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Cleaner Production Practices, Environmental Management and National Policy Development in Malaysia for Electroplating Enterprises

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ABSTRACT Cleaner technologies (CT) have been introduced into the Malaysian Small and Medium Enterprises (SME)-sector primarily by foreign donor supported project interventions. The establishment of the Environmental and Energy Technology Centre at SIRIM was funded by a grant from the Danish Co-operation for Environment and Development (DANCED), Ministry of Environment and Energy. Small and medium-scale enterprises (SMEs) were targeted within three sectors: Textile, food and electroplating industries. The paper illustrates the change in process from the perspective of electroplating SMEs by reviewing the cleaner production options chosen, presenting figures on the results achieved, and discussing the experiences gained. Reviewing the approach and results of the Centre, as well as the status of cleaner production (CP) in Malaysia, the paper outlines the challenges for national policy making, when moving from promotion by project intervention towards sustainable practices in the SME sector at large. The paper draws upon data collection conducted by the research project 'A Study on Promotion and Implementation of Cleaner Production Practices in Malaysian Industry - Development of a National Program and Action Plan for Promotion of Cleaner Production'.

(Cleaner production, environmental management, electroplating)

INTRODUCTION

In 1987-1995, the Council for Reuse and Less Polluting Technologies in Denmark, on basis of public funds, offered financial support for the development of cleaner technologies. By supporting pilot projects, the aim was to establish and demonstrate the advantages of cleaner technologies. The financial support program became an important element of the new Danish environmental policy, as expressed in the 1991 amendments of the Environmental Protection Act [1].

Following the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, the Danish Government decided to set up a special facility to contribute to restoring the global environment in accordance with the UNCED recommendations (Agenda 21). The facility - part of the Danish Environment, Peace and Stability Facility (EPSF) - was managed jointly by the Danish Ministry of the Environment and Energy (DANCED) and the Ministry of Foreign Affairs (DANIDA). DANCED activities were concentrated in two regions: South East Asia (Malaysia and Thailand) and Southern Africa.

In both regions, major project interventions were undertaken by DANCED to promote cleaner technologies in three selected industries: textile, food and electroplating. In Malaysia, an Environmental and Energy Technology Centre at SIRIM was established at SIRIM Berhad (formerly known as the Standards and Industrial Research Institute of Malaysia), which is a government-owned company under the Minister of Finance Incorporated. Among others, SIRIM's role is to act as the national technology development corporation and as a vehicle for technology transfer to enhance the customers' competitiveness.

Transfer of Cleaner Technology

These projects were based upon the expertise on cleaner technologies developed as a result of the support programme initiated by the Council for Reuse and Less Polluting Technologies in Denmark. The Danish Department of Environment had chosen to focus on three industrial sectors: Textile, food and electroplating, because these industries were perceived as contributing substantially to toxic emissions. They argued that only a selective effort targeting these sectors comprising quite a large number of factories would produce visible and significant results. One concern was the use of organic solvents which endangers the working environment and was assumed to pollute the atmosphere. The second concern was the emission of heavy metals, in particular chrome and other substances by the electroplating industry and the use of mercury, which complicates waste disposal. A third concern was the amount of organic matter in the waste water of the food industry, in particular fish processing plants.

Addressing these environmental hazards helped to build a knowledge resource base, which the Danish government decided to utilize in a general drive to promote system exports, and in a particular effort to market Danish environmental technologies. A basic rationale for DANCED funded projects was that they would prepare the market for delivery of hardware, thus supporting Danish industry. However, the transfer of cleaner technologies soon encountered problems. As an example, while the supply of an ion-exchange system to Malaysia was readily available from Danish companies, no support for this system could be found in Malaysia. Eventually, a local engineering company and also a local supplier were identified. Also, the economic downturn in Southeast Asia significantly reduced the prospects for Danish exports. The DANCED projects focused on capacity building, which did draw upon Danish knowledge resources on cleaner technologies in the training and education of staff.

