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THAILAND'S ELECTRONICS INDUSTRY:
MEETING ENVIRONMENTAL MANAGEMENT
CHALLENGES in the 1990s

by

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June 1993

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prepared for the United Nations
Industrial Development Organisation
Vienna, Austria

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I. Overview of Environmental Challenges Facing Asia's Rapidly Industrialising Economies

The rapidly industrialising economies of Asia have undergone profound transformations in the comparatively short period of a quarter century. For a number of those economies, Table 1 shows the sectoral GDP shares in 1965 and 1990. Except in the case of Japan, agriculture accounted for more than a quarter of GDP in 1965; in all countries except Indonesia, by 1990 it accounted for well under a fifth -- and in Korea and Taiwan under a tenth. In all cases, industry's share of GDP rose steeply.

Industrialisation has been accompanied by rapid urbanisation. In all cases except Japan (which was already highly urbanised in 1965), the share of the urban population has risen steeply from 1965-90. The combination of rapid industrialisation and rapid urbanisation has placed severe strains on the urban environment. Private automobile ownership has grown tremendously, resulting in high motor vehicle densities (see Table 2) and serious traffic congestion and mobile source pollution. Per capita energy consumption has also grown rapidly, adding to pollution loadings of sulphur oxides (SO_x), nitrous oxides (NO_x), and suspended particulates.

Industrial development in the region has passed through a number of phases. In an early phase, industries which expanded most rapidly tended to be resource- and labour-intensive. While the resource-intensive industries did in many cases cause environmental degradation (e.g., mining, forestry, agricultural processing), labour-intensive industries have generated relatively few environmental externalities. In a subsequent phase, most countries' industrial structures have integrated backward into intermediate products like iron and steel, non-ferrous metals, chemicals and chemical products, cement and non-metallic minerals, etc. These industries tend to be highly polluting, with the result that industrial pollution problems worsened during this phase. In a still later phase, the relative importance of these heavy industries has declined and new, knowledge- and skill-intensive industries have expanded rapidly. Japan is now well into this last phase while Korea and Taiwan are still in its early days. Thailand, meanwhile, has been moving in the last several years from a resource-intensive through an increasingly labour-intensive phase of industrial development; it is presently engaged in import substitution of intermediates needed by its construction and export-oriented manufacturing industries -- petrochemicals and plastics, non-metallic minerals, iron and steel, etc. As these are polluting industries, it thus faces the prospect of worsening industrial pollution before the situation improves. Meanwhile, among the most dynamic sectors are electronics and automotive components, both of which -- while not among the most heavily polluting sectors -- do generate sizeable quantities of hazardous waste (heavy metals, waste oils, solvents, acids, etc.). Thus, because of the rapid pace of industrial development, Thailand has an industrial structure in which environmental risks associated with traditional 'dirty' industries overlap with new environmental challenges associated

TABLE 1: Per Capita GNP and Sectoral Distribution of GDP

	GNP/ capita (US$)	Distribution of GDP (percent)					
		Agriculture		Industry		Services	
	1990	1965	1990	1965	1990	1965	1990
Japan	25,430	10	3	44	42	46	56
Korea, Rep. of	5,400	39	9	25	45	37	46
Taiwan	7,761	27	5	29	43	44	52
Thailand	1,420	32	12	23	39	45	48
Indonesia	570	51	22	13	40	36	38
OECD Average	20,170	5		43		54	

Sources: World Bank, *World Development Report 1992;* for Taiwan: *Statistical Yearbook of the Repubic of China 1991, Taiwan Statistical Data Book 1989,* and *Key Indicators of Developing Asian and Pacific Countries* (ADB, 1991).

TABLE 2. Growing Urbanisation, Energy and Motor Vehicle Use

	Population (millions)	Energy consumption per capita (kg. oil equivalent)		Urban share of population (%)		Number of motor vehicles per 1000 population	
	mid-1990	1965	1990	1965	1990	Year	
Japan	123.5	1,474	3,563	67	77	1991	490
Korea	42.8	380	2,170	32	72	1991	134
Taiwan	20.2	...	2,280	47[a]	76[a]	1991	620[b]
Thailand	55.8	82	352	13	23	1990	110
Indonesia	178.2	91	272	16	31	1989	47
Low/middle income country average/total	4,145.8	277	605	24	44		n.a.
OECD average/total[c]	831.1	3,649	5,179	72	77	1989	409

Notes:

a/ Localities with population of more than 50,000.
b/ Three-quarters of the motor vehicle stock in Taiwan consists of motorcycles (9.2 million).
c/ Refers to total of 'high-income' OECD member countries; excludes Greece, Portugal and Turkey.

Sources: World Bank, *World Development Report 1992*; OECD, *Environmental Indicators: A Preliminary Set*, 1991; IEA, 1992; various national statistical sources.

with relatively 'high tech' industries. Our concern here is with the environmental problems generated by the electronics industry, which is an increasingly important sector of Thailand's industrial economy.

II. The Electronics Industry in Thailand

A. Contribution to the economy

The electronics industry in Thailand has grown very rapidly over the last decade. In real terms, value added in the electrical/electronics machinery sector[1] rose an average 17 percent per annum from 1980-90, at a time when overall manufacturing value added (MVA) was growing by 10 percent per annum. Thus, the contribution of electronics/electrical machinery to MVA rose over the period from 3.2 percent to 6.0 percent (NESDB, 1992). While Thailand had an electronics industry prior to 1980, it was small and largely domestic market oriented. A few multinational semiconductor firms set up assembly plants in the mid- to late-1970s, but by 1980 electronics products still accounted for only 5.1 percent of total exports. The rapid expansion of the industry during the 1980s was largely geared toward export production, with the result that by 1990 electronics accounted for roughly 18 percent of total exports (BOI, 1991).

