SNAP CODE: **030204**

SOURCE ACTIVITY TITLE : **PROCESS FURNACES WITHOUT CONTACT**
Plaster Furnaces

NOSE CODE: **104.11.01**

NFR CODE: **1 A 2 f**

1 ACTIVITIES INCLUDED

This chapter covers emissions released from plaster furnaces as part of the production of plaster, depending on the technology applied (see section 3.3).

Basic steps of a typical gypsum manufacturing process, producing crude gypsum, is shown as an example in Figure 1. In this process gypsum is crushed, dried, ground, and calcined.

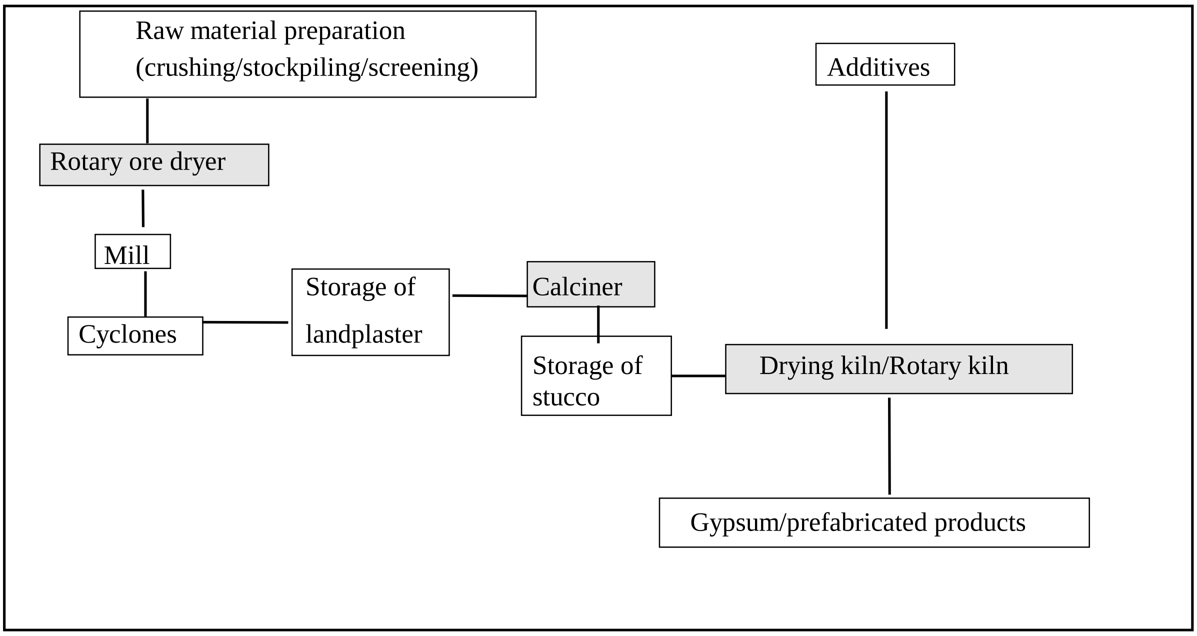

Figure 1: Basic steps of gypsum manufacturing process

Only combustion emissions are considered in this chapter (marked process steps in Figure 1).

2 CONTRIBUTION TO TOTAL EMISSIONS

The contribution of emissions released from plaster furnaces to the total emissions of the CORINAIR90 inventory is given as follows.

Table 1:Contribution to total emissions of the CORINAIR90 inventory (*28 countries*)

Source-activity	**SNAP-code**	**Contribution to total emissions [%]**							
		SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
Plaster Furnaces	030204	0	0	-	-	0	0	0.1	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
- = no emissions are reported

3 GENERAL

3.1 Description

Gypsum (calcium sulphate dihydrate $CaSO_4 \cdot 2\ H_2O$) is a naturally occurring mineral which is processed into a variety of products such as a Portland cement additive, soil conditioner, industrial and building plasters or gypsum wallboard /1/.

