SNAP CODE: **030321**

SOURCE ACTIVITY: **PROCESSES WITH CONTACT**
Paper-mill Industry (Drying Processes)

NOSE CODE: **104.07.01**

NFR CODE: **1 A 2 d**

1 ACTIVITIES INCLUDED

The activities described are related to the production of paper in paper mills. In this chapter only the drying process within a paper mill is taken into account. Other process emissions are covered by chapters B462, B463 and B464 respectively. However, in the following, also non-combustion emissions are mentioned.

2 CONTRIBUTION TO TOTAL EMISSIONS

The contribution of fuel use related emissions released from drying processes in paper mills to total emissions in countries 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
Paper-mill Industry	030321	0.1	0	0	-	0	0.1	0.1	-

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

This activity is not believed to be a significant source of $PM_{2.5}$ (as of December 2006).

3 GENERAL

3.1 Description of activities

After a beating process paper pulp is introduced into the paper mill in concentrations of about 1 %. Mineral pigments or fillers are added to improve the brightness, opacity, and surface smoothness. Substances added are for instance china clay, calcium sulphate, calcium carbonate, or titanium dioxide. The final drying process of the sheets consists in passing the sheets over a series of steamheated cylinders.

Paper mills produce pulp from wood, either by chemical or by mechanical processes. Other paper mills use purchased pulp, non-wood fibres, or recovered paper fibres to manufacture paper. The production of pulp and paper requires considerable amounts of steam and power.

Most mills produce their own steam in one or more industrial boilers which burn fossil fuels and/or wood residues. Mills that pulp wood with a chemical process (kraft, sulphite, soda, semi-chemical) normally combust their spent pulping liquor in a combustion unit, e.g., kraft recovery furnace, to recover pulping chemicals for subsequent reuse. These units are also capable of providing process steam and power for mill operations. (Pinkerton, 1993) Emissions from the steam generation in boilers have to be allocated to SNAP category 030100.
For the drying of 1 t of chemical pulp, 1,5 t of steam is necessary. (Ullmanns Enzyklopädie der Technischen Chemie)

3.2 Definitions

3.3 Techniques

Drying processes can be divided in the contact drying process, convective drying process and infrared drying process. The most common process used is the contact drying process, where the paper sheet is dried over a drying basket, which is fed by hot air (pressure of 1.5 - 3.5 at). The drying process of paper is influenced by the temperature of the drying basket, the thickness and density of the paper produced, the dehydrateability of the paper, etc. (Ullmanns Enzyklopädie der Technischen Chemie).

3.4 Emissions

Fuel use related pollutants released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and methane (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (N_2O) and ammonia (NH_3). According to CORINAIR90 the main relevant pollutants are SO_2, and CO_2 (see also table 1).

Emissions from boilers used to generate steam and power account for the majority of emissions from pulp and paper mills, with kraft pulp mill emission sources (recovery furnace, lime kiln, reduced sulphur gas oxidation) accounting for most of the remainder. It should be mentioned that a very recent analysis of SO_2 measurement data for combination boilers (boilers that co-fire coal or oil with wood residues) strongly suggests that a considerable amount of SO_2 capture occurs due to the alkaline nature of the wood ash (Pinkerton, 1993). Coal and oil combustion in boilers now accounts for 75 % of the total SO_2 emissions from paper mills (Pinkerton, 1993).

Emissions from fuel burning in boilers represent the majority of the total NO_x, while kraft pulping sources accounted for almost all of the remainder (Pinkerton, 1993). Total NO_x-emissions are affected by fuel use practices. Most mills have one or more multi-fuel boilers and fuel choices are often governed by availability and price (Pinkerton, 1993). Increased coal and wood use can result in increased NO_x-emissions, since add-on NO_x-controls are not obligatory in most areas (Pinkerton, 1993).

