SNAP CODE: **030306**

SOURCE ACTIVITY TITLE: **PROCESSES WITH CONTACT**
Primary Copper Production

NOSE CODE: **104.12.07**

NFR CODE: **2 C 5 / 1 A 2 b**

ISIC: **2420**

1 ACTIVITIES INCLUDED

This chapter presents information on atmospheric emissions during the production of copper in primary smelters. More than 80 copper smelters around the world employ various conventional pyrometallurgical techniques to produce more than 90 % of the total copper production (e.g. Pacyna, 1989). Generally there are 3 steps in this process: 1) roasting of ores to remove sulphur, 2) smelting of roaster product to remove a part of the gangue for production of the copper matte, and 3) converting of the copper matte to blister copper. Atmospheric emissions of sulphur dioxide and heavy metals on fine particles occur during all the above mentioned processes.

Both emissions from fuel combustion in the primary copper plants and industrial processes are discussed here.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

Emissions of sulphur dioxide from non-ferrous metal production, particularly copper production contribute less than 10% to the total global emissions of this pollutant. However, copper smelting can be the most important source of sulphur dioxide emissions in certain regions, such as the Kola Peninsula, the Urals, the Norilsk area, and the Fergana region in Russia, Lower Silesia in Poland, and the Gijon region in Spain.

The contribution of emissions released from primary copper 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 [%]**										
Primary Copper Production	030306	SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3	TSP*	PM_{10} *	$PM_{2.5}$*
Typical contribution		0.1	0	-	-	0.2	0	-	-	0.082	0.146	0.182
Highest value										0.260	0.435	0.530
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

Various trace elements can be measured as impurities in copper ores. During the copper production process they are emitted to the atmosphere. This process is the major source of atmospheric arsenic and copper (about 50 % of the global emissions of the element), and indium (almost 90 %), and a significant source of atmospheric antimony, cadmium and selenium (ca. 30 %), and nickel and tin (ca. 10 %) (Nriagu and Pacyna, 1988). The production of copper (and nickel) is the major source of these and other elements in regions with non-ferrous metal production. Contribution of primary copper production emissions of selected trace metals to the total emissions in Europe is presented in Table 2.2 (Pacyna, 1996).

Table 2.2: Contribution to the European emission of trace metals at the beginning of the 1990's (Pacyna, 1996)

Source-activity	SNAP-code	Contribution to the total emissions			
		As	Cd	Pb	Zn
Primary Copper Production	030306	29.4	10.5	4.8	6.2

Primary copper production is unlikely to be a significant source of sulphurhexafluoride (SF_6), hydrofluorocarbons (HFCs) or perfluorocarbons (PFCs), (ETC/AEM-CITEPA-RISOE 1997).

3 GENERAL

3.1 Description

The traditional pyrometallurgical copper smelting process is illustrated in Figure 3.1 (EPA, 1993). Typically, the blister copper is fire refined in an anode furnace, cast into "anodes" and sent to an electrolytic refinery for further impurity elimination. The currently used copper smelters process ore concentrates by drying them in fluidized bed dryers and then converting and refining the dried product in the same manner as the traditionally used process (EPA, 1993).

