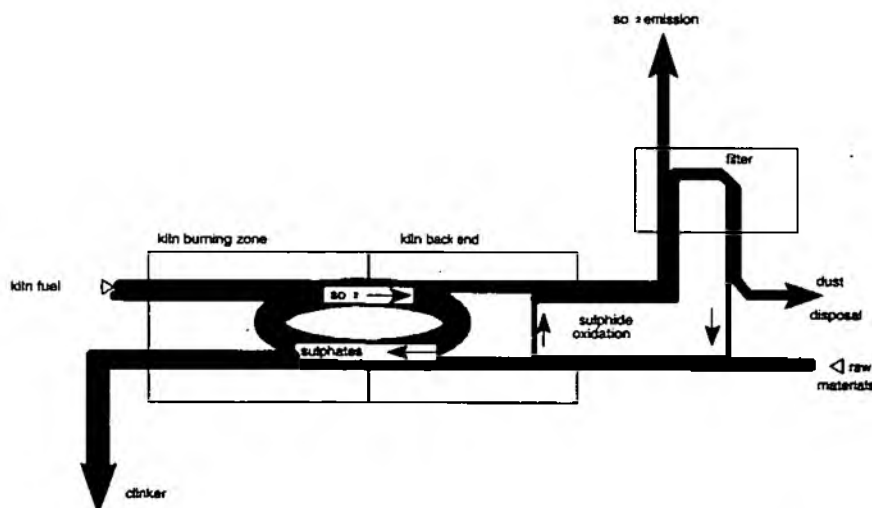
The proportion of sulphur released from cement kilns depends on the balance between the absorption and release of  $\text{SO}_2$  at various stages of the process. The mechanisms of sulphur release are not yet fully understood and the figures given in the discussion below are indicative of some kilns but there are exceptions. For instance, although it is generally accepted that dry process kilns are

better at absorbing  $\text{SO}_2$  than wet kilns, some wet kilns are particularly good absorbers giving sulphur retention in excess of 90%. The absorption capacity of a kiln varies with chemistry, alkali, sulphate and chloride balance, temperature, oxygen content and kiln design.

Figure 13 gives an indication of the sulphur cycle for a wet cement kiln system. Between 30 and 80% of the sulphates entering the kiln sintering zone may decompose and form  $\text{SO}_2$ , the exact amount being dependent on raw materials and kiln combustion conditions. Absorption of  $\text{SO}_2$  can then occur in the dust cloud within the kiln and the wet absorbing conditions in the chained zone towards the back end of the kiln as the kiln gases pass through the calcination and drying zones. However, due to the generally less effective contact between the kiln gases and the raw material, compared with a dry preheater kiln, more of the total sulphur may escape the absorption zone. Releases of  $\text{SO}_2$  will also occur from the raw material sulphide content being burned in the drying/heating zones (temperatures between 400–600°C). It is estimated that up to 30% of the total sulphur entering a wet kiln system could be emitted as  $\text{SO}_2$  in the kiln exhaust gases, the remainder being absorbed in the clinker and CKD. Of this release, up to 50% may be due to the sulphur content of the fuel assuming that low sulphur raw materials are used, although the contribution from raw material is often dominant.

Inspectors should be aware that if the excess air level falls below certain limits, a large increase in  $\text{SO}_2$  levels occur. This is due to the formation of local reducing conditions which will increase  $\text{SO}_2$  releases in the sintering zone and make absorption in the kiln back end less effective.

**Figure 13: Sulphur cycle for wet cement system**



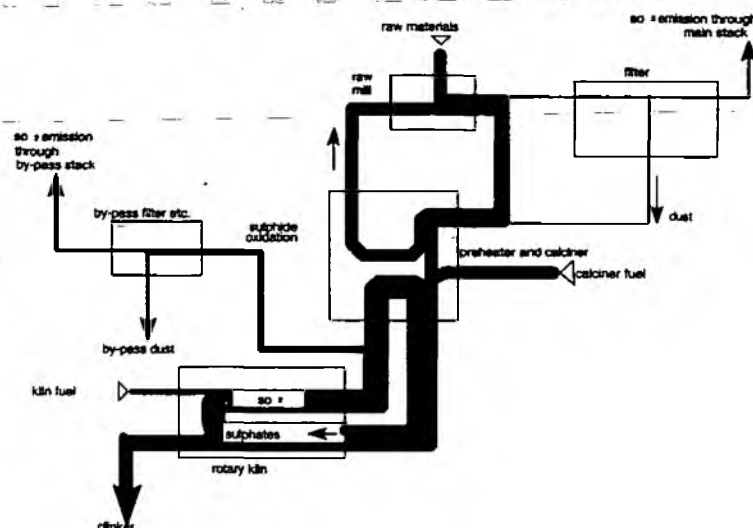
**Figure 14: Sulphur cycle in a preheater or precalciner kiln**

Figure 14 shows the sulphur cycle in a preheater or precalciner kiln. The release of sulphur from the exhaust gases in these kilns is mostly due to the sulphur content of the raw materials used. The lower stages of the preheater cyclones contain free lime, as the raw meal starts to calcine. As the cyclone preheaters act as very efficient solids-gas contactors,  $\text{SO}_2$  is absorbed rapidly by the lime and carried into the sintering zone. However, if the raw materials contain sulphides or other non-sulphate forms,  $\text{SO}_2$  will form in the upper stages of the preheater cyclones and be released with the exhaust gases.

This is because the temperature and free lime content are too low to reabsorb  $\text{SO}_2$  in the upper stages. The great majority of the sulphur present in the raw meal as iron sulphide will be released from the preheater. About half of this  $\text{SO}_2$  may be absorbed by the raw meal drying/milling system if it is in operation but this very much depends on mill design.

Precalciner systems provide more intimate contact between calcined materials where there is a higher free lime content and the kiln exit-gases and - therefore a greater proportion of  $\text{SO}_2$  can be absorbed than in preheater kilns. However, Inspectors should note that preheater or calciner kilns fitted with bypasses can lead to significant release of  $\text{SO}_2$  unless the bypass stream is abated. The bypass gases do not pass through the preheater cyclones and therefore the  $\text{SO}_2$  absorption in this section is lost.

In lime production, in most circumstances, only a small fraction of the sulphur dioxide generated within the kiln (whether originating from the raw materials or from the fuel) is released to

atmosphere, since it is mainly incorporated into the lime by chemical combination.

Fluidised bed kilns are particularly efficient at absorbing  $\text{SO}_2$  due to the high contact between gas and solid streams. However Inspectors should be aware that it is possible to operate rotary lime kilns without bypasses to reduce the absorption of sulphur into the quicklime product leading to higher  $\text{SO}_2$  levels in the kiln gases.

### Particulates

Due to the fineness of the raw materials used in the cement kilns, the generation of particulates is inevitable and they will pass to atmosphere in the kiln exhaust gases unless abatement techniques are used. Cement clinker cooler exhausts are also a source of particulate releases.

The cooling of clinker to a temperature suited for conveying and milling requires a greater volume of air than is needed for combustion in an efficient kiln system.

With grate coolers, after the maximum recovery of heat for preheating, pre-calcining and drying of materials and coal, the surplus air from the outlet (cool) end is vented to air via dust arrestment equipment, which must be capable of withstanding wide variations in air flow and temperature (flushes) arising from surges of material in the kiln.

The facility to use excess air does not exist with planetary coolers, which may have difficulty in achieving satisfactory clinker temperatures without using external or internal water spray systems. As cooling air is drawn through planetary coolers to the kiln by an induced draught fan, the possibility

Release  
routes

## Release routes

of dust emissions is greatly reduced. Rotary coolers also use internal water sprays but this practice adversely affects thermal efficiency.

Inspectors should also be aware of the possibility of the build up of rings of material around the circumference of rotary kilns. Break up of these rings ("ring fall") can produce surges of particulates which can cause problems for abatement equipment.

Lime processes produce dust from attrition within the kiln system and from fuel ash. However, the level of dust produced in shaft kilns is inherently lower than for rotary kilns. The hydration process also produces a particulate stream which, being wet, can be particularly difficult to abate.

The dust produced in lime kilns tends to be less dense than from cement production and in general more difficult to abate.

Particulates are also generated by all other process operations. Low level dust emissions, for instance, from material handling, can be more significant than dust releases from the kilns and hydrator operations.

### Other releases

#### Organic compounds

Evidence from measurements made by the cement industry suggests that the release of organic compounds from kiln systems is mainly due to small amounts of organic materials contained in the raw materials rather than due to the fuel. This is because the conditions with typical kilns (temperatures greater than 1400°C and residence times of more than three seconds) should efficiently destroy fuel organics, but, as with sulphur, any volatile organic content in the raw materials can be released into the kiln's exhaust gases without being exposed to high temperatures.

Dioxins can be formed in any combustion system provided that chlorine and organic compounds are available. The combustion conditions within kilns should help to ensure that any dioxins are effectively destroyed. However, heterogeneous catalytic formation ('de novo synthesis') at temperatures of 200–450°C is possible. This can occur due to the reaction of chlorine with any evaporated organics from the raw materials, as the kiln gases cool.