The Cleaner Technology Centre

A major project intervention funded by DANCED to promote cleaner technology was the Environmental and Energy Technology Centre at SIRIM in Malaysia [2, 3]. The first phase of the CT project established demonstration project for the three selected industries, and developed the organisational capacity of the Centre to audit and advice SMEs within these sectors. However, the objective of promoting CT beyond the demonstration projects was not sufficiently met. Thus, for the second phase, the emphasis shifted as reflected in changed title of the project: 'Cleaner Technology for Improved Efficiency and Productivity of the Malaysian Industry'. The revised overall objective stated that the project should "*reduce the environmental pollution from the small and medium scale industries and improve their compliance with environmental regulations at the same time as it may improve their overall productivity*". The improvement of the environmental performance and compliance with regulations of a significant number of small and especially medium scale industries were now to be motivated by the potential reduction of cost, increase of productivity and market opportunities. A key element in the second phase was to strengthen the CT Extension Service and Information Service established at SIRIM in applying a customer-oriented and market based approach towards the SME sector in Malaysia.

In 2000, a Swedish team evaluated all DANCED funded CT/CP activities in South East Asia (Malaysia and Thailand) and Southern Africa [4]. In reviewing their basic findings that the implementation of project activities was achieved, while the continuation and the dissemination of cleaner technology practices in industry were quite limited, the evaluation team compared three different approaches adopted by DANCED.

Approaches in CT/CP Promotion

The *centre approach*, which was adopted in Thailand and Malaysia, focused on one organisation to implement the outreach program in the country. The centre functions as focal point thereby attracting/channelling/making possible efforts by other contracting bodies after the initial establishing phases. It included 'public services' such as information services and awareness raising seminars along with more direct CP work with companies. The evaluation team concluded that the Centres had to face the challenge of finding new ways to generate income when the donor support is withdrawn, and particularly to be able to continue the public service activities.

Also, attracting companies to join CT projects has proved difficult.

The *three pronged approach* was launched in South Africa. Each project exclusively addressed one industrial sector, and it involved three types of local actors within that sector: An industry association, industry service providers (e.g. consultancies, research institutes etc.) and the industry itself. The activities undertaken within a project are very similar to activities undertaken in the Centre projects, however, as only one industry sector is addressed, these projects can be more specialised in, for example, training and awareness activities. It relies on two different actors and attempts to embed the CP capacity and awareness in stable structures that already exists and that already have a natural connection to the companies that the project seeks to influence.

The *policy approach* recognizes that CT efforts worldwide traditionally have had a focus at the technical operations level in industry and the typical actors "owning" the CP agenda have been, and still largely are, found in the realm of engineers. A strong tendency today is to try to complement the activities directed straight towards industry with policy-oriented activity in order to increase the incentives for industry to implement CT measures. Although the relevance is high in doing so, the process engaged implies new challenges with, for example, new competence requirements including insights in policy making and ability for effective communication with a variety of professionals from the policy domain.

In suggesting the policy approach the Swedish evaluation team clearly recognises the limitations in terms of institutional capacity building of the DANCED projects. While the problem analysis of these projects may have identified the institutional capacity constraints, it has proven largely beyond their scope to address them efficiently.

Cleaner Production in Malaysia

Cleaner production is not new to Malaysia. Since the decade of 1990s, several cases have been reported on the success of many industries in adopting CP, particularly on waste minimization. There are a number of examples of progress from local and multinational companies [5]. In the Malaysian's Outline Perspective Plan Three (OPP3) 2001-2010, the importance of CP has been clearly recognized. It specifically touches on the utilization of energy and materials, and pollution intensity per unit of production resulting from industrial-urban based growth and development that has been identified as a national environment-related issue.