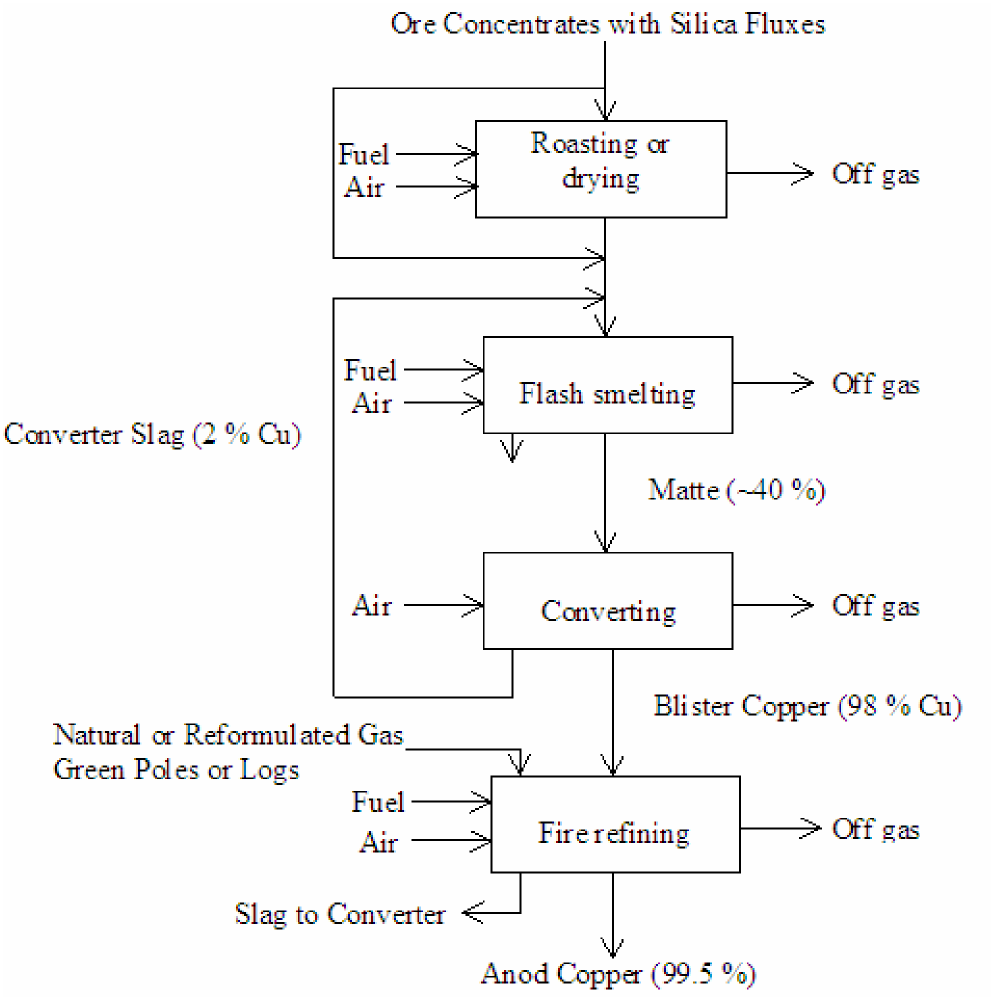
Concentrates usually contain 20-30 % Cu. In roasting, charge material of copper mixed with a siliceous flux is heated in air to about 650 C, eliminating 20 to 50 % of sulphur and portions of volatile trace elements. The roasted product, calcine, serves as a dried and heated charge for the smelting furnace.

In the smelting process, calcines are melted with siliceous flux in a flash smelting furnace to produce copper matte, a molten mixture of cuprous sulphide, ferrous sulphide, and some trace elements. Matte contains usually between 35 and 65 % of copper. Heat required in the smelting process comes from partial oxidation of the sulphide charge and from burning external fuel. Several smelting technologies are currently used in the copper industry, including reverberatory smelting, flash smelting (two processes are currently in commercial use: the INCO process and the OUTOKUMPU process), and the Noranda and electric processes.

In the reverberatory process heat is supplied by combustion of oil, gas, or pulverised coal. The temperature in the furnace can reach 1500 C. Flash furnace smelting combines the operations of roasting and smelting to produce a high grade copper matte from concentrates and flux. Most of flash furnaces use the heat generated from partial oxidation of their sulphide charge to provide much or all of the energy required for smelting. The temperature in the furnace reaches between 1200 and 1300 C. The Noranda process takes advantage of the heat energy available from the copper ore. The remaining thermal energy is supplied by oil burners, or by coal mixed with the ore concentrates. For the smelting in electric arc furnaces, heat is generated by the flow of an electric current in carbon electrodes lowered through the furnace roof and submerged in the slag layer of the molten bath (e.g. EPA, 1993; UN ECE, 1994).

Concerning emissions of air pollutants from the smelting operations, all the above described operations emit trace elements. Flash furnace smelting produces offgas streams containing high concentrations of sulphur dioxide. In contrary, electric arc furnaces do not produce fuel combustion gases, so flow rates are lower and so are the sulphur dioxide concentrations.

