Environmental Research Journal 2 (5): 217-221, 2008
ISSN: 1994-5396

Eco-Efficiency as a Decision Tool for Cleaner Production: Application for SMEs in Thailand

H. Phungrassami
National Center of Excellence for Environmental and Hazardous Waste Management,
Faculty of Engineering, Thammasat University, Pathumtani, 12120 Thailand

Abstract: Investment in cleaner production options is attractive economically as it reduces the cost of production. Of equally importance are the benefits realized from the reduction of environmental contaminants that result from unclean production processes. A decision making process can be adapted to translate cleaner production options into feasible investment options by using an eco-efficiency concept that will eliminate, or substantially reduce, such negative environmental impacts. The goal of this study was to demonstrate to Small and Medium Enterprises (SMEs) that a significant cost reduction in raw materials use can be realized, as well as being able to substantially reduce pollution loads, are possible at a low, or even no investment cost. The author's study shows that the amount of water, energy saving cost and chemical saving cost could be lower by at least 90, 7 and 8%, respectively.

Key words: Eco-efficiency, cleaner production, life cycle assessment

INTRODUCTION

SMEs are currently confronted with having to meet the requirements of the Thailand Effluent Standards and they rarely integrate the desirable and beneficial life cycle assessment concept to achieve cleaner production processes. Even though the 'cleaner production concept' was first introduced in Thailand more than 10 years ago, many industries and in particular most SMEs, are not familiar with this concept.

Cleaner production refers to a very heterogeneous group of pollution reduction approaches, that include good housekeeping and can often be implemented with very little, or even no investment. Other cleaner production options are to reuse or recycle materials and resources in the production process or process modification (Amsberg, 1995). Technology is available that offers a variety of waste minimization options, including process recovery and reuse, improved operating procedures and the use of waste exchanges these are representative of ways that have significantly low investment requirements (US EPA, 1996).

Investment in cleaner production measures is obviously attractive economically to manufacturers due to the reduced costs of raw materials, energy and water and waste treatment, as well as the benefit of increased production (Staniskis and Stasiskiene, 2003). However, SMEs have a particularly hard time making cleaner production investments for variety of reasons, that include availability or ability to secure funding and resistance to change. Therefore, a decision making process that can be adapted and improved to translate cleaner production into feasible investment options is a tangible solution. Thus, Life Cycle Assessment (LCA) and eco-efficiency are used as a decision making tool for cleaner production.

LCA is a technique for assessing the potential environmental impacts associated with a product or a service, by compiling an inventory of relevant environmental exchanges of the product throughout its life cycle and then evaluating the potential environmental impacts associated with a product, function or service (Ahmed, 2007).

The goal of this research was to demonstrate to a medium size industry located in Pathumtani province, Thailand that a reduction in raw materials used and, at the same time, a reduction in pollution loads can be obtained. All cleaner production options could be obtained at no cost or with only low investments, except for the acid recovery option. We were able to demonstrate this by following by the eco-efficiency concept using the ratio of cost reduction and environmental impacts.

MATERIALS AND METHODS

This methodology consists of the following phases, as shown in Fig. 1:

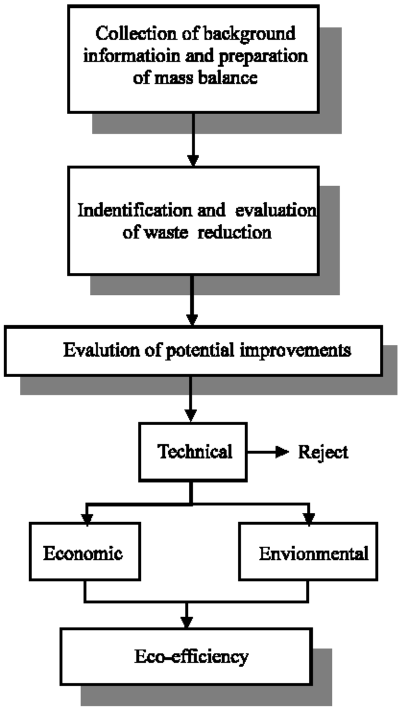

Fig. 1: Methodology framework

- Collection of background information, mainly inputs and outputs and preparation of mass balance.
- Identification and evaluation of waste reduction options by using the cleaner production concept.
- Evaluation of the potential improvements, from both the financial and environmental viewpoints.
- Interpretation of eco-efficiency.

