# German Contribution to the Review of the Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries

## Part I: Lime Manufacturing Industries

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Annex: Use of Alternative Fuels in Lime Manufacturing

## 1. Introduction

In order to gather information for the German contribution to the review of the BREF „Cement and Lime Manufacturing Industries" a survey was initiated by the German national group of experts. Members of the national expert group are representatives from public authorities and lime manufacturing industries. The survey generated data on about 100 lime kilns representing all kinds of kilns currently operated in Germany. Data was collected predominantly for the years 2001 – 2004, depending on the availability of recent measurements.

The following table shows the number of kilns with available data related to the different types of kilns.

| Kiln type | Number of kilns with available data |
|---|---|
| **Quicklime (soft to hard burned)** | |
| Shaft kilns | |
| Mixed feed shaft kiln | 36 |
| Double-inclined shaft kiln * | 8 |
| Multi-chamber shaft kiln * | 2 |
| Annular shaft kiln | 32 |
| Parallel-flow regenerative shaft kiln | 14 |
| Rotary kilns | |
| Long rotary kiln | 1 |
| Grate preheater rotary kiln | 4 |

* EuLA has summarized double-inclined and multi-chamber shaft kilns as „other kilns".

# 2. Present Consumption/Emission Levels in German Lime Kilns / Applied Techniques

The data presented below is based on an intensive exchange of information between the lime manufacturing industries and authorities in the national expert group.

## 2.1 Use of Energy

**Limestone Calcination**

The heat consumption of different kiln types in Germany is shown in the following table:

| **Kiln type** | **Heat consumption (MJ/tonne lime)** |
|---|---|
| **Quicklime (soft to hard burned)** | |
| Shaft kilns | |
| Mixed feed shaft kiln | 3300 – 4900 |
| Double-inclined shaft kiln | 4200 – 4800 |
| Multi-chamber shaft kiln | 3500 – 5200 |
| Annular shaft kiln | 3500 – 4600 |
| Parallel-flow regenerative shaft kiln | 2800 – 3900 |
| Rotary kilns | |
| Long rotary kiln | 7100 |
| Grate preheater rotary kiln | 5500 – 6200 |

The fuels used in German lime kilns are predominantly fossil fuels. Waste fuels are mainly used in annular shaft kilns, double inclined kilns and in rotary kilns. The types of fuel used in general are shown in the following table:

| **Kiln type** | **Fuels** |
|---|---|
| **Shaft kilns** | |
| Mixed feed shaft kiln | Mostly used fuels:<br>- coke<br>- pulverized lignite<br><br>Other fossil fuels: anthracite |
| Double-inclined shaft kiln | Mostly used fuels:<br>- coke / anthracite<br>- natural gas<br><br>Alternative / Waste fuels: used oil |

| Kiln type | Fuels |
|---|---|
| Multi-chamber shaft kiln | Mostly used fuels:<br>- pet coke<br>- coke<br><br>Other fossil fuels: natural gas, liquid gas |
| Annular shaft kiln | Mostly used fuels:<br>- natural gas<br>- coke / anthracite<br>- heavy fuel oil<br><br>Alternative / Waste fuels:<br>- used oil<br>- used solvents<br>- animal fat<br>- solid waste like plastics, paper, wood, saw dust |
| Parallel-flow regenerative shaft kiln | Mostly used fuels:<br>- natural gas<br>- pulverized lignite<br><br>Other fossil fuels: pet coke, coal, liquid gas<br><br>Alternative / Waste fuels: used oil |
| **Rotary kilns** | |
| Long rotary kiln | Mostly used fuels: pulverized lignite<br><br>Other fossil fuels: natural gas, pet coke, heavy fuel oil |
| Grate preheater rotary kiln | Mostly used fuels: pulverized lignite<br><br>Other fossil fuels: natural gas, pulverised coke<br><br>Alternative / Waste fuels:<br>- solid waste like specific waste from production<br>- solvents<br>- Animal meal |

The following measures were implemented at some lime kilns in Germany to reduce fuel energy consumption:

- optimizing the whole process,
- reducing excess air.

Electricity consumption was minimised in some cases by replacing quicklime mills with mills like high pressure grinding (e.g. Gutbett roller mill). Use of high pressure grinding mills was reported to generate electric energy savings of 2.5 kWh/$t_{quicklime}$. A reduction of electricity consumption could also be achieved by replacing wet scrubbers with fabric filters. In one case savings in electric energy of 2.9 kWh/$t_{quicklime}$ were reported.

## 2.2 Air Emissions

The most relevant air emissions from lime kilns are the following:

- dust
- nitrogen oxides ($NO_x$)
- sulphur dioxide ($SO_2$)
- carbon oxides (CO, $CO_2$)

The following emissions may also be of concern in the production of lime, depending on kiln design, operating conditions, the fuel used and the lime/limestone quality.

