

Estimation of Cost Index of a Waste Water Treatment Unit for Life Cycle Engineering - Cost index of an Inclined Solid-Liquid Separating Unit -

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SUMMARY

In this study, the cost index for an inclined Solid-Liquid Separating as a Suspended Solid removal unit for wastewater treatment systems is estimated as one of Life Cycle Engineering. The cost ratio for the consumption of stainless steel system materials as raw materials is the largest and accounts for 86.9 % of the total production cost, those for the consumption of non-stainless steel system materials as raw materials and electricity as utilities in the production processes follow and account for 8.7 and 4.4 % of the total production cost, respectively. As a countermeasure for the reductions of the production cost and the environmental loads, it is found that the thinning of the plate in case production & assembling process would be the most effective measure.

KEY WORDS: solid-liquid separating unit, cost index, life cycle engineering, life cycle assessment

1. INTRODUCTION

The recent sustainable rising in global atmospheric CO₂ concentration and the ensuing greenhouse effect is considered to be caused mainly by consumption of large amounts of fossil fuels due to increased human activities. On the other hand, the economical development and activities over the whole world have been recognized as an extremely important problem. Therefore, the decision making in the concept of sustainable development and the design methodologies for various industrial products are required in manufacturing industries.

Life Cycle Engineering (LCE)^{1,2,3} as one of the design methodologies is available for various industrial products. LCE analyzes the potential of economic (cost), environmental and technical (technological) impacts of products, services or processing methods over their whole life cycle (The Life Cycle Approach). This multidimensional perspective ensures the consideration of all relevant factors. Efficient and sound support for decision making is

provided by comprehensible presentation of results. At the same time, the methodology of LCE guarantees a high level of transparency, building an excellent basis for decision support.

Figure 1 shows a simple conceptual model of LCE. This LCE model is divided into the three categories (Environment, Cost and Technology). An optimal product specification, which takes into account all phases of the product life cycle is given by the maximum value of summing of each point (1~5) of the three categories.

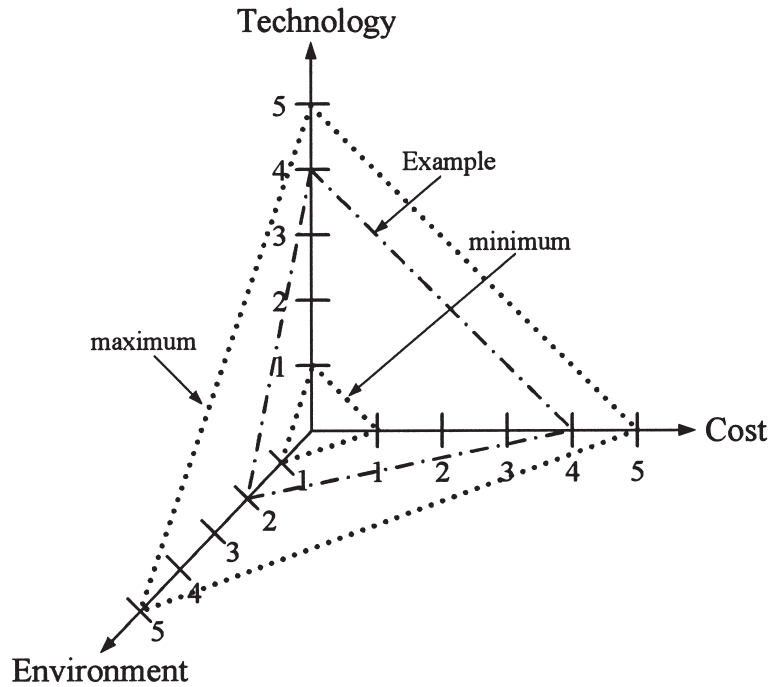


Figure 1. Concept of Life Cycle Engineering

In general, the integrated index of LCE (e.g. in the case of Personal Computer) can be expressed the following equations.

$$F_{LCE} = \alpha \sum F_{env} + \beta \sum F_{cost} + \gamma \sum F_{tech}$$

$$\sum F_{env} = F_{gw} + F_{od} + F_{acid} + F_{eutro} + \dots$$

$$\sum F_{cost} = F_{material1} + F_{material2} + \dots + F_{utility1} + F_{utility2} + \dots$$

$$\sum F_{tech} = F_{function1} + F_{function2} + \dots$$

where α , β and γ are the weighting factors, respectively. The each term in the three categories can be expressed as follows:

$\sum F_{env}$: the summation of the integrated indexes of detail weighting factors for environmental factors and/or loads (e.g. gw (global warming potential), od (ozone depletion potential), acid rain (acidification potential), eutrophication (eutrophication potential), etc.) for the product.