Figure 3.1: Typical primary copper smelter process (adapted from EPA, 1993)



The final step in the production of blister copper is converting. The rest of iron and sulphur in the matte is removed in this process leaving molten blister copper. Blister copper usually contains between 98.5 and 99.5 % pure copper with the rest consisting of trace elements, such as gold, silver, antimony, arsenic, bismuth, iron, lead, nickel, selenium, sulphur, tellurium, and zinc. There are various converting technologies applied in the copper production. The temperature in the converting furnace reaches 1100° C.

3.2 Definitions

Roasting	high-temperature process of the calcine production from ore concentrates.
Smelting	high-temperature process of the matte production from roasted (calcine feed) and unroasted (green feed) ore concentrates.
Converting	high-temperature process to yield blister copper from the matte.
Matte	impure product of smelting of sulphide ores.

3.3 Techniques

A description of primary copper process technology is given in section 3.1.

3.4 Emissions

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), trace elements, and selected persistent organic pollutants (POPs). The main relevant pollutants are SO_2 and CO, according to CORINAIR90 (see also Table 2.1) and selected trace elements. Concerning POPs, there are mostly dioxins and furans which are emitted from shaft furnaces, converters, and flame furnaces.

Primary copper smelters are a source of sulphur oxides (SO_x). Emissions are generated from the roasters, smelting furnaces, and converters (see Table 3.1). Fugitive emissions are generated during material handling operations. Remaining smelter operations use material containing very little sulphur, resulting in insignificant SO_2 emissions (EPA, 1995). Here only emissions from combustion processes with contact are relevant.

Table 3.1 shows typical average SO_2 concentrations from the various smelter units.

It can be assumed, that the SO_2 concentrations given in Table 3.1 take into account emissions from fuel sulphur and ore sulphur.

Table 3.1: Typical sulphur dioxide concentrations in off-gas from primary copper smelting sources (EPA, 1995)

Process unit	**SO_2 concentration [vol.-%]**
Multiple hearth roaster	1.5 - 3
Fluidized bed roaster	10 - 12
Reverberatory furnace	0.5 - 1.5
Electric arc furnace	4 - 8
Flash smelting furnace	10 - 70
Continuous smelting furnace	5 - 15
Pierce-Smith converter	4 - 7
Hoboken converter	8
Single contact H_2SO_4 plant	0.2 - 0.26
Double contact H_2SO_4 plant	0.05

3.5 Controls

Emission controls on copper smelters are employed for controlling sulphur dioxide and particulate matter emissions resulting from roasters, smelting furnaces, and converters. Control of sulphur dioxide emissions is achieved by absorption to sulphuric acid in the sulphuric acid plants, which are commonly a part of copper smelting plants. Reverberatory furnace effluent contains minimal SO_2 and is usually released directly to the atmosphere with no SO_2 reduction. Effluents from the other types of smelter furnaces contain higher concentrations of SO_2 and are treated in sulphuric acid plants before being vented. Single-contact sulphuric acid plants achieve 92.5 to 98 % conversion of SO_2 from plant effluent gas. Double-contact acid plants collect from 98 to more than 99 % of the SO_2. Absorption of the SO_2 in dimethylaniline solution has also been used in US-American smelters to produce liquid SO_2. (EPA, 1995).

Electrostatic precipitators (ESPs) are the common particulate matter control devices employed at copper smeltering facilities. The control efficiency of ESPs often reaches about 99 %. It should be added that most of the trace elements is condensed on very fine particles, e.g. <1.0 um diameter, and the control efficiency for these particles is lower, reaching about 97 % (e.g. Pacyna, 1987a).

A detailed description of control techniques and best available technologies for the primary copper production is available in UN ECE (1994).

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.

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.

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:

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

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.

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[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.

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.

The detailed methodology to estimate emissions of trace elements from the primary copper production is similar to the simpler one. However, more information on the type of the process, e.g. roasting, smeltering, or converting, 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 µm diameter are often carried out at major copper smelters worldwide. The results of these measurements are then used to estimate atmospheric emissions of several trace elements contained as impurities in copper ores.