- hydrogen chloride
- hydrogen fluoride
- organic compounds
- heavy metals
- polychlorinated dibenzodioxins and dibenzofurans (PCDD/F)
- hydrogen sulfide ($H_2S$)

The following subsidiary processes of a lime plant are additional sources of dust emissions:

- crushing of limestone
- limestone conveyors and elevators
- limestone storage silos
- grinding mills for quicklime
- quicklime conveyors and elevators
- quicklime silos or bunkers
- storage of solid fuels (e.g. pulverized lignite)
- dispatch of quicklime
- hydration of quicklime

Fugitive dust emissions may be released from open storage, road transport or conveyors of limestone and other mineral products at plant site.

Typical emissions from German lime kilns are indicated in the sections below. Flue gas treatment techniques are characterized, when applied.

### 2.2.1 Dust (PM)

**Limestone Calcination**

Shaft kilns

Nearly all German shaft kilns are equipped with fabric filters. After flue gas abatement with fabric filters dust emissions typically range from < 10 to < 20 $mg/m_n^3$ as half hourly average value. Fabric filters achieving these levels have an air-to-cloth ratio ranging from < 1 to 1.2 $m^3/m^2 \cdot min$. The separated dust from fabric filters is mostly used as product.

Dust emissions after wet scrubbers and gravel bed filters in Germany typically range from 30 to 60 mg/$m_n^3$. The German Technical Instructions on Air Quality Control (TA Luft 2002[1]) prescribe an emission limit value for dust of 20 mg/$m^3$ for the operation of all types of lime kilns (daily average value, related to 273.15 K, 101.3 kPa). Existing installations have to comply with this emission limit value no later than 30 October 2007. Therefore wet scrubbers and gravel bed filters in the lime industry will be replaced by October 2007.

The measured dust emission values do not depend on the type of fuel, i.e. on whether or not it is of fossil or waste origin. In case of waste co-incineration, e.g. in shaft kilns, dust emissions range from < 5 to < 10 mg/$m^3$ as daily average value. This is because of the requirements of the German Ordinance on the Incineration and Co-Incineration of Waste (German Waste Incineration Ordinance). If more than 60 % of the rated thermal capacity comes from waste (more than 40 % in case of hazardous waste), the emission limit value for dust is between 14 and 10 mg/$m_n^3$ (daily average value, related to 10 % oxygen), depending on the fraction of waste used as fuel. The dust emission limit values of the German Waste Incineration Ordinance entail higher costs for investments and maintenance of fabric filters.

Rotary kilns

In general German rotary kilns are equipped with electrical precipitators. After flue gas treatment with electrical precipitators dust emissions from rotary kilns typically range from < 10 to 20 mg/$m_n^3$ (half hourly average value).

**Connected and subsidiary processes**

Nearly all connected and subsidiary processes of a lime plant can generate dust emissions. Therefore dust is regularly separated in fabric filters, e.g. in the following processes:

- primary / secondary crusher
- limestone storage
- grinding mills for quicklime
- screening machines
- quicklime storage silos
- storage of solid fuels (e.g. pulverized lignite)
- handling of quicklime

Equipment for grinding and handling of quicklime is kept under slight suction. The dust emissions from these sources are < 10 mg/$m^3$ in case of well-maintained fabric filters. In practice, emission values of 20 mg/$m^3$ are safely achieved. Conveyors and elevators are constructed as closed systems, if dust emissions are likely to be released from dusty material. Roads used by trucks are paved and cleaned periodically in order to avoid fugitive dust emissions. In addition, spraying with water at the installation site is used to avoid fugitive dust emissions. Wherever possible, closed storage systems are used.

[1] All emission limit values of the TA Luft 2002 given in the following paragraphs have to be complied with by 30 October 2007. The emission standards for the lime industry do not refer to a fixed oxygen content. Air flows leading to waste-gas cooling or dilution are not taken into account in determining the mass concentration.

In raw material preparation operations like crushing and sieving dust separation is not normally applied, because of the moisture content of the raw material. To reduce emissions of dust, raw materials can be humidified by additionally spraying water during processing.

Dust emissions from stockpiles are reduced by using the following measures:

- Sufficient humidification of stockpiles, charging points and discharging points
- Use of conveyor belts with adjustable height

At the hydration of quicklime, fabric filters or wet scrubbers are used for dust abatement.

### 2.2.2 Oxides of Nitrogen ($NO_x$)

Typical emissions of $NO_x$ from various types of lime kiln in Germany are shown in the table below.

| **Kiln type** | **mg $NO_x/Nm^3$ [1]** |
|---|---|
| **Quicklime (soft to hard burned)** | |
| Shaft Kilns | |
| Mixed feed shaft kiln | < 100 - < 500 |
| Double-inclined shaft kiln | 300 - < 500 |
| Multi-chamber shaft kiln | < 500 |
| Annular shaft kiln | < 100 - < 500 |
| Parallel-flow regenerative shaft kiln | < 100 - < 400 |
| Rotary Kilns | |
| Long rotary kiln | ≤ 500 |
| Grate preheater rotary kiln | ≤ 1500 |

1 Nitrogen monoxide and nitrogen dioxide, to be indicated as nitrogen dioxide.
Emission concentrations are measured as half hourly average values,
$O_2$ content related to 10% to make values comparable

$NO_x$ emissions from shaft kilns are dependent upon the content of nitrogen in the fuels, the process temperatures, excess air and the manufactured product (soft-/hard burned lime). Optimized burner techniques can reduce the $NO_x$ emissions. It is important to adjust the burner technique very well to the incinerated fuel, especially in the case of fuel changes or use of liquid waste fuels. As a primary technique for $NO_x$ emission reduction, good experiences have been gained with atomizing the fuel in special injectors e.g. with pressed air. Additionally the flow rate of combustion air and the shape of the flame are optimized. In Germany no secondary abatement techniques are used for shaft kilns.

