

SNAP CODE: 030310**SOURCE ACTIVITY TITLE:** **PROCESSES WITHOUT CONTACT**
*Secondary Aluminium Production***NOSE CODE:** 104.12.11
104.12.12**NFR CODE:** 2 C 3 / 1 A 2 b**ISIC: 2420**

1 ACTIVITIES INCLUDED

This chapter includes information on atmospheric emissions during the production of Aluminium in secondary Aluminium smelters. Secondary Aluminium smelters produce about 50 % of the total Aluminium production in the United States (e.g. UN, 1994). Similar Aluminium production proportion is found in the Netherlands, France, Austria, and Italy. The secondary Aluminium industry is characterised by a large number of relatively small plants treating mostly so-called new scrap. This chapter describes the methods to estimate emissions of atmospheric pollutants during the secondary Aluminium operations (e.g. Parker, 1978).

2 CONTRIBUTIONS TO TOTAL EMISSIONS

There are various pollutants which can be emitted during the secondary Aluminium production, including smoke, acids, and particles. Major problems may arise due to emissions of Aluminium chloride and its hydrolysis product, hydrochloric acid. These emissions are not very significant on a global scale. However, a secondary Aluminium smelter can be an important emission source of pollution on a local scale.

The contribution of emissions released from secondary Aluminium production to total emissions in countries of the CORINAIR90 inventory is given as follows:

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 ₂ O	NH ₃	TSP*	PM ₁₀ *	PM _{2.5} *	
Secondary Aluminium Production	030310												
Typical contribution		0	0	0	-	-	-	-	-	0.103	0.194	0.125	
Highest value										0.285	0.525	0.301	
Lowest value										-	-	-	

* EU PM_{2.5} Inventory project for EU25 for the year 2000 (TNO, 2006), contribution to total national emissions, excluding agricultural soils

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

Secondary Aluminium production plants have the potential to emit cadmium, hexachlorobenzene, dioxins and furans, PAHs and sulphurhexafluoride (ETC/AEM-CITEPA-RISOE 1997).

3 GENERAL

3.1 Description

A secondary Aluminium smelter is defined as any plant or factory in which Aluminium-bearing scrap or Aluminium-bearing materials, other than Aluminium-bearing concentrates (ores) derived from a mining operation, is processed into Aluminium Alloys for industrial castings and ingots. Energy for secondary refining consumes only about 5% of that required for primary Aluminium production.

In most cases, the first step in the secondary Aluminium production is removal of magnesium from the scrap charge in order to prevent off-grade castings when the refined Aluminium is cast. As much as 1% of magnesium can be found in the scrap charge and its reduction to 0.1% is necessary. This reduction can be achieved by lancing the molten charge with chlorine gas during and after the melting cycle (Barbour et al., 1978).

After pre-treatment the scrap charge is subjected to melting and demagging (chlorination). Small crucible furnaces are used to produce Aluminium Alloys for casting. Larger melting operations use reverberatory furnaces.

The final step in the production process is chlorination to obtain a high quality Aluminium product.

3.2 Definitions

Secondary Aluminium production: - production of Aluminium from materials other than ores.

3.3 Controls

Secondary Aluminium processing faces the difficult problem of suppressing emissions of corrosive Aluminium chloride associated with hydrogen chloride. Two approaches have been employed for some time to deal with the problem (Barbour et al., 1978). The Derham process uses proprietary fluxes. It claims more than 97% magnesium-chlorine efficiency for the chlorination stage at magnesium levels of less than 0.1%.

The Alcoa fumeless process depends on effecting a stoichiometric chlorination of magnesium in a multi-stage enclosed settler-reactor tank after melting and prior to casting (Barbour et al., 1978). Efficient gas-liquid contact gives a selective magnesium chlorination reaction (99% efficiency).

Afterburners are used generally to convert unburned VOC to CO₂ and H₂O. Wet scrubbers are sometimes used.

Controls in secondary Aluminium production should also include effective dust collecting arrangements for dust from both primary exhaust gases and fugitive dust emissions. Fabric filters can be used reducing the dust emissions to below 10 mg/ m³.

4 SIMPLER METHODOLOGY

Emissions can be estimated at different levels of complexity; it is useful to think in terms of three tiers¹:

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.

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 and 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.

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.

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:

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

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

The detailed methodology (equivalent to Tier 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 Measurement Protocol Annex.

In this case, different emission factors for various production technologies should be used. An account of the effect of emission controls should be considered. The different emission factors will have to be evaluated through measurements at representative sites.