$\sum F_{cost}$: the summation of the cost of raw materials and utilities (e.g. iron, plastic, electricity, oil, etc.) required for the product.

$\sum F_{tech}$: the summation of functional units (e.g. word processor, spreadsheet-application, presentation program, etc.) of the product.

On the other hand, regarding various environmental impacts of products, Life Cycle Assessment (LCA) as a methodology for environmental impacts is known as one element of LCE. It can be described as an environmentally orientated information and planning tool, which helps to compare options and effectively identify improvement potentials.

In the author's previous work⁴⁾, regarding an inclined Solid-Liquid Separating (ISLS) unit, which is necessary on various industries as one of environmental protection systems and utilize for not only wastewater treatments but also production processes (e.g. concentration, recovery, cleaning, etc.). In order to measure the environmental loads (e.g. CO₂; well known as one of the representative greenhouse gases (GHGs)) for the ISLS unit as one of environmental protection systems, the CO₂ emissions and the emission factors of CO₂ (EF CO_{2s}) of an ISLS unit as a SS (Suspended Solid) removal unit for wastewater treatment systems were estimated by a process analysis as one of LCA. However, reports in which the cost and environmental loads for the product are simultaneously evaluated are few to date.

In this study, the cost index as the production cost ratio was estimated for the above ISLS unit. Furthermore, the relation between the cost index and the CO₂ emission ratio on the LCA⁴⁾ was compared as one of LCE.

2. UNIT DESCRIPTION

2.1 Functional principle and operational illustration

Figures 2 and 3 show the functional principle and the operational illustration of the ISLS unit. Regarding the functional principle and the unit operation, "Half - Cutting Principle" works in the operation of the screen. Particles (foreign elements) whose size is larger than a half of the slit width are collected on the screen, and particles whose size is smaller than the half size fall through below the screen together with water. The reduced possibility of clogging because of wedge-profile slots, and the flat screen surface insure that the collected particles slide down the screen smoothly.

2.2 Dimensional drawing and processing capacity

Figure 4 shows the dimensional drawing of this ISLS unit as one of the representative unit (standard type) and Table 1 shows the major processing capacity of this ISLS unit.

This ISLS unit has the following characteristics:

