SNAP CODE: **040301**

SOURCE ACTIVITY TITLE: **PROCESSES IN NON-FERROUS METAL INDUSTRIES**
Aluminium Production (electrolysis)

NOSE CODE: **105.12.21**
105.12.22

NFR CODE: **2 C 3**

1 ACTIVITIES INCLUDED

Production of primary aluminium, excluding alumina production.

2 CONTRIBUTION TO TOTAL EMISSIONS

Table 2.1 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
Aluminium Production	040301	0.1	0	0	-	0.4	0.1	-	-

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

For heavy metal emissions, specific figures for this source activity are available from Baart *et al.* (1995). /1/ The average relative contribution from the primary aluminium production industry to the total emission of heavy metals has been presented for European countries in table 2.

Table 2.2 Average relative contribution of the production of aluminium and the total non-ferrous industry to the total emission of heavy metals in European countries

	Contribution (%)	
Compound	Total non-ferrous industry (%)	Primary Aluminium production (%)
Cadmium	24	0.12
Chromium	0	-
Copper	11	-
Nickel	0	-
Lead	2.7	-
Zinc	28	0.004

- = not available

3 GENERAL

3.1 Description

Primary aluminium is produced by electrolytic reduction of alumina. The electrolytic process occurs in steel cells lined with carbon. Carbon electrodes extend into the cell and serve as anodes whereas the carbon lining of the cell is the cathode. Molten cryolite functions both as electrolyte and as a solvent for the alumina. Molten aluminium metal is deposited at the cathode and periodically tapped.

3.2 Definitions

Pots	Shallow rectangular cells lined with carbon.
Paste	Petroleum cake mixed with pitch binder.
Butts	Anode blocks prepared from paste by baking.

3.3 Techniques

Modern aluminium plant manufacture aluminium using pre-baked anodes, in older plant the Soderberg process is used. Other emissions include the anode preparation and, aluminium refining and casting activites.

3.4 Emissions during production activities

The main substances emitted are particulate matter, gaseous fluoride and particulate fluoride. The fluorides originate from the electrolyte. Emissions from the baking ovens include PAHs from the pitch binder. The dust produced contains some heavy metals.

3.5 Controls

Emission controls include wet scrubbers and fabric filters, the latter can incorporate a dry sorbant system for HF removal. Fugitive emissions from the pot room, particularly on older plant, can be significant.

4 SIMPLER METHODOLOGY

Emissions can be estimated at different levels of complexity; it is useful to think in terms of three tiers[1]:

Tier 1: a method using readily available statistical data on the intensity of processes ("activity rates") and default emission factors. These emission factors assume a linear relation between the intensity of the process and the resulting emissions. The Tier 1 default emission factors also assume an average or typical process description.

Tier 2: is similar to Tier 1 but uses more specific emission factors developed on the basis of knowledge of the types of processes and specific process conditions that apply in the country for which the inventory is being developed.

[1] The term "Tier" is used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and adopted here for easy reference and to promote methodological harmonization.

Tier 3: is any method that goes beyond the above methods. These might include the use of more detailed activity information, specific abatement strategies or other relevant technical information.

By moving from a lower to a higher Tier it is expected that the resulting emission estimate will be more precise and will have a lower uncertainty. Higher Tier methods will need more input data and therefore will require more effort to implement.

For the simpler methodology (equivalent to Tiers 1&2), where limited information is available, a default emission factor can be used together with production capacity information for the country or region of interest without further specification on the type of industrial technology or the type and efficiency of control equipment.

Consequently the simplified methodology is to combine an activity rate (AR) with a comparable, representative, value of the emissions per unit activity, the emission factors (EF). The basic equation is:

$$\text{Emission} = \text{AR x EF}$$

In the energy sector, for example, fuel consumption would be activity data and mass of material emitted per unit of fuel consumed would be a compatible emission factor.

NOTE: The basic equation may be modified, in some circumstances, to include emission reduction efficiency (abatement factors).

Default emission factors for this purpose are provided in Section 8.1.

5 DETAILED METHODOLOGY

If an extensive measuring program is available, the emissions can be calculated on the basis of the measurements of the dust emission and the composition of compounds over the total process.

The detailed methodology (equivalent to Tiers 3), to estimate emissions of gaseous pollutants from the cement production is based on measurements or estimations using plant specific emission factors - guidance on determining plant specific emission factors is given in the Measurement Protocol Annex.