6 RELEVANT ACTIVITY STATISTICS

Information on the production of Aluminium in secondary smelters, suitable for estimating emissions using of the simpler estimation methodology (Tier 1 and 2), is widely available from UN statistical yearbooks or national statistics. This information is satisfactory to estimate emissions with the use of the simpler estimation methodology.

The detailed methodology (Tier 3) requires more detailed information. For example, the quantities produced by various types of industrial technologies employed in the secondary Aluminium industry at plant level. This data is however not always easily available.

Further guidance is provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, volume 3 on Industrial Processes and Product Use (IPPU), chapter 2.2.1.3 "Choice of activity statistics".

7 POINT SOURCE CRITERIA

Secondary Aluminium smelters should be regarded as point sources if plant specific data are available.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Emissions from secondary Aluminium operations include fine particles, gaseous chlorine, and selected persistent organic pollutants.

Table 8.1 contains fuel related emission factors for secondary Aluminium production based on CORINAIR90 data in [g/GJ]. In the case of using production statistics the specific energy consumption (e.g. GJ/Mg product) has to be taken into account, which is process and country specific. Within CORINAIR90 a range for the specific energy consumption of 1.7 up to 3.5 GJ/Mg product has been reported.

Technique related emission factors, mostly given in other units (e.g. g/Mg product, g/m³), are presented in Tables 8.2 through 8.4 for SO_x, NO_x and NMVOC, respectively. No information exists on the type and efficiency of abatement techniques, but the factors in these tables seem to be valid for emissions from uncontrolled processes.

Table 8.1: Emission factors for secondary Aluminium production (based on CORINAIR)

Type of fuel	NAPFUE code	Emission factors						
		SO ₂ [g/GJ]	NO _x [g/GJ]	NM VOC [g/GJ]	CH ₄ [g/GJ]	CO [g/GJ]	CO ₂ [kg/GJ]	N ₂ O [g/GJ]
oil residual	203	143	100	3	5	12	73	10
oil gas	204	1,410	100			12	75	
gas natural	301						87-100	54-58

Table 8.2: Emission factors for SO₂ from secondary Aluminium production.

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country of origin
Sweating furnace	N/A	N/A	N/A	kg/tonne Al	1.75	E	USA
Smelting Furnace:							
-crucible	N/A	N/A	N/A	kg/tonne Al	1.25	E	USA
-reverberatory	N/A	N/A	N/A	kg/tonne Al	0.45	E	USA
Burning, drying	N/A	N/A	N/A	kg/tonne Al	0.15	E	USA
Heavily contaminated scrap input	N/A	N/A	N/A	kg/tonne Al	0.54	E	USA
Pouring, casting	N/A	N/A	N/A	kg/tonne charged	0.01	E	USA
Process heaters	N/A	N/A	gas oil	kg/m ³ fuel	17.2 x S	E	USA
	N/A	N/A	residual oil	kg/m ³ fuel	19.0 x S	E	USA

N/A = Data not available
S = sulphur content of fuel

Table 8.3: Emission factors for NO_x from secondary aluminium production

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Sweating furnace	N/A	N/A	N/A	kg/tonne Al	0.3	E	USA
Smelting furnace							
-crucible	N/A	N/A	N/A	kg/tonne Al	0.85	E	USA
-reverberatory	N/A	N/A	N/A	kg/tonne Al	0.38	E	USA
Burning, drying	N/A	N/A	N/A	kg/tonne Al	0.25	E	USA
Annealing furnace	N/A	N/A	N/A	kg/tonne Al	0.75	E	USA
Pouring, casting	N/A	N/A	N/A	kg/tonne Al	0.005	E	USA
Slab furnace	N/A	N/A	N/A	kg/tonne Al	0.75	E	USA
Can manufacture	N/A	N/A	N/A	kg/tonne Al	0.35	E	USA
Rolling, drawing, extruding	N/A	N/A	N/A	kg/tonne Al	0.35	E	USA
Process heaters	N/A	N/A	gas oil	kg/m ³ fuel	2.4	E	USA
	N/A	N/A	residual oil	kg/m ³ fuel	6.6	E	USA