- Simple structure
- Low price is made possible by lot production

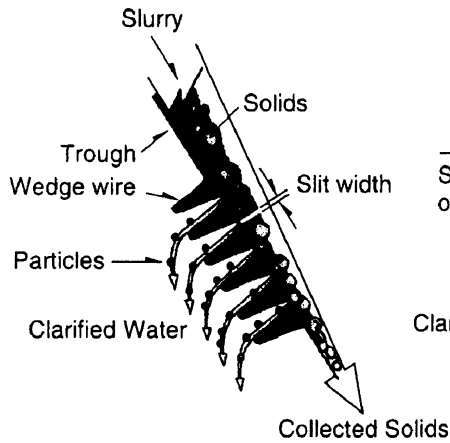


Figure 2. Functional principle

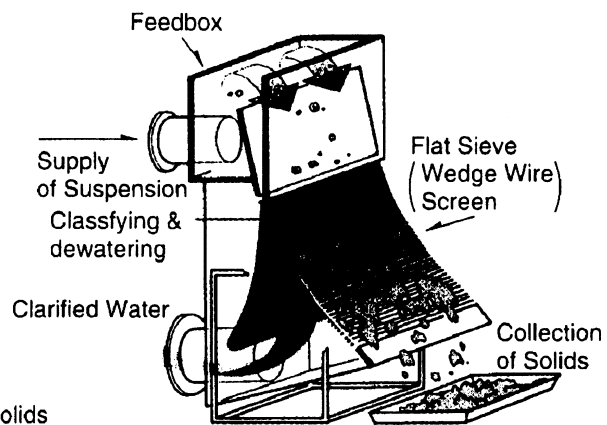


Figure 3. Operational illustration

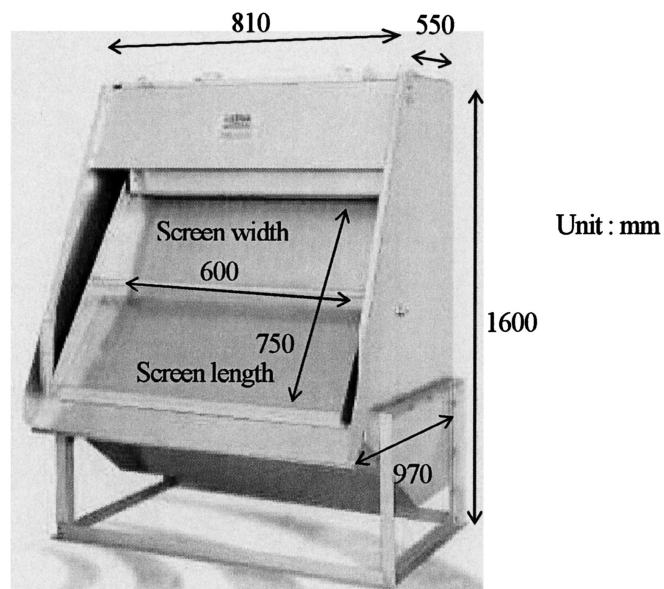


Figure 4. Dimensional drawing (standard type)

Table 1. Processing capacity (standard type)

| Kind of Waste Water | Applied Slit Width (mm) | Capacity* (m ³ /H) |
|--|----------------------------|----------------------------------|
| Fruits processing waste water | 0.5 0.75 1.0 | 25 ~ 40 |
| Waste water after processing leavings of school meals | 0.5 0.75 1.0 | 25 ~ 40 |
| Bean curd waste water | 0.4 0.5 0.75 | 25 ~ 40 |
| Fish processing waste water | 0.75 1.0 1.5 | 25 ~ 40 |

*The capacity differs depending upon various factors such as kinds of solids, concentration, existence of oily substance, etc.

- Wide capacity: 5-200 m³/H
- * Screen width: 300-3000 mm
- * Screen length: 750-900 mm
- *Slit width: 0.15-2.0 mm

Therefore, this ISLS unit can be applied for various uses under various conditions.

2.3 Production process

Figure 5 shows the outline of production processes of this ISLS unit.

These production processes are classified into three main processes.

- (1) Screen production process
- (2) Case production & assembling process
- (3) Frame production process

In the screen production process (1), the wedge wire screen is composed of stainless steel wire and stainless steel rods. The stainless wire for the screen is wound on rods and welded into rods, and then the wedge wire screen is cut, expanded and cut for dimensional drawing.

In the frame production process (3), the frames of this unit are composed of stainless steel shape, the frames are produced by cutting and bended for dimensional drawing as the case frames.

In the case production & assembling process (2), the case of this unit is mainly composed of stainless steel plate, wedge wire screen and frame. Firstly, a plate is cut for dimensional drawing by the laser cutting unit as the case, bored for bolts and pipes, and bended. Secondary, the frames produced by frame production process and the screen produced by screen production process are welded into the case and assembled as one unit. Finally, this unit is pickled in acid liquid, washed and inspected, and then packed and delivered.

3. METHODOLOGY

3.1 Function and functional unit

In order to quantify, specify and average inputs for the production system of this ISLS unit, the function was defined as the removal of SS for wastewater treatment systems. The functional unit was defined the function per one product (one ISLS unit).

3.2 System boundary

Figure 6 shows the system boundary for the cost index of this ISLS unit. The products production process included within the whole life cycle process was defined as this system boundary. Therefore, excluding transportation & distribution, use and recycle & disposal processes. The cost was defined as the cost of materials and utilities required in the product production process.