The rapid increase in electronics production and exports during the 1980s was accompanied by a radical transformation in the industry's structure. In 1980, the active components sector (overwhelmingly semiconductor assemblies) accounted for 93 percent of total electronics exports. By 1990, that share had fallen to 22 percent. Meanwhile, the office automation (mostly computers and peripherals) equipment share of electronics exports rose from less than one percent to 38 percent. That growth was attributable largely to the rapid expansion of computer disk drive production in Thailand. (Production of computer keyboards and other peripherals also grew rapidly, but in value terms they are a small fraction of disk drives.) Another noteworthy development over this period has been the surge in consumer electronics exports, especially in the late 1980s. From 2.3 percent of electronics exports in 1987, consumer electronics jumped to 22 percent of those exports by 1990. This owed much to the influx of foreign direct investment (fdi), notably from Japan, during this period.

Actual employment figures for electronics are difficult to obtain, but figures on the estimated numbers of workers employed by electronics projects approved by the Board of Investment (BOI) give some indication of the sector's importance. From 1962 to 1990, the cumulative total of workers in BOI-approved electronics projects equaled 216,700. Of those, roughly 170,000 were to be employed in projects approved from 1987 onward. The number of

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[1] Data on manufacturing value added by sector do not disaggregate electronics from electrical machinery. Apart from domestic electrical appliances, however, the electrical machinery sector is relatively slow-growing as compared with electronics.

workers employed in those projects which actually started up from 1962 to 1990 totalled 72,680. (The latter figure does not necessarily reflect the number of workers actually employed in electronics as of 1990 for two reasons. First, there have presumably been some changes in the numbers of workers employed by projects since their year of start-up. Second, not all electronics firms are registered with the BOI.) Another estimate of electronics employment -- for end-1990 -- puts the figure at roughly 144,000 workers. Overall manufacturing sector employment in Thailand totalled roughly 3 million in 1990, so electronics represented at least 2.4 percent of the total (on the conservative estimate of 72,680 workers) and perhaps 4.8 percent of the total (assuming 144,000 is more accurate).

Electronics' higher value added contribution than employment contribution is not surprising since, being a relatively skill-intensive industry, it has a relatively high value added per worker compared with many other light manufacturing industries. It should be noted, however, that the value added figures apply to a slightly broader category (electronics and electrical equipment) than the employment figures (electronics only).

B. <u>The evolution of Thailand's electronics industry</u>

Thailand's electronics industry started out in the 1960s as an import substituting one, supplying consumer electronics and some telecommunications equipment to the domestic market. It evolved toward greater export-orientation in the 1970s, with several investments by leading US semiconductor firms in chip assembly plants. While that sector has grown, in the early 1980s chip plants were joined by a new generation of investments in disk drive production and a variety of other computer peripherals. Since the mid-1980s, electronics production has expanded in almost all areas, driven by a new wave of foreign direct investment originating in Japan and to a lesser extent the 'four dragons' (Taiwan, Korea, Singapore, and Hong Kong). The industry is heavily foreign-owned though there are a few noteworthy locally owned assembly operations which act as subcontractors or original equipment manufacturers (OEMs) for multinationals or overseas customers. These include a few semiconductor assembly plants and a large disk drive facility. Some of the major Thai industrial groups -- e.g., Siam Cement and Saha Union -- have diversified in the last half decade into electronics. With the influx of Japanese (and to a lesser degree Korean) investment, the consumer electronics industry has expanded rapidly to serve both a growing domestic market and the international market. Telecommunications equipment (mostly but not only subscriber equipment) has also been a growing area of investment in the last several years. This is related in part to the major expansion of Thailand's telecommunications network.

Whereas through the early 1980s the electronics industry was quite highly concentrated, with a few key firms in each major sector, since then the number of small and medium sized firms has grown rapidly. From 1980-84 the average number of workers employed per project was roughly 440; from 1987-90 the average was 230. The average capital investment per project, meanwhile, was Baht 324 million from 1980-84 and only Baht 225 million from 1987-90. The number of electronics/electrical machinery sector enterprises (with over 7 employees or 2 hp of machinery) registered with the Department of Industrial Works (DIW) almost trebled between 1979 and 1989 -- from 409 to 1,121 (TDRI, 1990). The growing number of smaller size firms in the industry poses new challenges for environmental management. The relatively few, large firms (pre-1985) -- even if they could not always be trusted to adopt sound environmental management practices on their own -- could at least be monitored fairly easily for compliance with government environmental regulations. With the larger number of smaller firms now operating, the monitoring and enforcement effort has become far more complicated. Thus far, the government's resources devoted to monitoring and enforcement have not expanded accordingly.

III. The Major Environmental Impacts of the Electronics Industry

The electronics industry is not among the dirtiest industries in the world, but neither is it an entirely clean one. It generates a variety of wastes, more than a few of them toxic and hazardous. Moreover, the electronics industry has strong links to certain supplier and supporting industries that are significantly more polluting than electronics itself -- notably, chemicals and plastics, and metal plating and finishing.

