Proposal for a New Evaluation Method for Green & Sustainable Chemistry

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INTRODUCTION

Various groups have proposed many metrics and evaluation methods for Green & Sustainable Chemistry (GSC) and some of them are actually utilized in some area. However, most of them require a lot of basic data and rather complicated procedures to evaluate the improvement by GSC technology. This paper shows a new simple and easy method, which compares the current technology with the improved technology from the viewpoint of products or processes by GSC technology, and which shows the overall improvement from several aspects. This method is useful in R&D, business activity and policy making as well as for enlightenment and education of GSC.

In a chemical production process, for instance, the innovative effects of GSC technology might be defined to as follows,

To reduce the number of processes to a large degree

To improve process yields without production of by-product

To moderate process condition such as temperature, pressure

To use and generate substances that possess little or no toxicity

To change reaction solvents from organic compounds to water

If these effects are evaluated with ease and shown in a simple way, everyone would understand the effects at a glance.

One of our aims in this paper is to propose a new method that evaluates the effect of the improvement of technology from the viewpoint of GSC easily. The other aim is to propose a new method that shows pertinent details of the GSC effect clearly.

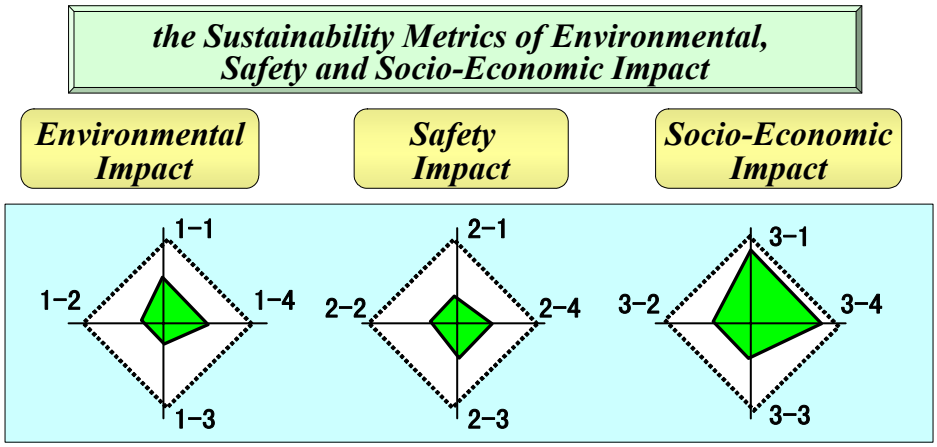
OUTLINE

As well known, sustainability is generally described as three aspects, Environmental, Economic and Social aspects. However, after careful study, we arrived at the tentative conclusion that green and sustainability are successfully illustrated as follows,

1) Environmental impact
2) Human health and product/production safety impact
3) Social and Economic impact

These viewpoints indicate the improved effect by GSC technology very clearly and simply. “Human health and the product/production safety” is an important viewpoint to express the effect by GSC technology. We might say that people may have a deep interest in health and safety. Non-specialists in this field are eager for the viewpoint of health and safety of products and processes by a GSC technology. This viewpoint is easy for them to understand the GSC effect. Of course, the Economical impact and the Social impact are also important, but they could be depicted in one viewpoint.

We might term this method “the Sustainability Metrics of Environmental, Safety and Socio-Economic Impact” and you could image this method as figure 1. In this method, the smaller the quadrilateral area is, the better for GSC.



Environmental Impact	1-1) Energy consumption 1-2) Waste volume 1-3) Material consumption 1-4) Emission to the environment
Safety Impact	2-1) Health safety in production, usage and disposal 2-2) Health safety of the raw material 2-3) Disaster safety in production, usage and disposal 2-4) Disaster safety of the raw material
Socio-Economic Impact	3-1) Loss of user benefit 3-2) Loss of global benefit 3-3) Loss of social benefit 3-4) Loss of producer benefit

..... Current Technology

——— Alternative / Innovative Technology

Figure 1. Result image of the Sustainability Metrics of Environmental, Safety and Socio-Economic Impact. The outer line shows a current or old technology and the inner line shows an alternative or innovative technology by GSC.