N/A = Data not available

Table 8.4: Emission factors for NMVOCs from secondary aluminium production

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Sweating furnace	N/A	N/A	N/A	kg/tonne Al	1.20	E	USA
Smelting furnace							
-crucible	N/A	N/A	N/A	kg/tonne Al	1.25	E	USA
-reverberatory	N/A	N/A	N/A	kg/tonne Al	0.10	E	USA
Burning, drying	N/A	N/A	N/A	kg/tonne Al	16.00	E	USA
Foil rolling	N/A	N/A	N/A	kg/tonne Al	0.65	E	USA
Foil converting	N/A	N/A	N/A	kg/tonne Al	1.20	E	USA
Annealing furnace	N/A	N/A	N/A	kg/tonne Al	0.002	E	USA
Slab furnace	N/A	N/A	N/A	kg/tonne Al	0.002	E	USA
Pouring, casting	N/A	N/A	N/A	kg/tonne Al	0.07	E	USA
Can manufacture	N/A	N/A	N/A	kg/tonne Al	150.0	E	USA
Rolling, drawing, extruding	N/A	N/A	N/A	kg/tonne Al	0.045	E	USA
Process heaters	N/A	N/A	gas oil	kg/m ³ fuel	0.024	E	USA
	N/A	N/A	residual oil	kg/m ³ fuel	0.034	E	USA
	N/A	N/A	natural gas	kg/m ³ fuel	44.85	E	USA
	N/A	N/A	process gas	kg/m ³ fuel	44.85	E	USA

N/A = Data not available

Particle emission factors cited in CEPMEIP are presented in Table 8.5.

Table 8.5: Emission factors for fine particles from secondary aluminium production (CEPMEIP, kg/ton)

Technology	Abatement type	TSP	PM ₁₀	PM _{2.5}	Uncertainty
Conventional plant	ESP, settlers, scrubbers; moderate control of fugitive sources	1.5	1.2	0.48	1.5
Modern plant (BAT)	fabric filters for most emission sources	1	0.9	0.405	1.5
Older plant	limited control of fugitive sources	2	1.4	0.55	1.5

NOTE: The uncertainty range (95% confidence) in the emission factor is expressed as a factor. The lower limit of the uncertainty range can be found by dividing the emission factor by the uncertainty factor, whereas the upper limit of the uncertainty range can be found by multiplying the range with the uncertainty factor. Example (first row in the table): The uncertainty in the emission factor for PM_{2.5} from a conventional plant with an ESP settlers, scrubbers and moderate control of fugitive sources is 1.5. The emission factor with uncertainty range will therefore be 0.48 kgam per tonne with an uncertainty range of 0.32 (0.48/1.5) to 0.72 (0.48x1.5).

Hexachloroethane has been used in the secondary Aluminium industry and in Aluminium foundries in the form of tablets for degassing purposes in refining operations, resulting in hexachlorobenzene (HCB) emissions. An emission factor of 5 g HCB/ tonne Aluminium produced has been reported (in PARCOM, 1992).

Concentrations of dioxins and furans in the flue gas passing the control equipment in the secondary Aluminium production are presented in Table 8.6 after a compilation of data by the Working Group of the Subcommittee on Air/Technology of the Federal Government /Federal States Emission Control Committee in Germany (Umweltbundesamt, 1996).

Table 8.6: Concentrations of dioxins and furans in the flue gas after passing the control devices, in ng TEQ/m³ *1

Process	Emission Control Device	PCDD/F Concentration	Data Quality Code
Drum furnace with convertors	Hydrated lime fabric filters	0.1 - 13.7	D
Hearth trough kiln	Hydrated lime fabric filter	0.01 - 0.7	D
Smelting and casting furnace	No treatment	0.06 - 0.09	D
Induction furnace	Fabric filters	0.01 - 0.3	D
Al smelting plant	Fabric filters	0.02 - 0.23	D

*1 TEQ = toxic equivalency factor established by NATO/CCMS

In general, concentrations of dioxins and furans in the flue gas after the control device vary substantially due to differences in operational processes employed.

Secondary Aluminium Also generates so called climate gases, including CF₄, C₂F₆, and SF₆. A temporal increase of about 2% per year in CF₄ has been measured in the global atmosphere (in Stordal and Myhre, 1991). The current concentration of SF₆ in the atmosphere is 1 to 2 ppt, and the rate of increase has recently been estimated to be 7.4 % per year in the period from 1979 to 1989 (Rinsland et Al., 1990). However, no data are available to the authors of this chapter regarding emission factors of these gases for the secondary Aluminium production.

9 SPECIES PROFILES

Not applicable.

10 UNCERTAINTY ESTIMATES

It is rather difficult to assess current uncertainties of emission estimates for pollutants emitted during the secondary Aluminium production. The uncertainties of SO₂ emission estimates can be assessed in a similar way as the uncertainties of the estimates for the fossil fuel combustion (see chapter B 111).