Gypsum ore, from quarries and underground mines, is crushed and stockpiled near a plant. As needed, the stockpiled ore is further crushed and screened. If the moisture content of the mined ore is greater than about 0.5 wt.-%, the ore must be dried in a rotary dryer or a heated roller mill. Ore dried in a rotary dryer is conveyed to a roller mill. The ground gypsum leaves the mill in a gas stream and is collected in a product cyclone. Ore is sometimes dried in the roller mill by heating the gas stream, so that drying and grinding are accomplished simultaneously and no rotary dryer is needed. The finely ground gypsum ore is known as landplaster, which may also be used as a soil conditioner. /3/

3.2 Definitions

Plaster, gypsum	These expressions are often used synonymously. In this chapter plaster is used for dehydrated landplaster (produced at lower temperatures of ca. 200 °C) and gypsum is used for calcinated landplaster (produced at higher temperatures of ca. 900 °C).

3.3 Techniques

In order to obtain boiled plaster (calcium sulphate semihydrate $CaSO_4 \cdot \frac{1}{2}\ H_2O$), the gypsum ($CaSO_4 \cdot 2\ H_2O$) must be partially dehydrated at a temperature of about 120 °C. After further dehydration of the boiled plaster at a temperature of about 200 °C, stucco is obtained. Then after calcination at a temperature of about 1,300 °C building plaster is formed.

Two different combustion techniques are used: kettle calciners (combustion without contact between product and flue gas), and rotary kilns (combustion with contact between product and flue gas). In practice, plaster is obtained by dry processing in kettle calciners at a temperature of about 120 to 180 °C. α-Gypsum is also obtained by dry processing mostly within directly fired rotary kilns at a temperature of about 300 - 900 °C.

Normally, plaster is fed to kettle calciners or flash calciners, where it is heated to remove three-quarters of the chemically bound water to form stucco. Calcination occurs at approximately 120 to 150 °C and 1 Mg of gypsum calcines to about 0.85 Mg of stucco. /1/
In kettle calciners, the plaster or the gypsum is indirectly heated by hot combustion gas passed through flues in the kettle and the stucco product is discharged into a “hot pit” located below the kettle. Kettle calciners may be operated in either batch mode or continuous mode. In flash calciners, the plaster or the gypsum is in direct contact with hot gases and the stucco product is collected at the bottom of the calciner. /1/

Some plants use residual fuel oil, but the majority uses clean fuels such as natural gas or distillate fuel oil. /3/ For the heating of rotary kilns shell burners are installed which are fed by gas or oil.

3.4 Emissions

Particulate matter is the dominant pollutant in gypsum processing plants; combustion sources emit mainly gaseous pollutants. Here only emissions released from plaster furnaces are considered.

Relevant pollutants are sulphur oxides (SO_x), nitrogen oxides (NO_x) and carbon dioxide (CO_2). Emissions of volatile organic compounds (non-methane VOC and methane (CH_4)), carbon monoxide (CO) and ammonia (NH_3) are of less relevance. Normally, emissions of nitrous oxide (N_2O) are not relevant[1]. Emissions of heavy metals are of less relevance.

Emissions of sulphur dioxide (SO_2) in the flue gas of plaster furnaces depend on the sulphur content of the fuel used and are mostly relevant for the production of calcinated plaster. For the case of combustion with contact in rotary kilns a sulphur retention of SO_2 occur at higher temperatures.

The formation of nitrogen oxides (NO_x) can be split into “fuel-NO”, “thermal-NO” and “prompt-NO” as discussed in the chapter “Combustion Plants as Point Sources” (section 3). For the production of gypsum the dominating NO_x formation mechanism mainly depends on the operation temperature.

Emissions of heavy metals depend on the type of fuel used and are only relevant when using heavy fuel oil. Most heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn, V) are normally released as compounds (e.g. as chlorides) in association with particulates (see also chapter B111 on “Combustion Plants as Point Sources” (section 9). In the case of combustion with contact in rotary kilns the intake by the feed material has to be considered too, but also a heavy metal retention in the raw material occurs.

3.5 Controls

SO_2 emissions of plaster furnaces are only controlled by the use of low sulphur fuels (e.g. switch from oil to gaseous fuels containing less sulphur).

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[1] The amount of N_2O reported in CORINAIR90 (see Table 1) is considered to be too high.

For the control of NO_x emissions from plaster furnaces only primary measures are relevant (e.g. optimisation of furnace conditions and/or burners).