Collection of background information and evaluation of waste reduction options: In order to understand the product process, a thorough comprehensive study tour through the entire factory area was conducted; its production process, consumption of raw and auxiliary materials including water and energy and generated wastes. The information was collected and recorded together with visual observation notes, discussion with workers and questionnaires. This background information was used in order to assess the present performance of the factory. The initial visit helped in identifying major priority problem areas in the factory that needed attention and improvement and hence, resulted in the need to conduct detailed and exhaustive data collection at these points (Visvanathan *et al*., 1998). Then, a mass balance across the entire production processes was established in order to evaluate the waste reduction options.

Evaluation of the potential improvement

Life cycle assessment: LCA is a tool that quantifies the inputs and outputs and evaluates the potential environmental impacts during the entire life cycle of a product, material and/or service. Inputs and outputs encompass the consumption of natural resources and emission of pollutants to the environment. The life cycle of a product or service consists of raw material acquisition, manufacturing, use, distribution and end of life stages (Lee and Inaba, 2004). As for the environmental impact, LCA will provide endpoints as a unit of measure. To calculate a single score, one of the well known methods is to the Eco-indicator 99. Eco-indicator 99 scores are based on an impact assessment methodology that transforms the data of the inventory table into three comprehensive damage scores; human health, ecosystem quality and resources (Gutierres *et al*., 2008).

Cost reduction analysis: Total Cost Assessment (TCA) is a capital budgeting method which compares all the relevant costs and benefits between alternative investments or process change (Myla *et al*., 1996). Some SMEs, however, are not yet sufficiently knowledgeable to perform TCA. Therefore, a simple cost reduction analysis was used for evaluating the costs and benefits of cleaner production investments in the factory.

Eco-efficiency: Eco-efficiency is the adoption of a management philosophy that stimulates the search for environmental improvements that yield parallel economic benefits (Sinkin *et al*., 2008). In addition, eco-efficiency is increased by activities that create economic value while continuously reducing ecological impacts and the use of natural resources. The objective of this evaluation is to finance on favorable terms the implementation of high priority cleaner production investments with economic and environmental benefits. Then, eco-efficiency can be shown as Eq. (1).

$$\text{Eco} - \text{efficiant} = \frac{\text{Ecomonic benefit}}{\text{Environmental impact}} \qquad (1)$$

RESULTS AND DISCUSSION

Factory information: This factory service is the repair of metal plates. The main method of repair is to use a physical-chemical treatment on the surface of the metal plates. Briefly, the metal plates are checked by inspection workers to determine what procedure of treatments should be used. Then, the plates are sent to the chemical room for cleaning the surface by using chemical agents. After cleaning, the plates are sent to a joining process for welding and blending, respectively. After final inspection, the plates are shipped to customers.

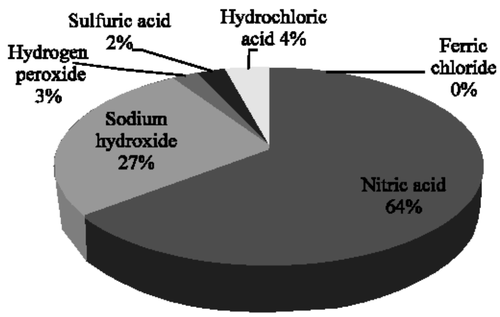

Fig. 2: Chemicals used in the chemical room

After the collection of detailed data and drawing a process flow diagram, including performing mass balance, the author found that the process of cleaning the surface was the main environmental problem. Thus, this area was chosen to implement the cleaner production concept. The activities of this room were cleaning the surface of the metal plate by using an alkaline cleaner, stripping to remove the coating by using acid, the type of acid depended on the type of plates. Alkaline cleaning was operated at 71-88°C for 10-60 min, depending on the operational procedure. After cleaning by alkaline cleaner, the metal plates were rinsed with rinsing water and dried for about 30 min. After drying, the metal plates were sent to the next process stage outside the chemical room. Stripping was performed at 21-104°C for a duration of 1-3 h. After stripping by acid, the metal plates were again rinsed with rinsing water and sent to the subsequent process stage, also outside the chemical room. In general, it was noted that the chemical tanks that were equipped with a heating arrangement, had the heaters switched on all the time. The energy consumption in this selected area was approximately 28.200 kWh/month. The percentages of used chemicals in the selected area are shown in Fig. 2. Since, the factory did not have a separate water meter in the chemical room, the water consumption had to be based on the workers' experience and on-site measurement at the factory it was estimated to be 400 m^3/month.