6 RELEVANT ACTIVITY STATISTICS

Information on the production of copper in primary 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 copper industry at plant level. This data is however not always easily available. Therefore, the application of the detailed estimation methodology may be complicated unless the statistical data are available directly from a given smelter.

Some statistical yearbooks provide information about the production of blister copper. No information is easily available on the content of impurities in the copper ores from different mines or even mining regions.

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

Primary copper smelters should be regarded as point sources, very often high point sources, e.g. with over 100 m high stacks if plant specific data are available.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

The traditional roasters produce emissions with an average of 1 to 4 % of sulphur dioxide and 3 to 6 % of the weight of the charged concentrate as particulate. This type of roaster also produces substantial amounts of fugitive emissions. The fluid bed roaster, which is now becoming common, produces between 10 and 15 % of sulphur dioxide; up to 80 % of the calcine concentrate will leave the roaster in the flue gas (Environment Canada, 1982). The flue gases from the traditional smelter furnace contain between 1 and 2 % of sulphur dioxide, which can be increased to 2.5 % by oxygen enrichment of the air. Flash smelting produces sulphur dioxide concentrations as high as 80 % when only oxygen is used, or up to 10 to 15 % when no oxygen is used (Environment Canada, 1982). Finally, the conventional converters produce emissions with sulphur dioxide concentrations ranging from almost 0 to 10 % and averaging about 4 to 5 %. Sulphuric acid is the most common sulphur product recovered from metallurgical gases. A production schematic for single and double contact sulphuric acid plant is shown in Figure 8.1. Reference emission factors for comparison with users own data are provided in Section 8.2.

Figure 8.1: Single and double contact sulphuric acid plant schematic (adapted from Environment Canada, 1982)