For rotary kilns low-$NO_x$ burners are used. For the first time in the German lime industry a trial with selective non catalytic nitrogen reduction (SNCR) is being carried out at one plant. There urea is added as a reduction agent in the grate preheater. At the moment efficiency data for the SNCR technique is not yet available. Data will probably be available at the end of 2006.

$NO_x$ emission limit values in Germany

For the operation of lime kilns, the TA Luft 2002 prescribes 0.50 g/$m_n^3$ as emission limit value for nitrogen oxides (nitrogen monoxide and nitrogen dioxide), to be indicated as nitrogen dioxide. The emission limit value is defined as daily average value. For the production of dead-burned quicklime or dead burned dolomite in rotary kilns the emission limit value for nitrogen oxides is 1.5 g/$m_n^3$ (daily average value). If more than 60 % of the rated thermal capacity comes from waste (more than 40 % in case of hazardous waste), the emission limit value for nitrogen oxides is between 320 and 200 mg/$m_n^3$ (daily average value, related to 10 % oxygen), depending on the fraction of waste used as fuel according to the German Waste Incineration Ordinance.

### 2.2.3 Sulphur Dioxide ($SO_2$)

Emissions of $SO_x$ from all German lime kilns are normally < 100 mg/$m^3$. In the majority of lime burning operations, the quicklime captures most of the sulphur from the limestone and the fuel. The efficient contact between the kiln gases and the quicklime usually ensures efficient absorption of sulphur dioxide. For this reason, flue gas treatment techniques are not operated in Germany.

$SO_2$ emission limit values in Germany
The TA Luft 2002 provides in general 0.35 g/$m_n^3$ as emission limit value for sulphur oxides (sulphur dioxide and sulphur trioxide), to be indicated as sulphur dioxide. The emission limit value is defined as daily average value. If more than 60 % of the rated thermal capacity comes from waste (more than 40 % in case of hazardous waste), the emission limit value for sulphur oxides is 50 mg/$m_n^3$ (daily average value, related to 10 % oxygen), according to the German Waste Incineration Ordinance.

### 2.2.4 Oxides of Carbon (CO)

Typical emissions of CO from different lime kilns in Germany are shown in the table below:

| Kiln type | g CO/$Nm^3$ |
|---|---|
| Quicklime, soft- to hard-burned | |
| Shaft Kilns | |
| Mixed feed shaft kiln | 6 to 42 |
| Double-inclined shaft kiln | < 2 |
| Multi-chamber shaft kiln | < 2 |
| Annular shaft kiln | 1 to < 3 |
| Parallel-flow regenerative shaft kiln | < 1 |
| Rotary Kilns | |
| Long rotary kiln | < 1 |
| Grate preheater rotary kiln | < 1 |

In general it has to be noted that – in contrast to other combustion processes – the CO emission level of lime kilns does not indicate incomplete combustion. The operating conditions of lime kilns are always determined by product requirements, i.e. by requested properties of the burned lime. As higher CO emissions correspond to a higher energy consumption of the kiln (+1% CO in the waste gas is equal to an additional energy consumption of about 200 kJ/kg lime), lime kilns are usually operated in a way that keeps CO emissions as low as possible, depending on the individual products. In general, the CO level in the waste gas is kept below 3% by process optimization measures. In order to reduce CO emissions, process optimization is the only choice. Secondary abatement techniques for reducing CO are not available.

In mixed feed shaft kilns CO emissions are fairly high. However, some lime applications require hard-burned lime, which is mainly produced in mixed feed shaft kilns. The CO emissions of mixed feed shaft kilns are determined by on the so-called Boudouard reaction (see Figure 1).