Proposed modifications in the production process: Process modifications, including good housekeeping, were recommended to make production measures cleaner. The modifications recommended were mainly directed at reducing water consumption, chemical consumption and generated chemical waste and energy consumption at the chemical room.

In general practice, after stripping or alkaline cleaning, the metal plates were sent for washing off the acid or alkaline by using rinsing water which was in an overflowing rinsing tank. Rinsing time and the degree of cleaning were not specified in the procedure. The degree of cleaning was estimated only from the workers' experience. The counter current rinsing technique is one of the effective techniques for reducing water consumption, but due to the limited fixed area and fixed tank sizes in the chemical room. Therefore, three pollution prevention techniques were selected instead for this process that required only slight modification, namely: timed rinsing control, conductivity control and using a spray gun. The current rinsing technique practice showed that it consumed a large volume of rinsing water in comparison to the timed rinsing control or spray gun techniques proposed. The current average current water consumption was 32 L/basket of metal plates. However, the average water consumption for a spray gun was only 3 L/basket. Therefore, the factory could save 90% of water consumption by implementing this method for a very small investment.

The energy consumed and the activities of workers relating to the use of energy in the chemical room were observed. The average energy used for heating a tank was 7.920 kWh/month. These heaters were used to build up the temperature to the optimum range for stripping or alkaline cleaning. In this particular operation, the workers kept some of the heaters open on for the whole day or for the whole night, even though the tanks were not used on that day or night. In fact some tanks were used for only 3-4 h day^{-1}. The daily report could be a tool to report and estimate the time and type of metal plates which will go in to chemical room. The workers would then know what time they should turn off or turn on the tank heaters. In this way, the factory could reduce the energy used by 3 kWh/tank/h if the operators turn on the tank heater for just 1 h less in the current operation.

Chemical recovery techniques are used to separate the plating chemical from the rinse water or other solutions or to concentrate them, thereby making them available for reuse/recycling. There are a variety of options to fulfill this chemical recovery, such as evaporation, reverse osmosis or diffusion dialysis and so on. These cleaner production options require capital investment for the equipment. To choose among these options requires carefully considered judgment based on in-depth knowledge and experience. Therefore, life cycle assessment and simple cost reduction analysis by using eco-efficiency had to be performed.

Evaluation of potential improvements: The company and the author reached an agreement whereby the company would install a system with the main purpose of recovering nitric acid. Then, three acid recovery technologies were chosen; evaporator, reverse osmosis and diffusion dialysis.

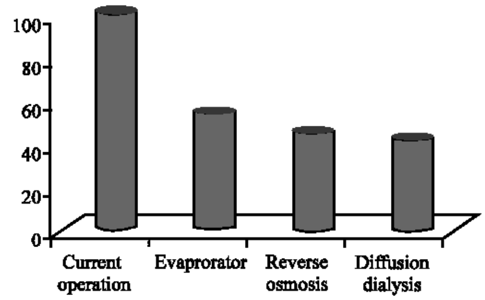

Fig. 3: Percentage of environmental impacts of each cleaner production option

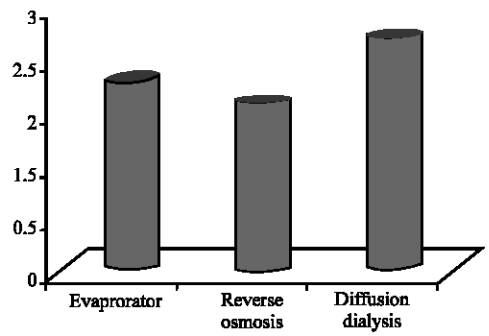

Fig. 4: Factor X for cleaner production options

An evaporator is a device that evaporates water to the atmosphere. The commercial evaporator used for recovery in this plating shop consisted of a pump to remove the solution, a blower to move air, a heat source, an evaporator chamber in which the solution and air can be mixed and a mist eliminator to remove any entrained liquid from the exit air stream (http://www.p2pays.org/ref%5C03/02454.htm).