Research has indicated that trace amounts of chlorinated aromatic compounds can also be formed in the preheater section of dry cement kilns.

#### Oxides of carbon and CO trips

Carbon dioxide is inevitably produced by the kiln process from the calcination stage and from the burning of fuel.

Carbon monoxide can arise due to the incomplete combustion of fuel and from any organic carbon content of the raw materials. The contribution from the raw materials, due to preheating, will be exhausted with the kiln gases, again similarly to sulphur.

Inspectors should be aware that carbon monoxide contributions from raw materials in cement production can be very significant compared with that from combustion.

Control of CO levels is critical in cement and lime kilns when EPs are used for particulate abatement, to ensure concentrations are kept well below the lower explosive limit. If the level of CO in the EP rises (typically to 0.5% by volume) then the electrical system is tripped to eliminate the risk of explosion. This leads to unabated particulate releases from the kiln which can cause considerable local dust nuisance. CO trips can be caused by unsteady state operation of the combustion system often caused when feeding solid fuels. Solid fuel feeding systems must be designed to prevent surges of fuel into the burner. The moisture content of solid fuels is a particularly critical factor in this respect and must be carefully controlled to prevent hold ups or blockages in the fuel preparation and feeding systems.

#### Metals and chlorine

Metals released from the kiln system arise from quantities contained in the raw materials and fuel.

The release of metals is characterised by cycles within the kiln system and their volatility. Metals (and compounds of the those metals) fall into three classes:

- refractory (relatively non-volatile), including barium, beryllium, chromium, arsenic, nickel, vanadium, aluminium, titanium, calcium, iron, manganese and copper;
- semi-volatile, such as antimony, cadmium, lead, selenium, zinc, potassium and sodium; and
- volatile, such as mercury and thallium.

Metals are released from the kiln system absorbed into the clinker or quicklime, in the kiln exhaust gases or in CKD/lime dust. The high alkali content and the scrubbing action within kilns favour retention of metals within the clinker/quicklime. Measurements on cement kilns indicate that <0.1%



of refractory metals and <0.5% of semi-volatile metal compounds entering the kiln are released in the kiln exhaust gases. However, semi-volatile metals tend to condense on the CKD and in some cases concentrations can be many times greater than in the clinker. Volatile metals partially remain in the kiln exit gases.

Metal chlorides tend to be more volatile than the elemental form. In cement production chlorine tends to leave the kiln in the form of alkali salts in the CKD. The cement industry can therefore encourage the formation of alkali metal chlorides to reduce the residual levels of alkalis in the clinker.

### Ammonia

Inspectors should be aware that there are a few cement sites throughout the world where ammonia or ammonium salts are contained in the raw materials fed to the kiln. The ammonia can react with chlorides and perhaps sulphates to form ammonium salts which leave the kiln with the exhaust gases. On cooling through the EP or in the atmosphere, dense plumes of condensed ammonium salts can form. There is currently only one cement site in the UK where this is apparent.

### Fuels

Fuels will contribute to potential pollutant releases from cement and lime processes and the effect of using any fuel must be fully assessed by the operator and carefully considered by the Inspector before authorisation is granted.

The main fuels currently used in the UK cement industry are coal and petroleum coke, although oil, LPG and gas are used in addition by the lime industry. Solid fuels are pulverised and dried in mill systems before feeding directly, or indirectly via storage silos, to the burners with primary combustion air. Secondary air is introduced (via the clinker coolers in cement production) to complete combustion and utilise recovered heat. Careful design of solid fuel systems is required to ensure steady firing rates (see 'CO trips' above).

Other fuels can be used by the industry such as substitute liquid fuels (SLF) (for instance solvent waste residues) and substitute solid fuels (such as waste tyres either whole or chipped).

In assessing the use of any fuel Inspectors should consider the points below.

### Physical state of the fuel

Liquid fuels tend to be easier to handle and burn and can lead to more stable kiln conditions. For

instance, it has been found that switching some of the solid fuel burning to SLF at some sites has resulted in reductions of NO<sub>x</sub> due to improved flame characteristics. Fuel storage and handling can also contribute to releases. For example, SLF should be stored in bunded tanks and vapour return lines used to minimise VOC release on filling.

### Composition of the fuel

The type and amounts of constituents of the fuel which contribute to pollutant releases should be assessed. Inspectors should consider the need to set limits on individual constituents such as sulphur, metals, chlorine and PCBs. The setting of limits on certain fuel constituents may be particularly appropriate for processed fuels.

Sulphur content may affect releases of SO<sub>2</sub> with lower input likely to lead to lower releases unless pollution abatement is in place.

The inherent nitrogen content of the fuel is also important with respect to fuel NO<sub>x</sub> releases. For instance, burning petroleum coke may result in increased NO<sub>x</sub> releases compared to coal.

Metal content has two main effects. Volatile metals, such as mercury, tend to pass out of the kiln in the exhaust gases so any increases in fuel mercury content may be reflected in increased releases. Semi-volatile metals will tend to condense onto CKD/lime dust and Inspectors should assess the consequences of any subsequent disposal.

See Section 1.6 for further discussion on these issues.

### Kiln system

The type of kiln system and the effectiveness of the abatement equipment fitted affect the choice of fuels.

For semi-volatile metals, the effectiveness of the particulate abatement system is important as these metals will be associated with fine particulate matter. Therefore efficient particulate abatement can be used to control the release of these metals in the kiln exhaust gases. Any dioxins present also tend to be associated with the fine particulate matter.

### Classification of the fuel

Although the most important factor when considering the use of any fuel in kiln systems is the environmental consequences of that use, certain fuels may be classified as waste under the Waste Management Licensing Regulations<sup>(9)</sup>. Some fuels may also, therefore, fall into the category of

**Release  
routes**

## Release routes

hazardous waste under the Hazardous Waste Incineration Directive<sup>(10)</sup>. Fuels such as SLF derived from waste solvent are considered by the Agency to be wastes and burning of these fuels will therefore be subject to the requirements of the Directive<sup>(10)</sup>. However, Inspectors should note that the ultimate decision on the classification of these fuels rests with the Courts. Further guidance is given in Section 3.2.

Inspectors should be aware that trials to burn certain waste derived fuels, such as SLF and tyres are subject to Agency protocols. Inspectors should seek guidance on the status of any such protocols before authorising any trial burns.

### 1.6.2 Release routes

Releases to the environment commonly associated with the processes described are listed in Table 3.

**Table 3:**  
Potential release routes for prescribed substances and other substances which may cause harm

SOURCE RELEASES				Substances						
To:	Air	Water	Land	Particulate matter	Oxides of sulphur	Oxides of nitrogen	Oxides of carbon	VOCs	Metals & their compounds	Halogens & their compounds
Prescribed substances (defined in SI 472):	A	W	L							
Other substances which may cause harm:	a	w	l							
Quarry operations				AWI						
Raw material preparation, handling and storage				AW						
Fuel preparation, handling and storage				AW				A		
Kiln				AL	A	A	A	A	AL	AL
Cooler <sup>Note 1</sup>				A						
Hydrator <sup>Note 2</sup>				A						
Cement milling <sup>Note 1</sup>				A						
Product handling and storage				A						
Notes:										
1. Cement processes only.										
2. Lime processes only.										

## 2 Techniques for controlling releases

### Introduction

#### 2.1 Introduction

The standard techniques for pollution abatement are outlined in various reference sources including:

- Separation Processes Service<sup>(11)</sup>, manuals and reports;
- Effluent Processing Club<sup>(12)</sup>, manuals and reports;
- Air Pollution Advisory and Review Group<sup>(13)</sup>, reports;
- BAT Review Reports on Pollution Control; and
- HMIP/EA Technical Guidance Notes relating to IPC.

These techniques need to cover releases from raw materials reception/storage, internal transportation, processing, waste materials internal transport and storage pending disposal.

The process should be designed and operated in such a way that the substances released have the minimum impact on the environment. The operator's proposals should include a reasoned argument, in terms of the selected combination of primary process and abatement equipment, of why they represent BATNEEC to:

- prevent releases of prescribed substances or if not, to minimise them and render them harmless;
- render harmless releases of other potentially harmful substances; and
- provide the BPEO to minimise the environmental effect of operating the process.

This should then be confirmed by conditions in the authorisation. Since the priority is to prevent releases, emphasis should be placed on the avoidance of processes and abatement techniques which create wastes.

Prevention or minimisation by re-use, recovery and recycling procedures should be applied whenever possible, within the criteria for BATNEEC and BPEO.

In general, pollution control equipment should be kept running during start-up and shut-down for as long as is necessary to ensure compliance with release limits in authorisations.

All plant and equipment should be subject to regular preventative maintenance programmes, in line with operational requirements, to ensure continued optimum performance.

More details of the methods available for preventing or reducing releases are listed in BAT Review Report on Pollution Control in the Cement Industry and Pollution Control in the Lime Industry<sup>(14)</sup>. The most important techniques include, but are not restricted to, those given below.

#### 2.2 Techniques for controlling releases into air

Inspectors should also refer to Section 4.2 where the economic implications of using some of the techniques listed below are assessed.