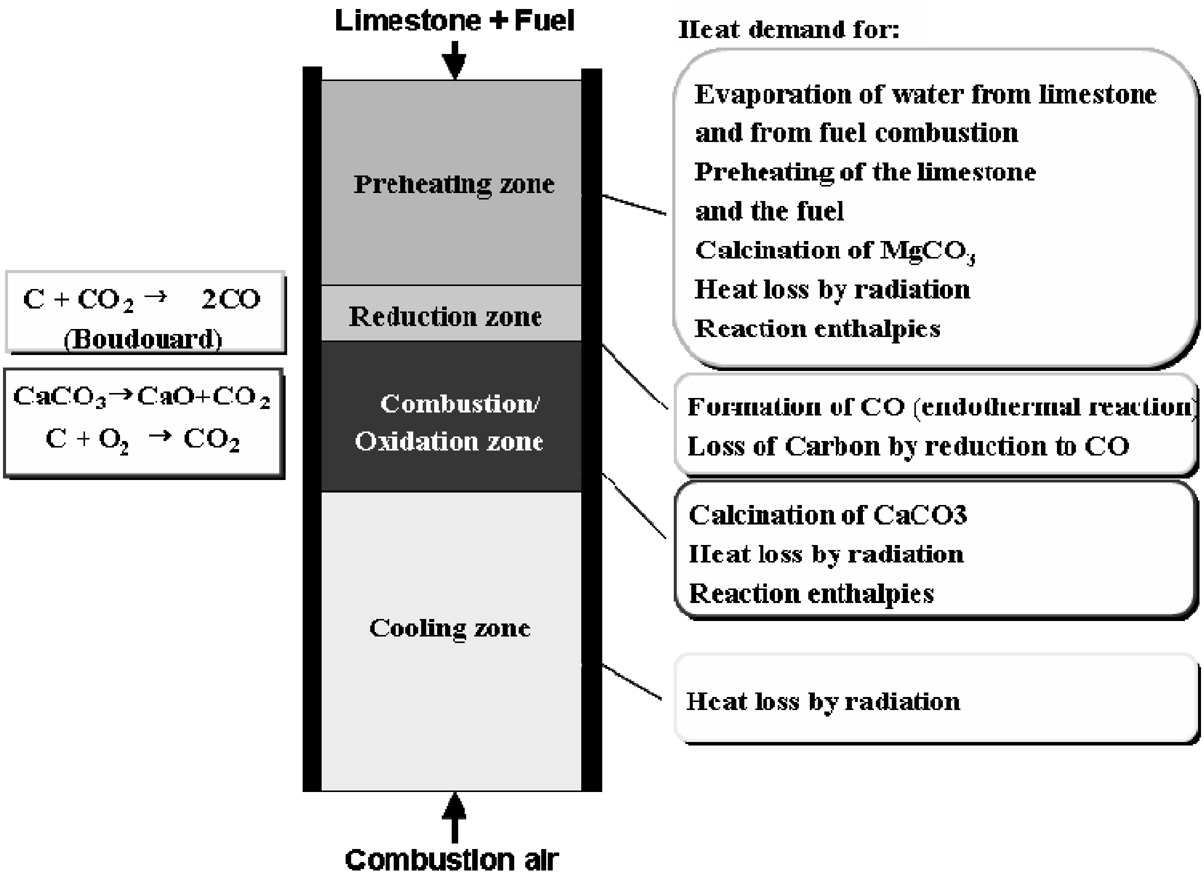


**Figure 1 Chemical reactions and energy use in a mixed feed shaft kiln**

The Boudouard reaction is mainly determined by the temperature profile of the fuel in the oxygen free atmosphere. Other relevant factors are the grain size and the reactivity of the fuel, the homogeneity of the feedstock, the air velocity and the initial $CO_2$ content. The CO generation rate rises with higher temperatures in the reduction zone. Therefore it is impossible to fully prevent CO emissions from mixed feed shaft kilns.

## 2.2.5 Hydrogen Chloride and Hydrogen Fluoride (HCl and HF)

Typical emissions of HCl and HF from various types of German lime kilns are shown in the table below.

| Kiln type | mg HCl / $Nm^3$ [1] | mg HF / $Nm^3$ [1] |
|---|---|---|
| **Quicklime (soft to hard burned)** | | |
| Shaft Kilns | | |
| Mixed feed shaft kiln | < 15 | < 1 |
| Double-inclined shaft kiln | < 10 | < 1 |
| Multi-chamber shaft kiln | no measurement data available | no measurement data available |
| Annular shaft kiln | < 20 | < 2 |
| Parallel-flow regenerative shaft kiln | < 10 | < 1 |
| Rotary Kilns | | |
| Long rotary kiln | < 5 | < 1 |
| Grate preheater rotary kiln | < 5 | < 1 |

1 Emission concentrations are measured as half hourly average values, related to 10% $O_2$ to make values comparable

Hydrogen chloride emissions from shaft kilns are mainly dependent upon the content of chlorine compounds in the lime stone (50 -100 ppm). In the majority of lime burning operations most of the chlorine compound present for example in the fuel is usually captured by the quicklime. The efficient contact between the kiln gases and the quicklime usually ensures efficient absorption of hydrogen chloride. HCl emissions tend to be higher when dry lime stone is burned. In one case hydrogen chloride emissions could be reduced by injecting water into the flue gas.