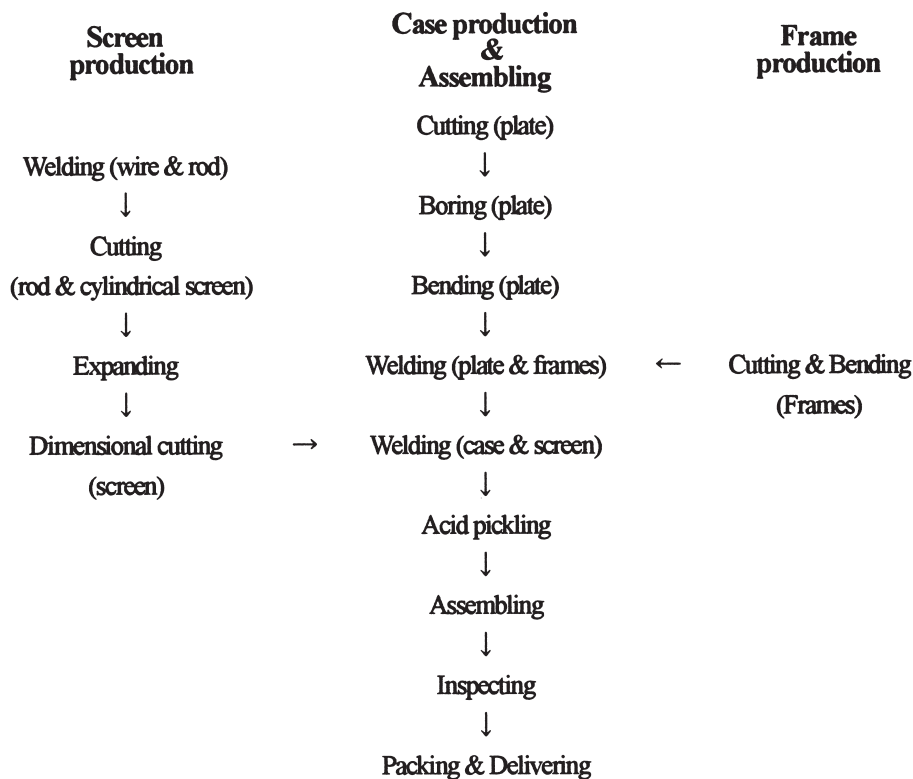


Figure 5. Outline of production processes

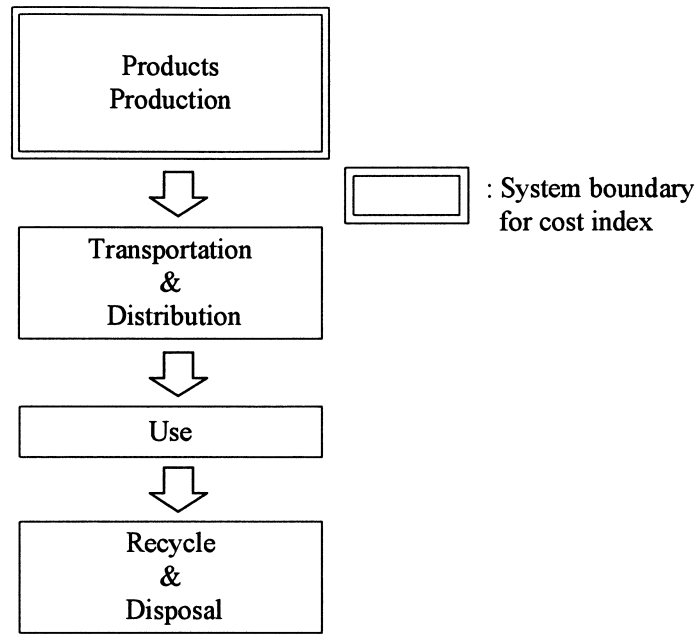


Figure 6. System boundary for cost index

3.3 Life cycle inventory (raw materials and utilities)

3.3.1 Data of inputs for production process

Regarding raw materials for the production processes, the input amounts of stainless steel system materials (6 kinds, e.g. wire, plate, shape, etc.) and non-stainless steel system materials (12 kinds, e.g. liquefied nitrogen, grinding stone, argon gas, etc.) for the production of this ISLS unit were collected. Regarding utilities for the production processes, the input amount of electricity for the production processes of this ISLS unit was collected.