##### 2.2.1 Particulate matter

There are various options available for dealing with the main process exhaust gases which may include one or more of the following techniques depending upon the particular process and the type of dust to be treated. Inspectors should be aware that release from the kiln exhaust may not be as significant as from other parts of the process such as materials handling, crushing and grinding.

##### Electrostatic precipitators

EPs have found wide application de-dusting cement kiln, clinker cooler and cement mill exhausts. They are also used on rotary lime kiln exhausts. EPs are characterised by their ability to operate under conditions of high temperature (up to 370°C) and, unlike fabric filters, high humidity. In some cases conditioning towers are installed upstream of the EP in order to introduce water vapour into the gas stream and improve precipitator performance. Significant changes in the gas conditions entering EPs can be induced by the intermittent operation of raw meal mills through which kiln gases are exhausted. Careful management of the start-up and shut-down of these mills is required to eliminate sudden changes in gas conditions and optimise EP performance. EPs inherently have low pressure drops, thereby reducing the power consumption of induced draught fans.

A disadvantage of EPs is the risk of sparking off explosions of partially burned fuel or gas mixtures, resulting from incomplete combustion in the kiln. The risk is minimised by automatically tripping the EP when the carbon monoxide content of the kiln gas entering the EP reaches a pre-set level (below the lower explosive limit). Particulate releases will rise significantly during CO trips so every effort should be made to minimise their duration and frequency. Short duration EP trips would be



expected to result in lower mass particulate releases over time compared to the alternative of stopping and restarting the kiln. Equipment suppliers are developing technology that reduces voltages instead of completely tripping the system based on careful monitoring of CO levels thereby reducing the periods when the EP is off line. This technology has yet to be proved in industrial conditions and will require careful evaluation of the safety aspects.

Suppliers of EPs claim that they can design and supply equipment capable of achieving exit dust loadings of less than  $30 \text{ mg/Nm}^3$  and which can consistently achieve exit dust loadings on a day-to-day basis of less than  $40 \text{ mg/Nm}^3$ . This represents the concentration level at which dust in the exhaust gas plume is almost invisible. The enhanced designs now being offered by the suppliers represent an extension of existing technology rather than the application of new unproven principles.

Existing EP installations can often be upgraded without total replacement of the equipment. Upgrade techniques include the introduction of vanes to even out gas flows, upgrading of electrical systems and optimising rapping cycles.

#### **Fabric filters**

Fabric filters are favoured in many gas cleaning operations due to their simplicity, reliability, efficiency and economic competitiveness. Further, modern designs allow on line maintenance without seriously reducing filtering efficiency. Fabric filters have been used on cement kiln exhausts in other countries but are not favoured by the UK cement industry. Fabric filters are used by the lime industry on kiln exhausts with careful control of temperature using air to air heat exchangers. Fabric filters are also used on cement, raw meal and coal mills.

Although fabric filters are unlikely to induce explosion of incompletely combusted fuel or explosive gas mixtures, they may be damaged if such explosions are initiated elsewhere. Explosion venting should be installed, particularly in pulverised fuel systems where fire detection and automatic suppression are also necessary.

The application of fabric filters is limited by both humidity and temperatures of gas-laden streams. Further disadvantages of fabric filters include their relatively high operating costs due to inherently higher pressure drops.

One advantage of fabric filters is the absorption of  $\text{SO}_2$  that can occur in the alkaline cakes of collected dust on the surface of the bags, particularly in lime production.

#### **Ceramic filters**

A more recent innovation is the use of ceramic filters which are able to withstand corrosion and high temperatures up to  $900^\circ\text{C}$ , provided the correct materials of construction are used. The ceramic filters give high collection efficiencies with comparable pressure drops to bag filters and eliminate the problems of fabric bag failure or EP trips. Particulate release levels of less than  $10 \text{ mg/Nm}^3$  are reported from installations in other industries. However, the flows involved in the cement and lime industry would make for large ceramic filter installations consisting of many individual ceramic elements. If larger ceramic elements are developed, more compact units will become available. Lime industry experience has shown problems with air slaking of quicklime onto the ceramic surfaces thus causing the filters to blind.

#### **Gravel bed filters**

Gravel bed filters do not have the same temperature limitation as fabric filters. They are capable of cleaning gases with temperatures in excess of  $500^\circ\text{C}$ , although they also function best at low humidities. They are suited to clinker cooler operations and are capable of achieving between  $50 - 100 \text{ mg/Nm}^3$  but not much lower.

#### **Wet scrubbing and lime hydrator exhaust**

Various wet scrubbers are in use mainly in the lime industry as they give rise to liquid effluent which, if not recycled into the process, requires treatment and disposal. This has implications when considering the BPEO.

However, wet scrubbers are more suited to the abatement of lime hydrator than kiln exhausts.

A common issue with lime hydrators is the very visible water vapour plume. The entrained dust particles act as condensation nuclei thereby causing the plume to be more persistent than would otherwise be the case. Some plants are fitted with a purpose designed wet scrubber while others are fitted only with cyclones, irrigated cyclones or simple water sprays which will not achieve the releases given in Section 1.5.

Use of a wet scrubber with a lime hydrator ideally requires that the water usage should match the needs of the hydrator to avoid a disposal problem of the resulting alkaline milk of lime. In addition, the scrubber should not be susceptible to the effects of build-up of solid deposits. An option is the use of a low energy scrubber in which a rotating fibre mop is used in place of the normal impeller of a centrifugal fan. This is a compact unit

## Particulate releases from other process operations

which carries out the dual function of inducing the required gas flow through the hydrator and scrubbing the outlet gases. Release levels of 50 mg/m<sup>3</sup> are possible but routine maintenance must be rigorously carried out to maintain this release level.

### 2.2.2 Particulate releases from other process operations

#### Housekeeping

A high standard of housekeeping should be maintained in all areas with particular attention being paid to those parts of the plant where process and waste materials are stored or loaded. Loading and unloading of vehicles should only be done in designated areas provided with proper hard-standing. Hardstanding areas should be constructed with appropriate falls to an adequate drainage system.

#### Materials handling

The receipt, handling and storage of all materials should be carried out so as to minimise the emission of dust to the air.

Stocks of dusty material, should be stored in silos or covered storage, vented to air if necessary through suitable arrestment equipment.

Bulk cement, clinker and quicklime should be stored in closed buildings or silos. These silos should be vented to suitable arrestment plant, for example bag filters. Storage silos should be equipped with audible or visual high level alarms to warn of overfilling. The correct operation and use of such alarms should be checked regularly.

Seating of pressure relief valves to all silos should be checked periodically.

For emissions from ancillary processing equipment (crushing, screening, blending, packing, loading, etc.), dust containment and arrestment should be the preferred option. However, it is recognised that in some cases, such as remote mineral conveyors, suppression techniques where properly designed, used and maintained, can be an effective alternative means of control.

The transfer of cement or lime should be by air slide, elevator, screw feeder, enclosed chain conveyor, gravity or pneumatic means or suitably enclosed belt conveyor. Transport of other dusty materials, such as clinker, inside buildings should be carried out so as to prevent or minimise airborne dust emissions. Where conveyors are used, they should be of sufficient capacity to handle

maximum loads and should be provided with protection against wind-whipping, for example by fitting side boards. Conveyor discharges should be arranged to minimise free fall at all times. Where dusty materials are conveyed outside buildings, above ground conveyors (or other mechanical means) should be fully enclosed and extracted to suitable arrestment plant.

Other materials which may generate airborne dust emissions, for example crushed rock, coarse aggregate, or coal should be delivered, stored and handled so as to prevent or minimise dust emissions – for example by dampening or covering.

Road vehicles or rail wagons should be loaded in such a way as to minimise airborne dust emissions. If they are loaded with dry materials, this should be carried out where local dust control measures are provided, for example extract ventilation to arrestment plant.

The packing of lime and cement into bags should be carried out using purpose-designed plant fitted with extraction equipment and the displaced air ducted to suitable arrestment plant, for example bag filters. Arrestment plant should be fitted with a failure warning device, for example a pressure drop sensor and alarm.

All spillages should be cleaned up promptly using, for example, a vacuum cleaner or vacuum system. Particular attention should be paid to preventing and cleaning up deposits of dust on support structures and roofs in order to minimise wind entrainment of deposited dust.

In designing a new process, consideration should be given to a layout which minimises vehicle movement on site.

### 2.2.3 Oxides of nitrogen

The following techniques can be applied to reduce oxides of nitrogen discharges to the atmosphere.

#### Kiln Control

Careful control of kiln burning parameters will reduce NO<sub>x</sub> formation and level out the variability of releases. Control of oxygen content is critical to NO<sub>x</sub> control. Generally the lower the oxygen content at for instance a cement kiln back end, the less NO<sub>x</sub> is produced. However, this has to be balanced against increases in CO and SO<sub>2</sub> at lower oxygen levels.

Several cement equipment suppliers have developed expert automatic control systems based usually on the control of the burn by monitoring NO<sub>x</sub> levels.

## Particulate releases from other process operations

These systems have found favour with several cement manufacturers and, it is claimed, can lead to significant reductions on the overall release of  $\text{NO}_x$ .

