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Process Life Cycle Assessment with Modified Allocating Method in PCB Producing Factory

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Applying life cycle assessment in PCB (printed circuit board) production, most of environmental impacts come from outside-factory-process due to power generation, especially, and other raw material productions. Relatively, small environmental impacts of inside-factory-process make it difficult to compare them. To overcome this problem, allocating environmental impacts of outside-factory-process on inside-factory-process. It helps to identify the environmental impacts of each process and find sources of environmental impacts. Also, life cycle assessment shows reduction of environmental impacts after copper recycling process.
Keyword: Process life cycle assessment, PCB product, Copper recycling

Introduction

Life cycle assessment is a method that quantifies environmental impacts. It contains environmental impacts not only that is discharged in the factory where products are manufactured but also that come out from producing raw material, using products, and wasting or recycling products.

Life cycle assessment was carried out in actual factory that produces PCB (printed circuit board), to quantify environmental impacts and design copper recycling technique through electrolysis. Producing PCB, epoxy resin and copper are main raw materials and these materials pass such processes as conditioning, etching, plating and rinsing.

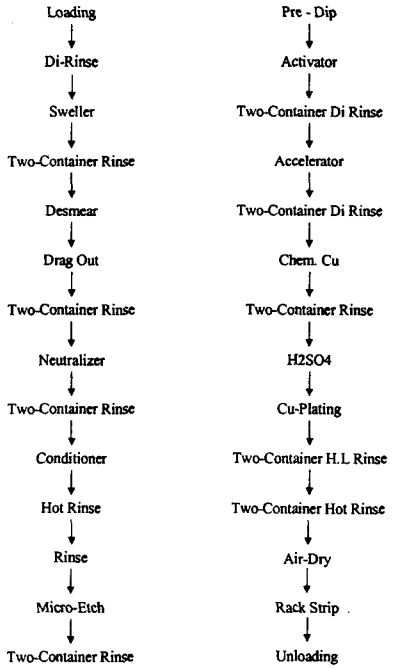


Fig. 1 Processes of Producing PCB

Data Collecting and Processing

To start life cycle assessment, every used resource and dumped waste in processes must be quantified. Power, industrial water and copper those are expected to be immense parts of environmental impact are focused in this paper.

Amounts of power and industrial water used in process were measured in-situ with nondestructive meters like digital cramp

(Yokogawa, 234304) and digital flowmeter (Polysonics, DCT7088). Amounts of used power were allocated on each process by the number of equipped vibrators, heaters and pumps. Amounts of industrial used water were measured directly on each process but they are so unsteady that mean values through 3 days were selected.

Amounts of Cu were measured by AAS through direct sampling from each process and records in factory were cited to decide amounts of other chemicals used in each process.

Then, sum of all used and dumped materials during a month were gained by factory operating time during a month. Dividing these values with amounts of products during a month, quantities of all used and dumped materials to produce a unit product (here, 1 m^2 PCB is used as unit product) were attained.

Finally, using database of software Gabi 3 professional, environmental impacts of outside-factory-processes were standardized and total environmental impacts to produce a unit product were achieved.

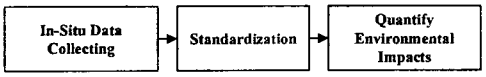


Fig. 2 Data Processing

Environmental Impacts between outside and inside factory

Environmental Impacts are classified to categories like acidification, aquatic ecotoxicity, eutrification, global warming, human toxicity, ozone depletion, photochemical oxidation and terrestrial ecotoxicity. Results of Life cycle assessment in this factory show that large parts of environmental impacts are from outside-factory-processes.

In acidification, 91% is caused from outside-factory-process. They are mainly due to sulfur dioxides those are emitted in power generation. Also, producing epoxy resin, deionized water and

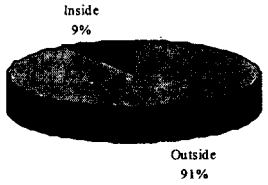


Fig. 3 Proportion of Acidification from Outside-Factory-Processes

sodium hydroxide discharge sulfur dioxides and nitrogen oxides that cause acidification, too.

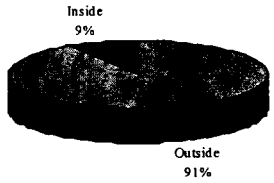


Fig. 4 Proportion of Aquatic Ecotoxicity from outside-factory-process

In aquatic ecotoxicity, 96% is caused from outside-factory-process. Polycyclic aromatic hydrocarbon (PAH) from power generation is dominant substance. Also, Formaline and Copper affect aquatic ecotoxicity.

In other categories, similar results are revealed. From 70% to 99% of environmental impacts are caused from outside-factory-process.