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Improvement of emission factors is necessary in order to obtain more accurate emission estimates for the secondary aluminium production. This improvement should focus on preparing individual emission factors for major production techniques, currently employed in the secondary aluminium industry. In this way, a detailed approach methodology for emission estimates can be applied. Obviously, it will be necessary to obtain relevant statistical data on the production of aluminium in various secondary melting furnaces.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

National emission estimates can be disaggregated on the basis of production, population or employment statistics.

13 TEMPORAL DISAGGREGATION CRITERIA

The secondary Aluminium production is a continuous process. No temporal disaggregation is needed.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

Barbour A.K., Castle J.F. and Woods S.E. (1978) Production of non-ferrous metals. In: Industrial Air Pollution Handbook, A. Parker (ed.), Mc Graw-Hill Book Comp. Ltd., London.

16 VERIFICATION PROCEDURES

Estimated emission factors could be best verified by measurements at plants using different industrial technologies.

17 REFERENCES

Barbour A.K., Castle J.F. and Woods S.E. (1978) Production of non-ferrous metals. In: Industrial Air Pollution Handbook, A. Parker (ed.), Mc Graw-Hill Book Comp. Ltd., London.

Bremmer H. J. (1995) Secundaire Non-Ferroindustrie; RIVM-report 773006174; RIZA-report 92.003/74.

Economopoulos A.P. (1993) Assessment of sources of air, water, and land pollution. A guide to rapid source inventory techniques and their use in formulating environmental control strategies. Part one: Rapid inventory techniques in environmental pollution. World Health Organization, Geneva.

EPA (1990) AIR Facility Subsystem, EPA-Doc. 450/4-90-003, Research Triangle Park.

ETC/AEM-CITEPA-RISOE (1997) Selected nomenclature for air pollution for CORINAIR94 inventory (SNAP 94), version 0.3 (Draft).

PARCOM (1992) Emission Factor Manual PARCOM-ATMOS. Emission factors for air pollutants 1992. P.F.J. van der Most and C. Veldt, eds., TNO Environmental and Energy Research, TNO Rept. 92-235, Apeldoorn, the Netherlands.

Parker A. (ed) (1978) Industrial Air Pollution Handbook, McGraw-Hill Book Comp. Ltd., London

Rinsland, C.P. Goldman, A., Murcray, F.J. Blatherwick, R.D., Kusters, J.J., Murcray, D.G., Sze, N.D. and Massie, S.T. (1990) Long-term trends in concentrations of SF₆, CHClF₂ and COF₂ in the lower stratosphere from analysis of high-resolution infrared solar occultation spectra. *J.Geophys. Res.*, *95*, 16477-16490.

Stordal F., and Myhre G. (1991). Greenhouse Effect and Greenhouse Warming Potential for SF₆. NILU Rept. 74/91. Norwegian Institute for Air Research, Kjeller, Norway.

Umweltbundesamt (1996). Determination of requirements to limit emissions of dioxins and furans. Report from the Working Group of the subcommittee Air/Technology of the Federal Government/Federal States Immission Control Committee, Texte 58/95, Umweltbundesamt, Berlin.

U.S. EPA (1973) Compilation of air pollutant emission factors. 2nd edition. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

UN (1994) Statistical Yearbook - 1992. United Nations, Department for Economic and Social Information and Policy Analysis, Statistical Division, New York, NY.

Visschedijk, A.J.H., J. Pacyna, T. Pulles, P. Zandveld and H. Denier van der Gon, 2004, Coordinated European Particulate Matter Emission Inventory Program (CEPMEIP), In: P. Dilara et. Al (eds), Proceedings of the PM emission inventories scientific workshop, Lago Maggiore, Italy, 18 October 2004, EUR 21302 EN, JRC, pp 163 - 174

18 BIBLIOGRAPHY

For a detailed bibliography the primary literature mentioned in AP42 or the PARCOM-ATMOS Manual can be used.

19 RELEASE VERSION, DATE AND SOURCE

Version : 2.2

Date : November 1997

Original author
and update by: Jozef M. Pacyna

Norwegian Institute for Air Research (NILU)
Norway

Supported by: Otto Rentz, Dagmar Oertel
University of Karlsruhe (TH)
Germany

Updated with emission factors (CEPMEIP) for particulates by:
Tinus Pulles and Wilfred Appelman
TNO
The Netherlands
May 2006

20 POINT OF ENQUIRY

Any comments on this chapter or enquiries should be directed to:

Jozef Pacyna

NILU - Norwegian Institute of Air Research
PO Box 100
N-2027 Kjeller
Norway

Tel: +47 63 89 8155
Fax: +47 63 89 80 50
Email: jozef.pacyna@nilu.no