HCl and HF emission limit values in Germany
The TA Luft 2002 provides 30 $mg/m_n^3$ (60 $mg/m^3$) as emission limit value for hydrogen chloride (HCl) and 3 $mg/m^3$ (6 $mg/m^3$) for hydrogen fluoride (HF) as daily average value (in parentheses: half hourly average values). In case of co-incineration of waste according to the German Waste Incineration Ordinance, 10 $mg/m^3$ for HCl (60 $mg/m^3$) and 1 $mg/m^3$ for HF (4 $mg/m^3$) are set as daily average value (in parentheses: half hourly average values), related to an oxygen content of 10%.

## 2.2.6 Organic Compounds

Data from TOC emission measurements were not available for double-inclined shaft kilns and multi-chamber shaft kilns. Measured TOC emissions from mixed feed shaft kilns varied within a very broad range, from < 5 $mg/m_n^3$ up to> 50 $mg/m^3$, depending on actual process conditions. For this reason, this type of kiln is not suitable for waste incineration.

TOC emissions of annular shaft kilns and rotary kilns ranged regularly between 5 and < 50 $mg/m_n^3$. Kilns of this type that co-incinerated waste like solvents or waste oil did not have o higher emissions of TOC.

Measurement results for benzene, as representative of volatile organic compounds (VOC), for the different types of kilns showed values < 1 $mg/m^3$, where measured. At one mixed feed shaft kiln, benzene levels of 14.6 $mg/m^3$ and TOC levels of 995 $mg/m^3$ were measured. This kiln also releases higher PCDD/F emissions (see paragraph 2.2.8) and will be put out of operation by the end of 2006.

TOC emission limit values in Germany

The TA Luft 2002 provides 50 $mg/m_n^3$ as emission limit value for organic compounds, expressed as total organic compounds (TOC). The emission limit value is defined as daily average value.

### 2.2.7 Heavy Metals

The survey showed that emissions of heavy metals are not relevant in Germany, regardless of kiln type and incinerated fuel. Measurements at all types of kilns have shown typical values for Cd within a range of < 0,001 – 0,05 $mg/m^3$. Typical emission levels for Σ As, Pb, Cr, Cu, Ni, Se, Te from shaft kilns are within a range of 0.01 – 0.04 mg/ $m^3$. At rotary kilns emissions of Σ As, Pb, Cr, Cu, Ni, Se, Te were higher in some cases (up to 0.16 mg/ $m^3$). Mercury emissions from all types of kilns in general were < 0.05 $mg/m^3$. Special attention has to be paid to the possible contamination of co-incinerated waste fuels with mercury (e.g. waste wood). Because of the volatility of mercury relevant higher mercury emissions may occur. Therefore the mercury input via alternative fuels has to be limited.

Heavy metal emission limit values in Germany

The TA Luft 2002 provides in general emission limit values for three different classes of heavy metals (Class I: 0.05 $mg/m^3$ for Σ Hg, Tl ; Class II: 0.5 $mg/m^3$ for Σ Pb, Co, Ni, Se, Te; Class III: 1 $mg/m^3$ for Σ Sb, Cr, readily soluble cyanides (e.g. NaCN), readily soluble fluorides (e.g. NaF), Cu, Mn, V, Sb). For carcinogenic substances such as Σ As, benzo(a)pyrene, Cd, water-soluble compounds of cobalt, chromium(VI) compounds (except for barium chromate and lead chromate) the emission limit value according to the TA Luft 2002 is 0.05 $mg/m^3$. As lime kilns are not a relevant source of heavy metal emissions, emission limit values are set only for kilns co-incinerating waste. Results of individual measurements at shaft kilns showed measured values well below the emission limit values of the TA Luft.

For co-incineration of waste the following emission limit values are stipulated according to the German Waste Incineration Ordinance (oxygen content 10 %):

| Heavy metals | Emission limit value |
|---|---|
| Hg | 0.03 mg/$m^3$ (daily average value),<br>0.05 mg/$m^3$ (half hourly average value) |
| Σ of Cd, Tl | 0.05 mg/ $m^3$ (half hourly average value) |
| Σ of As, Co, Cr, Cu, Mn, Pb, Sb, Sn and V | 0.5 mg/$m^3$ (half hourly average value) |

Emission levels measured in case of waste co-incineration were well below these emission limit values.

## 2.2.8 Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans (PCDD/Fs)

Typical emissions of PCDD/Fs from various types of German lime kilns are shown in the table below.

| **Kiln type** | **ng TE PCDD/F / $Nm^3$ [1]** |
|---|---|
| **Quicklime (soft to hard burned)** | |
| Shaft Kilns | |
| Mixed feed shaft kiln | 0.01 - ≤ 0.1 [2] |
| Double-inclined shaft kiln | 0.001 - < 0.1 |
| Multi-chamber shaft kiln | no measurements available |
| Annular shaft kiln | 0.003 - < 0.1 |
| Parallel-flow regenerative shaft kiln | 0.001 - < 0.1 |
| Rotary Kilns | |
| Long rotary kiln | < 0.1 |
| Grate preheater rotary kiln | < 0.1 |

1 Emission concentrations are measured as six hourly average values and related to 10% $O_2$ to make values comparable

2 In one case 0.26 ng TE /$m^3$ was measured at a mixed feed shaft kiln. This kiln will be taken out of operation by the end of 2006 (also see section 2.2.6).