Reverse osmosis recovers plating chemicals from plating rinse water by removing water molecules with a semi-permeable membrane. The membrane allows water to pass through but blocks metals and other additives. Diluted or concentrated rinse waters are circulated through the membrane at a pressure greater than aqueous osmotic pressure. The recovered chemical can be returned to the plating bath for reuse (http://www.p2pays.org/ref%5C03/02454.htm).

Diffusion dialysis is a commercialized membrane separation technology that can be used for the recovery of a wide variety of acids from high strength, metal contaminated solutions. It is extremely easy to install and operate, requiring only a source of deionized water and electricity (http://www.estcp.com/documents/techdocs/199705.pdf). About 95% of the nitric acid was recovered, estimated from an equipment specification.

Next, the Eco-indicator 99 was calculated by using the estimation of chemical reduction from equipment specification and discussed with suppliers, as shown in Fig. 3. The diffusion dialysis produced the lowest environmental impacts due to a higher percentage of acid recovery, followed by reverse osmosis and the evaporator.

Eco-efficiency: Once the result of the reduction of chemical use and environmental impacts were calculated, then the comparison between before and after modification of suggested options was analyzed. Eco-efficiency was modified to Factor X. The Factor X of a process was defined by Eq. 2. These results were plotted on eco-efficiency (Factor X) as shown in Fig. 4, where the reference process is the current operation:

$$\text{Factor X} = \frac{\text{Eco} - \text{efficiency of the evaluated process}}{\text{Eco} - \text{efficiency of the reference process}} \quad (2)$$

The way to increase efficiency is to reduce the environmental impact of the process or to increase the cost saving. Although, the evaporator showed the highest cost saving option over a 10 year period, the environmental impacts were higher than those of reverse osmosis and diffusion dialysis. Then, the conventional cleaner production judgment points to the evaporator as having the best payback period. If, however, the environmental impacts were taken into consideration, the diffusion dialysis was the most eco-efficient, as shown in Fig. 4. It could reduce the chemical cost by 8 and the environmental impacts by 58% compared to the current operation.

CONCLUSION

The study demonstrated the cleaner product for SMEs application. Then, life cycle assessment and cost reduction together with the eco-efficiency technique were carried out to identify the best alternative of cleaner production options. Diffusion dialysis was identified as the most eco-efficient option. This method is easy to use for SMEs and provided important information for choosing the best among the alternatives. In addition, the amount of water saved was at least 90% and the energy cost saving of 7 % were made by using little or no cost investment.

REFERENCES

Ahmed, M.T., 2007. Life cycle assessment, a decision-making tool in wastewater treatment facilities: Wastewater Reuse-Risk Assessment, Decision-Making and Environmental Security, Springer, pp: 305-314.

Amsberg, J.V., 1995. Policy approaches to promote cleaner production in Argentina, Brazil and Chile, Latin America and the Caribbean Region. The World Bank.

ESTCP, 1999. Spent Acid Recovery Using Diffusion Dialysis. http://www.estcp.com/documents/techdocs/199705.pdf.

Gutierres, Y.B., B.A. Diaz and S. Lozano, 2008. Eco-efficiency of electric and electronic appliances: A Data Envelopment Analysis (DEA). Environ Model Assess, Springer.

Lee, K.M. and A. Inaba, 2004: Life Cycle Assessment: Best Practices of ISO14040 series, APEC.

Myla, C., S. Jensen,, S. Haynes, and W. Marquardt, 1996. Analysis of pollution prevention investments using total cost assessment: Case study in the metal finishing industry, Pacific Northwest Pollution Prevention Resource Center.

NEWMOA, The Northeast Waste Management Officials' Association, Pollution Prevention for the Metal Finishing, http://www.p2pays.org/ref%5C03/02454.htm.

Sinkin, C., C.J. Wright, and R.D. Burnett,, 2008. Eco-efficiency and firm value. J. Accounti. Public Policy, 27 (2): 167-176.

Staniskis, J. and Z. Stasiskiene, 2003. Environmental Management Accounting for CP Investment Project Development, Environmental Research, Engineering and Management, 1 (23): 60-69.

Visvanathan, C., M. Parasnis, and A. Janesiripanich,, 1998. Multimedia environmental audit in a rice cracker factory in Thailand: A model case study. J. Cleaner Prod., 6: 93-101.

US. EPA, 1996: International Waste Minimization Approaches and Policies to Metal Plating.