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Sensitivity Analysis in Life Cycle Inventory for a Personal Computer

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Inventory analysis for cathode copper and its by-products was carried out. Two allocation methods, mass-based and monetary value-based, respectively, were adopted to show the difference in CO_2 emission intensity of these products. Inventory analysis for production of a personal computer was also conducted. CO_2 intensity of cathode copper, gold and silver production depended significantly on the allocation method. Inventory analysis results for production of a personal computer depended significantly on the allocation method in the copper production process. Although the share of gold by weight in the personal computer was almost negligible, gold could not be omitted from the inventory analysis because the CO_2 intensity of gold was high when calculated with the market value-based allocation method.

KEY WORDS: Inventory analysis, Sensitivity analysis, Cut-off criteria, Allocation method

INTRODUCTION

Sensitivity analysis in constructing a life cycle inventory is a necessary step to assess the influence on the final results of the changes in input parameters or decisions. One of the key elements to be considered in conducting sensitivity analysis is methodological choices; i.e. allocation rules. In fact, most industrial processes yield more than one product. Therefore, the materials and energy flows as well as associated environmental releases shall be allocated to the different products according to clearly stated procedures. In ISO-14041, it is suggested that allocation should be avoided by dividing the unit process into two or more subprocesses or expanding the product system to include the additional functions related to the products [1]. However, these procedures are often not feasible in many cases. Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way which reflects the underlying physical relationship between them. Where physical relationship alone cannot be established or used as the basis for allocation, input and output data might be allocated between coproducts in proportion to the economic value of the products [1].

Production of cathode copper is associated with the production of other products, such as gold, silver and sulfuric acid. Thus, the results of inventory analysis of cathode copper will be affected by the allocation method. A personal computer consists of various materials including cathode copper, gold and silver. In this case, the results of inventory analysis of production will depend on the allocation method of the copper production process.

In this study, inventory analysis of production of cathode copper and its by-products was made. Two allocation methods, mass-based and monetary value-

value-based, respectively, were adopted to show the difference in CO_2 emission intensity of these products. Inventory analysis of production of a personal computer was also conducted. The effect of allocation methods in cathode copper, gold and silver production was investigated to show the differences in CO_2 emissions from predominant materials.

INVENTORY ANALYSIS

1) Inventory analysis of cathode copper, silver and gold production

In Japan, approximately 70% of cathode copper is produced by flash smelting technology [2]. Most copper concentrates consumed in smelting are imported. Inputs and outputs in the production of cathode copper using flash smelting technology were obtained from the literature [3], and are shown in Fig. 1. Materials and energy consumption in producing copper concentrates were similarly obtained from the literature [4]. Production of cathode copper is associated with production of gold, silver, sulfuric acid and other products. In this work, we focused on cathode copper, gold, silver and sulfuric acid. Gold and silver are contained in anode slime from electrolysis of cathode copper, which is also electrically recovered by succeeding electrolysis. Electricity consumption during electrolysis of gold and silver was calculated by Faraday's law.

CO_2 intensity (kg-CO_2 /kg-product) for cathode copper, gold and silver were calculated using the database of the life cycle assessment software "NIRE-LCA ver. 2" developed by the authors. Mass-based and monetary value-based allocation methods were adopted to show the differences in CO_2 emission intensity of these products.

2) Inventory analysis for production of a personal computer

The materials list for a personal computer (Table 1) was obtained from a computer company. CO_2 emissions in production of the personal computer were calculated. The effect of allocation method in cathode copper, gold and silver production was investigated to show the differences in CO_2 emissions from predominant materials for CO2 emissions in the production of the computer.

RESULTS AND DISCUSSION

The CO_2 intensity (kg-CO_2 /kg-product) of cathode copper, gold and silver production was found to depend significantly on the allocation method (Table 2). The allocation method made a particularly large difference in the CO_2 intensity of gold. The contributions to CO_2 emissions of each process in production of these materials are also shown in Fig. 2. Mining and separation were the predominant processes for cathode copper and silver production, while electrolysis was a major contributor to CO_2 emissions in the production of gold.

The CO_2 emissions in production of the personal computer are shown in Tables 3 and 4. When CO_2 intensity of cathode copper, gold and silver was calculated with the mass-based allocation method, the predominant materials for CO_2 emissions were steel, paper and epoxy resin. However, when the CO_2 intensity of cathode copper, gold and silver was calculated using the market value-based allocation method, gold and copper became the predominant materials for CO_2 emissions. Thus, the results of inventory analysis for production of a personal computer depend significantly on the allocation method in copper production. Although the share of gold by weight in the personal computer was almost negligible, gold could not be omitted from the inventory analysis because the CO_2 intensity of gold production was high when calculated using the market value-based allocation method.

SUMMARY

The CO_2 intensity of cathode copper, gold and silver depended significantly on the allocation method. The results of inventory analysis for production of a personal computer depended significantly on the allocation method in the copper production process. It is suggested that sensitivity analysis should be conducted in inventory analysis of products that use these materials. Although the share of gold by weight in the personal computer was almost negligible, gold could not be omitted from the inventory analysis because the CO_2 intensity of gold production was high when calculated using the market value-based allocation method.