### Low $\text{NO}_x$ (or low primary air) burners

The principle of these burners is the reduction of localised hot spots by the use of induced gas swirl and low primary air rates. There is some debate as to the effectiveness of these burners in reducing  $\text{NO}_x$ , but there is no doubt that in some applications reduction in  $\text{NO}_x$  of up to 30% has been achieved. These burners are only suitable for rotary kilns.

### Selective non-catalytic reduction

Injection of ammonia into kiln systems reduces  $\text{NO}_x$  formation by chemically reducing it to nitrogen and water. Some cement equipment suppliers offer such systems and substantial reductions in  $\text{NO}_x$  are claimed. The technique relies on injecting ammonia or ammoniated water into the kiln system at a point where temperatures of around 900–950°C occur. Thus its application to preheated and precalciner kilns is relatively straightforward in principle, although there can be technical problems. Other kiln systems pose physical injection problems into the required temperature zone. This technology could also be applied to lime production.

Inspectors should be aware of the possibility of ammonia slippage with this technique unless  $\text{NO}_x$  levels are monitored and the addition of ammonia closely controlled. There may also be the potential for the formation of ammonium chloride fume if excess ammonia is present.

### Kiln configuration/staged combustion techniques

In lime production, kilns based on fluidised bed techniques tend to produce the least  $\text{NO}_x$ .

Of cement kilns, precalciners produce the lowest specific  $\text{NO}_x$  releases, with wet kilns generally giving the highest releases due to the higher fuel requirements. Some kiln suppliers have developed low  $\text{NO}_x$  kiln technology. This technology relies on producing reducing zones, for instance in the lower section of a precalciner chamber where  $\text{NO}_x$  is chemically reduced. The excess CO produced in these zones is oxidised in other areas of the system such as the upper sections of calciner chambers.

## Fuel

Some fuels have higher nitrogen contents than others.

The physical state of fuels also affects  $\text{NO}_x$  releases. Liquid fuels are easier to control and tend to produce less thermal  $\text{NO}_x$  than solid fuels due to the reduction in local hot spot formation. For solid fuels, thermal  $\text{NO}_x$  evolution seems to be related to fineness; the finer the grind, the lower the  $\text{NO}_x$  again probably related to hot spots.

There is evidence to show that the burning of tyres and tyre chips significantly reduces  $\text{NO}_x$  levels in cement production. This reduction is probably due to formation of reducing zones where the tyres are being burned. Tyres can be introduced into rotary kilns using properly designed feed systems. Tyre chips are not usually burnt in the main kiln burner but are used to fuel the calciners or the preheater cyclones in cement processes.

### 2.2.4 Sulphur dioxide

Several techniques can be applied to minimise  $\text{SO}_2$  releases.

#### Kiln Type

Most lime kiln technology ensures that  $\text{SO}_2$  is absorbed in the quicklime with fluidised beds and shaft kilns being good absorbers.

In cement production, preheater and calciner kilns offer the highest levels of inherent absorption of  $\text{SO}_2$  into the clinker whilst wet kilns generally provide less effective absorption.

#### Raw materials and fuel selection

If sulphur does not enter the kiln system then it cannot be released. Limiting sulphur contents of both raw materials and fuels will therefore reduce releases of  $\text{SO}_2$ .

Selective quarrying techniques may provide the possibility of leaving high sulphur seams of limestone in the quarry. Also the blending of limestones of differing sulphur contents may lead to more uniform release concentrations of  $\text{SO}_2$ . However, the practicable application of this technique may be difficult.

#### Kiln control

As with  $\text{NO}_x$ , close control of kiln conditions, particularly oxygen level, can reduce releases of  $\text{SO}_2$  and should reduce the variability of the release.

## Lime injection

Lime injection can be used in several ways to reduce  $\text{SO}_2$  releases but it is not widely used and the effectiveness can vary from plant to plant.

Limewater can be injected into gas streams prior to particulate abatement equipment. As water injection is often used to reduce temperatures prior to EPs, this technique can often be readily adopted technically in both the cement and lime industry although running costs must be considered.

Dry lime can be injected into the top cyclone of preheated cement kilns. Tests by equipment suppliers indicate that 6–7 times more than the stoichiometric requirement is needed to achieve a given reduction, which has running cost implications.

## Bypass streams – cement kilns

Bypass streams can contain high concentrations of  $\text{SO}_2$ . This  $\text{SO}_2$  can be abated by the addition of hydrated lime to the conditioning tower prior to particulate abatement.

An equipment supplier also offers gas suspension absorbers that both cool and desulphurise the bypass gas stream, although the technique is not yet well proven on cement processes. The technique uses CKD (with or without added lime) as the absorption medium.

## Flue gas desulphurisation

Wet and dry techniques can be applied to any lime or cement kiln process and operate successfully at an industrial scale on at least two cement plants (outside the UK). However, the economic implications of using these techniques must be carefully considered. Both techniques rely on using lime in wet or dry states to absorb  $\text{SO}_2$ . The resulting gypsum can be used in cement milling in place of imported gypsum. Up to 75% reductions in  $\text{SO}_2$  can be achieved.

## 2.2.5 Other releases

### Carbon filters

One equipment supplier markets a two-stage travelling bed filter system using activated coke. The only unit in operation is outside the UK on a precalciner cement process. The activated coke system not only removes  $\text{SO}_2$ , but heavy metals and organic compounds. The plant also uses ammonia injection to minimise  $\text{NO}_x$  releases and the activated coke removes any consequent ammonia slippage. Removal efficiencies of up to 80% are

reported. The spent coke is used to fuel the kiln process.

The temperatures within the carbon bed have to be carefully controlled to prevent burning of the material within the bed.

Considerable capital investment is required to install such equipment and its use in the lime industry has yet to be proven.

## Dioxins and metals

Although the release of dioxins can be abated by fitting carbon filters, the primary method of minimising releases is by careful control of kiln conditions. The gas residence times, temperatures and oxygen contents within kiln systems are such that any dioxins should be efficiently destroyed. However, Inspectors should ensure that the conditions for de novo synthesis after the kiln are avoided. Therefore, kiln exit gas streams should be quickly cooled through the de novo temperature region between 450 and 200°C.

Dioxin formation needs sources of organic materials and chlorine and thus the limiting of chlorine input may have some effect.

Dioxins tend to adhere to particulate matter and therefore efficient particulate abatement will remove dioxins from the gas phase. Certain metals are also associated with particulate matter and their release can also be reduced in this manner.

## Chimneys and vents

## 2.3 Chimneys and vents

### 2.3.1 General

Operators should make an appropriate assessment of vent and chimney heights required to provide adequate dispersion of prescribed substances, and other substances which might cause harm, whose release cannot be prevented. This should include process failures. Some guidance is given in HMIP Technical Guidance Note D1<sup>(4)</sup>.

For many processes it will be necessary for dispersion modelling to be carried out which takes into account local meteorological data, local structures and topography, as well as other local releases. This will be particularly important for sites with any large volume emission, significant non-combustion sources or multiple release points and sites where there are sensitive receptors nearby. Operators should provide clear information on the parameters used and the assumptions made in their use of dispersion models. The assessment of background concentrations of pollutants will be particularly relevant. Statutory air quality

## Techniques for controlling releases into water

standards<sup>(7)</sup> and other recognised criteria should be taken into account.

The Agency may validate the assessment made by the operator using the appropriate calculations or dispersion models available.

### 2.3.2 Wet plumes

Wet plumes do not disperse well and tend to ground easily. Additionally there can be local visual amenity issues and, in severe cases, loss of light issues. Therefore the gas should be discharged at conditions of temperature and moisture content that avoid saturation under a wide range of weather conditions.

The normal option is to add heat, however, the use of energy should be balanced against the benefits gained. Plumes must be abated sufficiently to ensure good dispersion but a limited visible plume may be acceptable in cold damp conditions.

Alternatively moisture can be removed by cooling and condensation followed by reheat. However, where this is not an inherent part of a wet scrubbing process (where temperature is typically reduced to around 70°C for scrubbing purposes), the disadvantage would be the generation of a significant liquid effluent stream.

As a further option, to minimise expense and energy use, operators may wish to guarantee to reduce load under extreme weather conditions rather than to over design a plume abatement system.

### 2.4 Techniques for controlling releases into water

Lime and cement production does not normally produce significant quantities of liquid wastes, surplus water usually being limited to surface run off process/cooling water only. However, Inspectors should note the following general guidance.

Process waters, site drainage waters, emergency fire water and chemically contaminated waters should, where appropriate, be contained and where necessary treated before release to controlled waters or sewer.

Areas where spillages are most likely, such as storage tanks and sampling points, should be bunded. Rainwater collected from bunds should not be disposed of via surface water drains or soakaways and the composition of any wastes collected should be checked prior to treatment or disposal. Bunds should:

- be impermeable;

- have no outlet;
- drain to a sump;
- be designed to catch leaks from any likely failure of the tank or its fittings;
- be hydraulically tested on initial construction and subsequently where there is any doubt about their integrity (noting the need for care in the disposal of any contaminated water);
- have a capacity at least 110% of the largest tank;
- where not frequently inspected, be fitted with a high level probe and an alarm as appropriate;
- have the fill points within the bund where possible.