Data on the pollution intensity of the electronics industry are not available for Thailand but David Wheeler and associates (Wheeler, Martin, Afsah and Hettige, 1993) at the World Bank have mapped the pollution intensities per unit of output of US industries broken down by 3- and 4-digit ISIC classifications. The 4-digit ISIC numbers which encompass the bulk of the electronics industry are 3825 (office machines and computers) and 3832 (radios, televisions, telecommunications equipment, and active components). On two measures -- toxic chemicals and bioaccumulative metals -- the electronics industry records sizeable releases, but it still ranks low in comparison with such industries as: industrial and agricultural chemicals, leather and leather products, and synthetic resins -- in the case of toxics; non-ferrous metals, iron and steel, basic industrial chemicals, pottery and china, and leather -- in the case of bioaccumulative metals.

Some data are available for Thailand on the quantities of hazardous waste generated by different industries. In 1991, the basic metal industry was by far the largest hazardous waste generator, producing some 1.31 million tonnes (mostly heavy metals). The next largest was the fabricated products sector, with 192,000 tonnes (including heavy metal sludge, acid waste, and alkaline waste). Transport equipment followed with 111,000 tonnes. Next was electrical (including electronics) machinery, ranking ahead of chemical products and generating 87,000 tonnes of hazardous waste (including the same general categories of waste as for fabricated products) (TDRI, 1990).

The pollution problems created by the electronics industry are of two principal sorts: localised problems like water and soil pollution, principally from releases of inadequately treated waste water and unsafe disposal of toxic sludges; global problems like ozone depletion and climate change.

A. Local pollution problems

First, there are local problems resulting from toxic chemicals and heavy metals in waste streams. The two activities generating the most serious environmental problems are cleaning/degreasing operations and electroplating. The former makes use of a variety of industrial solvents (chlorinated and non-chlorinated), many of which are toxic and some of which are carcinogenic. The materials removed from the electronic components or assemblies during cleaning/degreasing include oils and solder residues, notably lead. Electroplating also makes use of certain toxic chemicals but its main by-products are metals. Thus, both types of operation generate waste streams which need to be managed carefully. In some cases, this calls for heavy metals removal and waste water treatment; in others, the safe disposal of waste sludges; in still others, the recovery and recycling of waste products. In addition, in the numerous operations requiring handling of toxic or carcinogenic chemicals, adequate environmental health and safety procedures are needed within the workplace to minimise worker exposure.

One area of concern is the continued use by some electronics plants in the region -- including in Thailand -- of suspected carcinogens that have been banned in the United States and certain other OECD countries and for which there are readily available, safer substitutes. One such product is 1,1,1 - trichloroethylene (TCE), which is a cleaning solvent common in semiconductor factories.

Process-specific environmental and worker exposure issues

There are certain common types of environmental problems affecting most if not all electronics operations. Localised air pollution is not a major concern in the electronics industry, though air quality inside the workplace can be an important occupational health issue. In the case of water, BOD discharges are not a major problem but discharges of acidic waste water can be. The principal environmental management issues facing the electronics industry are: the safe storage and handling of hazardous chemicals; the proper treatment of waste water with loadings of toxics and heavy metals; the proper storage/disposal of heavy metal sludges; the recovery and recycling of certain hazardous wastes to reduce storage/disposal problems. Waste water (pre-)treatment systems are likely to be the principal environmental investments for most electronics firms. Firms may also choose to invest in recovery/recycling systems for a variety of chemicals and heavy metals. Until such time as adequate off-site hazardous waste treatment/disposal facilities exist, electronics firms must also make provision for safe on-site storage. While capital investments may not be high, storage takes up often valuable space. Following is a process-specific review of some of the more significant environmental problems associated with the electronics industry per se and with its most important supplier/supporting industries.

Semiconductors

<u>Tin dip/plate</u>

This area uses a number of potentially hazardous substances, including several metals (lead, tin, copper, zinc) and acids (hydrochloric, sulphuric).

Waste water needs to be tested for metal content. If it exceeds acceptable levels (given by Thai or international standards), then heavy metals precipitation/removal is required. Waste water may also need to undergo pH neutralisation if acid content is high.

<u>Environmental test</u>

This process refers to the testing of electronic components for their reliability in harsh environments -- e.g., temperature extremes and fluctuations, moisture, radiation, physical stress, etc. It is a particularly crucial procedure in the case of components destined for military or other high-reliability applications. Radioactive gases (e.g., Krypton-85) are sometimes used for leak testing. Very strict safeguards are needed to prevent worker exposure.

Printed circuit board fabrication

In printed circuit board fabrication, there are two techniques of printing circuitry on the substrate -- additive and subtractive. The former is used principally in commercial production and the latter in research and development. In the subtractive method, part of the copper cladding on the base plate (or laminate) is etched away with chemicals so that only the desired circuit pattern remains. In the etching process, residues containing copper and toxic chemicals are generated and need to be recovered and either recycled or disposed of properly.

Printed circuit board assembly

<u>Soldering</u>

If not protected by masks and adequate ventilation, workers in the soldering area risk inhalation of solder fumes which contain high concentrations of lead. Proper ventilation systems are therefore crucial in this area. The blood lead level of workers should be tested periodically. If the exhaust gases are not to become a source of air pollution upon exiting the factory, (packed water) scrubbers need to be installed. Scrubber discharge can then be routed to a heavy metals recovery (and pH neutralisation) system.

