THE EFFECT OF SULPHUR ON PRIMARY ZINC ECOPROFILE CALCULATIONS

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ABSTRACT

The production of primary zinc is also associated with the production of other products, such as sulphuric acid, cadmium, lead, mercury and silver amongst other things. When allocating the inputs and outputs the sulphur is frequently omitted from the allocation procedure, the reason being that sulphur is a by-product and therefore is incidental to the primary zinc production process. Unfortunately the result of this assumption is that no environmental burdens are ascribed to the by-products containing sulphur — instead all of these burdens are attributed to the zinc and other metallic by-products. Using examples derived from a recent ecoprofile of primary zinc production, which covered nearly 75% of European production, this paper shows the effects on the inventory of excluding and including sulphur in the partitioning process.

INTRODUCTION

Primary zinc production in Europe occurs via two processes: the electrometallurgical process and the pyrometallurgical process. Approximately 80% of European primary zinc production is via the electrometallurgical process. Figure 1 shows flow diagrams for these two routes, starting with the delivery of concentrate and ending with the production of special high-grade (SHG) zinc ingot. The electrometallurgical process is shown on the left-hand side of Figure 1, and the pyrometallurgical process is on the right-hand side. In both cases, the sulphur within the concentrates, which is bonded with zinc (as ZnS), lead (as PbS), iron (as $Fe_{1-0.8}S_2$), copper ($CuFeS_2$) and other elements, is released as sulphur dioxide in the first stage of each metal extraction process. Other by-products are released at different stages of each process, and some of these are also shown in Figure 1.

Traditionally, the sulphur released in the roasting and sintering stages has been omitted from the allocation procedure, with the result that the sulphur dioxide liberated in these stages attracts zero environmental burdens. Whilst this approach may have its attractions in determining inventory data for sulphuric acid production, it is at the expense of the primary zinc inventory data i.e. the zinc and other metallic by-products attract all of the burdens. Since the majority of primary zinc manufacture in Europe is via the electrometallurgical process, this paper considers the effect of excluding and including the sulphur in the allocation process. A similar treatment of the pyrometallurgical process yields comparable results.

THE ROASTING FURNACE

Figure 2 shows the simplified inputs and outputs for a typical roasting furnace. The only problem in processing this data in order to calculate an inventory is in determining the co-product allocation method to be used, since the system has multiple products. The simplest method of allocating the inputs and outputs is by a partitioning on a mass basis. Figure 3 shows a system with multiple products that has been broken down into three separate sub-systems. Each of these sub-systems obeys the standard physical laws obeyed by the original system.

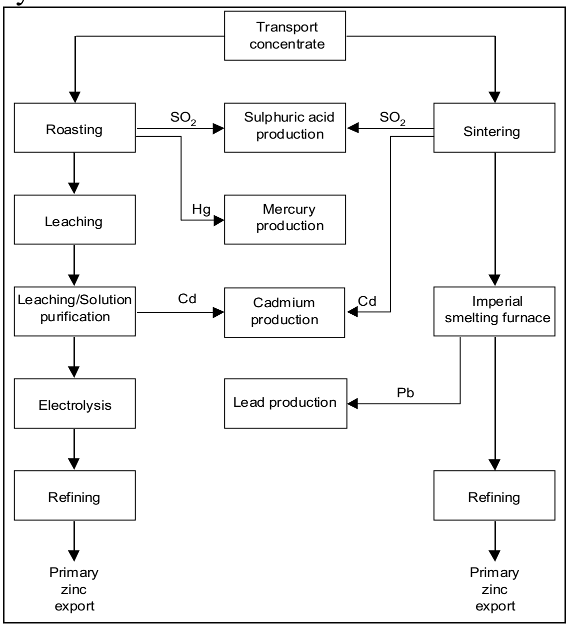

Figure 1. The two main routes for producing primary zinc in Europe. See text for details.