PCDD/Femission limit values in Germany

The German TA Luft 2002 and the German Waste Incineration Ordinance provide 0.1 ng/TE $m_n^3$ as emission limit value for PCDD/Fs. The emission limit value is defined as average value for a sampling period of 6 to 8 hours, and related to an oxygen content of 10 % in case of waste co-incineration.

### 2.2.9 Hydrogen sulphide ($H_2S$)

In general, $H_2S$ emissions may arise at mixed feed shaft kilns. In one case in which 30 % coke from China and 70 % anthracite was used as fuel, $H_2S$ emissions ranged from 6 to 9.5 mg/m$^3$. With exclusive use of anthracite, $H_2S$ emissions ranged between not detectable and < 1.6 mg/m$^3$. A trial to reduce $H_2S$ in a flue gas substream using a regenerative afterburner was successful. Subsequent trials at another installation, operating mixed feed shaft kilns were not successful, however. Regenerative afterburners for lime kilns are not available at present. Reducing the sulphur content in the fuels seems to be more effective.

$H_2S$ emission limit values in Germany

For mixed feed shaft kilns, the TA Luft 2002 provides that hydrogen sulphide emissions in waste gas shall not exceed a mass concentration of 3 mg/m$^3$ where possible; the best available primary and other techniques to further reduce hydrogen sulphide emissions shall be applied.

## 2.3 Monitoring of emissions

Continuous measurements

In Germany emissions of $NO_x$ and $SO_2$, and – in some cases – dust emissions are measured continuously. In case of waste co-incineration, emissions of dust and $NO_x$', and – in some cases – SO2 and TOC are measured regularly.

Periodic measurements

Periodic measurements are carried out for the following pollutants, unless monitored continuously:

- Dust
- $SO_2$
- $NO_x$

Depending on input fuels – especially in the case of waste co-incineration –, process conditions and the relevance of the emissions, additional measurements are carried out for the following pollutants:

- CO
- TOC
- HCl
- HF
- heavy metals
- benzo-a-pyrene
- PCDD/F

Recurrent measurements are usually required at three-year intervals in the case of plants using only fossil fuels. In case of co-incineration of waste or alternative fuels recurrent measurements usually have to be carried out once a year.

## 2.4 Noise

Extraction and processing of limestone as well as lime production inevitably includes noisy operations. Noise emissions may occur throughout the whole process chain from blowing in the quarry to shipping of the final products.
Noise abatement is of particular importance for the lime Industry, as lime plants are often situated close to housing areas. Various techniques for noise abatement are applied at lime plants in order to comply with the noise levels provided for neighbourhood protection.

In Germany, the Technical Instructions on Noise Control (TA Lärm) specify different standards for ambient noise levels, depending on land use and the time of day. For example, the acceptable noise level in housing areas at night time is 35 dB(A), while the whole-time level in industrial areas is 70 dB(A). The maximum acceptable noise levels at particular observation points are fixed as limit values in the permit of a plant. If an existing installation already exhausted this noise limit, no substantial change of the plant would be authorized unless the expected noise level of the future plant was 6 dB(A) below the limit.

Noise abatement schemes

Best practice to reduce noise emissions from lime plants in Germany is to develop a noise abatement scheme for the whole site, taking into account all noise sources at the production site, noise abatement costs, legal requirements as well as neighbourhood concerns.
The most effective noise abatement scheme does not necessarily include noise reduction measures at the loudest unit, because noise levels decrease significantly with distance to the source. Accordingly, a combination of measures at noise sources close to the affected areas may be more efficient. In some cases organisational measures, such as reducing night time activities, may be sufficient to reduce nuisances for the neighbourhood and to comply with legal requirements.

Development of a noise abatement scheme usually includes the following steps:

1. Listing all major sound sources and determining their sound pressure levels.
2. Determination of the affected areas, e.g. housing areas.
3. Computer-based calculation of the noise propagation (based on three-dimensional modelling of the site and its surroundings)
4. Ranking of the noise sources according to their relevance for individual affected areas (separately for day and night time)
5. Evaluation of noise abatement measures with regard to their relevance for the noise level in affected areas and estimated costs
6. Identification of the most cost-effective combination of measures that ensures compliance with the legal requirements as well as acceptance in the neighbourhood.

Technical noise abatement measures

Noise abatement in the lime industry may be achieved by various different measures. The most effective combination of measures has to be identified individually for each plant or production site (see above).

The following technical measures may be applied in the lime industry:

- Appropriate choice of location for noisy operations
- Enclosure of noisy operations, e.g. kiln feeding, lime discharge, product shipping
- Installation of noise barriers, e.g. at the dumper loading facility
- Sound insulation of machine buildings
- Sound insulation of wall breaks, e.g. by installation of a sluice at the entrance point of a belt conveyor
- Installation of sound absorbers at air outlets, e.g. the clean gas outlet of dedusting units
- Reduction of flow rates in ducts
- Sound insulation of ducts
- Decoupled arrangement of noise sources and potentially resonant components, e. g. of compressors and ducts

## 2.5 Waste

The separated solid fraction from limestone washing (natural impurities such as silica, clay and ultra-fine particles, see chapter 2.6) can be utilised

- for recultivation or covering of contaminated (e.g. acid) grounds,
- as raw material in the cement industry or
- for soil improvement in agriculture.