Post-solder defluxing

This process is intended to remove flux and solder residue from the printed circuit boards after soldering. The chemical composition of the flux determines the degree of toxicity of the residue. In the event that a zinc chloride flux is used, then the zinc in the residue needs to be recovered. Also, the solder dross normally contains lead similarly requiring recovery. Since the defluxing process utilises solvents, these also need to be managed properly. Commonly, azeotropes of CFC-113 and 1,1,1-trichloroethane (methyl chloroform) are used as defluxing agents; these are not toxic but ozone-depleting, so their proper management is discussed in the following section on global environmental problems.

Metalworking

Metal cleaning

Electronic equipment contains a variety of metal parts which need to be fabricated either by the electronics firms themselves or by outside contractors. These include: mechanical components and metal casings for computer disk drives, micromotors, lead frames for integrated circuits, parts for electron guns used in cathode ray tubes (CRTs), connectors, power supplies, fans, casings for computers, keyboards and other peripherals. Depending on the particular product and process, the wastes generated differ somewhat, but there are a few fairly common wastes which need to be managed. These include metal scrap, lubricating oils, and degreasing solvents. Recovery and recycling should be feasible for solvents. Depending on the metal and the quantities, recovery and recycling may also be feasible. For small shops, however, there is probably not enough waste volume to justify in-house recycling, so a common recycling facility may be needed.

Electroplating

Metal plating and finishing are sometimes performed within electronics plants and sometimes by outside contractors. In the electronics industry, tin, aluminium, nickel and copper plating are employed. By-products of the plating process can include solvents (e.g., toluene), acidic and alkaline wastes, waste oil, salts, chromium and cyanide, in addition to trace metals.

On-site chemical storage

Chemical storage is a concern common to all types of electronics plants. There are two areas where chemical management is needed: storage in stocks and in-process use. The former is a less difficult problem; the main concerns are to prevent leakage from storage tanks/drums and to ensure against explosions and suppress fires in the case of flammable substances (e.g., solvents like alcohols and acetone). In-process chemical control involves not only containment of leaks and precautions against fire/explosion but also minimisation of worker exposure to toxics and carcinogens. As a rule, secondary containment is needed in chemical storage and use areas to guard against contamination of soil or ground water. Ventilation is also critical to reduce health risks as well as the risk of explosion. Another concern is the compatibility of chemicals stored together. For example, corrosives should not be stored in close proximity to flammables.

Control technologies and procedures

While much of the pollution control effort in the electronics and related industries relies on 'end-of-pipe' treatment of waste streams, an increasingly favoured approach involves closed loop systems in which waste products are recovered, recycled, and reused -- including waste water. This waste minimisation approach can be attractive not only environmentally but economically.

B. Contribution to global environmental problems

Besides creating local pollution problems, certain electronics industry activities can contribute to global environmental threats. In particular, certain chemicals used widely in electronics -- principally as cleaning solvents -- are ozone-depleting substances (ODS) which are controlled under the Montreal Protocol (MP). Some of those same chemicals as well as others used in the industry contribute to global warming. In countries like Thailand which are Parties to the MP, electronics firms must therefore find ways of rapidly phasing out their use of such ozone-depleting chemicals. The particular ODS most commonly employed in electronics production are chlorofluorocarbon (CFC)-113 and 1,1,1 - trichloroethane (or methyl chloroform -- MC). Both are chlorinated solvents and it is their chlorine atoms which react in stratospheric ice and dust particles to break down ozone (O_3) molecules, thereby thinning the ozone layer that protects the earth from the sun's harmful ultraviolet (UV-B) radiation.

Thailand's policy response to the ozone depletion problem

Thailand was an original signatory to the Montreal Protocol and ratified the agreement on 7 July 1989. The government has also adopted the London Amendments which call for an accelerated phase-out of ODS, with most controlled substances phased out by the developed countries by the year 2000. (The Copenhagen Amendments of 1992 call for a further acceleration in the phase out to 1996 for many ODS.) Thailand qualifies as an Article 5 developing country under the MP by virtue of the fact its annual consumption of Annex A substances (which includes the major CFCs and halons) is less than 0.3 kg. per capita. This means that it can avail of a 10-year grace period in accomplishing its ODS phase out.

To monitor and control the consumption of ODS, Thailand has classified the controlled substances under the MP as hazardous substances, thereby allowing for their regulation under the Toxic

Substances Act of 1967 (amended in 1992). The Department of Industrial Works (DIW) of the Ministry of Industry is the government body charged with responsibility for monitoring and controlling hazardous substances, including ODS. Thailand relies entirely on imports for these chemicals. Prior permission is now required before a company can import any ODS. Once the shipment has landed, the importer must file a declaration stating the exact quantity imported. The DIW has adopted a policy of not allowing new companies to import ODS unless they have a factory operating license, in which case the imports are tied to factory capacity. Also, in August 1991, the Ministry of Industry encouraged the BOI not to extend promotional privileges to any firms using ODS (ICF Inc., SIAMTECH International, and TDRI, 1992).