Releases to water may be direct, for example process effluent or cooling water, or indirect, for example, from plant surface water drains. In either case the water may contain relatively low concentrations of certain substances, but if large volumes of water are involved, the mass releases of those substances can be substantial. The following general principles should be applied in sequence to control releases to water:

- Any use of water should be minimised, thereby minimising the amount of contaminated water to be dealt with.
- Methods of avoiding or reducing contamination, or risk thereof, of process or surface water should be considered.
- Water should be recycled within the process from which it issues, by treating it first if necessary. Where that is not practicable it should be recycled to another part of the process which has a lower water quality requirement.
- Ultimately, surplus water is likely to need treatment to meet the requirement to prevent, or minimise and render harmless. Generally any physico-chemical treatment will be more efficient on the more concentrated individual or similar effluent streams than treating the whole mixed effluent. However, the inherent properties of dissimilar waste streams can be usefully employed to avoid adding further chemicals, for example by balancing waste acid and alkaline streams to control the resultant pH. An exception to the preference for treating waste streams individually would be when biological treatment is proposed and treatment of the whole mixed effluent overcomes an inhibitory effect of any individual waste stream.

Further techniques can be found in reference 14.

### 2.5 Techniques for controlling releases to land

The aim for all processes covered by this Note should be to prevent the creation of waste



containing substances prescribed for release to land or which could cause harm. Where this is not possible, releases should be minimised by attention to raw materials and process routes, and by recycling wastes arising within the process or re-using them elsewhere.

The key pollutants likely to be present in releases to land can be derived from a knowledge of the process, materials of construction, corrosion/erosion mechanisms and materials related to maintenance, validated as necessary by the appropriate analytical techniques. The presence of substances created by abnormal operation should be identified, since process abnormalities can carry through substances into the solid waste that are not normally present.

The most significant potential solid waste from cement and lime processes is particulate matter collected in dust abatement devices. This dust tends to concentrate trace impurities in fuels and raw materials such as certain volatile metals and dioxins. Calcium oxide is a prescribed substance and its release to land should be prevented or minimised and rendered harmless using BATNEEC.

Whether recycling is possible will depend on site-specific factors such as the particular fuels, raw materials, products and methods of operation. Section 1.6 gives further details.

In cement production, inspectors should expect this material to be recycled to the production processes whenever practicable. This recycle may be directly into the kiln or kiln feed (alkali content being the limiting factor) or by blending with finished cement products. Alternative uses may be found for material that cannot be recycled. For example CKD

has been used in civil engineering and construction (lightweight aggregates and blocks).

For lime processes direct recycle of kiln dust back to the kiln process is difficult and alternative uses of the materials should be examined (similar to CKD).

Adequate facilities should be provided for the on-site storage, handling, loading and transportation of wastes prior to their removal from the area covered by IPC site authorisations.

If no uses can be found for collected dust, then disposal to controlled landfill will be necessary.

## Odour and noise

### 2.6 Odour and noise

#### 2.6.1 Odour

Efforts should be made to identify substances present in emissions to air which may give rise to odours. BATNEEC must be used to prevent an offensive odour being noticeable outside the boundary of the site where the process is carried on.

#### 2.6.2 Noise

Kilns burning any material defined as waste under the Waste Management Licensing Regulations<sup>(9)</sup> will have to be regulated taking into account the relevant objectives of the Regulations which include noise control.

Inspectors may be required to regulate noise emissions. Reference should be made to any separate guidance on techniques and standards which may be produced by the Agency.

## Reference conditions

**Table 4:**  
**Benchmark**  
**release levels**

## 3 Benchmark releases

Substance	Benchmark release levels <sup>Note 1</sup>	
	Kiln exhaust gases <sup>Note 2</sup>	All other contained releases <sup>Note 3</sup>
Particulates	40 <sup>Note 4</sup>	50
Oxides of sulphur expressed as SO <sub>2</sub>	200 <sup>Note 5</sup>	
Oxides of nitrogen expressed as NO <sub>2</sub>	900 <sup>Note 6</sup>	

**Notes:**

1. Dilution air must not be used merely to achieve a particular release concentration.
2. Based upon new lime kilns and new preheater/calcliner cement kilns and including cement kiln bypass streams. The particulate releases also apply to cement mill exhausts. The spot release concentrations from kilns are very variable. Research into this variability is being carried out by the industry. The benchmark values are based on 24 hour average releases from the kiln (excluding periods of start-up, shut-down and non operation). Limits in authorisations will need to be phrased to reflect the variability of a particular release, for instance, longer averaging periods may be appropriate for some releases.
3. Including lime hydrators and clinker coolers.
4. This release concentration would be exceeded during CO trips if EPs are used for abatement.
5. This reflects the use of low sulphur raw materials. The need to abate higher concentrations must be assessed in the light of the technical options and economics given in this Guidance Note.
6. Reference should be made to Section 1.4 to appreciate the dependence of NO<sub>x</sub> levels on process characteristics and the raw materials used.

### 3.1 Reference conditions

The reference conditions of substances in releases to air from point sources are:

for combustion gases – dry, temperature 273 K (0°C), pressure 101.3 kPa (1 atmosphere), 11% v/v oxygen:

for non-combustion gases – temperature 273 K (0°C), pressure 101.3 kPa (1 atmosphere).

These reference conditions relate to the benchmark release levels given in this Note and care should always be taken to convert benchmark and proposed releases to the same reference conditions for comparison. The authorisation may employ different reference conditions if they are more suitable for the process in question.

To convert measured values to reference conditions see HMIP Technical Guidance Note M2<sup>(15)</sup> for more information.

Releases may be expressed in terms of mg/m<sup>3</sup>, g/h, g/te(product) as appropriate.

### 3.2 Benchmark release levels to air

#### General

Table 4 gives benchmark release levels for key substances in the context of the processes

concerned at the time of writing. They are not emission limits but are subject to consideration of site-specific BATNEEC and BPEO when framing conditions in an authorisation. Refer to Section 1.1 with regard to their use.

#### Dioxins

Inspectors should be aware of the potential for the release of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans ("dioxins") from combustion processes. An achievable release of 0.1 ng/m<sup>3</sup> ITEQ is appropriate.

#### Carbon monoxide

Whilst levels of 300-500 mg/m<sup>3</sup> are achievable in some cases, primary control to minimise CO may prejudice other interrelated releases, for example NO<sub>x</sub>.

### 3.3 Mandatory emission limits

#### General

All releases must be controlled and minimised to ensure that ambient air quality beyond the process boundary complies, as a minimum, with air quality standards<sup>(7)</sup>.

## Benchmark release levels to air

**Table 5:**  
**Mandatory**  
**requirements**  
**when**  
**burning**  
**40% or**  
**more**  
**hazardous**  
**waste**

Substance	Emission limits (mg/m <sup>3</sup> )*		Monitoring requirements	Compliance conditions
	Daily average	Half hourly average		
Particulates	10	30 (10)	continuous	Daily averages to be less than these limits; and either: all 30 min averages over a year to be less than limits; or, 97% of 30 min averages over a year to be less than bracketed limits
VOCs as carbon	10	20 (10)	continuous	
HCl	10	60 (10)	continuous	
HF	1	4 (2)	spot when HCl can be used as a surrogate	
SO <sub>2</sub>	50	200 (50)	continuous	Daily averages to be less than these limits and either: all 30 min averages in 24 hours to be less than limits; or 95% of 10 min averages over a year to be less than 150
CO	50	100	continuous	
	New plants	Existing plants		
Cd and Tl in total	0.05	0.1	6 monthly	All average values over the sample period to be less than these limits
Hg	0.05	0.1	6 monthly	
Pb, Cr, Cu, Mn, Ni, As, Sb, Co, V and Sn in total	0.5	1.0	6 monthly	
Dioxins TEQ	0.1 ng/m <sup>3</sup>	0.1 ng/m <sup>3</sup>	6 monthly	From 1/1/97 if measurement method agreed by EC, otherwise 1 ng/m <sup>3</sup>

\* Reference conditions are dry, temperature 273 K, pressure 101.3 kPa, 11% oxygen.

### Hazardous Waste Incineration Directive<sup>(10)</sup>

The burning of hazardous wastes in cement and lime kilns will fall under the Hazardous Waste Incineration Directive which must be brought into UK law by 31 December 1996. All new and substantially modified plant must comply from that date. Existing plant, as defined under Article 2(4), must comply with the Directive by 30 June 2000. However, Inspectors should seek to ensure that new or substantially modified plant proposed by 31 December 1996 complies with the Directive within the constraints of BATNEEC and the BPEO.

It is likely that this Directive will be given effect in UK law by a Direction from the Secretary of State to relevant enforcing authorities requiring that authorisation conditions secure compliance with all relevant requirements of the Directive. Detailed guidance will be issued when details of the Direction are known.

The Directive recognises the burning of hazardous waste in plants not intended primarily for that purpose, such as cement and lime kilns. The

Directive requires that if more than 40% of the heat input to a kiln is supplied by fuel classified as hazardous waste under Article 2(2), then the requirements given in Table 5 must be applied.