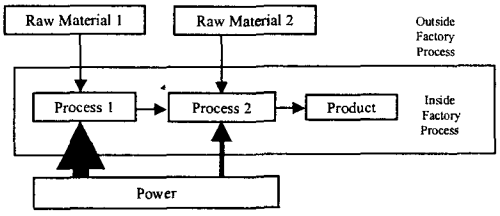
One of the objectivities applying life cycle assessment in PCB producing factory is to evaluate inside-factory-processes how much they affect environmental impacts. However, so most part of environmental impacts are due to outside-factory-processes, that different methods to evaluate processes are needed.

Modified Allocating Method for Process Life Cycle Assessment

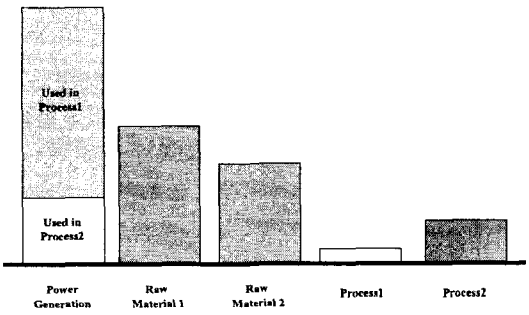
Classical life cycle assessment is focused on products. It means that all environmental impacts from producing raw materials to wasting product

are included. However, in many cases, results of life cycle assessment are not appropriate to focus on inside-factory-processes. To reduce environmental impacts through improving inside-factory-processes, environmental impacts of inside-factory-processes must have considerable parts of total impacts. Therefore, modified allocation method was devised.

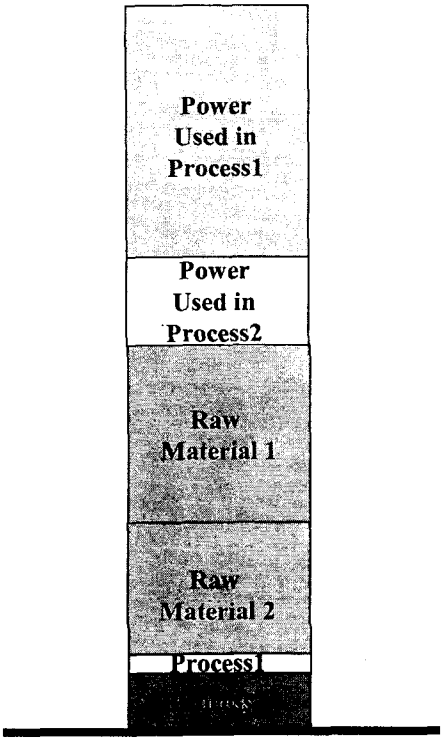
In modified allocation method, all environmental impacts from outside-factory-processes are imposed on inside-factory-processes with proportion of using products of outside-factory-process. If a process spends 50% power of total power in a factory, 50% of total environmental impacts from power generation are imposed on that process. All other raw materials are imposed as same way, too.



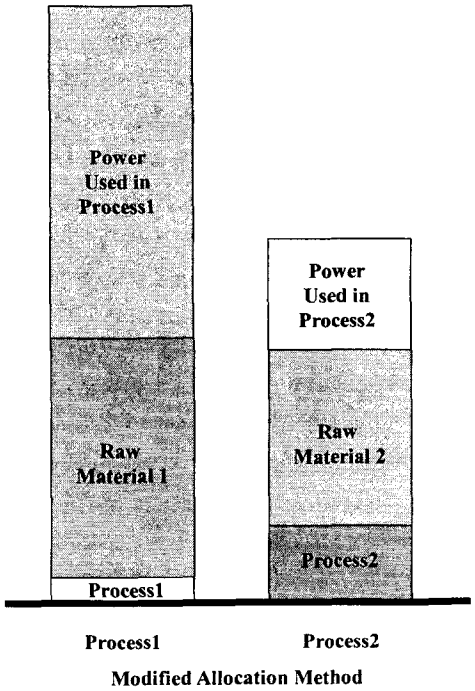
Conceptional Flow Process



Environmental Impacts of All Processes



Classical Life Cycle Assessment of Product



Modified Allocation Method

Fig. 5 Conceptional deference between classical life cycle assessment & modified allocation method