Phaseout of CFC-113 and methyl chloroform (MC) use in electronics

Solvent cleaning constituted about 43 percent of total ODS use (ODP-weighted[2]) in Thailand in 1991; of that, 34 percent consisted of CFC-113 and the other 9 percent methyl chloroform (MC)[3]. The 1991 imports of CFC-113 amounted to almost 3,500 metric tonnes (MT), two-and-a-half times more than in 1986 -- the base year for control purposes in the MP. Imports of MC doubled over the same period. Consumption of CFC-113 was divided roughly evenly between electronics cleaning and metal/precision cleaning. In the case of MC, electronics cleaning accounted for about 58 percent of consumption and metal/precision cleaning the remainder.

A few large foreign electronics and metal fabricating firms account for a large share of total CFC-113 and MC use in Thailand. In 1991, a single Japanese company -- which manufactures miniature ball bearings, micromotors, and computer peripherals for export -- is estimated to have consumed roughly half of all ODS used as solvents (on an unweighted basis). The second largest ODS user in solvent cleaning is the leading US hard disk drive manufacturer. Thus far, the control effort in Thailand has been directed at those large foreign-owned firms. One component of that effort has been a tripartite agreement involving Thailand, Japan, and the United States. Under the non-binding agreement, Japanese and US electronics firms operating in Thailand are supposed to phase out their CFC use there on the same schedule as in their home countries.

Were the tripartite agreement to be implemented, it would initially reduce the demand for ODS in Thailand quite substantially. Whether that reduction is permanent, however, depends on the effectiveness of government's efforts to control growth in demand from other ODS users. In particular, Thailand

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[2]ODP = ozone depletion potential, which is a factor comparing a chemical's potency with respect to ozone destruction to that of CFC-11, which is assigned an ODP = 1. The estimated ODP of CFC-113 = 0.8 and that of MC = 0.1.

[3]On an unweighted basis, methyl chloroform consumption was more than twice as large as CFC-113 consumption in 1991.

has played host in recent years to a wave of foreign direct investment from countries in Asia other than Japan -- notably Hong Kong, Korea, Singapore and Taiwan. Many firms from those countries are in the electronics or related industries. They are not parties to the tripartite agreement and, depending on how rapidly their operations in Thailand grow, they could cause the consumption of ODS for solvent cleaning to continue to rise in the future. Moreover, there are a growing number of Thai electronics firms in the subcontracting and original equipment manufacturing (OEM) business whose ODS consumption is not governed by the tripartite agreement. Thus, the government needs to regulate the growth in their demand for ODS. It may also be necessary to offer certain of the Thai firms and the smaller foreign-invested firms financial assistance to undertake the conversion to ODS alternatives. The incremental costs of conversion should in theory be reimbursable from the Multilateral Fund established under the Montreal Protocol (MP) to facilitate ODS phase-out by Article 5 developing countries.

IV. Policies and Programmes for Addressing Electronics-Related Pollution Problems

The government of Thailand presently faces major environmental challenges on several fronts simultaneously. Given limited human, technical, and financial resources, it must establish clear priorities -- addressing the most urgent problems first. This requires some evaluation of relative environmental risks. A good example of the application of environmental risk assessment in Thailand is to be found in USAID (1990), which determined that lead exposure -- principally from the burning of leaded gasoline -- is among the most serious urban environmental problems in Thailand. Reduction in IQ levels of children raised in Bangkok was estimated to be a major social cost associated with high ambient lead levels. Soon after this study was published, the Thai government introduced measures to speed the phase-in of unleaded gasoline. Such assessments can thus be a powerful influence on government priorities and policy directions. Since the environmental picture is evolving very rapidly in Thailand with the growth of new industries and new types of environmental risk, it may be worthwhile to produce updated environmental risk assessments at fairly frequent intervals -- perhaps every 3-4 years.

A. Policy concerns

Thailand has a relatively well developed system of environmental regulations -- including both ambient and emission/effluent standards -- for the most critical pollutants and major sources. Nevertheless, environmental quality is evidently worsening along a number of dimensions. The major problem appears to lie in inadequate monitoring and enforcement. Thailand is not alone in this respect, but enforcement problems appear to be especially pronounced there. One difficulty is the strong competition for skilled labour coming from the rapidly expanding private sector, which has drawn many qualified people away from government service in recent years. This trend is difficult to remedy via a realignment of public/private sector pay scales since the necessary adjustments would place unacceptable strains on public finances. As an alternative, the government needs to devise policy measures which provide stronger incentives to polluters to self-police -- either individually or collectively, e.g., through industry associations -- or which open up profitable opportunities for independent environmental auditing firms to monitor and report on the environmental performance of industrial and other polluting enterprises. The National Environmental Quality Act of 1992 is a step in the right direction, but the provisions on third-party auditing remain to be tested in practice.

B. Investment requirements

The Thai government has begun to address the financing needs of firms wishing to undertake pollution control investments. The recently established Environment Fund (capitalised initially at around US$200 million) is one initiative. This fund should eventually be placed on a self-financing basis through its replenishment out of pollution charges. Another financing scheme is the environmental lending facility recently created by the semi-governmental Industrial Finance Corporation of Thailand (IFCT). This facility, which lends approximately US$8 million annually, has received supplementary funds of US$24 million in a loan from the Japanese Overseas Economic Co-operation Fund (OECF). Once loan repayments commence, presumably the IFCT facility will become self-financing. Special attention needs to be given to ensuring that financing is made available on favourable terms to small- and medium-scale enterprises, since they are the most likely to find pollution control investments difficult to afford otherwise. They may also need technical assistance in the selection of appropriate pollution control technologies; therefore, financing should be made available for the costs of hiring environmental consultants and not solely for the purchase of plant and equipment. Indeed, it may happen that an environmental consultant can recommend ways to achieve significant reductions in pollution loadings with only modest fixed investments -- e.g., through improvements in engineering and management practices.