3.3.2 Data quality

Regarding the input amounts of raw materials and utilities, these values were obtained from the annual consumption for the production processes, and were input amounts for 10 products (10 units), and also were calculated as input amounts of one product (one unit). Therefore, the calculated values should be accounted to the averaged values for one product (one unit).

3.3.3 Cost index for Life Cycle engineering

In this study, the cost index was defined as the cost ratio (%) of raw materials and utilities in the each process for the total production cost of one product. The cost index and the production cost as one of LCE for one product were estimated from the preceding inventory data and the cost of raw materials and utilities.

Regarding the estimation method of the production cost of one product, the cost of raw materials were calculated by multiplying the consumed weight of each material by the cost (e.g. unit: ¥/kg-material and ¥/m³-material) of each material. The cost of consumption amount of the utility (electricity) was calculated by multiplying the amount of

consumed electricity of each process by the cost of purchased electricity (unit: ¥/kWh), and then the total cost of one product was estimated by summing up the cost of each material and utility, and the cost index (each cost of raw materials, utilities and processes) was estimated by dividing the each cost of raw materials and utilities in the each process and each process by the total cost of one product. The cost data of each material and utility in 2005 were collected and used in this study.

In this study, the cost index was estimated for the above ISLS unit (one unit). Furthermore, the relation between the cost index and the CO₂ emission on the LCA of the author's previous study⁴⁾ was compared as one of LCE. (The data of the input amounts of raw materials and utilities for the cost index is the same as that of the CO₂ emission on the LCA⁴⁾, and the emission factor of each raw materials and energy was quoted from the databases^{5,6,7,8)}).

4. RESULTS AND DISCUSSION

Table 2 shows the cost index for one ISLS unit (product). The cost ratio for the consumption of stainless steel system materials as raw materials is the largest and accounts for 86.9 % of the total production cost, those for the consumption of non-stainless steel system materials as raw materials and electricity as utilities in the production processes follow and account for 8.7 and 4.4 % of the total production cost, respectively.

Regarding raw materials (stainless steel system materials), the cost ratio for the consumption of plates in case production & assembling process is the largest and accounts for 65.2 % of the total production cost (56.7 % in this category), those for the consumption of pipe in the case production & assembling process and wire in screen production follow and account for 9.8 and 8.7 % (11.3 and 10.0 % in this category), respectively.

Regarding raw materials (non-stainless steel system), the cost ratio for the consumption of liquefied nitrogen in case production & assembling process is the largest and accounts for 7.8 % of the total production cost (89.6 % in this category), those for the consumption of argon gas in case production & assembling process and acid pickling reagent in case production & assembling process follow and account for 0.5 and 0.2 % of the total production cost (5.6 and 2.2 % in this category), respectively.

Regarding utilities (electricity), the cost ratio for the electricity consumption of case production & assembling process is the largest and accounts for 3.5 % of the total production cost (79.8 % in this category), those for the electricity consumption of screen production and frame production follow and account for 0.8 and 0.1 % of the total production cost (18.4 and 1.8 % in this category), respectively. In particular, the cost ratio for electricity consumption by laser cutting unit in case production & assembling is the largest and accounts for 2.3 % of the total production cost (52.9 % in this category).

Figure 7 shows the comparison between the cost index and the CO₂ emission ratio⁴⁾ for this ISLS. It is found the ratio for the consumption of stainless steel system materials in both the cost index and the CO₂ emission ratio is the largest, and the CO₂ emission ratio for electricity consumption in production process is approximately 5 times as large the cost ratio for electricity consumption in production processes. This reason is that the power plants in Japan

are largely dependent on the thermal power generation (e.g. electricity configuration in 2005⁹⁾).