The detailed methodology to estimate emissions of trace elements from the cement production is similar to the simpler one. However, more information on the type of the process, e.g. wet and dry kilns, as well as on the type of the industrial technology should be made available. This information shall be used to estimate specific emissions for at least a specific industrial technology.

Measurements of the emission rate and chemical composition of fine particles with $< 1.0\ \mu m$ diameter are often carried out at major cement kilns world-wide. The results of these measurements are then used to estimate atmospheric emissions of several trace elements contained as impurities in the raw materials and fuel.

Reference emission factors for comparison with users own data are provided in Section 8.2.

6 RELEVANT ACTIVITY STATISTICS

Standard national or international production statistics should be used.

7 POINT SOURCE CRITERIA

The primary aluminium plants usually are connected to high chimneys and can be regarded as point sources if plant specific data are available.

8 EMISSION FACTORS

8.1 Default Emission Factors For Use With Simpler Methodology

Table 8.1ai Emission factors for the electrolysis process

Substance	**Emission factor (g/Mg aluminium produced)**
Fluoride (gas)	350
Fluoride (particles)	950
Fluoranthene	4.5
Benz(a)pyrene	0.12
Sulfurdioxide	14200
Carbondioxide	1550000
Carbonmonoxide	135000
Nitrogenoxides	2150
Cadmium	0.15
Zinc	20
Nickel	15

Particulate emission factors are provided in Table 8.1aii from USEPA AP42 with 'expert judgement' estimates of PM_{10} and $PM_{2.5}$.

Table 8.1aii PM Emission factors for the electrolysis process

Activity	Abatement	Emission factor, g/tonne material produced		
		TSP	PM_{10}	$PM_{2.5}$
Electrolysis	Uncontrolled	49,000	37,000	25,000
	Fugitive	5,000	2,900	1,400
	Spray tower	56,000	42,000	28,000
	Dry alumina fabric filter	900	900	900
	ESP/dry + secondary scrubber	400	400	300

Table 8.1b Emission factors for the anode production process

Substance	**Emission factor (g/Mg aluminium produced)**
Fluorides (gas)	40
Fluorides (particles)	2
Fluoranthene	30
Benz(a)pyrene	1.4
Sulfurdioxide	900
Carbon dioxide	2200
Carbon monoxide	400
TSP	380
PM_{10}	280
$PM_{2.5}$	190

8.2 Reference Emission Factors For Use With Detailed Methodology

The emission factors presented are derived from the SPIN document, based on the Emission Inventory in the Netherlands. Particulate emission factors are from USEPA AP42 with estimates of PM_{10} and $PM_{2.5}$ based on USEPA speciation profiles and 'expert judgement'.

Table 8.2ai Emission factors for the electrolysis process

Substance	**Emission factor range** (g/Mg aluminium produced)
Fluoride (gas)	200-500
Fluoride (particles)	400-1500
Fluoranthene	3-6
Benz(a)pyrene	0.10-0.14
Sulfur dioxide	11000-17500
Carbon dioxide	1500000-1600000
Carbon monoxide	120000-150000
Nitrogen oxides	1300-3000
Cadmium	0.1-0.2
Zinc	15-25
Nickel	10-20

Table 8.1aii PM Emission factors for the electrolysis process

Activity	Abatement	Emission factor, g/tonne material produced		
		TSP	PM_{10}	$PM_{2.5}$
Electrolysis	Uncontrolled	47,000	24,000	16,000
Prebake cell	Fugitive	2,500	1,500	700
	Multicyclone	10,000	5,800	4,000
	Dry alumina scrubber fabric filter	900	900	900
	ESP + spray tower	2,300	1,300	600
	Spray tower	56,000	32,000	16,000
	Floating bed scrubber	56,000	32,000	16,000
	Coated fabric filter	900	900	900
	Crossflow packed bed	13,200	7,700	3,700
	Dry + secondary scrubber	400	400	400
Soderberg cell	Uncontrolled	49,000	25,000	16,000
(horizontal)	Fugitive	5,000	1,600	850
	Spray tower	11,000	6,400	4,400
	Floating bed scrubber	10,000	5,800	4,000
	Scrubber + wet ESP	900	900	900
	Wet ESP	900	900	900
	Dry alumina scrubber	900	900	900

Table 8.2b Emission factors for the anode production process

Substance	**Emission factor range** (g/Mg aluminium produced)
Fluorides (gas)	10-80
Fluorides (particles)	n.a.
Fluoranthene	20-40
Benz(a)pyrene	1.0-1.8
Sulfur dioxide	800-1000
Carbon dioxide	2000-2400
Carbon monoxide	n.a.
TSP	380
PM_{10}	280
$PM_{2.5}$	190

9 SPECIES PROFILES

A profile for PAH emissions from a single aluminium plant in the Netherlands is given in table 5. This table can be used to get at least a first estimation of PAH emissions for cases where only information about a single substance (in most cases benz(a)pyrene) is available.