C. Managerial and technical assistance

While firms may need financial and technical assistance to implement pollution reduction measures, the thrust of such assistance should be to encourage waste-reducing process improvements rather than merely 'end-of-pipe' treatment. The former have the potential of offering both economic gains for the individual enterprise and environmental gains for society.

One approach to strengthening plant-level environmental management would be to institute an industrial environmental audit programme (see USAID/Philippines, 1991). Firms that agree to participate in the programme could be eligible for low-interest loans to finance waste minimisation investments.

An environmental specialist familiar with the electronics industry would conduct an environmental audit, or pollution reduction appraisal, of each participating facility. First, the auditor would advise industrial managers on strategies to minimise waste and make use of by-products. Second, the auditor would advise on the installation of pollution control equipment to deal with residual pollution. Among the variables to be examined during the audit are: the reagents and other materials used in production, the manner in which they are handled, energy use, standard housekeeping practices, engineering controls, ventilation and exhaust systems, waste handling, treatment, and disposal. Records on levels of hazardous substances in waste water (pre- and post-treatment) and in air would be examined and compliance with existing operating permits and performance standards ascertained.

Following the audit, the auditor would submit to the firm as well as to the government a report containing its assessment of existing practice and a series of specific recommendations for improving environmental performance. The recommendations would focus on technically and financially feasible process changes, with an emphasis on those that can reduce material and energy requirements and waste generation. Where waste cannot be eliminated, consideration should be given to recovery and recycling. If the firm accepts the audit results and agrees to adopt the measures recommended, it would become eligible for financial assistance; the degree of conditionality of any loans would of course depend on the expected financial rate of return from any required investments. A follow-up audit could be conducted after one year. This would provide the basis for determining the effectiveness of the measures proposed both in environmental and in economic terms.

D. Common environmental infrastructure

There may be instances in which individual firms cannot under any circumstances afford their own pollution control facilities. Even if the equipment were given away free, the operating costs alone might be a sufficient deterrent to utilisation of waste treatment facilities. Firms with small turnovers are most likely to find in-house treatment facilities unaffordable. Under those conditions, it would be preferable if there were a common facility to provide waste treatment services to many firms with similar waste streams. This approach is already practiced in Thailand in the case of the Bang Khuntien hazardous waste treatment facility (see Siwabut, 1992). The construction of the facility was financed by the Department of Industrial Works (DIW), but its day-to-day operation has been contracted out to a private environmental management firm. It serves some 250 (mostly small) factories that generated collectively around 50,000 tonnes of toxic and hazardous waste in 1990. The principal industries served by the facility are electroplating and textile dyeing and the waste streams consist primarily of heavy metal-contaminated waste water and solid waste. Besides a range of physical-chemical treatment processes, the facility also has a controlled landfill for disposal of treated waste.

The government is planning construction of several more such treatment plants -- in Ratchaburi, Chonburi, Saraburi, and possibly Rayong. A critical issue facing the government and the managers of those facilities is how to devise a charge system that allows cost recovery while not encouraging illegal dumping.

Common facilities may also be needed for the recycling of certain waste products generated by industrial firms. In the case of the electronics industry, solvent recovery/recycling is one area which could benefit from such facilities. This is particularly important as the government seeks to encourage reduced consumption of chlorinated solvents that are controlled under the Montreal Protocol (MP). While CFC recycling is only an interim solution until all firms have been able to convert their operations to non-CFC using alternative technologies, it is important as a means of smoothing the transition for firms not yet able to afford investment in alternative cleaning systems. The price of virgin CFCs can be expected to rise as world production is phased out in the next few years; this should make CFC recycling economically more attractive. It may be that rising CFC prices will make recycling commercially viable, but if not then the government may need to offer a subsidy to encourage investment in common recycling facilities. An important consideration in the case of CFC-113 recycling is certification of the quality of the recycled product, since electronics firms generally require solvent of a very high degree of purity. Without guarantees of solvent quality, customers are unlikely to purchase the recycled product at any price.

V. The Role of International Organisations

The development of the electronics industry in Thailand is governed to a large degree by the decisions of multinational corporations, which still predominate. A few Thai firms have emerged in recent years as large subcontractors and original equipment manufacturers (OEMs) supplying the world market. One Thai-Japanese joint venture -- Thai CRT -- is manufacturing a major electronic component of televisions and computers. For the most part, these foreign-owned or Thai-foreign companies have access to advanced technologies and engineering know how which should make them perfectly capable of adopting state-of-the-art pollution control and waste treatment technologies with minimal government support. International corporate policy may in some cases dictate a common set of environmental standards worldwide, but many companies are inclined to tailor their practices to the environmental standards in the host country. This implies that the host country government's environmental policy regime, the stringency of its standards, and the rigour with which they are enforced are important influences on firm behaviour. There may be reason to expect that, on average, multinational firms are more likely to comply with environmental standards than local firms; this may be because they stand to lose more from being tagged environmental 'outlaws'. Still, if standards are too lax, even compliance will yield few environmental benefits.