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Table 2. Cost index of ISLS unit

| Material and Energy | | Cost index (%) | |
|---|------------------------------|----------------|-------|
| | | Subtotal | Total |
| Stainless steel system | Wire | 10.0 | 8.7 |
| | Plate | 65.2 | 56.7 |
| | Shape | 4.4 | 3.9 |
| | Bolt | 7.8 | 6.8 |
| | Pipe | 11.3 | 9.8 |
| | Welding rod | 1.3 | 1.1 |
| Subtotal | | 100.0 | 86.9 |
| Non-Stainless steel system | Liquefied nitrogen gas | 89.6 | 7.8 |
| | Grinding stone | 0.1 | 0.0 |
| | Argon gas | 5.6 | 0.5 |
| | Acid pickling reagent | 2.2 | 0.2 |
| | Miscellaneous | 2.6 | 0.2 |
| Subtotal | | 100.0 | 8.7 |
| Electricity consumption in production process | Screen production | 18.4 | 0.8 |
| | Case production & assembling | 79.8 | 3.5 |
| | Frame production | 1.8 | 0.1 |
| Subtotal | | 100.0 | 4.4 |
| Total | | | 100.0 |

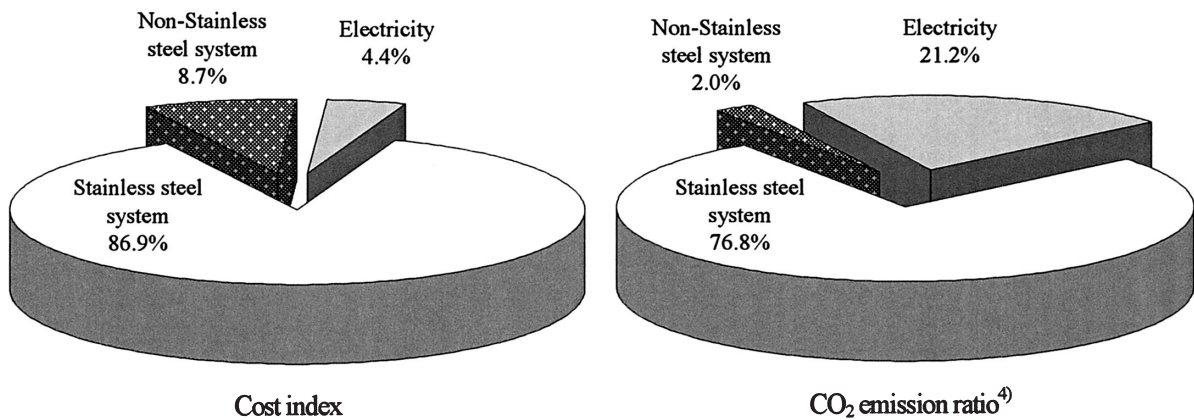


Figure 7. Comparison between cost index and ratio of CO₂ emission ratio

From the preceding results, it is found that the reductions of the production cost and the CO₂ emission as environmental loads for the consumption of stainless steel system materials are required as the LCE for this unit.

Therefore, as a countermeasure for the reductions of the production cost and the CO₂ emission for the consumption of stainless steel system materials, it is clear that the thinning of the plate in case production & assembling process would be the most effective measure. However, it is necessary to avoid the decreasing of the strength of this unit by the detail structure and strength simulation for this unit or to reinforce the structure by utilizing the beams for this unit.

For the case of approximately 30 % of the thinning of the plates (e.g. the plate thickness: $t = 1.5$ to 1.0 mm), the production cost and the CO₂ emission would be reduced by the reduction of approximately 10 and 15 % from those by using the current plates, respectively.

5. CONCLUSION

In this study, the cost index for an ISLS unit as a SS removal unit for wastewater treatment systems are estimated as one of LCE. Furthermore, the relation between the cost index and the CO₂ emission ratio on the LCA⁴⁾ is compared.

The cost ratio for the consumption of stainless steel system materials as raw materials is the largest and accounts for 86.9 % of the total production cost, those for the consumption of non-stainless steel system materials as raw materials and electricity as utilities in the production processes follow and account for 8.7 and 4.4 % of the total production cost, respectively.

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