If the heat obtained from burning hazardous waste is 40% or less of the total kiln heat input at any time then, in accordance with Annex II of the Directive, the emission limit values in Table 5 only apply to that portion of the exhaust gases generated by combustion of the waste. Overall emission limit values are based on prorating between the limits in Table 5 any existing authorised kiln limits based on the exhaust gas flows resulting from incinerating the waste and the flows from the kiln process when fired on non hazardous waste fuels. Inspectors are advised to consult Annex II of the Directive, which contains detailed instructions, before setting any emission limits.

The Directive also requires that the authorisation for the process explicitly lists the types and quantities of hazardous wastes which may be used in the process. In addition, where the hazardous waste provides 40% or less of the thermal input to

**Benchmark  
release  
levels to  
water**

the process, the authorisation shall specify the minimum and maximum mass flow rates of hazardous wastes, minimum and maximum calorific values and the maximum concentration of pollutants, for example PCB, PCP, chlorine, fluorine, sulphur and heavy metals.

Inspectors should seek guidance on which fuels are considered hazardous waste. Further guidance may also be obtained in IPC Guidance Note S2 5.01 Waste Incineration<sup>(16)</sup>.

### **3.4 Benchmark release levels to water**

Guidance is given on benchmark release levels for key substances in the context of the processes concerned at the time of writing. They **are not** emission limits but are subject to consideration of site-specific BATNEEC and BPEO when framing

conditions in an authorisation. Refer to Section 1.1 with regard to their use.

Unless wet scrubbing techniques are employed, releases to water consist of site drainage, and process/cooling water only. On this basis, suspended solids levels of 30 mg/l should be achievable.

### **3.5 Releases to land**

Separate legislation<sup>(9)</sup> deals with the disposal of controlled wastes to a licensed waste management facility, the consignment of special wastes and the duty of care on persons who produce, import, carry, keep, treat or dispose of controlled waste, and they should not be covered in the authorisation. Where controlled waste is finally disposed of by deposit to land, the operator must advise the Agency.

## 4 Financial implications and monitoring requirements

### Financial implications

#### 4.1 Financial implications

In determining a case the Agency must translate BATNEEC into conditions to be included in the authorisation. The BATNEEC criterion requires that a judgement be made, balancing cost against environmental damage. The operator should have constructed a BATNEEC case after examining the range of technically feasible process and/or abatement options. BATNEEC is not concerned with the financial health or resources of a particular operator. Excessive costs are viewed in the context of the process and the industry concerned, and costs of controlling releases should not be disproportionate to the environmental benefits delivered.

In the absence of scope for efficiency savings, there are two elements to the ability of a representative operator in any industry to bear extra abatement costs. One relates to the financial resources typically available for capital expenditure, whether from cash reserves or from external sources such as loans or equity. The other depends on the extent to which costs can be passed on to customers, passed back to suppliers, or absorbed by lower returns within the industry.

What follows is a summary of the detailed information contained in the BAT report for the cement and lime sector.<sup>(14)</sup> Inspectors are advised to consult the report for more information concerning particular companies.

##### 4.1.1 Cement industry

###### UK Industry structure and market

The UK cement manufacturing industry is comprised of three principal companies and is highly competitive. Imports account for about 8% of the total UK market.

Cement is sold into four main markets: ready mixed concrete (rmc), bagged cement (mainly via builders merchants), concrete products (such as tiles, blocks, pipes, slabs etc) and site mixing. Rmc accounts for around 45% of the total, site mixing only 3%, with bagged and concrete products (approximately equally) sharing the remainder.

In general, the market for cement is dominated by a relatively small number of large buyers in the construction materials sector. These buyers operate very price conscious purchasing policies and are able to exert significant pressure on cement prices.

This and threat from imports have led to cement prices declining by 40% since 1986. Financial analysts indicate that the price of bulk cement is around £40/tonne.

###### Competition from imports and substitute materials

International competition is the main threat, although UK producers themselves have the facilities to import cement.

At present the principal imports are from Greece and Eastern Europe.

The capacity available to supply the UK market from overseas plant is substantial and UK prices are effectively capped by threat of imports. In the medium term competition from substitute materials (for instance replacing concrete with metal in construction) may be a significant economic threat. Competition to cement exists in the form of non-concrete construction materials and direct substitutes for cement in concrete. Competition from alternative construction materials is present in certain market sectors, such as building frames and road surfacing. Direct competition from substitutes to cement as a component in concrete, in the form of blast furnace slag and pulverised fuel ash, exists in most bulk cement applications.

###### Current industry financial performance

Overall the profitability of the industry is around 10% as a proportion of turnover (pre tax, pre interest profits basis).

Return on Capital Employed (ROCE) is very variable but is estimated to average approximately 10% based on historic costs.

###### Costs of release control techniques

The approximate costs of employing some of the techniques given in Section 2.2 are given in Table 6. These costs are based on a 2,000 tonnes/day plant dry kiln with preheater. They do not include civil work and ducting and should be treated with caution as they will vary considerably with local conditions.

In addition to the costs of controlling releases Inspectors should be aware that the recently introduced tax on landfill disposal may add additional production costs.

## Financial implications

**Table 6:**  
Approximate costs of pollution control techniques in the cement industry

Technique*	Pollutants reduced*	Approximate capital cost (£ millions)	Approximate annual operating cost (£'000)	Approximate cost per tonne (£/tonne)
EP replacement	Kiln particulates	2-4	100	0.5-1
Bag filter replacement	Kiln particulates	3-6	700	1.7-2.5
EP upgrade	Kiln particulates	0.8-1.2	100	0.3-0.4
Selective quarrying	SO <sub>2</sub>	0.2	100	0.2
Lime addition to preheater	SO <sub>2</sub>	0.5	100-750	0.2-1.3
Dry flue gas desulphurisation	SO <sub>2</sub>	4-8	900	2.2-3.1
Wet flue gas desulphurisation	SO <sub>2</sub>	8-10	2,900	6-6.4
Fuel selection (switch to low sulphur coal)	SO <sub>2</sub>	-	660-1,130	0.9-1.6
Fuel selection (switch to SLF or tyres)	SO <sub>2</sub> , NO <sub>x</sub>	-	-	0.1-1.1 saving
Kiln expert control system/ low NO <sub>x</sub> burner	NO <sub>x</sub>	0.75	50-90	0.4-0.5
Low NO <sub>x</sub> technology	NO <sub>x</sub>	1.5	0.75	0.4
Ammonia injection	NO <sub>x</sub>	0.75-1.5	150-350	0.6-1.3
Activated coke filter	SO <sub>2</sub> , organics, metals	10-15	1,750	4.8-6.0

\* Refer to Section 2.2 for details.

### Economic implications of additional pollution control costs

Due to the presence of the potential competition from imports, there is limited opportunity for UK cement producers to pass on additional costs through higher prices. Any net increase in costs would have to be funded by reduced profits but the potential for offsetting costs against savings made elsewhere in the process should be explored.

Given that the current average return on capital employed for the industry of around 10% is lower than other capital intensive industries then any substantial reduction in income would have a detrimental effect on investment in, and output of, the sector.

As a result of this relatively low expected return, general investment in the industry is low. Continuing capital expenditure on non remunerative environmental projects by the industry is estimated to be equivalent to about £0.5/tonne cement produced with another £0.5/tonne operating cost. Any further investment in environmental projects could reduce the return on investment to levels further below the rate of return required by shareholders.

As a result companies could opt to import cement thus leading to closures of the least profitable plant(s).

The total capital and operating costs of environmental control which the industry as a whole might afford without a significant erosion of the return on investment would be less than £1/tonne.

### 4.1.2 Lime industry

#### UK industry structure and market

The majority of lime processes in the UK lime industry are owned by large mining and mineral processing companies, which typically have a range of interests outside the lime sector. Major companies involved in the sector include ARC, Redland Aggregates, Minorco Minerals (through Tilcon and Buxton Lime) and RMC Industrial Materials. These companies can have sales figures in excess of £1bn. A few independent operators remain, such as Singleton Birch, which have turnovers between £10m and £15m.

The production of lime is carried out both in house and commercially. In house production, in

## Financial implications

which the lime is produced for use within the same company, is carried out by three operators, with about 30 – 40% of total lime production. In-house uses include sugar refining and steel production. The rest of the market is covered by commercial lime producers dominated by six companies. Imports account for a very small proportion of the market.

The uses and end markets for lime are very varied. The principal uses of lime are in the smelting of iron and steel, for building materials (as additions to mortars, and as air entraining agents for concrete blocks) and for environmental applications. Consumption by these sectors accounts for just under 70% of the UK market (captive and non-captive).

UK lime consumption is summarised in Table 7.

**Table 7:**  
**Approximate UK lime usage 1994**

Sector	Consumption (000's tonnes) as CaO
Agricultural	10
Iron and steel	1,300
Chemical use	60
Building materials	240
Sugar manufacturing	100
Environmental	250
Other uses	180
Total	2,140

### Intra-industry competition

There is now overcapacity in the UK lime industry and competition is becoming more intense. This is evidenced by falling prices of calcined lime products in recent years.

The low price of lime in the UK, together with high transport costs and the limited shelf life (reactivity falls over time) of the product, have reduced imports to negligible levels. Prices of imported lime to coastal steel works vary considerably from competitive market rates (£50 – £400/tonne) but given an increase in UK lime prices, competition from these sources could be expected to emerge.

