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IT Pollution Problems in Asia*

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Throughout the world the fast-paced march of IT (Information technology) has made semiconductor manufacturers busy and changed the face of economies mainly in the US and Asia. It is safe to say that Asia is becoming a center of IT production. In a previous article, High-Tech Pollution (*Economic Journal of Hokkaido University*, Vol. 23, 1994), I demonstrated why we cannot overlook the IT industry's environmental impacts. The leaky underground organic solvent tanks of semiconductor plant in Silicon Valley ignited public concern over drinking water contamination, congenital anomalies, high spontaneous abortion rates, cancer, and other problems already in the 1980s. But this problem is no longer confined to Silicon Valley. The IT industry is expanding into Asia and bringing pollution with it. Taiwan's Hsinchu Science-based Industrial Park, one of the world's biggest IT bases, has contaminated surface water, soil-groundwater, and must deal with waste organic solvents. This article is an attempt to get a handle on the globally expanding IT industry and the environmental problems it causes by examining the overall process from the production, distribution, and consumption of IT products to their disposal in Asia.

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Key Words : IT Industries, Semiconductor Production, Water Pollution, Industrial Wastes, Environmental Economics

1. Asia as a Center of IT Production

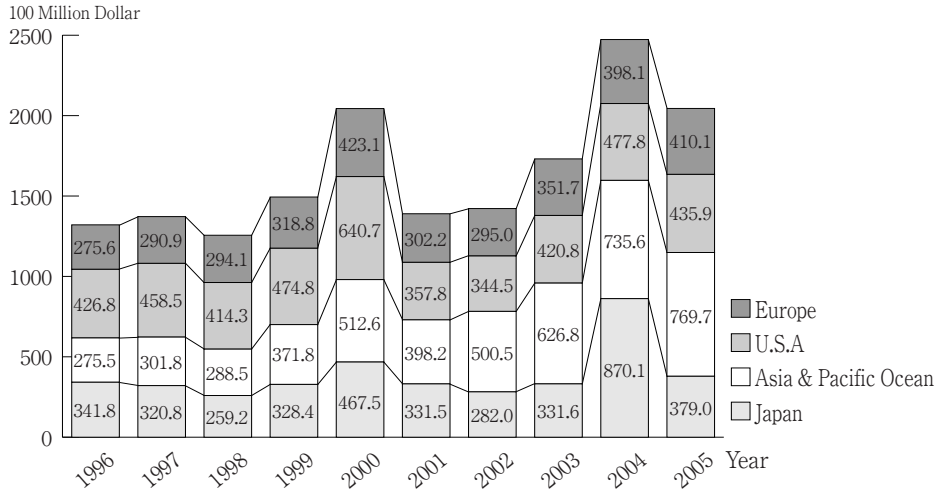
1.1 The Quickly Growing IT Industry

The rapidly growing use of personal computers, cellular telephones, and information-related consumer electronics sustains the high demand for semiconductors. Since 2000, demand for semiconductors has grown outside of computers to information-related consumer electronics (automobile navigation systems, digital cameras, games, portable terminals, DVD players, digital TVs, and video players). In particular Asia is increasingly becoming the world center for producing them.

*This article is partly based on the chapter 2 of my book *IT Pollution*, (in Japanese), Iwanami Shoten Publisher, Tokyo, 2001.

This is corroborated by the figures. In 1993 the Asia-Pacific semiconductor market, excluding Japan and the US, accounted for only 18% of the world market, but in 1998 it eclipsed Japan, and in 2000 it accounted for 25% ($ 51.3 billion), as opposed to Japan's 22% ($ 46.7 billion) (Fig. 1).

Figure 1 . Market Share of Semiconductor by Area



Achievements from 1996 to 2001, Estimates from 2002 to 2005

Source : WSTS

Semiconductor market sizes of Asian countries excluding Japan were, first, China including Hong Kong at $ 13.1 billion, Taiwan second at $ 12.2 billion, Singapore third at $ 10.7 billion, and South Korea fourth at $ 9.7 billion.