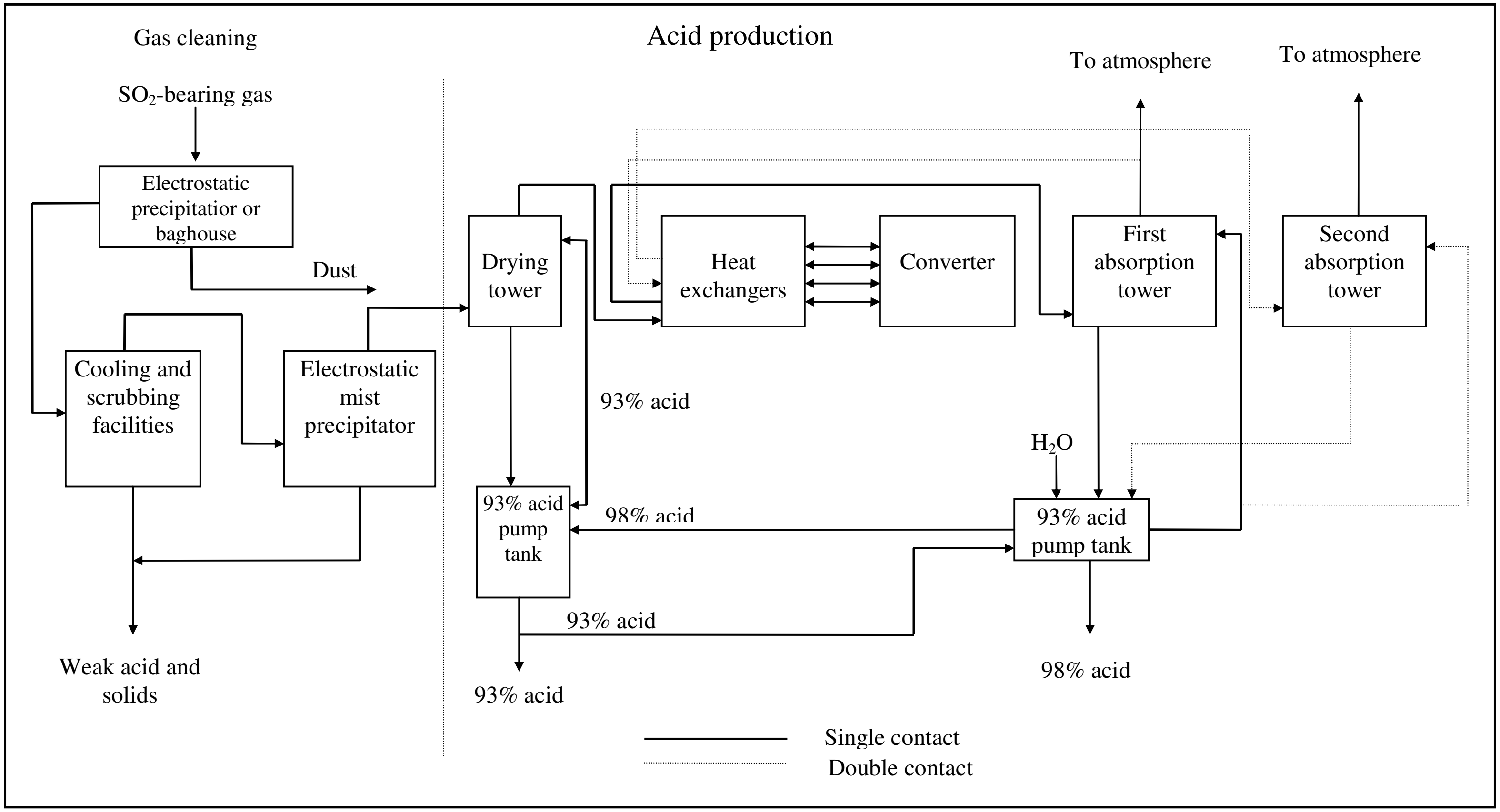

Table 8.1: Default Emission Factors for use with simpler methodology (Pacyna et al, 2002)

Pollutant	**Emission Factor** *Limited control*	**Emission Factor** *Abatement*	**Units**
Arsenic	1000	30	g/tonne copper
Cadmium	200	3	g/tonne copper
Chromium	1	0.1	g/tonne copper
Copper	4000	250	g/tonne copper
Mercury	0.1	0.1	g/tonne copper
Nickel	1500	50	g/tonne copper
Lead	2000	100	g/tonne copper
Selenium	100	15	g/tonne copper
Vanadium	7	1	g/tonne copper
Zinc	1000	200	g/tonne copper
Dioxins and furans	SS	SS	g/tonne copper
Particulate matter*			
TSP	1200		g/tonne copper
PM_{10}	960		g/tonne copper
$PM_{2.5}$	720		g/tonne copper

*CEPMEIP emission factors for a conventional plant, see also table 8.2f2 for information on uncertainty

Table 8.2a: Production data and maximum sulphur dioxide emissions for sulphuric acid processes (adopted from Environment Canada, 1982)

Sulphuric acid recovery process	SO_2 removal	SO_2 concentration in input gas (vol. %)	Maximum sulphur dioxide emissions in gas after treatment
Single contact process	97.5 %	7 %	5.7 g SO_2/m^3
	97.5 %	6 %	4.8 g SO_2/m^3 17 kg SO_2/t H_2SO_4
Double contact process	99.5 %	10 %	1.7 g SO_2/m^3 3.3 kg SO_2/t H_2SO_4
	99.5 %	6 %	1.0 g SO_2/m^3 3.3 kg SO_2/t H_2SO_4
	99.0 %	10 %	3.5 g SO_2/t H_2SO_4 6.6 kg SO_2/t H_2SO_4
	99.0 %	6 %	1.9 g SO_2/m^3 5.5 kg SO_2/t H_2SO_4

Table 8.2b: Emission factors for primary copper production based on CORINAIR90 data in [g/GJ].

		Emission factors						
Type of fuel	NAPFUE code	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]
coal bc briquettes	107	632[2]	702[2]				112[2]	
oil residual	203	419-1,470[1], 419-1,030[2]	123-150[1], 123-150[2]	7[1][2]	1[1]	5-15[1], 5-20[2]	76-79[1], 77-79[2]	15[1][2]
oil gas	204	1,410[1]	100[1]			12[1]	73[1]	
Data quality rating		B	B	D	D	C	C	D

[1] CORINAIR90 data, area sources

[2] CORINAIR90 data, point sources

Table 8.2c: Emission factors for SO_2 in kg/tonne ore processed, unless specified otherwise (EPA, 1995)