For the control of particulate matter fabric filters are often used. Electrostatic precipitators (ESP) are installed at rotary ore dryers, roller mills, kettle calciners and conveying systems. Although rotary ore dryers may be controlled separately, emissions from roller mills and conveying systems are usually controlled jointly with kettle calciner emissions. Moisture in the kettle calciner exit gas improves the ESP performance by lowering the resistivity of the dust. /cf. 3/

4/5 SIMPLER AND DETAILED METHODOLOGY

Here both approaches refer to the calculation of emissions based on emission factors and activities, which are jointly discussed in the following. The “simpler methodology” is considered as an overall approach, where activity data refer to production figures. The “detailed methodology” is considered as the recommended approach, where activity data concerning the fuel consumption in plaster furnaces is available in a plant specific way. The simpler and the detailed methodologies cover all relevant pollutants.

The annual emission is determined according to Equation (1) by an activity and an emission factor:

$$E_i = EF_i \cdot A \tag{1}$$

E_i	annual emission of pollutant i
EF_i	emission factor of pollutant i
A	activity

The activity A and the emission factor EF_i have to be determined on the same level of aggregation by using available data. The CORINAIR90 methodology requires for plaster furnaces activity data, which are related to the type of fuel consumed in [GJ/a].

4.1 Simpler methodology

The simpler methodology corresponds to an approach, which takes into account activity rates derived from data of comparable installations or from literature data. Here, it is assumed, that the required activity data (according to CORINAIR90) are not available (see Equation (1)). In practice, statistics (see also section 6), which provides often only the amount of plaster produced in [Mg/a], have to be used.

In order to approximate activity data referring to the energy input into plaster furnaces in [GJ/a] the specific energy consumption has to be taken into account as given e.g. in Equation

(2):

$$A_{COR} = F \cdot A_{Stat} \tag{2}$$

A_{COR}	activity in CORINAIR-compatible unit (energy input [GJ])
F	specific energy consumption (energy input/mass plaster produced [GJ/Mg])
A_{stat}	activity directly obtained from statistics (mass plaster produced [Mg])

However, the simpler approach leads to significant uncertainties. Therefore, no emission factors are provided in this edition.

4.2 Detailed methodology

The detailed methodology corresponds to a plant specific approach, which takes into account as far as possible plant specific information. Here, CORINAIR90 compatible activity data for plaster furnaces (related to the type of fuel consumed in [GJ/a]) are directly available (Equation (1)).

Emission factors for the pollutants SO_2, NO_x, NMVOC, CH_4, CO, CO_2 and N_2O are given in Table 2 (see section 8) based on literature data depending on the type of fuel used. Emission factors related to the product are given in footnotes.

6 RELEVANT ACTIVITY STATISTICS

The following statistics can be used to determine the amounts of plaster produced or energy consumed:

- United Nations (ed.): Industrial Statistics Yearbook 1991; Volume I: Commodity Production Statistics; New York 1993; ISIC 2909-02 (Mining and quarrying: crude gypsum)

7 POINT SOURCE CRITERIA

Plaster furnaces should be considered as area sources. Gypsum plants are considered as point source according to the CORINAIR90 methodology, only if the whole plant emits more than 1,000 Mg/year of SO_2, NO_x, NMVOC or NH_3. In this case, plaster furnaces within a gypsum plant have to be reported collectively as part of a gypsum plant.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

The following Table 2 contains emission factors for the relevant pollutants based on literature data. Oil and gas are mainly used as fuels, but in several plants solid fuels are burned.