The Asia-Pacific is the world region with the fastest growing semiconductor market, and in the next two or three years it will approach the US market in size. In Taiwan, South Korea, Malaysia, Singapore, Thailand, and other places the high-tech IT industry has been rapidly expanding since 1990, and the engine of its growth has been exports, which became more competitive due to currency depreciation triggered by the 1997 currency crisis. South Korea's DRAM exports and Taiwan's foundry production, which will be discussed below, both increased, while Japanese and Western IT equipment makers produced more in Asia. And even within Asia itself, Taiwan, South Korea, and other more-developed countries and regions divided up manufacturing tasks by shifting production to less-developed ASEAN states and to mainland China.

1.2 Types of Semiconductor Production

Different manufacturers perform different types of semiconductor produc-

tion. First, manufacturers can be divided into "captive makers" such as IBM, which produce semiconductors in-house for their own electronic equipment, and "merchant makers" like Intel, which produce them mainly to sell. Some of Japan's general electronics manufacturers are captive makers while at the same time selling some of their products. In addition to marketing distinctions like these, other makers fall into the following categories.[1)]

(1) Integrated production and sales makers : Companies that do everything from semiconductor development, design, and manufacturing to sales. Many of Japan's semiconductor makers fall into this category. As general electronics makers, they produce electronics, while supplying semiconductors for their own products and also selling semiconductors to other companies.

(2) Fabless makers : Do not have their own production lines, but commission manufacturing to other companies, and sell the products under their own brand. Often found in the US and Taiwan.

(3) Semiconductor IP providers : Design chips and determine their specifications and standards, then license the functional blocks as semiconductor intellectual property (IP) mainly to semiconductor makers. Do not produce semiconductors themselves.

(4) Foundry makers : Companies that specialize in manufacturing (the front end). Formerly their main customers were the fabless makers, but recently they perform more production under commission from the integrated production makers. Taiwan's major semiconductor makers are this type.

(5) Subcontractors and test houses : These are the subcontractors that perform only back-end tasks (assembly), and the test houses whose only business is testing.

As semiconductor production tasks are further divided among makers, developments in the forms of production in Asia include the siting of manufacturing facilities throughout Asia by US and Japanese integrated makers, the specialization of semiconductor manufacturing into DRAMs as in South Korea, and manufacturing by foundry makers as in Taiwan. As the globalization of IT

1) *IC Guidebook* by the Japan Electronics and Information Technology Industries Association, 2000, pp. 29−30 (in Japanese).

production continues, a likely scenario will be, for example, that a semiconductor component is designed in Silicon Valley, produced in Taiwan (front end), assembled in Singapore (back end), and sold in Puerto Rico.

The share of IT-related products (personal computers, office equipment, communications equipment parts, and semiconductor electronic parts) in world trade has been growing by 10 to 20% annually in both imports and exports, except during the IT recession of 2001. IT-related goods in Asian trade constitute a force that rapidly increases Japan's IT imports and exports. But the IT industry's interdependence in Asia is a fragile arrangement. Because IT products are still heavily dependent on the US market, a decline in exports to the US would have immediate and easily felt repercussions in Asia.

1.3 Slow Times for Semiconductors in Japan

In the US, Intel and other companies are maintaining their advantageous position by specializing their semiconductor production in high-added-value CPUs (although memory goes for a few dollars, a CPU costs at least $ 100), while Taiwan, South Korea, and others are expanding their shares through low pricing. Meanwhile, Japan's semiconductor industry has been in the doldrums for a long time. Japan continues to let its share of the world market languish below 30%.

Why has this happened? While this matter is not this article's theme, I would like to consider it for a moment. The conclusion boils down to four points.

First, Japan has gotten behind in basic research on the changes in the physics and principles of semiconductor technology, such as those on the ultrafine and quantum levels.[2)]

Second, after the conclusion in 1980 of the VSLI Technology Research Consortium put together by industry with government support, there was a 15-year hiatus in national projects for semiconductor development.

Third, the lack of a clear apportionment of roles in industry-government-academia collaboration on semiconductor research and development has been an impediment to R&D.