A. General areas of technical and financial assistance

Locally owned firms pose the biggest policy challenge. Small and medium sized enterprises are most likely to find strict environmental standards burdensome and to need some assistance in complying with them. Government needs to mount a credible enforcement effort, but it is likely to be more effective if it can offer a 'carrot' along with the 'stick'. International organisations may be able to help government in devising policies and programmes which reduce the costs of adjustment to stricter environmental standards as well as providing technical assistance directly to those industrial enterprises which must make the necessary adjustments.

Information. Small and medium scale enterprises are likely to need help in tracking down information on pollution control technology options. Such technology information systems can probably be kept up-to-date most easily if they are managed by an industry association rather than by a government office. In the case of Thailand, the Federation of Thai Industries (FTI) has taken an interest in providing information and technical assistance to its members on pollution control options. Moreover, within FTI there are various 'clubs' organised along industry lines. It may be worth exploring whether there is an interest among 'electronics club' members in having such a 'clean technology' information system. The system need not be confined to that particular club's members, however, since certain of the control/treatment technologies are similar across industries. A clean technology information system could be established as an FTI-wide initiative. If a government counterpart agency is sought, either the Ministry of Science, Technology, and Environment (MOSTE) or the Ministry of Industry (MOI) could be approached.

Up-to-date information on the toxicological properties of new chemicals and materials used in Thailand's industrial sector is also critical. An environmental data base for use by Thai industry should also contain such information. With rapid industrial transformation, new and unfamiliar chemicals are appearing in Thailand continually. Firms need to be able to take adequate precautions not only to protect their personnel from exposure to toxics but also to control their release into the environment. It should be possible to access data bases on toxicological testing results from countries like the United States, Japan or the United Kingdom. Information on proper procedures for safe handling and disposal of various toxic chemicals is also needed. Technical assistance may be needed, however, both in identifying and in evaluating the relevant data bases; financial assistance may be needed to cover subscription (or acquisition) costs.

Consultancy. The new basic environmental law (NEQA/92) provides the mandate for initiating a third-party environmental monitoring/auditing programme. Technical and financial assistance from international organisations could help bolster that initiative. In the first place, an accreditation programme is needed to determine a firm's eligibility to act as an environmental auditor. Technical assistance could be useful in the development of such a programme. Staff training of the prospective environmental auditing firm may be one condition of accreditation, in which case foreign financial and technical assistance could directed at strengthening the training effort. The environmental auditors need not be limited in their responsibilities to monitoring and reporting pollution levels. They should also act as consultants to the firms they audit on how to improve their environmental performance cost effectively. Thus, technical assistance could be more broadly directed toward building up the expertise of local environmental consultants.

Foreign technical assistance should work, wherever possible through the existing institutional framework. In the case of training courses for environmental auditors, for example, it may be possible to utilise the staff and facilities of a centre like the Environmental Research and Training Centre (ERTC), which is operated by the Office of the National Environment Board under the auspices of the Ministry of Science, Technology and Environment (MOSTE) and which was established with foreign technical and financial assistance from the Government of Japan.

Financing. The Thai government has initiated in recent years a few financing schemes for environmental investments. These include the Environment Fund created with a budgetary contribution and the environmental facility of the Industrial Finance Corporation of Thailand (IFCT). In both cases, administrators of the funds cannot be expected at first to have the necessary expertise to evaluate effectively the feasibility of proposed investments in pollution control or cleaner process technologies. There is therefore a need to provide at least basic training to loan officers on environmental technology evaluation. As pollution control investments become more widespread, loans for that purpose are likely to become a more important part of the portfolios of other financial institutions as well. It may, therefore, be appropriate to consider offering short-courses on environmental loan evaluation for the interested personnel of financial institutions as a group -- perhaps in cooperation with a banking trade association.

Monitoring and enforcement. Even if third party environmental auditors should assume a greater role in Thailand's environmental management effort, there will still be need for government pollution inspectors -- or pollution control officers (PCOs) -- to monitor and enforce government regulations. Presently, the number of such personnel attached to the Department of Industrial Works (DIW) appears seriously inadequate to the task at hand -- especially in light of the rapid growth in the number of polluting enterprises in the last several years. While the government is trying to increase the number of PCOs -- especially in heavily polluted areas -- training is needed to prepare the new PCOs adequately for their responsibilities.

There may be scope, therefore, for foreign technical and financial assistance to strengthen the training effort for government pollution control officers. In accordance with efforts to decentralise the monitoring and enforcement effort, it is necessary to decentralise the training effort as well. Thus, it may be useful to consider a series of training workshops located in the major areas of concentration of polluting enterprises for the purpose of training local pollution control officers. Besides government officers, it may also be worthwhile to open the workshops to participants from local community organisations and non-governmental organisations (NGOs) who can provide valuable support in the monitoring and enforcement effort.

Training of private sector environmental managers. If industrial firms are expected to assume greater responsibility for pollution control, they need personnel knowledgeable about environmental management. For the ordinary small or medium sized enterprise it will not be possible to hire an environmental specialist, so general managers or production managers must be given the necessary training to perform environmental management functions. Training courses are already offered by the DIW for private sector managers/engineers on waste water treatment. This training effort could be extended perhaps to cover other areas like in-process waste minimisation and recycling and hazardous chemicals/waste management. Special efforts need to be made to reach personnel from small-scale enterprises, especially since such enterprises may find it difficult to spare managers' time.

B. Sector-specific technical and financial support

With regard to the electronics industry per se, there are a few types of technical assistance which could prove valuable. They are enumerated and briefly described.