Process type	Abatement type	Abatement efficiency	Emission Factor	Data Quality	Country or Region
Multiple hearth roaster	N/A	N/A	140.00	E	USA
Reverberatory smelting furnace after roaster	N/A	N/A	90.00	E	USA
Converter, all configurations	N/A	N/A	311.50	E	USA
Ore concentrate dryer	N/A	N/A	0.50	E	USA
Reverberatory smelting furnace with ore charge, without roasting	N/A	N/A	160.00	E	USA
Fluidized bed roaster	N/A	N/A	18.00	E	USA
Electric smelting furnace	N/A	N/A	120.00	E	USA
Flash smelting	N/A	N/A	410.00	E	USA
Roasting, fugitive emissions	N/A	N/A	0.50	E	USA
Reverberatory furnace, fugitive emissions	N/A	N/A	2.00	E	USA
Converter, fugitive emissions	N/A	N/A	65.00	E	USA
Anode refining furnace fugitive emissions	N/A	N/A	0.05	E	USA
Slag cleaning furnace, fugitive emissions	N/A	N/A	3.0	E	USA
Converter slag returns, fugitive emissions	N/A	N/A	0.05	E	USA
Slag cleaning furnace	N/A	N/A	3.75	E	USA
Reverberatory furnace with converter	N/A	N/A	160.00	E	USA
Fluidized bed roaster with reverberatory furnace and converter	N/A	N/A	180.00	E	USA
Concentrate dryer with electric furnace, cleaning furnace and converter	N/A	N/A	0.50	E	USA
Concentrate dryer with flash furnace and converter	N/A	N/A	0.50	E	USA
Multiple hearth roaster with reverberatory furnace and converter	N/A	N/A	140.00	E	USA
Fluidized bed roaster with electric furnace and converter	N/A	N/A	300.00	E	USA
Reverberatory furnace after multiple hearth roaster	N/A	N/A	90.00	E	USA
Electric furnace after concentrate dryer	N/A	N/A	120.00	E	USA
Flash furnace after concentrate dryer	N/A	N/A	410.00	E	USA
Electric furnace after fluidized bed roaster	N/A	N/A	45.00	E	USA
Primary metal production, process heaters *1	N/A	N/A	17209xS -19006xS S=Sulphur content	E	USA

*1 in g/m^3 fuel
N/A = Not available

Table 8.2d: Emission factors for NO_X in kg/tonne ore processed, unless specified otherwise (EPA, 1995)

Process type	Abatement type	Abatement efficiency	Emission Factor	Data Quality	Country or Region
Multiple hearth roaster	N/A	N/A	1.80	E	USA
Reverberatory smelting furnace after roaster	N/A	N/A	2.90	E	USA
Converter, all configurations	N/A	N/A	0	E	USA
Reverberatory smelting furnace with ore charge, without roasting	N/A	N/A	5.15	E	USA
Primary metal production, process heaters *1	N/A	N/A	2400-6600	E	USA

*1 in g/m^3 fuel
N/A = Not available

Table 8.2e: Emission Factors for VOC in g/tonne ore processed, unless specified otherwise (EPA, 1995)

Process type	Abatement type	Abatement efficiency	Emission Factor	Data Quality	Country or Region
Multiple hearth roaster	N/A	N/A	4.5	E	USA
Reverberatory smelting furnace after roaster	N/A	N/A	7.5	E	USA
Ore concentrate dryer	N/A	N/A	2.0	E	USA
Reverberatory smelting furnace with ore charge, without roasting	N/A	N/A	1.5	E	USA
Primary metal production, process heaters *1	N/A	N/A	24-34	E	USA

*1 in g/m^3 fuel
N/A = Not available

Table 8.2f1: Emission factors for particulate matter in kg/tonne ore processed, unless specified otherwise (EPA, 1995)