Table 2: Emission factors for plaster furnaces

Type of fuel				NAPFUE code	Emission factors						
					SO_2 [g/GJ]	NO_x[5] [g/GJ]	NMVOC[6] [g/GJ]	CH_4 [g/GJ]	CO [g/GJ]	CO_2 [kg/GJ]	N_2O [g/GJ]
s	coal	hc	sub-bituminous	102	680[3]	249[3]	15[3]	15[3]	79[3]	98[3]	14[3]
s	coal	hc	coke oven coal	107	0.4 - 436[3]	0.3 - 249[3]	15[3]	15[3]	22 - 1,534[3]	105[3]	14[3]
s	coke		petroleum	110	275[3]	249[3]	1.5[3]	1.5[3]	79[3]	97[3]	14[3]
s	biomass		wood	111	5.2[3]	249[3]	48[3]	32[3]	1,429[3]	92[3]	4[3]
l	oil		residual	203	1,260 - 1,323[3]	150 - 249[3]	3[3]	3[3]	79[3]	76[3]	14[3]
l	oil		gas	204	305[3]	249[3]	1.5[3]	1.5[3]	79[3]	73[3]	14[3]

Type of fuel				NAPFUE code	Emission factors						
					SO_2 [g/GJ]	NO_x 5) [g/GJ]	NMVOC 6) [g/GJ]	CH_4 [g/GJ]	CO [g/GJ]	CO_2 [kg/GJ]	N_2O [g/GJ]
g	gas		natural	301	4)	249 3)	4 3)	4 3)	83 3)	55 3)	3 3)
-	not specified		-	-		800-1,400 1)2) g/Mg product					

1) EPA /2/

2) 800 g/Mg for rotary ore dryer, 1,400 g/Mg for continuous kettle calciner and flash calciner

3) CORINAIR90 data

4)	SO_x	9,611	g/Mm^3 fuel	Mineral products, process heaters (NAPFUE 301) /2/
5)	NO_x	800	g/Mg product	Gypsum, rotary ore dryer /2/
		1,400	g/Mg product	Gypsum, continuous kettle calciner and flash calciner /2/
6)	VOC	2	g/Mg product	Gypsum, rotary ore dryer, (NAPFUE 301) /2/
		10	g/Mg product	Gypsum, continuous kettle calciner and flash calciner (NAPFUE 301) /2/
		33.6	g/m^3 fuel	Mineral products, process heaters, (NAPFUE 203) /2/

9 SPECIES PROFILES

For combustion without contact species profiles for oxides of sulphur and nitrogen are comparable to those released from combustion installations. Details can be found in chapter B111 on “Combustion Plants as Point Sources” (section 9).

10 UNCERTAINTY ESTIMATES

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Weakest aspects discussed here are related to emission factors and activities. CORINAIR90 data can only be used to give a range of emission factors. Further work should be invested to develop emission factors by taking into account technical or fuel dependent parameters.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Spatial disaggregation can be achieved by the relation to the number of industrial employees in industrial areas, the number of plants in the area considered, etc.

13 TEMPORAL DISAGGREGATION CRITERIA

Temporal disaggregation of annual emission data (top-down approach) provides a split into monthly, weekly, daily and/or hourly emission data. Temporal disaggregation of annual emissions released from plaster furnaces can be obtained by taking into account the

- time of operation and
- variation of load.

Data for the annual time of operation should take into account, that

- plants produce plaster during the whole year,
- the production of plaster in kettle calciners is a discontinuous process.

The load of a gypsum plant is determined by the variation of production due to varying demand for products. Information concerning the variation in the demand for plaster can only be obtained directly from plant operators.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

As outlined in the chapter on “Concepts for Emission Inventory Verification”, different general verification procedures can be recommended. Verification procedures for activity data and emission factors can be related on a national level and on a plant level.

Emission data for plaster furnaces can be verified on a territorial unit level (e.g. national level) by comparing the annual emissions related to a territorial unit to independently derived emission estimates (e.g. obtained by using population equivalents). Another possibility is the use of emission density comparisons of e.g. emissions per capita or emissions per GDP between countries with comparable economic structures.

Verification on a plant level takes into account e.g. the number of plaster furnaces within the plants considered. The verification on a plant level relies on comparisons between calculated emissions/emission factors and those derived from emission measurements.

17 REFERENCES

/1/ US-EPA (ed.): Compilation of Air Pollutant Emission Factors, Vol. 1: Stationary Point and Area Sources, 1985; AIR CHIEF Version 2.0 Beta; 1992

/2/ EPA (ed.): AIRS Facility System, EPA-Document 450/4-90-003; Research Triangle Park; 1990.

/3/ US-EPA (ed.): AP42-CDrom; 1994

18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE AND SOURCE

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20 POINT OF ENQUIRY

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