Waste minimisation. A foreign technical assistance programme could be designed which has as its main purpose to provide technical assistance to small and medium scale electronics enterprises (SMEEs) for the purpose of reducing waste generation -- through process innovation and the installation of closed-loop recycling systems. The programme would involve only limited financing requirements, since the emphasis would be on assisting firms in making improvements that are both cost-saving and environment-saving. Improved engineering and management practices are likely to be central to the effort, with only small investments in plant and equipment required. Recovery of heavy metals and recycling of waste water as well as of industrial solvents would be priority areas for technical assistance. Foreign specialists may need to be hired initially for a few man-months to provide training to local consultants in industrial environmental auditing techniques, with specific reference to the electronics industry.

Sampling and evaluation of waste streams. For SMEEs to be able to manage properly their industrial wastes, they must have a way of sampling and analysing the composition of their waste streams. This requires equipment which not many small firms can afford and technical expertise which not many have. It is important, therefore, that they be able to avail of public or private laboratories for such evaluation at moderate cost. There are a few private laboratories serving the electronics and other industries in Thailand which have state-of-the-art equipment. In addition, there are laboratories at a few universities, and ERTC may also have the necessary equipment to conduct evaluation/analysis of waste streams. As a first step, it would be useful to conduct an inventory of existing environmental laboratory facilities in Thailand, their equipment and testing/analytical capabilities.

An arrangement could be made between the government and the relevant laboratory(ies) for the latter to perform contract analytical services on behalf of SMEEs, with the bulk of the costs to be covered by the government. The SMEEs would be expected initially to shoulder a part of the cost, since participation in the evaluation programme could yield certain benefits. If firms are found, for example, to have waste streams containing pollutant levels well within government standards, they could qualify for a refund (perhaps with a small incentive bonus). If they are in violation, the government would offer them the option of technical assistance and low-cost financing to bring them into compliance with standards. The alternative would be to pay a fine, in addition to which they would be expected to reduce their pollution loadings at their own expense. Those not agreeing to the 'voluntary monitoring/ evaluation' programme would still be subject to periodic monitoring by the Department of Industrial Works (DIW) and would face even stiffer penalties if found in violation of standards.

Common recycling facilities. A final area for possible international support is the examination of the economic and technical feasibility of establishing common recycling facilities for wastes generated by SMEEs. Already, as noted above, there is a common hazardous waste treatment facility in operation for electroplating and textile dyeing firms. Several more are in various stages of preparation. These facilities focus, however, on the removal of hazardous substances from waste water for safe disposal. Quantities of waste requiring safe disposal can be expected to continue to climb with industrial growth. With the increased difficulty of finding suitable hazardous (and other) waste disposal sites in many countries -- and with the environmental benefits to be realised from reduction in the volume of hazardous waste -- recovery and recycling of waste products needs to be given more careful study. In addition, in the electronics industry, there is the need for recycling of chlorinated solvents as a transitory measure until firms have phased out their use of such ozone depleting substances in accordance with the terms of the Montreal Protocol.

Just as with waste treatment facilities, recycling facilities may only be economical for SMEEs if they are provided in common for a sizeable number of firms -- though the number is likely to be smaller for the latter than for the former. The investment costs are generally lower for recycling than for waste treatment (depending on the level of treatment). For recycling, those costs include not only the equipment and technology needed for the separation and treatment of different components of the waste stream, but also instruments for the analysis of the recycled product. It is important useful to know under what conditions private firms would find it profitable to invest in the common recycling business. For example, it may be that they would undertake such investments only if assured of adequate means for quality certification of recycled materials/products. In that event, there may be justification for the government's subsidising the costs of such product evaluation. It would be worthwhile exploring whether existing laboratories in the public or private sector possess the capabilities to perform such analysis and certification on a contract basis. International technical assistance could be useful in assessing the economic feasibility of common recycling of certain wastes from the electronics industry and also perhaps in the actual establishment of a recycling facility.

C. Regional co-operation for electronics-related pollution control

Thailand's electronics industry is part of an increasingly integrated regional industrial structure. Many of the multinational subsidiaries operating in Thailand have other affiliates in the region. In addition, domestic firms supply networks of customers scattered among several countries. Naturally, within multinationals there is relatively free transfer of know how across national boundaries, whether for pollution control or other purposes. In the case of regional supplier networks, the scope for cross-border technology transfer is somewhat more limited. Yet, there are sizeable potential benefits to all countries in the region from a more widespread diffusion of waste reduction and cleaner production technologies.

The countries that comprise ASEAN (the Association of South-East Asian Nations) do make an effort at regional consultation on environmental issues, though each country remains free to set its own environmental standards. ASEAN could serve as a venue not necessarily for the harmonisation of standards across countries but at least for the formulation of guidelines for environmental good practice by electronics and other regionally-based industrial firms. It might also be useful to consider a regional programme of technical co-operation which would seek to encourage the exchange of information and know how on industrial pollution control among electronics firms (and perhaps also among other industrial firms). Such co-operation could be facilitated through the formation of an ASEAN-affiliated committee of electronics industry executives (with rotating membership) which would be responsible for proposing concrete programmes and projects to foster the widespread adoption of good environmental practices by the region's electronics industry. Should the concept work at the ASEAN level, it could be extended to the other sub-regions of Economic and Social Commission for Asia and the Pacific (ESCAP) and eventually perhaps to ESCAP as a whole.

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