### Competition from substitutes

The principal alternatives to calcined lime products, the main forms of which are "quicklime", hydrated lime and burnt dolomite are limestone and dolomite and other alkalis (eg sodium hydroxide).

Competition from these products is reviewed for each of the main markets for lime.

### Iron and steel

Iron and steel manufacturing has traditionally used only quicklime and burnt dolomite. There is, however, growing interest in substituting limestone for some burnt dolomite which means that calcination takes place during the primary stages of the smelting operation. The practice has been developed in the US, and to date has been trialed at one UK steel furnace. The applicability of the technique is limited by the operating conditions of the individual smelters (relatively low temperatures and high "free space" in the boss are required). Bosses are not readily modified to accept the raw material since this requires an entire rebuild which occurs once every 20–25 years and can cost of the order of £100m. In total it is estimated that the UK steel industry could convert 20% of its lime usage to limestone, representing a little over 10% of the UK market (captive and commercial).

### Building products and construction

In this sector lime competes with cement and chemical admixtures (used as air entraining agents) in the production of lime/cement mortars, and other calcium containing compounds (such as cement, pulverised fuel ash, or blast furnace slag) in the manufacture of aerated concrete products and fire resistant boards. The use of these materials has increased in recent years taking away some of the market from lime.

### Environmental uses

For environmental applications, lime competes with sodium hydroxide, calcium carbonate, and other "waste" derived alkalis from a variety of sources. This tends to be a more price sensitive market than other sectors with consumers able to switch relatively easily between products.

### Other uses

Comparatively little substitution is possible in the chemicals and water treatment markets where the calcined form is generally required.

### Current industry financial performance

Information on financial performance of firms in the lime industry has been difficult to obtain and consolidated accounts from the parent companies only provide an indication of the profitability of the lime business. Financial data are available for only two companies in which lime production accounts for the majority of the companies



## Financial implications

**Table 8:**  
*Approximate costs of pollution control techniques in the lime industry*

Technique*	Pollutants reduced*	Approximate capital cost (£ millions)	Approximate annual operating cost (£'000)	Approximate cost per tonne (£/tonne)
EP replacement	Kiln particulates	1-3	20	5-14
Bag filter replacement	Kiln particulates	2-4	600	26-36
EP upgrade	Kiln particulates	0.5-0.9	20	3-5
Selective quarrying	SO <sub>2</sub>	0.2	80	3
Lime injection	SO <sub>2</sub>	0.8	30	5
Dry flue gas desulphurisation	SO <sub>2</sub>	3-6	400	25-39
Wet flue gas desulphurisation	SO <sub>2</sub>	6-8	400	39-48
Fuel selection (switch to low sulphur coal)	SO <sub>2</sub>	-	30-60	0.8-1.6
Kiln expert control system/low NO <sub>x</sub> burner	NO <sub>x</sub>	0.7	-	3
Ammonia injection	NO <sub>x</sub>	3-4	250	21-26

\* Refer to Section 2.2 for details.

activities. These data together with confidential responses from the industry are the only sources of information from which the profitability of lime manufacture can be estimated. Bearing in mind these limitations it is estimated that the average (pre-tax, post-interest) profitability of commercial lime production is now in the range of 5-10% return on turnover, having decreased markedly over the last 5 years. Information on return on capital has not been forthcoming.

### Costs of release control techniques

Environmental releases from lime processes and the techniques employed for their control are similar to those proposed for cement processes. Table 8 shows the costs of the main pollution control techniques applicable to lime processes, presented in terms of actual costs and cost per tonne of lime produced. Owing to the small size of a typical lime plant compared to a cement process (100 tpd for lime compared to 2,000 tpd for cement), control costs are, in nominal terms, generally lower than at a typical cement works, although unit costs are higher. For certain control techniques, however, cost is more closely related to the nature of the process than plant size. In particular, the fine dust size of lime materials substantially increases the costs of dust controls in materials handling measures, and SNCR costs are higher than cement processes as a result of lower kiln operating temperatures.

In addition to the costs of controlling releases Inspectors should be aware that the recently introduced tax on landfill disposal may add additional production costs.

### Economic implications of additional pollution control costs

The profitability of lime production is not known with any degree of certainty, but firms appear to have made adequate profits even in a depressed market with sustained levels of capital investment. With some industry re-structuring now taking place, average profitability should improve.

Substitutes to lime are prevalent and provide competition in a number of markets. Due to the low price of lime in the UK, imports are not significant at present, but should prices rise significantly, the potential threat from imports will increase. Consequently, opportunities for passing on costs to customers are limited to certain niche markets, such as chemicals and water treatment.

Overall, owing to the wide range of producers, production processes and markets in the lime sector, it is not considered suitable to describe the economics of a typical plant against which the ability of other plants to afford additional pollution control costs can be judged.

In general though, the industry should be able to afford to improve its overall environmental performance.



## 4.2 Monitoring

National Measurement Accreditation Service, NAMAS).

### Monitoring

### 4.2.1 General

There is an expanding series of HMIP/Environment Agency Technical Guidance Notes on monitoring, containing information on theory and methodology, and providing technical information on monitoring techniques (see *Associated Publications* at the end of this Note).

Conditions in the authorisation should require the results of all monitoring to be reported in line with the IPC standard authorisation format.

The operator should provide a clear statement of the potential for release of all substances which might cause harm to the environment, and propose an unambiguous set of procedures for measuring or otherwise estimating releases of key pollutants.

Information should be provided on release routes, methods of relevant monitoring or sampling and analysis, and periods and frequency of assessment. Evidence should be provided that quality assurance procedures are in place to ensure all monitoring and test results are sufficiently accurate and reliable (for example by reference to British/international standards and accreditation with the UK Accreditation Service, UKAS – formerly the

When setting standards of release in authorisations reference should be made to the application to ensure that such conditions are assessable by means described by the operator, and are properly enforceable.

The requirements and frequency of sampling, analysis and monitoring are site- and/or process-specific, influenced by consideration of the anticipated volume and composition of the waste streams, and the potential risk to the environment.

Releases to air from kiln systems are highly variable. Therefore continuous monitoring for particulates, SO<sub>x</sub> and NO<sub>x</sub> is particularly useful to indicate trends in plant performance. There are mandatory monitoring requirements under the Hazardous Waste Directive<sup>(10)</sup> for certain pollutants released to air. Further details are given in Section 1.5.

### 4.2.2 Records and reporting

Instructions on reporting and monitoring, and records and notifications relating to incidents, are given with the IPC standard authorisation format.

# References

1. The Environmental Protection (Prescribed Processes and Substances) Regulations 1991  
SI 1991 No 472, ISBN 0-11-013472-9 as amended by:  
The Environmental Protection (Amendment of Regulations) Regulations 1991  
SI 1991 No 836, ISBN 0-11-013836-8;  
The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1992  
SI 1992 No 614, ISBN 0-11-023614-9;  
The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1993  
SI 1993 No 1749, ISBN 0-11-034749-8;  
The Environmental Protection (Prescribed Processes and Substances) (Amendment) (No 2) Regulations 1993  
SI 1993 No 2405, ISBN 0-11-035405-2;  
The Environmental Protection (Prescribed Processes and Substances, etc) (Amendment) Regulations 1994  
SI 1994 No 1271, ISBN 0-11-044271-7;  
The Environmental Protection (Prescribed Processes and Substances, etc) (Amendment) (No 2) Regulations 1994  
SI 1994 No 1329, ISBN 0-11-044329-2; and  
The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1995  
SI 1995 No 3247, ISBN 0-11-053799-8
2. Integrated Pollution Control: A Practical Guide (HMSO) April 1994, ISBN 0-11-752750-5; and Guidance Notes to Applicants for Authorisation – processes prescribed for regulation under IPC, available from the Environment Agency
3. HMIP Technical Guidance Notes, Monitoring Series (see Associated Publications on page 41)
4. Guidelines on Discharge Stack Heights for Polluting Emissions  
HMIP Technical Guidance Note (Dispersion) D1 (HMSO) June 1993, ISBN 0-11-752794-7
5. Environmental, Economic and BPEO Assessment Principles for Integrated Pollution Control  
Environment Agency Technical Guidance Note (Environmental) E1 (to be published 1996)
6. EC Directive on the Combating of Air Pollution from Industrial Plants (Framework)  
(84/360/EEC) (OJL 188, 16/7/84)
7. The Air Quality Standards Regulations 1989  
SI 1989 No 317, ISBN 0-11-096317-2
8. The Surface Waters (Dangerous Substances Classification) Regulations 1989  
SI 1989 No 2286
9. The Control of Pollution (Special Waste) Regulations 1980  
SI 1980 No 1709, ISBN 0-11-007709-1;  
The Controlled Waste Regulations 1992  
SI 1992 No 588, ISBN 0-11-023588-6;  
The Environmental Protection (Duty of Care) Regulations 1991  
SI 1991 No 2839, ISBN 0-11-015839-5;  
Waste Management, The Duty of Care, A Code of Practice (HMSO) ISBN 0-11-752557-X;  
The Controlled Waste (Registration of Waste Carriers and Seizure of Vehicles) Regulations 1991,  
SI 1991 No 1624, ISBN 0-11-014624-7;  
The Environmental Protection (Waste Management Licensing) Regulations 1994  
SI 1994 No 1056, ISBN 0-11-044056-0;  
The Environmental Protection Act 1990 Parts II and IV  
The Controlled Waste Regulations 1992  
DOE Circular 14/92, ISBN 0-11-752665-7; and  
Environmental Protection Act 1990 – Part 2: Waste Management Licensing;  
The Framework Directive on Waste  
DOE Circular 11/94, ISBN 0-11-752975-3 – Annex 4, paragraphs 4.4 and 4.5
10. EC Directive on the Incineration of Hazardous Waste 94/67/EC (OJL 365, 31/12/94)
11. Separation Processes Service, Harwell Laboratory, Didcot, Oxfordshire OX11 0RA
12. Effluent Processing Club, Harwell Laboratory, Didcot, Oxfordshire OX11 0RA
13. Air Pollution Advisory & Review Group, Air and Environmental Quality Division, Department of the Environment, Romney House, 43 Marsham Street, London SW1P 3PY
14. Pollution Control in the Cement Industry and Pollution Control in the Lime Industry DOE Research Reports available from the Environment Agency's National Centre for Technical Guidance
15. Monitoring Emissions of Pollutants at Source  
HMIP Technical Guidance Note (Monitoring) M2 (HMSO) January 1994, ISBN 0-11-752922-2