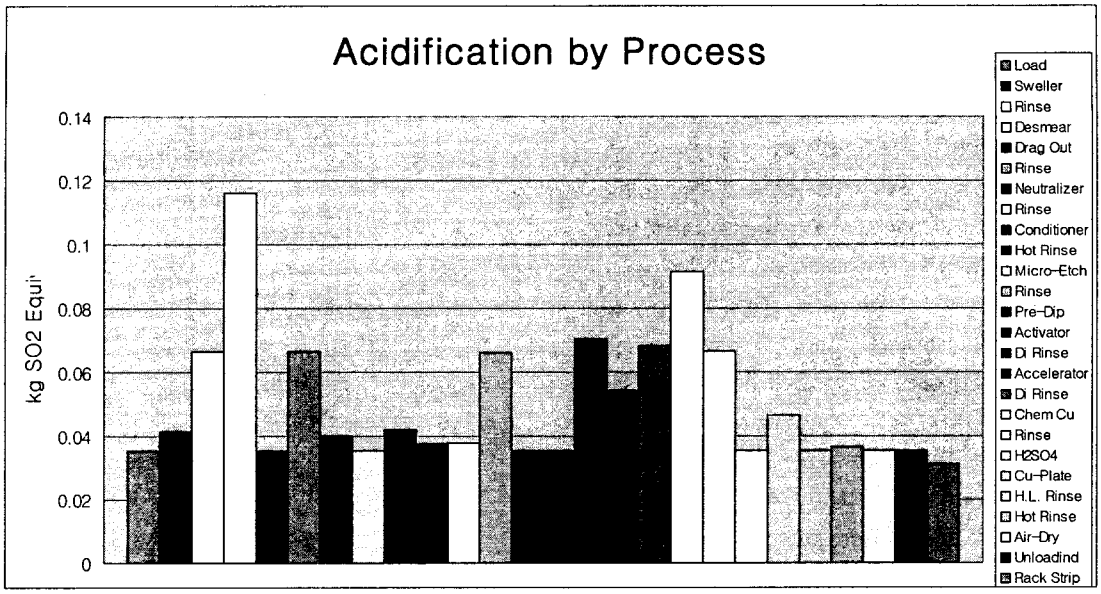


Fig. 6 Process Life Cycle Assessment in Acidification After Allocation

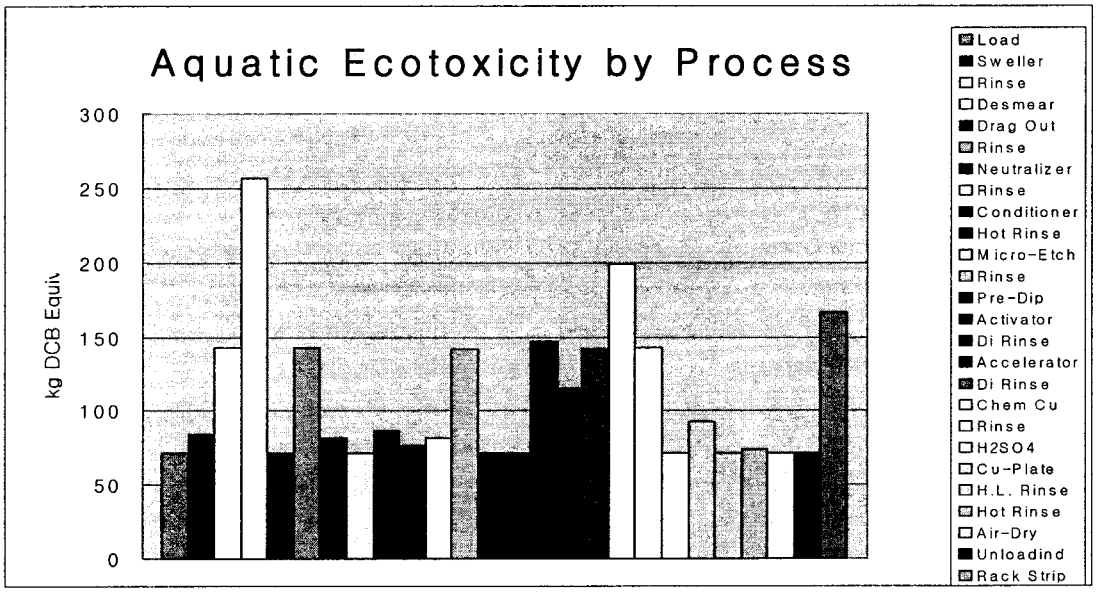


Fig. 7 Process Life Cycle Assessment in Aquatic Ecotoxicity

Results after modified allocation method

Modified allocation method made inside-factory-processes have considerable portions to be comparable.

In results of acidification, 'Desmear' and 'Chem Cu' processes cause large parts of impacts in acidification. It is owing to both processes spend large quantity of power. Also, 'Di-Rinse' processes, which spend much deionized water, cause considerable parts of impacts.