The CP component activity intends to support the present initiatives by the Department of Environment (DOE) in preventing, minimizing and control of industrial environmental pollution problems through legislative approach. In the past, the Malaysian Government has adopted the "end-of-pipe" approach for industrial pollution control, in which human resource; capital and environmental resources are invested in pollution discharge control at the end of the production line to meet the regulatory requirements. The emphasis of the approach has many limitations, primarily not providing incentive for further environmental protection initiatives, as well as – indirectly - discouraging industries from implementing cost-effective control measures.

Despite many promotional activities and incentives initiated by the government, the implementation of CP is still limited to certain quarters of industry, particularly those owned by multi-national companies. Small and medium industries (SMEs) are still, in general, reluctant to adopt CP, mainly due to perceived additional cost in adopting a new "cleaner" technology.

Electroplating Smes in Malaysia

In Malaysia there are more than 300 electroplating companies and the majority of them are small and medium scale industries (SMEs). About 30 per cent of them are located in the Klang Valley and Selangor. The electroplating process utilizes a wide variety of chemicals, depending on the types of metals that are processed for electroplating and the types of metallic coating that the facility applies to the processed substrates. Since parts are typically processed in a water–based solution containing a combination of these chemicals and are then rinsed, the chemicals purchased by an electroplating facility normally will find their way into one or more wastewater streams, can be emitted into the air through process exhaust systems, and can find their way into the soil through leaking from landfills and from past land disposal practices or poor facility maintenance.

Many electroplating facilities also generate concentrated wastes that may contain high concentrations (in the range of gm per litre) of toxic metals such as lead, cadmium, or hexavalent chromium, or other toxics such as chlorinated solvents and cyanide. These waste streams typically originate from stripping operations, unrecoverable contamination of electroplating solutions, or use of processing solutions with a finite utility life. Quantities of waste generated are so variable that a generalization cannot be made. Some facilities generate no more than a few litres of waste per day, while others generate 40 cubic meters per week.

Electroplating involves processing the part to be electroplated through a series of water-based solutions containing one or more chemicals that either clean, deoxidize, or coat the part. Because each processing step utilizes specialized chemicals that would react unfavourably with the subsequent process, every processing step is followed by a water rinse. The rinse water thus becomes contaminated with the processing chemicals and needs to be treated for purification prior to discharge. Rinsing is performed in either flowing-water rinse tanks or in counter flow or controlled-flow rinse tanks that conserve water usage. Certain processes are equipped with accessory equipment such as filters, heat exchangers, and air scrubbers. These accessories can be additional sources of chemical wastes, along with other operations such as process tank maintenance, pickling, de-rusting and etching of metallic parts, solvent degreasing, and production of de-ionised water for critical rinsing and tank makeup. The equipment used for electroplating operations can be as primitive as a series of tanks made from plastic drums and rectifiers, all the way to automated systems driven by computers, process controllers, and programmed hoists.

Pollution Prevention Options

The most commonly practiced pollution prevention option in electroplating is the utilization of drag-out rinses. These involve use of water bearing rinse tanks where parts are rinsed in after processing but before rinsing in a flowing-water rinse. The water and chemicals collected in the drag-out rinse are returned to process tank to make up for the evaporative losses.

The second most popular pollution prevention alternative is substitution. For example, there are several different chemicals available for zinc plating, including some that contain cyanide and others that do not. By successfully making enough changes to allow the use of non-cyanide zinc-plating process, cyanide can be eliminated from the facility.

The electroplating industry utilizes numerous recovery-and-recycle techniques to return a portion or all of the process chemicals to the origin. The typical plater will first evaluate the efficacy of drag-out rinsing; will determine if a viable, less polluting or non-polluting substitute exist; and will make those changes before investing in recovery-and-recycle equipment.

Recovery-and-recycle equipment is generally expensive, requires reduction of water usage to be economically feasible, and increases the maintenance workload and operational complexity of the electroplating facility. However, such systems can reduce the amount of solid waste generated by the electroplater and can often yield net saving in chemical costs that can often pay for the equipment in a matter of a few months.