REFERENCES

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Table 1 Materials list for a personal computer

Material	Weight (g)	Share (%)
Steel	6154	45.4
Paper carton	1935	14.3
Paper	1722	12.7
Copper	901	6.6
PS	595	4.4
ABS	353	2.6
Epoxy resin	346	2.6
Aluminum	326	2.4
Glass	310	2.3
PVC	218	1.6
Phenol resin	153	1.1
PBT	88	0.6
POM	84	0.6
PE	76	0.6
Polycarbonate	67	0.5
Pb	65	0.5
Sn	59	0.4
Synthetic rubber	25	0.2
Stainless steel	24	0.2
PET	23	0.2
Brass	15	0.1
Polyimide	6	0.0
TLPC	4	0.0
Silver	1	0.0
PMMA	1	0.0
Gold	1	0.0
Total	13552	100.0

Table 2 CO_2 intensity (kg-CO_2/kg-product) of cathode copper, silver and gold production

	Allocation method	
	Mass-based	Market value-based
Cathode copper	1.2	2.7
Silver	1.6	290
Gold	3.1	14000

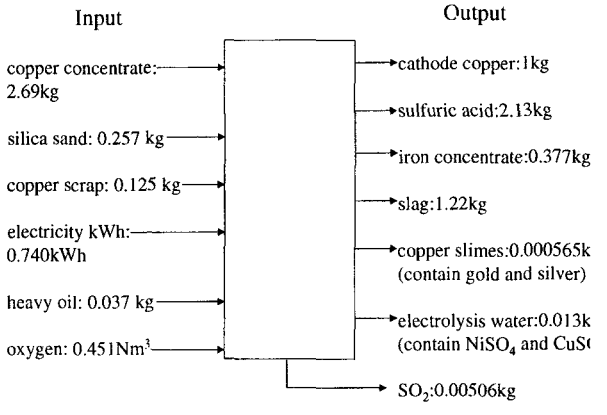

Figure 1 Inputs and outputs in the production of cathode copper using flash smelting technology

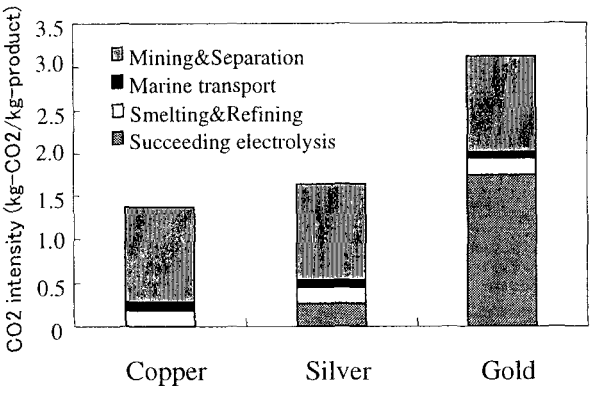

Fig. 2: Contributions of each process to CO2 emissions in production of copper , silver and gold (calculated with mass-based allocation method)

Table 3 CO_2 emissions in production of a personal computer; CO_2 intensity of copper, silver and gold was calculated using the mass-based allocation method

Material	CO_2 emissions (g-CO_2)	Share (%)
Steel	9800	40.8
Paper	3900	16.3
Epoxy resin	1800	7.5
PS	1400	5.8
Paper carton	1300	5.4
Copper	1100	4.6
ABS	890	3.7
Glass	600	2.5
Aluminum	450	1.9
PVC	410	1.7
Phenol resin	390	1.6
Polycarbonate	380	1.6
POM	310	1.3
PBT	280	1.2
Sn	170	0.7
Pb	130	0.5
PET	72	0.3
PE	72	0.3
Stainless steel	71	0.3
Synthetic rubber	56	0.2
Brass	47	0.2
Polyimide	36	0.2
TLCP	20	0.1
Gold	2.5	0.0
PMMA	2.1	0.0
Silver	1.9	0.0
Total	24000	100.0

Table 4 CO_2 emissions in production of a personal computer; CO_2 intensity of copper, silver and gold was calculated using the market value-based allocation method

Material	CO_2 emissions (g-CO_2)	Share (%)
Gold	11000	30.6
Steel	9800	27.2
Paper	3900	10.8
Copper	2400	6.7
Epoxy resin	1800	5.0
PS	1400	3.9
Paper carton	1300	3.6
ABS	890	2.5
Glass	600	1.7
Aluminum	450	1.3
PVC	410	1.1
Phenol resin	390	1.1
Polycarbonate	380	1.1
Silver	350	1.0
POM	310	0.9
PBT	280	0.8
Sn	170	0.5
Pb	130	0.4
PET	72	0.2
PE	72	0.2
Stainless steel	71	0.2
Synthetic rubber	56	0.2
Brass	47	0.1
Polyimide	36	0.1
TLCP	20	0.1
PMMA	2.1	0.0
Total	36000	100.0

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