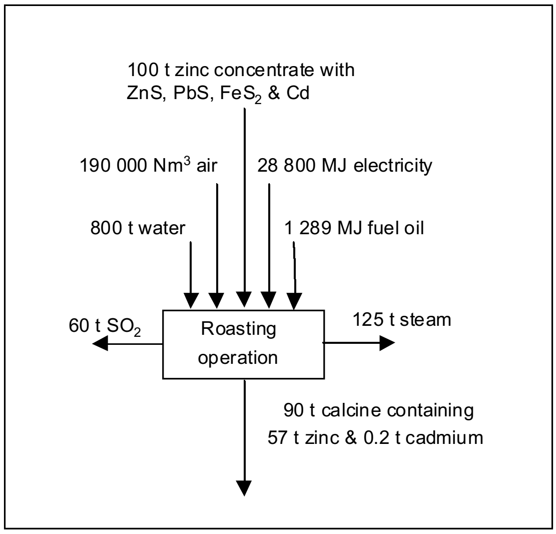

Figure 2. Simplified flow diagram showing the inputs to and outputs from a typical roasting furnace.

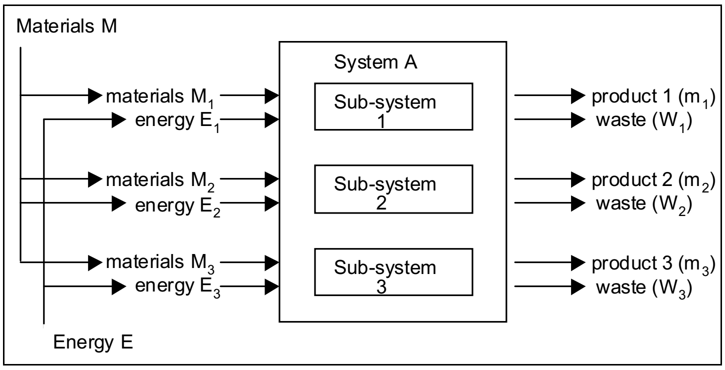

Figure 3. A single system (system A), broken down into three separate sub-systems.

Since the system is being partitioned by mass, the materials requirement for sub-system 1 is given by

$$M_1 = M \times \frac{m_1}{(m_1 + m_2 + m_3)} \qquad (1)$$

The mass feeds to sub-systems 2 and 3 are obtained similarly. Exactly the same procedure can be used for allocating energy consumption and waste emission.

ROASTING FURNACE CO-PRODUCT ALLOCATION

Although the roaster produces calcine and sulphur dioxide, normalising to the masses of these two products is not particularly useful as the calcine typically contains 60-64% zinc, with the content of other recovered metals in the calcine being less than 1%. For this reason, the most suitable choice of normalising parameter for the roasting furnace (and indeed for all operations in the primary zinc production system) is the mass of recovered products. For the primary zinc producing industry this is effectively the recovered elemental masses of zinc, cadmium, lead, mercury etc. however the problem that arises is how should the sulphur dioxide be handled? Table 1 shows the effect of normalising the roaster inputs to the masses of zinc and cadmium in the calcine summed with the mass of sulphur dioxide. The portion of Table 1 labelled 'Raw data' shows the inputs to and outputs from the roaster depicted in Figure 2. The central portion of the table labelled 'Normalising parameter' lists the total masses of zinc, cadmium and sulphur dioxide that emerge as products and by-products. The portion of the table labelled 'Normalised data' shows the inputs and outputs normalised to the total output mass of zinc, cadmium and sulphur dioxide.

Table 1.

Partitioning of zinc concentrate roaster with operating characteristics as shown in Figure 2.

Raw data				Normalising parameter		Normalised data	
Inputs	Electricity	28,800	MJ			0.246	MJ
	Fuel oil	1290	MJ			0.011	MJ
	Zinc concentrate	100	t			0.853	kg
	Water	800	t			6.826	litre
	Air	190,000	Nm^3			1.455	Nm^3
Outputs	Steam @ 40 bar	125	t			2.987	MJ
	Calcine with:	[90	t]				
	Zinc	57	t	57,000	kg zinc	0.487	kg Zn
	Cadmium	200	kg	200	kg cadmium	0.001	kg Cd
	SO_2	60	t	60,000	kg SO_2	0.512	kg SO_2
Total zinc, cadmium & sulphur dioxide				117,200	kg		

Clearly, the drawback here is that production of sulphur dioxide is attracting the majority of the roaster burdens. Table 2 shows the effect of normalising the roaster in the traditional manner, i.e. excluding the sulphur dioxide.