Direct reuse involves the reuse of a waste material without processing it either as a feedstock in a production process or as a substitute for a commercial process. Recycled chemicals are used or reused in other industrial processes or are used as substitutes for other chemical products.

CP Successes in Malaysian Smes

The DANCED funded demonstration projects made use of ion exchange and counter rinse [11]. One was *Kilang Sadur Elektrik QUALITY Sdn. Bhd. (QEP)*, which is typical a SME providing commissioning plating for the automotive and electronic industries. When the law made it mandatory for all electroplating companies to have treatment plants, QEP installed a 20 gallons/min treatment plant, which cost around RM 300, 000. The pollution prevention installation at QEP comprises two ion exchange units. One system is installed at the zinc plating line, while the other is installed at the chromate line. Three-stage counter-flow rinsing is implemented with the desired rinsing flow rate. The purpose of these units is to clean the final rinses and keep them completely deionised. Part of the deionised water is sent in counter-current flow with the product in process. The counter-current flow is balanced with the compensation for the evaporation from the various plating tanks. The rinse water becomes more and more concentrated with plating chemicals dragged out from the plating tank during the counter-current rinsing process. The rinse water with plating chemicals can be regarded as diluted plating solution and subsequently used for topping up the plating solution.

The overall benefits of the pollution prevention installations are to reduce the water consumption by about 80 per cent and to save plating and treatment chemicals especially from the systems installed in the zinc plating and chromating lines. In fact, the continuous wastewater stream from the zinc plating and chromating lines were almost eliminated. Wastewater is only produced during regeneration of the ion exchange units. At the present production capacity, regeneration takes place once a month. Currently, QEP has no problems in complying with the regulations; even through treatment is only carried out during weekends for just a couple of hours. With the reduction in wastewater and therefore in sludge volume, the waste management cost is reduced accordingly. With the ion exchange system, the final rinse tank is crystal clear with a conductivity of 0.2 μs. The plated products were cleaned more effectively resulting in higher plating quality.

Metal Polishing Industries Sdn. Bhd. makes three layer nickel and chromium (bright and hard) plating on one production line with a capacity of 800 m^2 per day. The company was established in 1992 and relocated in 1998 to Bukit Kemuning Electroplating Park, Shah Alam, which includes a centralised wastewater treatment plant. It employs 33 people with operation of approximately 10 hours per day. It was one of the model plants selected under the Japan International Cooperation Agency (JICA) - SIRIM Cleaner Production project in 2001 [6]. In 2002, it was certified ISO 14001. The main customers are motorcycle-assembling factories. The plant has 1,200 square meters of building area. There is a wastewater treatment centre in this electroplating park; therefore, the factory does not need its own wastewater treatment facility. The production line has 37 tanks starting from degreasing of raw materials to drying of final products. It is operated in 2 or 3 shifts continuously every day, depending on the volume of orders from clients.

Wastewater is sent to the centralised wastewater treatment facility in the electroplating park. The plant plans to reduce the volume of wastewater to save the cost of wastewater treatment. Exhaust air from the plant goes through ventilation units for a nickel/chromium plating line and it has no steam boiler. Sludge generated from the plant is sent to an external company for further treatment on commission. No recycling is practiced.

The post treatment of chromium plating is one target to improve productivity. As a result of poor washing after chromium plating, some additional work to wipe and repair is needed. Customers sometimes complain about defects in the products. Moreover chromium plating is carried out under undesirable conditions of operating temperatures, low speed of plating, etc. These factors may cause low productivity.

Existing problematic issues in the factory that need CP measures are summarized as follows. The rinsing water consumption was 600-800 m^3/month, which is not so much as compared with the same industry in Japan. However, the high cost of wastewater treatment had decreased the factory's productivity. Therefore, it was reduction and minimization of the rinsing water consumption without degrading product quality was one of the main objectives for factory.