METHODOLOGY

LCA is a useful tool for assessing the environmental impacts and potential impacts with regard to a product or a system. It considers the entire life cycle of a product from resource extraction to waste disposal. On the other hand, our approach is to provide a tool for assessing these impacts of a product or a process only in the specific area related to the distinctly improved technology by GSC, not the entire life cycle. Limitation of the assess area helps

to save the labor and time for the assessment. In addition, by the limitation the assessment could focus easily on the specific point of the improved technology.

We designed the three-impacts evaluation method, which expresses triple bottom line of sustainability Environmental, Economical and Social impacts, and four categories of each line to share the common understanding among different sectors. This method can be objectively and universally suitable for GSC metrics.

Four items to evaluate environmental impact is as follows,

1-1) Energy consumption

1-2) Waste volume

1-3) Material consumption

1-4) Emission to the environment

Four items to evaluate the impact of the Human health and product/production Safety & Security is as follows,

2-1) Health safety in production, usage and disposal

2-2) Health safety of the raw material

2-3) Disaster safety in production, usage and disposal

2-4) Disaster safety of the raw material

The health safety means toxicity to the living body such as carcinogenic property, an inflammation and so on. And the disaster safety means reactivity of chemical substances such as the flammability and the explosion power and so on. It is important with GSC technology to improve these safeties in the product and/or at the process. Therefore, in this method we propose to evaluate these safeties with regard to “the raw material" and “in production, usage and disposal”. We tried to classify kinds and degrees with regard to health safety and disaster safety of products. At this moment we concluded that Risk phrases (R-phrases) defined by European Union are appropriate for the classification and Toxic Potential Indicator (TPI) developed by Fraunfoher IZM is suitable for the extent. TPI can show various harmful levels by one absolute value.

R-phrases or combination of R-phrases describe the kinds of hazards associated with chemical products. R-phrases of a substances are easily obtainable, because they are usually indicated, for example, on each label and material safety data sheet for chemical compounds.

TPI is calculated by using TPI-Calculator by Fraunhofer IZM. The TPI-Calculator is a fast and easy-to-use tool that calculates the toxicological potential of substances based on maximum threshold values and categories such as R-phrases.

We propose that Social and Economic impacts could be judged from the viewpoint of global, social, user and producer benefits. We can illustrate each benefit as follows,

Global benefit

- Decrease in global environment load
- Reduction of use of exhaustible resources
- Protection and regeneration of the natural environment
- Prevention of the natural disaster
- Increase of food supply, etc.

Social benefit

- Enlargement in the employment
- Contribution to the coming generation
- Contribution to the local society
- Industrial invitation
- Prevention of the urbanization, etc.

User benefit

- Depreciation in the price
- Improvement in the performance
- Improvement in the safety
- Improvement in the product cycle
- Decrease in amount of use, etc.

Producer benefit

- Improvement in the profit
- Acquisition of the product label
- Improvement in the corporate entity power
- Improvement in the corporate image
- Decrease in environment countermeasure cost, etc.

Social and Economic impacts are evaluated by four losses of each benefit, that is,

3-1) Loss of user benefit

3-2) Loss of global benefit

3-3) Loss of social benefit

3-4) Loss of producer benefit

In general, there are several kinds of the methods to evaluate these benefits. For example, the panel method by multiple people including the third person, and the questionnaire method are illustrative. In this metrics we selected the panel method that firstly evaluators give individual evaluation results in Socio-Economic impacts, then discuss among evaluators to conclude to one result of four losses.

CASE STUDY

As a case study of this evaluation method, we applied this method for the evaluation of Electrolytic soda processes with the objective of GSC. Electrolytic soda processes are the main technologies for the production of chlorine and caustic soda by the electrolysis of brine solution. Three commercial processes, Mercury Cell Process, Diaphragm Cell Process and Membrane Cell Process, are in use around the world, however the processes consume large quantity of electric power and have high potential for hazard. We evaluated these processes by using our new metrics. As a result, we found how handy to explain the improvement about these processes, how easy to comprehend the difference and how readily to promote GSC technology. And Membrane Cell Process is most preferable from the viewpoint of GSC among other existing processes.

CONCLUSION

We proposed a new method to evaluate GSC technology from the viewpoint of Environmental, Safety and Socio-Economic Impact. The evaluation result of the soda processes, which we presented as a concrete instance, expresses the excellent point of this method clearly. We showed how easily our new method is applicable to evaluate product/process. We do expect this evaluation method will contribute strongly to the diffusion of GSC.

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