Releases to air that are not related to energy generation are (European Commission, 2001) mainly volatile organic compounds (VOC). This emission is usually of minor importance. Situations where emissions of volatile organic compounds need to be controlled are related to a limited number of paper mills of different types. In the exhaust air of paper mills that utilise

volatile organic additives in the production process those substances are measured in low concentrations. Most volatile components of virgin pulps have been lost to atmosphere by the time that the pulp reaches the paper machine. However, in the dryer section of the paper machine or after coating the paper web is heated up to 100°C to evaporate the residual water. Apart from the water vapour also volatile components from the fibre material and from chemical additives are released. Usually no special abatement techniques for these emissions are applied in paper mills because the released loads are rather small.

Examples of operations where higher concentrations of VOCs are released are the following (European Commission, 2001):

- Coating of paper with coating colours that contain organic solvents, although the basis of coating colours is exclusively aqueous (lower concentrations of various volatile substances (as e.g. formaldehyde, alkyl substituted aromatics, lower alcohols) can be measured in the exhaust of every coating machine).
- Preparation of papers with resins and production of speciality papers by using volatile additives.

Examples of volatile organic compounds (VOCs) which are released to the atmosphere are the following (European Commission, 2001):

- Alcohols
- Formaldehyde contained in urea or melamine formaldehyde (UF/MF) resins used as wet strength agents
- Acetone and other ketones
- Phenols (only in special cases)
- Solvents used for cleaning machine fabrics (usually a minor application)
- Organic acids and residual monomers of polymers

In a few special cases particulates from some finishing operations may raise concern (European Commission, 2001).

3.5 Controls

SO_2 control systems (scrubbers, lime injection) are installed in the mills. NO_x-controls are not obligatory in most areas (Pinkerton, 1993).

The concentrations of organic substances in the exhaust air of paper mills can usually be considered as low so that no abatement technique for air emissions is required (European Commission, 2001).

The emission of some single substances of concern in the exhaust air of coating machines as e.g. acrylonitrile (occur only when acrylonitrile butadiene binder systems are used) can be avoided or reduced by careful choice of coating colour recipes. Coating colour recipes that contain carcinogenic compounds should be avoided. Formaldehyde is normally more difficult to prevent because it has different sources as wet strength agents, preservatives, biocides etc. (European Commission, 2001).

4 SIMPLER METHODOLOGY

The emissions of the paper industry as a whole might be calculated by establishing a relationship with economic statistics.

5 DETAILED METHODOLOGY

A detailed methodology is possible if sufficient measurements are available for the situation in the individual plant.

6 RELEVANT ACTIVITY STATISTICS

Production and energy consumption statistics, for instance as produced by the United Nations or IEA are available.

7 POINT SOURCE CRITERIA

Paper production plants can be considered as point sources if plant specific data are available.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

The measured concentration of total organic carbon varies significantly. Values between 2 and 135 mg/Nm3 have been measured. A specific load between 0.05 - 0.5 kg orgC_{total}/t of paper was determined in the exhaust of the seven investigated mills (European Commission, 2001). Formaldehyde in concentrations between 0.1 - 4.8 mg/Nm^3 have been measured (European Commission, 2001).

The following Table 2 contains fuel related emission factors for paper mills based on CORINAIR90 data in [g/GJ]. In the case of using production statistics the specific energy consumption (e.g. GJ/Mg pulp) has to be taken into account, which is process and country specific. At this stage no data for the definition of appropriate conversion factors are available. Emissions from the steam generation in boilers have to be allocated to SNAP category 030100.