The dust from fabric filters (see chapter 2.2.1) can be used in different kinds of commercial product.

## 2.6 Water use and purification

The raw materials from the quarry usually comprise impurities such as sand or clay, which may hamper the kiln process or affect the quality of the final products. For this reason, in most cases the limestone is cleaned with water before entering the kiln.

The water demand for limestone washing is 0.5 to 2 $m^3$ per ton of raw material, depending on the nature and amount of impurities. After being used, the washing water contains 50 to 200 ml suspended solids per litre, corresponding to a solids content of 5 to 20 g/l. In general, the washing water is not loaded with any other pollutants.

The water used for limestone washing is usually taken from surface waters or from lowering of the groundwater during excavation. Other common sources for washing water are rainfall and wells.

Suspended solids are removed from the washing water by:

- Settling pits (which may later be left for recultivation) or by
- Dehydration in filter presses.

The purified water from both systems is re-used in the washing process (see Figure 2). The water recycling rate is about 85%, only 15% are process losses and need to be replaced by fresh water.

Treatment in the thickener and mechanical dehydration generate press cakes with a residual moisture content of 10 to 20%. See Section 2.5 for information on utilisation of press cakes.

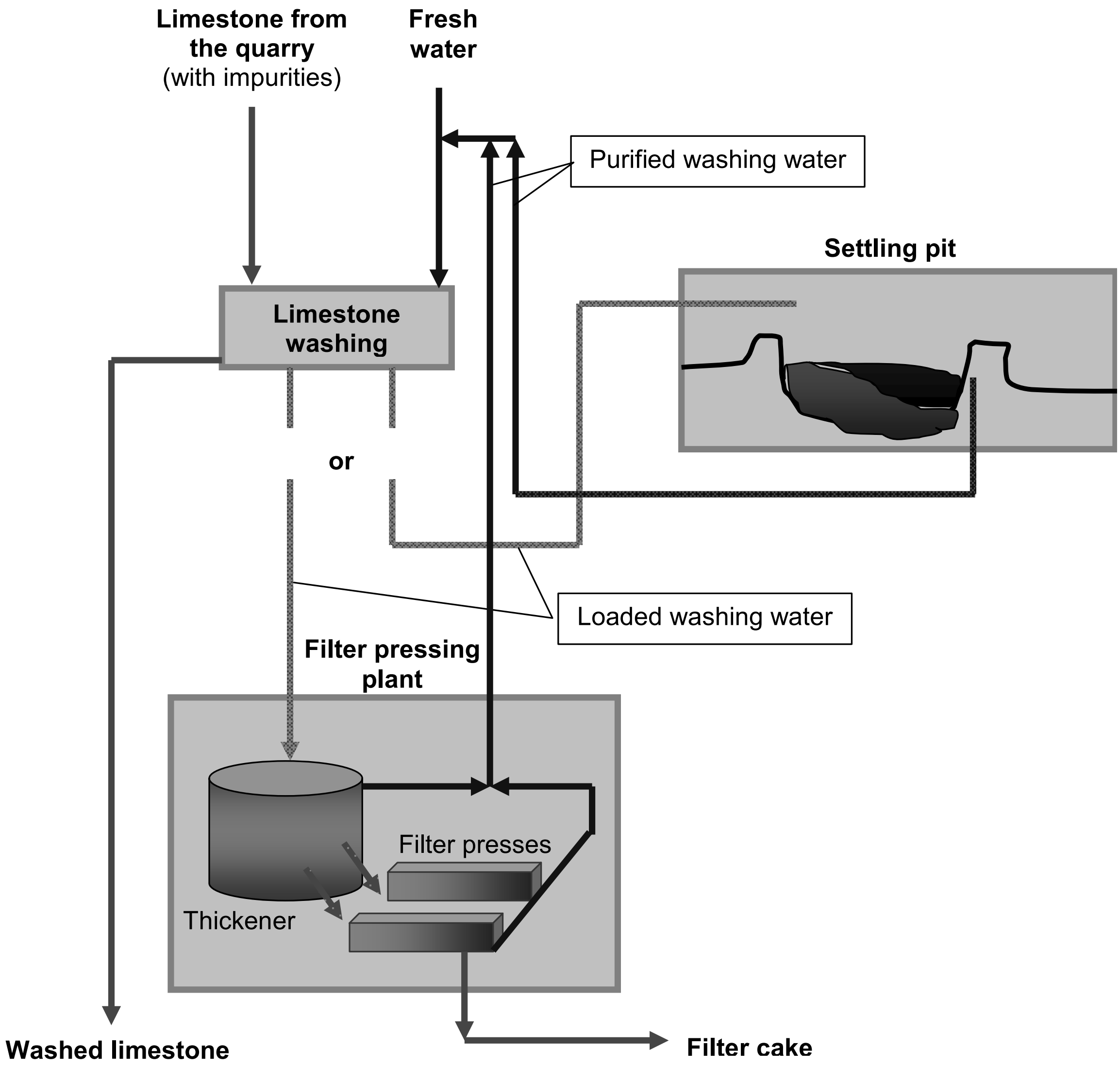


**Figure 2: Material flow scheme for limestone washing and washing water purification**

## 3. Use of Alternative / Waste Fuels

High calorific waste can substitute primary fuel in lime kilns. Therefore a constant waste quality is essential (e.g. sufficient calorific value, low heavy metal, chlorine and ash content, the waste has to be suitable for the burners). Furthermore the waste fuel has to be available in sufficient quantity. Normally different types of combustible wastes or wastes with separable high calorific fractions are prepared in special waste management facilities. For more information see BREF “Best Available Techniques for the Waste Treatments Industries”, chapter 4.5 “Techniques to consider for the preparation of waste to be used as fuel”.

The technologies used to prepare and blend certain waste fuel qualities depend on the characteristics of the input material and the requirements of the users. The following types of non-hazardous solid wastes are treated (for example sorting, crushing, pelletising) in waste facilities:

- mono waste material with high calorific value like used tyres, animal meal
- mixture of different mono waste materials (e.g. production-specific textile or plastic waste)
- separated high calorific fraction of mixed municipal waste, mixed commercial waste or mixed construction and demolition waste (mixed waste consists of several and very diverse components; apart from combustible fractions like paper-, cardboard, rubber and wood residues; it contains varying amounts of inert materials sand, stone, ceramics, ferrous / non-ferrous metals and organic wet materials).