In results of aquatic ecotoxicity, 'Desmear' and 'Chem Cu' processes play major roles of impacts as same reason in acidification. Remarkable, 'Rack Strip' process causes large impacts because 'Rack Strip' process releases a large quantity of copper.

Results of other categories are skipped because they shows similar pattern.

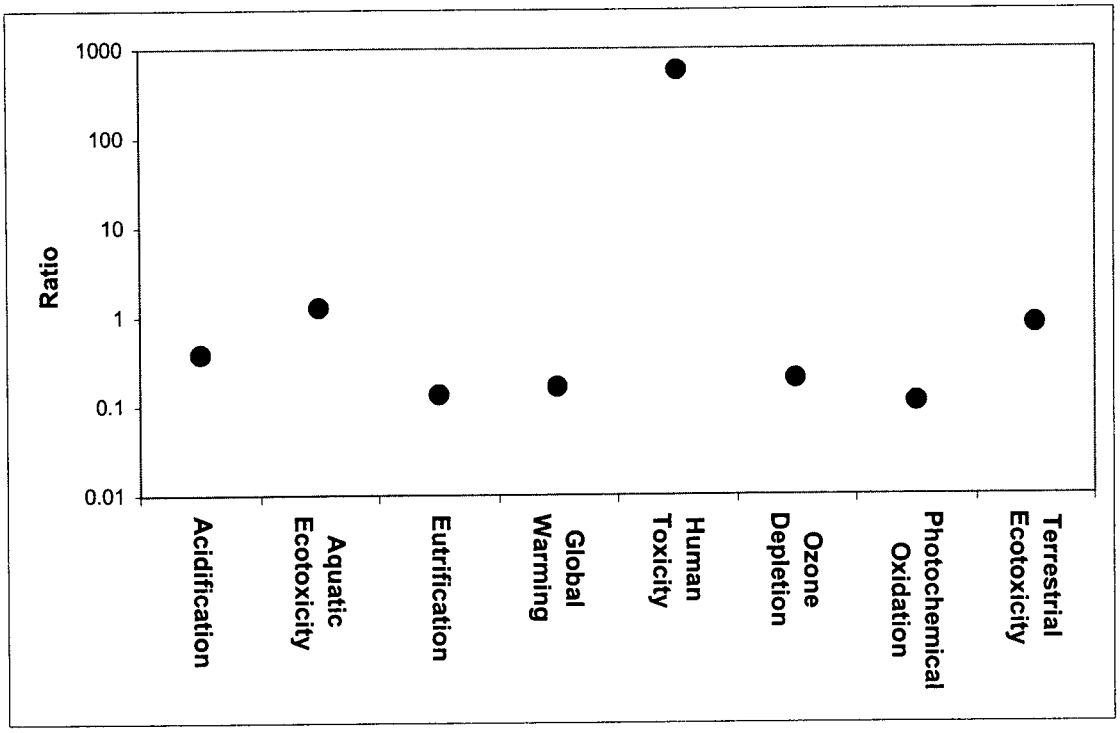


Fig. 8 Simulation Result of Electrolysis to Recover Copper

Applying Life Cycle Assessment to Reduce Environmental Impacts

Life Cycle Assessment itself cannot reduce environmental impacts but it can quantify changes of environmental impacts when other impacts reducing techniques are applied.

Experiment to recycle copper in wastewater was executed. Electrolysis was used to recycle cupper. This method uses power to remove copper in wastewater to reduce environmental impacts and removed copper will be reused in processes. Eventually, total copper consumption in factory will be reduced. However, so this technique needs extra-power, that total environmental impact reduction is not guaranteed. Life cycle assessment gives results of simulation based on laboratory scale experiment.

Results shows that environmental impacts are reduced after copper recycling in most categories, though human toxicity becomes as high as over 500 times before recycling. It is due to power generation in Korea depends on fossil fuel over 60%. When fossil fuel is in combustion, polycyclic aromatic carbon is released, which affects this result. However, so its initial values, which are from 6.64 e^{-15} to 3.61 e^{-12} (kg DCB equivalent), are relatively small that it is not fatal.

Conclusion and Discussions

Life Cycling Assessment in PCB producing factory to identify environmental impact of each process shows that power generation used in factory plays a major role in environmental impacts. Outside-factory-processes, including power generation and raw material production affect 70~99% of total environmental impacts in each categories.

Classical life cycle assessment can give total environmental impacts of a product but it is not informative to compare each process. Modified allocation method, which is imposing environmental impacts of raw materials production on inside-factory-process with proportion of their usage, gives comparable information.

Electrolysis experiment for recycling copper was executed to reduce environmental impacts and life cycle assessment quantified the reduction of environmental impacts.

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