Process type	Abatement type	Abatement efficiency	Emission Factor	Data Quality	Country or Region
Multiple hearth roaster	N/A	N/A	22.50	E	USA
Reverberatory smelting furnace after roaster	N/A	N/A	25.00	E	USA
Converter, all configurations	N/A	N/A	18.00	E	USA
Ore concentrate dryer	N/A	N/A	5.00	E	USA
Reverberatory smelting furnace with ore charge, without roasting	N/A	N/A	25.00	E	USA
Fluidized bed roaster	N/A	N/A	27.50	E	USA
Electric smelting furnace	N/A	N/A	50.00	E	USA
Flash smelting	N/A	N/A	70.00	E	USA
Roasting, fugitive emissions	N/A	N/A	1.30	E	USA
Reverberatory furnace, fugitive emissions	N/A	N/A	0.20	E	USA
Converter, fugitive emissions	N/A	N/A	2.20	E	USA
Anode refining furnace fugitive emissions	N/A	N/A	0.25	E	USA
Slag cleaning furnace, fugitive emissions	N/A	N/A	4.00	E	USA
Slag cleaning furnace	N/A	N/A	5.00	E	USA
Reverberatory furnace with converter	N/A	N/A	25.00	E	USA
Fluidized bed roaster with reverberatory furnace and converter	N/A	N/A	27.50	E	USA
Concentrate dryer with electric furnace, cleaning furnace and converter	N/A	N/A	5.00	E	USA
Concentrate dryer with flash furnace and converter	N/A	N/A	5.00	E	USA
Multiple hearth roaster with reverberatory furnace and converter	N/A	N/A	22.50	E	USA
Fluidized bed roaster with electric furnace and converter	N/A	N/A	27.50	E	USA
Reverberatory furnace after multiple hearth roaster	N/A	N/A	25.00	E	USA
Electric furnace after concentrate dryer	N/A	N/A	50.00	E	USA
Flash furnace after concentrate dryer	N/A	N/A	70.00	E	USA
Electric furnace after fluidized bed roaster	N/A	N/A	50.00	E	USA
Fire (furnace) refining	N/A	N/A	5.00	E	USA
Reverberatory furnace after fluidized bed roaster	N/A	N/A	25.00	E	USA

N/A = Not available

Table 8.2f2: Emission factors for fine particulate matter in kg/tonne primairy copper produced (CEPMEIP)

Process type	Abatement	Unit	TSP	PM_{10}	PM_{2-5}	Uncertainty
Conventional installation	ESP and settling chambers; moderate control of fugitive emission	kg/tonne primairy copper produced	1.2	0.96	0.72	3
Modern plant (BAT)	Fabric filters for most emission sources	kg/tonne primairy copper produced	0.5	0.475	0.4	3
Older plant	Limited control of fugitive sources	kg/tonne primairy copper produced	10	3.0	1.0	3

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 with 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 table): The uncertainty in the emission factor for $PM_{2.5}$ from a conventional plant with an ESP and settling chambers and moderate control of fugitive emission sources is 3. The emission factor for $PM_{2.5}$ with uncertainty range will therefore be 1.2 kg per tonne with an uncertainty range of 0.4 (1.2/3) to 3.6 (1.2 x 3).

A list of emission factors for several trace elements emitted from copper smelters is presented in Table 8.8. Results of measurements carried out in various countries were used to estimate these factors. The factors can be differentiated only as those relevant for a smelter with limited or improved control equipment. Limited control of emissions relates to a case of smelter equipped with ESP, the most common emission control installation in copper smelters worldwide, having control efficiency of about 99 %. Improved control of emissions relates to a case of smelter equipped with advanced emission control installation, such as high efficiency ESP, fabric filters, and/or wet scrubbers. Control efficiency of at least 99.9 % should be achieved in such smelter. It is assumed that all major copper smelters in the UN ECE region are equipped with at least limited control installations. Therefore, no uncontrolled emission factors are presented in Table 8.8.

Information available from the above mentioned measurements does not allow for further differentiation of emission factors with respect to either various industrial processes involved in the primary copper production or different production technologies used at present. Therefore, the factors in Table 8.8 can only be used in a simpler emission estimation methodology.