## 16. Waste Incineration

- IPC Guidance Note-S2-5.01 (due to be published October 1996)

## Abbreviations and definitions

BATNEEC	Best Available Techniques Not Entailing Excessive Cost
BOD	Biochemical Oxygen Demand
BPEO	Best Practicable Environmental Option
CKD	Cement Kiln Dust
COD	Chemical Oxygen Demand
EA	Environment Agency (for England and Wales)
EP	Electrostatic precipitator
EPA90	The Environmental Protection Act 1990
EPAQS	Expert Panel on Air Quality Standards
HMIP	Her Majesty's Inspectorate of Pollution
HSE	Health and Safety Executive
IPC	Integrated Pollution Control
ITEQ	International Toxicity Equivalents
LPG	Liquefied Petroleum Gas
NO <sub>x</sub>	Oxides of Nitrogen
PCB	Polychlorinated byphenols
PCP	Polychlorophenol
PFA	Pulverised Fuel Ash
RMC	Ready Mixed Concrete
ROCE	Return on Capital Employed
SLF	Substitute Liquid Fuels
SNCR	Selective Non Catalytic Reduction
TEQ	International Toxicity Equivalents
TOC	Total Organic Carbon
VOC	Volatile Organic Compound

## Associated publications

The following are available from HMSO bookshops (see back cover), their accredited agents, and some larger bookshops.

### Series 2

#### Chief Inspector's Guidance Notes (prepared by Her Majesty's Inspectorate of Pollution)

##### Fuel Production Processes, Combustion Processes (including Power Generation)

S2 1.01 Combustion processes: large boilers and furnaces  
50MW(th) and over

November 1995, £9.95 ISBN 0-11-753206-1

**Supersedes IPR 1/1**

IPR 1/2 Combustion processes: gas turbines

September 1994, £4.00 ISBN 0-11-752954-0

S2 1.03 Combustion processes: compression ignition engines  
50MW(th) and over

September 1995, £7.95 ISBN 0-11-753166-9

**Supersedes IPR 1/3**

S2 1.04 Combustion processes: waste and recovered oil burners  
3MW(th) and over

September 1995, £7.95 ISBN 0-11-753167-7

**Supersedes IPR 1/4**

S2 1.05 Combustion processes: combustion of fuel  
manufactured from or comprised of solid waste in appliances  
3MW(th) and over

September 1995, £9.95 ISBN 0-11-753168-5

**Supersedes IPR 1/5-1/8**

S2 1.06 Carbonisation processes: coke manufacture

September 1995, £9.95 ISBN 0-11-753176-6

**Supersedes IPR 1/9**

S2 1.07 Carbonisation and associated processes: smokeless fuel,  
activated carbon and carbon black manufacture

September 1995, £9.95 ISBN 0-11-753177-4

**Supersedes IPR 1/10**

S2 1.08 Gasification processes: gasification of solid and liquid  
feedstocks

November 1995, £9.95 ISBN 0-11-753202-9

**Supersedes IPR 1/11**

S2 1.09 Gasification processes: refining of natural gas

November 1995, £9.95 ISBN 0-11-753202-7

**Supersedes IPR 1/12 and 1/13**

S2 1.10 Petroleum processes: oil refining and associated  
processes

November 1995, £14.00 ISBN 0-11-753204-5

**Supersedes IPR 1/14 and 1/15**

S2 1.11 Petroleum processes: on-shore oil production

November 1995, £8.25 ISBN 0-11-753205-3

**Supersedes IPR 1/16**

S2 1.12 Combustion processes: reheat and heat treatment  
furnaces 50MW(th) and over

September 1995, £8.50 ISBN 0-11-753178-2

**Supersedes IPR 1/17**

#### IPC Guidance Notes (prepared by the Environment Agency)

##### Mineral Industry Sector

S2 3.01 Cement manufacture, lime manufacture and associated  
processes

September 1996, £21 ISBN 0-11-310120-1

**Supersedes IPR 3/1 and IPR 3/2**

S2 3.02 Asbestos processes

September 1996, £15 ISBN 0-11-310118-x

**Supersedes IPR 3/3**

S2 3.03 Manufacture of glass fibres, other non-asbestos mineral  
fibres, glass frit, enamel frit and associated processes

September 1996, £21 ISBN 0-11-310121-x

**Supersedes IPR 3/4 and IPR 3/5**

S2 3.04 Ceramic processes

September 1996, £17 ISBN 0-11-310119-8

**Supersedes IPR 3/6**

##### Waste Disposal and Recycling Sector

S2 5.01 Waste incineration

October 1996

**Supersedes IPR 5/1, 5/2, 5/3, 5/4, 5/5 and 5/11**

S2 5.02 Making solid fuel from waste

July 1996, £15.00 ISBN 0-11-310114-7

**Supersedes IPR 5/6**

S2 5.03 Cleaning and regeneration of carbon

July 1996, £13.00 ISBN 0-11-310115-5

**Supersedes IPR 5/7**

S2 5.04 Recovery of organic solvents and oil by distillation

July 1996, £17.00 ISBN 0-11-310116-3

**Supersedes IPR 5/8 and IPR 5/10**

## Series 1

### Chief Inspector's Guidance Notes (prepared by Her Majesty's Inspectorate of Pollution)

#### Metals Production and Processing

IPR2/1 Iron and steel making processes: integrated iron and steel works  
October 1994, £13.00 ISBN 0-11-752961-3

IPR2/2 Ferrous foundry processes  
October 1994, £10.00 ISBN 0-11-752962-1

IPR2/3 Processes for electric arc steelmaking, secondary steelmaking and special alloy production  
October 1994, £10.00 ISBN 0-11-752963-X

IPR2/4 Processes for the production of zinc and zinc alloys  
November 1994, £7.50 ISBN 0-11-753024-7

IPR2/5 Processes for the production of lead and lead alloys  
November 1994, £7.50 ISBN 0-11-753025-5

IPR2/6 Processes for the production of refractory metals  
November 1994, £6.50 ISBN 0-11-753026-3

IPR2/7 Processes for the production, melting and recovery of cadmium, mercury and their alloys  
November 1994, £7.00 ISBN 0-11-753027-1

IPR2/8 Processes for the production of aluminium  
November 1994, £8.50 ISBN 0-11-753028-X

IPR2/9 Processes for the production of copper and copper alloys  
November 1994, £7.00 ISBN 0-11-753029-8

IPR2/10 Processes for the production of precious metals and platinum group metals  
November 1994, £8.00 ISBN 0-11-753030-1

IPR2/11 The extraction of nickel by the carbonyl process and the production of cobalt and nickel alloys  
November 1994, £7.50 ISBN 0-11-753031-X

IPR2/12 Tin and bismuth processes  
November 1994, £7.50 ISBN 0-11-753032-8

#### Chemical Industry Sector

IPR4/1 Petrochemical processes  
January 1993, £8.50 ISBN 0-11-752738-6

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#### Environmental

E1 Environmental, economic and BPEO assessment principles of Integrated Pollution Control  
(To be published 1996)

## Relevant DOE publications

A review of "The potential effects of release of krypton-85"  
£4.95, DOE Publications Sales Unit, Block 3, Spur  
2, Room 1/2, Government Buildings, Lime Grove,  
Eastcote, HA4 8SE

Integrated Pollution Control: a practical guide  
(HMSO) £5.00 ISBN 0-11-752750-5

### **Secretary of State's Process Guidance Notes**

#### **Processes Prescribed for Air Pollution Control by Local Authorities**

A list of these notes is available from:

Department of the Environment  
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The Agency's National Centre for Technical Guidance gives guidance on techniques and standards in support of Integrated Pollution Control (IPC): Government Buildings, Burghill Road, Westbury-on-Trym, Bristol BS10 6EZ  
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