Table 2: Emission factors for paper mills[3)]

	Type of fuel			NAPFU E code	Emission factors SO_2 [g/GJ]	NO_x [g/GJ]	NMVOC [g/GJ]	CH_4 [g/GJ]	CO [g/GJ]	CO_2 [kg/GJ]	N_2O [g/GJ]	NH_3 [g/GJ]
s	coal	hc	steam	102	992[1)]	150[1)]	15[1)], 5[2)]	15[1)], 1[2)]	70[1)], 20[2)]	98[1)], 91[2)]	14[1)], 75[2)]	2[2)]
s	coal	hc	sub-bituminous	103	992[1)]	150[1)]	15[1)]	15[1)]		99[1)]	14[1)]	
s	coal	hc/bc	patent fuels	104	701[1)]	150[1)]	15[1)]	15[1)]	70[1)]	94[1)]	14[1)]	
s	biomass		wood	111	5.2[1)] 343[2)]	115-200[1)] 972[2)]	50[1)]	30[1)]	10[1)]	92[1)2)]	4-14[1)]	
s	waste		wood	116	5.2[1)] 0.8-20[2)]	115[1)] 100-117[2)]	50[1)] 3-10[2)]	30[1)] 1[2)]	30[2)]	83[1)]	4[1)] 4-25[2)]	2[2)]
s	sludge		sewage	118			10[2)]	1[2)]	30[2)]		4[2)]	2[2)]
l	oil		residual	203	28-149[1)] 168-190[2)]	123-180[1)]	3-7.4[1)] 3[2)]	1-3[1)], 1[2)]	5-15[1)] 10[2)]	76-79[1)] 76[2)]	2.5-14[1)] 5[2)]	2[2)]
l	oil		gas	204	139-305[1)]	80[1)]	1.5-2[1)]	1-1.5[1)]	12[1)]	73[1)]	14[1)]	
l	kerosene			206	69[1)]	80[1)]	2[1)]	1[1)]	12[1)]	71[1)]	14[1)]	
l	gasoline		motor	208	45[1)]	80[1)]	2[1)]	1[1)]	12[1)]	71[1)]	14[1)]	
g	gas		natural	301	0.5-8[1)]	60-100[1)]	4[1)]	4[1)]	13[1)]	55-57[1)]	2.5-3[1)]	
g	gas		liquified petroleum gas	303	2[1)]	20-100[2)]	1[3)], 2[2)]	1-4[1)], 1[2)]	13[1)], 10[2)]	60-65[1)],56[2)]	3[1)], 2[2)]	

[1)] CORINAIR90 data, area sources [2)] CORINAIR90 data, point sources

[3)] It is assumed, that emission factors cited within the table are related to combustion sources in paper mills; other process emissions are not covered.

9 SPECIES PROFILES

The species profile of emissions from combustion is dependent on the fuel used for heat generation. Releases to air that are not related to energy generation are mainly formaldehyde and acrylonitrile (European Commission, 2001).

10 UNCERTAINTY ESTIMATES

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspects discussed here are related to emission factors from CORINAIR90.

The fuel specific emission factors provided in table 3 are related to point sources and area sources without specification. CORINAIR90 data can only be used in order to give a range of

emission factors with respect to point and area sources. Further work should be invested to develop emission factors, which include technical or fuel dependent explanations concerning emission factor ranges.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

National emission estimates can be disaggregated on the basis of plant capacity, employment or population statistics if plant specific data are not used/available.

13 TEMPORAL DISAGGREGATION CRITERIA

Paper production is usually a continuous process.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

Samenwerkingsproject procesbeschrijvingen industrie Nederland (SPIN) Papier en Kartonindustrie. RIVM report 736301135 (1991)(in dutch)

16 VERIFICATION PROCEDURES

Verification may be done by comparing the calculated emissions with measurements at an individual plant.

17 REFERENCES

European Commission (2001), Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques (BREF) in the Pulp and Paper Industry, December 2001

Pinkerton, J. E. (1993), Emission of SO_2 and NO_x from Pulp and Paper Mills; in: Air & Waste; 10(1993)43; p. 1404-1407

Ullmanns Enzyklopädie der Technischen Chemie, Bd. 17, S. 531 ff.

18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE AND SOURCE

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20 POINT OF ENQUIRY

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