For reduction of water consumption, three CP options were worked out as follows:

1. Control of city water flow rate to rinsing tanks

The inlet pressure of city water becomes higher during midnight than in the daytime. Therefore, it was necessary to control the valve operation frequently in order to prevent excess water flowing to the rinsing tanks. However, there are many valves to control and operators sometimes miss or forget to control them. To improve operation and control of the city water flow rate, it was studied and decided that by installing a pressure control valve at the inlet point of city water together with the flow meters at the inlet points of the rinsing tanks, this problem was solved.

2. Reusing of rinsing water

Rinsing water in Rinsing Tank (alkaline treating tanks) was discharged outside the factory as wastewater. However, it was found that this rinsing water could be reused as rinsing water.

3. *Recycling of rinsing water*

If the concentration of ionic contaminants in rinsing water can be lowered to a certain level, it is possible to recycle this rinsing water. It was also found that rinsing water from the chromium plating and nickel-plating tanks could be recycled by installing an ion exchange system.

Generally, higher suspended solid (SS) concentration found in plating solution will lower product quality through the appearance of burn stains and will also lower the electroplating efficiency. The SS concentration in bright chromium plating solution was too high, and it was concluded that installing a filter unit for this bright chromium-plating tank would lower the SS concentration.

In this factory, a certain percentage of the product had gone out of specification because there were yellow remains and burn stains on the surface. This was a serious problem for the factory. After the factory audit, it was found that the main reason for the problem was the volume of rinsing water used which was too low. It seemed that actual operating volume was only 0.1 turn over per hour because measured electrical conductivity values (μS/cm) of water of the three rinsing tanks were 1000, 200 and 100, which were too high. The concentration of SS in the bright chromium-plating bath was too high; possibly contributing to the problem with burn stains. These conductivity values could be reduced to less than 50 μS/cm if CP was introduced, with a chosen ion exchange system installed to make full recycling of rinse water possible.

Reduction of chemical consumption is very important because it will not only reduce wastewater discharge but also increases productivity. Normally, chemicals used in the electroplating factory are lost through the following two routes. One is through the product. Some amount of chemicals in the drag out solution tends to adhere on the surface of the products. The other is through an incomplete chemical reaction itself. For reduction in chemical loss, it is very effective to return the dragged out solution to the original tank. There are various methods in use to return the dragged out solution to the original tank. In order to reduce the loss of chemicals, it is very effective to return the dragged out solution to the original tank.

In the first step mentioned above, only yellow remains and burn stains problems have been explained: however, there are other problems in these electroplating industries. These problems should be studied in future as a target for improvement or product quality. As a recommendation, it is judged that a suitable design and careful maintenance of hooks for raw materials and a suitably shaped design for raw materials can give 100 per cent production yield without any yellow remains and burn stains problems.

Among the CP options, the following five CP measures were selected as suitable measures (Table 1).

- Installation of a pressure controller for city water inlet line,
- Installation of area flow meters,
- Installation of a diaphragm pump,
- Installation of a filter unit, and
- Installation of an ion exchange system

Total cost reduction of RM 93,000 per year was expected as follows:

- Reduction of rinsing water and city water by 6 per cent: RM 9,000 per year
- Reduction of labour cost for additional works to wipe and repair final product RM 84,000 per year.

After installation of an ion exchanger system for the post chromium plating rinsing tank, it was expected that the rinsing effects would be increased and the frequency of off-specification products decreased (Table 2). The total investment cost was roughly estimated at RM 216,000.

Before the implementation of cleaner production, total output was RM 1 million. Afterwards, it was reduced to RM 900,000. Energy consumption was reduced from 193,000 kWh to 171,000 kWh after cleaner production. In total, electricity bills were reduced from RM 49,794.00 to RM 44,118.00. The combined savings on all items are calculated in Table 3.