Table 9.1 Relative profile for PAH emissions from aluminium production (Benz(a)pyrene put at one)

Substance	Relative amount
Naphthalene	90
Anthracene	5
Phenanthrene	20
Fluoranthene	20
Chrysene	3
Benz(a)anthracene	3
Benz(a)pyrene	1
Benz(k)fluoranthene	3
Benz(ghi)perylene	0.3

10 UNCERTAINTY ESTIMATES

The overall 'Uncertainty' in national emission inventories may be significant – as illustrated in Table 9.1.

Table 9.1 Uncertainty estimate for selected pollutants in the UK air emission inventory (NAEI, 2005).

Pollutant	Estimated Uncertainty (%)
PM_{10}	-20 to +50
$PM_{2.5}$	-20 to +30
$PM_{1.0}$	-10 to +20
$PM_{0.1}$	+/- 10
Sulphur Dioxide	+/- 3
Oxides of Nitrogen	+/- 8
NMVOCs	+/- 10
Ammonia	+/- 20

There is uncertainty in both the aggregated emission factors and activity data used to estimate emissions i.e. the imprecision and error to be expected from the application of an 'average' emission factor or activity statistic to estimate emissions from a specific sector - an artificial grouping of 'similar' sources.

The uncertainty is partly the result of how emission factors are developed and applied. In the case of primary particulate matter, the expanded statistical uncertainty is made up of: between plant variance, within plant variance, and uncertainties associated with the measurement methodology used and the aggregation of data. The measurement data in Annex 1 illustrates the variability in emission factors that occurs from between plant variance.

Process measurements, from which emission factors are developed at individual facility level, are subject to both systematic and random errors in the determination of mass concentration, mass emission, size distribution, and analytical errors etc.

In addition bias may exist in emission factors arising from:

1. Assumptions made about the abatement used on 'typical' industrial installations. For example emission factors 'age', the factors widely used in the Guidebook and hence by many countries as default emission factors in their national inventories become out of date. Recent measurement work suggests that they may overestimate emissions from the industrial processes subject to more modern industrial emissions regulation. They may, however, still be fully representative for older plant, small plant, or for poorer fuels;
2. Assumptions about the relationship between TSP and PM10/$PM_{2.5}$. The technical literature is comprehensive for TSP and the data quality can be good if measurements have been made using the international standard methods that are available (typically the 95% confidence limit ~10%). But a variety of methods are used for particle size fractionation and as yet there are no harmonised international standards to ensure comparability. Published measurement data for PM10 is sparse, that for $PM_{2.5}$ emissions more so. An added complication is that the methodology for the determination of TSP differs from that of PM10 and $PM_{2.5}$ and so the two need not correlate directly.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The contribution of heavy metals from the dust and the PAH emissions are the weakest aspects at the moment.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

13 TEMPORAL DISAGGREGATION CRITERIA

Primary aluminium production can be considered as a continuous process.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

Environmental Protection Agency, COMPILATION OF AIR POLLUTANT EMISSION FACTORS AP 42, Chapter 12.1

Spindocument Productie van primair aluminium ; RIVM (report no. 736301131); November 1992 (in Dutch)

PARCOM-ATMOS Emission Factors Manual Actualised version 1993.

16 VERIFICATION PROCESSES

17 REFERENCES

1. A.C. Baart, J.J.M. Berdowski, J.A. van Jaarsveld; Calculation of atmospheric deposition of contaminants on the North Sea; IWAD; ref. TNO-MW-R 95/138; TNO MEP; Delft; The Netherlands; 1995
2. AP 42 (5th edition), October 1998, US Environmental Protection Agency. http://www.epa.gov/ttn/chief/ap42/ch12/index.html

18 BIBLIOGRAPHY

For a detailed bibliography the primary literature mentioned in AP 42 or the PARCOM-ATMOS Manual may be used.

19 RELEASE VERSION, DATE AND SOURCE

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20 POINT OF ENQUIRY

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