Table 8.2g: Compilation of emission factors for primary copper production (in g/tonne Cu produced)

Element	Global Emission Survey (Nriagu & Pacyna, 1988)	Measurements in Poland (Pacyna et al., 1981)	Measurements in Germany (Jockel and Hartje, 1991)	Measurements in Sweden (PARCOM, 1991)	Estimates in Canada (Jaques, 1987)	PARCOM program (PARCOM, 1992)	Suggested	
							Limited control	Impact control
Arsenic	1000-1500	~1000	15-45	100	600	50-100	500-1500	15-50
Chromium					1		1	?
Cadmium	200-400		3-10	15	550	6-15	200-500	3-10
Copper	1700-3600	1700-3600		300	200-12320		1500-4000	200-300
Indium	1-4						1-4	?
Manganese	100-500						100-500	?
Nickel	900				10-3410		900-3000	10-100
Lead	1300-2600	2300-3600	70	250	860-16700	250-2000	1000-4000	50-250
Antimony	50-200	~100			20		50-200	10-20
Selenium	50-150						50-150	10-20
Tin	50-200						50-200	?
Vanadium	5-10						5-10	?
Zinc	500-1000	~970		200		200-850	500-1000	100-200
Bismuth		~150					100-200	?
Mercury			0.06				?	0.10
Control	Unspecified	ESP, ca. 99% efficiency	High efficiency control equipment	Limited abatement (usually ESPs, fabric filter, wet scrubbers)	Based on questionnaires. Most plants use ESPs with 99 % efficiency	Unspecified	Common ESPs with 99% efficiency	Advanced control with at least 99.9% efficiency
Quality Data code	D	C	C	C	E	E	D	D

Concentrations of dioxins and furans in the flue gas after passing the control equipment in the primary copper production are presented in Table 8.9 after a compilation of data by the Working Group of the Subcommittee Air/Technology of the Federal Government/Federal States Emission Control Committee in Germany (Umweltbundesamt, 1996).

Table 8.2h: Concentrations of dioxins and furans in the flue gas after passing the control devices, in ng TEQ/m^{3}*1

Process	Emission Control Device	PCDD/F Concentration	Data Quality Code
1. Shaft furnace:		9.7	D
-old installation	Fabric filter		
-new installation	Fabric filter	1.5 - 2.0	C
2. Converter:			D
-using liquid black copper, and scrap	Fabric filter	0.16 - 0.6	
-using copper matte	ESP	0.001 - 0.005	D
3. Anode kiln	Fabric filter	0.05 -1.1	D
(flame furnace)			
4. Suspended melting	ESP	0.0001 - 0.007	D
furnace			

*1 The 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 the large differences in the materials used and different operational processes employed. For new installations controlled with fabric filters the concentrations would be up to 2.0 ng TEQ/m^3, while for older plants these concentrations can be by one order of magnitude higher.

Data from this table can be presented in a form of emission factors. These factors would range from 0.25 to 22.0 µg 1-TEQ/tonne of the copper produced.

9 SPECIES PROFILES

At present no reliable information exists on physical and chemical species of trace elements emitted during the primary copper production. It can be assumed that the majority of trace elements volatilized from the ores and then from semi-products in the production process enter the atmosphere on fine particles.

Very general information collected by Pacyna (1987b) appears to indicate that oxides and sulphates are the major chemical forms of atmospheric trace elements from the primary copper production.

10 UNCERTAINTY ESTIMATES

It is rather difficult to assess current uncertainties of emission estimates for pollutants emitted during the primary copper production. The uncertainties of sulphur dioxide emission estimates can be assessed in a similar way as the uncertainties of the estimates for the fossil fuel combustion (see chapter B111).

Recently it was concluded that up to 50 % of uncertainties can be assigned to the emission estimates of most of the trace elements emitted from major point sources in Europe (Pacyna, 1994). Similar uncertainty can be assigned for emission estimates of these compounds from the primary copper production.

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 primary copper production. This improvement should focus on preparing individual emission factors for major industrial technologies currently employed in roasting, smelting, and converting processes in the copper 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 the calcines, matte, and blister.

The fuel specific emission factors provided in Table 8.2b 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 production, population or employment statistics.

13 TEMPORAL DISAGGREGATION CRITERIA

The primary production process is a continuous process. No temporal dissaggregation is needed.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

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16 VERIFICATION PROCEDURES

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

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No additional documents to those in Section 17.

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