Table 2.

Partitioning of zinc concentrate roaster with operating characteristics as shown in Figure 2.

Normalising parameter		Normalised data		Normalising parameter		Normalised data	
		0.503	MJ			0.330	MJ
		0.023	MJ			0.015	MJ
		1.749	kg			1.147	kg
		13.986	litre			9.174	litre
		2.980	Nm^3			1.955	Nm^3
		6.121	MJ			4.015	MJ
57,000	kg zinc	0.997	kg Zn	57,000	kg zinc	0.654	kg Zn
200	kg cadmium	0.003	kg Cd	200	kg cadmium	0.002	kg Cd
				30,000	kg sulphur	0.344	kg S
57,200 kg zinc & cadmium				87,200 kg zinc, cadmium & sulphur			

Compared to Table 1, the normalised roaster requirements per kg of output in the left half of Table 2 have more than doubled. If instead the roaster data is partitioned a third way, by the mass of zinc, cadmium and sulphur, the data appear as shown in the right half of Table 2. Clearly, changing the partitioning parameter can, as in this example, have a marked effect on the normalised quantities.

The advantage of adopting this latter approach to partitioning the process — i.e. normalising the process to the (elemental) mass of materials that eventually leave the system as products — is that burdens are attached to the extracted products up to and including the point where they 'leave' the system as finished products. Whilst this paper illustrates the effect of this approach on primary zinc ecoprofile data, this methodology is also well-suited to analyses of primary steel production, primary copper production and in fact any system that produces multiple products at various points within an overall process.

Steam Co-product

The roasting furnace produces steam as a co-product along with the materials outputs. When this steam is recovered for use elsewhere on the site, the process generating it is given an energy credit equal to the specific enthalpy of the steam recovered — for steam generated @ 40 bar the specific enthalpy is 2.801 MJ/kg. No air, water or solid waste emissions are assigned to this recovered energy — all of these burdens are assigned to the other co-products i.e. the quantity of steam generated is not included in the normalising parameter. When this co-product steam is taken into another process the receiving process is charged with an energy equal to the credit given to roasting furnace.

THE EFFECT ON THE ECOPROFILE OF PRIMARY ZINC

To illustrate the effect on the ecoprofile data for primary zinc production, of including and excluding the sulphur from the roaster co-product allocation procedure, Table 4 shows gross energy data for the production of SHG zinc/zinc alloy. Note that the term 'gross' means that this is the cradle-to-gate energy and includes energy consumption from all ancillary operations, tracking all operations back to the extraction of raw materials from the ground.

Table 4.

Gross energy in MJ to produce 1 kg of SHG zinc/zinc alloy, showing the effect of excluding and including sulphur from the roaster co-product allocation.

Fuel type	Sulphur excluded from roaster co-product allocation	Sulphur included in roaster co-product allocation
Electricity	49.27	48.10
Oil fuels	4.00	3.94
Other fuels	-2.71	-0.99
Total energy	50.56	51.05

The effect of excluding and including the sulphur in the roaster co-product allocation can be clearly seen: including the sulphur results in smaller absolute normalised roaster data when compared with the normalised data set from which the sulphur was excluded. Thus, whilst the gross electricity and oil fuels energy figures are lowered, the corresponding smaller normalised quantity of steam generated as a co-product is reflected in the reduced energy credited to the process. With regard to the total gross energy use the difference between the two methods of treatment is about 1%.

CONCLUSIONS

The traditional method of partitioning the outputs from primary zinc smelters has the drawback that by-products, such as sulphur dioxide, can attract no environmental burdens. This is clearly not the case in practice, as energy and other resources have been expended in order to get the sulphur out of the ground and delivered to the roasting furnace. The method proposed here is to partition each operation on a mass basis, taking the elemental masses of the products as the normalising parameter. In this way, whenever a by-product leaves the main production sequence, only the environmental burdens associated with processing it up to and including the point at which it leaves are included in its inventory data. The overall effect on the ecoprofile data for primary SHG zinc is small. The effects on the ecoprofile data for sulphur dioxide and hence sulphuric acid are relatively more pronounced, but this method of partitioning reflects more accurately the characteristics of the system.