Typical requirements of the lime industry for limiting the input of relevant pollutants and for other waste parameters are listed in the Annex.

Liquid waste fuels are prepared by blending different wastes like used solvents or waste oil with suitable caloric values in special waste management facilities. Normally only simple pre-treatment (removal of bottoms, sediments and water) is necessary. In some cases, e.g. machining oil/emulsion, chemical processes are necessary to remove metallic pollutants and additives.

Liquid waste fuels mostly are hazardous wastes. This has to be taken into account when handling (e.g. storing, feeding) liquid waste fuel. Therefore vapour recovery is used to avoid emissions of organic compounds. Vapour recovery systems are operated in a way which ensures that the flow of organic substances is permitted only upon connection of the vapour recovery system, and that the vapour recovery system and attached facilities release no gas to the atmosphere during normal operation, with the exception of releases necessary for safety reasons. For more information see Annex.

**Example: Co-incineration of waste oil in an annular shaft kiln**

The shaft kiln is equipped with a fabric filter. Typical temperatures in the 10 combustion chambers of an annular shaft kiln range from 1140°C to 1300°C. The incinerated waste oil was delivered by a special waste oil collecting and blending facility. Before feeding the waste oil to the burner the waste oil passes through a filtration sieve with a mesh size of 200 µm. The quality of the waste oil (calorific value approx. 30 - 39 MJ/kg; water content approx. 4 – 13 % by weight) incinerated in the annular shaft kiln is shown in the following table below. The table shows typical analysis results from the year 2002.

| **Pollutant** | **Unit** | **Typical content of pollutants in waste oil after filtration (200 µm)** |
|---|---|---|
| Sulphur | % by weight | 0.34 - 0.55 |
| Total-chlorine | % by weight | 0.03 – 0.04 |
| Hg | mg/kg | $\leq$ 0,05 |
| Cd (mg/kg) | mg/kg | 0.2 - 0.3 |
| Tl (mg/kg) | mg/kg | < 0,5 |
| Heavy metals:<br>Σ Sb, As, Pb, Cr, Co, Cu, Ni, Mn, V, Sn | mg/kg | 42 – 244 |
| Σ 6 PCB 28, 52, 101, 153, 138, 180 | mg/kg | < 1 |

The results of individual emission measurements in the year 2002 are shown in the following table. Waste oil was the only fuel used during the measurements.

| **Parameter** | **Unit** | **Range of individual half hourly measurements** [1] |
|---|---|---|
| Dust | mg/m³ | 1 -11 |
| TOC | mg/m³ | < 4 |
| CO | g/m³ | 0.06 – 1.2 |
| $NO_x$ | mg/m³ | 110 – 240 |
| $SO_2$ | mg/m³ | 1 – 13 |
| HF | mg/m³ | < 0.2 |
| HCl | mg/m³ | 11 –19 |
| Heavy metals<br>Σ Cd, Tl<br>Hg<br>Σ Sb ... Sn | mg/m³ | <br>< 0.01<br>< 0.01<br>< 0.04 |
| PCDD/F | ng TE/ m³ | < 0.004 |

1 oxygen content 10 %, 273.15 K, 101.3 kPa, dry gas