Table 1. Total investment cost for CP changes

		Quantity	RM
a.	Pressure controller	1 set	5,000
b.	Area flow meters	5 set	15,000
c.	Diaphragm pump	1 set	5,000
d.	Filtering unit	1 set	71,000
e.	Ion exchanger system	1 set	230,000
	Total		**326, 000**

Table 2. Investment for CP Measures

No.	Item	Quantity	Amount (RM)
CP 1	Installation of a pressure controller for city water inlet	1 set	5,000
CP 2	Installation of area flow meters	5 set	10,000
CP 3	Installation of diaphragm pump	1 set	9, 000
CP 4	Installation of a filtering unit	1 set	87, 000
CP 5	Installation of an ion exchanger system	1 set	105, 000
	Total		**216, 000**

Note: In these investments, all cost of design, equipment & machinery, construction material, transportation, construction, operator manual, commissioning & training and spare parts are included.
The total investment for the CP introduction resulted in RM 216,000.

Table 3. Total savings for 4 months after introduction of cleaner production

Items	Amount	Savings in terms of RM / 4 months
City water	403 m^3 x 1.92 RM/m^3	773.76
Chrome rinse/sludge	10 m^3 of chrome rinse + sludge	534.47
Electricity	26,000 kWh x 0.258 RM/kWh	6,708.00
Manpower	2 workers x RM600/worker x 4 months	4,800.00
	Total	**12,816.23**

CONCLUSION

The paper has shown the limitations of project interventions for developing sustainable cleaner technology practices. The DANCED funded Centre at SIRIM did develop its capacity as an implementing organisation, and it has helped to verify the potential gains for SMEs. Such financial gains are clearly documented by the case studies of two electroplating plants. However, the dissemination of the cleaner technology to the industry at large involves the development of institutional capacity within the context of a wide range of stakeholders influencing environmental performance in industry at a different level.

An evaluation of the DANIDA-funded environmental assistance in Southeast Asia, which was conducted in 2003, stated that the CT-activities in Malaysia were too technology focused [7]. Rather, a broader Clean Production approach should be adopted to identify the most cost-effective ways of reducing waste and effluence, some of which may be achieved through no cost or low cost housekeeping options. The evaluation team referred to World Bank research papers showing that industries will implement pollution abatement measures when the cost of abatement is lower than the cost of pollution in terms of user charges or similar cost (Annex M). They conclude that the take-up by industry would likely have been much better, if the Department of Environment (DOE) had introduced charges on the disposal of waste water in the electroplating sector while CT was being actively promoted in this sector. By heavily subsidizing demonstration projects, economic viability is not proven, for example in terms of return on investment.

The fragmented regulatory efforts and promotional activities call for a national policy development aimed at a focussed institutional capacity building to improve environmental management practices. In this process, a networking approach is needed to secure commitment and resources of all relevant stakeholders within the regulative network, the business network and the knowledge network [8]. The 8th Malaysia Plan does designate SIRIM as a National Cleaner Production Centre [9]. However, the first step must be to define a comprehensive action plan combining measures specifically targeting the barriers, in particular as perceived by the small and medium scale enterprises

The research project 'A Study on Promotion and Implementation of Cleaner Production Practices in Malaysian Industry - Development of a National Program and Action Plan for Promotion of Cleaner Production [10], has explored a much wider scope of possible activities compared to the CP efforts directed straight towards industry. Actions can be taken in a wide variety of areas including the following:

- Increase the profitability of CP measures by, for example environmental taxation
- Ease financing of CP investments
- Introduce legal incentives for CP
- More effective enforcement of legislation
- Raising attention to the issue by information
- Subsidies for CP services
- Benchmarking of company performance
- Training and education

Policies for improved environmental performance do not come ready-made. Notwithstanding the availability of policy guidelines, standards and management tools, there is no blueprint for social change. As stakeholders negotiate regulatory frameworks, institutional arrangements, performance practices and capacity building activities, a reinvention of available concepts and procedures and their configuration will have to be conducted in response to the specific needs, interests and resources in the Malaysian context.

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