And **fourth**, there are no strong specialized semiconductor makers because semiconductors are made by divisions of the general electrical makers, which did not establish their own strategic targets or make such investments.

By contrast, in the US the 1985 Young Report, whose purpose was to strengthen competitiveness, led the way to an apportionment of roles that resulted from a review and improvement of industry's relationship with science and technology. While the discovery and understanding of scientific principles

2) Fujimura, S., *The Semiconductor State Makes a Comeback*, (Handoutai－Rikkoku Hutatabi), 2000, Nikkan Kogyo Shimbun (in Japanese).

is mainly the province of universities, SEMATECH and other consortia perform research and development for devices in response to new principles, and venture businesses make the new devices. This is said to be one of the conditions underlying the revival of the US economy in the 1990s.

To one extent or another in the US, Europe, and Asia, academic and industry collaboration with national projects, and the cultivation of venture businesses were used to help the semiconductor industry. In Asia the industry has developed in various ways：[3)] （1） investment by big capital, like the *chaebol* of South Korea, （2） integrated small and medium enterprises as in Taiwan, and （3） transnational corporations, as in Malaysia and Singapore. But looking behind any of these reveals the presence of government assistance.

Japan felt at ease because of its past successes, and was slow to realize what was happening, and take appropriate action. Japan will not be able to extricate itself from this long stagnation without an integrated effort that includes a place in national strategy, basic research by universities and research institutes on new principles, research and development by consortia on devices that apply new principles, and companies including venture companies that develop new devices.

1.4 China Becomes the World's Factory

Plans for building new semiconductor front-end plant capacity included a total of 1.4 trillion yen for Japan in 2000 alone. Yet, by 2006 Taiwan will have 19 production lines for the most-advanced 300-mm wafers, which is the largest number of such lines in the world, although this may be delayed because of the US economic slowdown as mentioned previously （Table 1）.

Table 1. Semiconductor Facilities in Taiwan

	200-mm Wafers	300-mm Wafers
TSMC	6	7 （2）
UMC	5	5 （1）
POWERCHIP	1	2 （1）
PROMOS	1	2 （1）
NANYA	2	1
MACRONIX	2	1
WINBOND	2	1

Note : Figures in 300 mm column are the numbers of facilities planned to be running by 2006.
Numbers in parentheses are those facilities already running.
Source : *Nikkei Shimbun*, March 30, 2002.

3） John Mathews and Dong-Sung Cho, *Tiger Technology,* Cambridge U.P. , 2000.

Taiwanese companies are building new production centers in China, and attracting new component makers and assembly makers from other countries. Jiang Zemin's son started an enterprise with the son of a Taiwanese businessman, and they are planning to build a semiconductor plant in Shanghai. This is symbolic of a trend. Already 3,000 of Taiwan's 4,500 electronics manufacturers have in some way or another established a presence in China.

China produces more desktop computers than Japan and South Korea, and in Asia it now ranks second only to Taiwan. In cell phones China is third in Asia behind South Korea and Japan. In 2000 China eclipsed Taiwan in personal computer-related production and became third behind the US and Japan. At the present rate, over the next five to 10 years Chinese versions of Hsinchu Science-based Industrial Park will appear throughout China.

Japanese companies are likewise shifting production of advanced parts to China and other countries. Year-round 24/7 production is possible abroad, personnel costs are sometimes 1/20th those of Japan, and capital investment costs are likewise low. For these and other reasons, overseas production allows lower production costs and the rapid acceleration or slowing of production. At the same time, however, this can also mean worsened working conditions and weakened efforts for safety in workplaces. We need to inquire whether health damage and environmental deterioration are not behind the recent "price revolution."

2. Taiwan: The Hsinchu Science-based Industrial Park and Environmental Degradation

2.1 Foundry IT Production

Taiwan has eclipsed Japan in the production of notebook computers and is poised to become the world's biggest producer. Its growth is astounding. Notebook computer brands of the world's top 10 companies are all made either in Taiwan, or by Taiwanese companies in China.

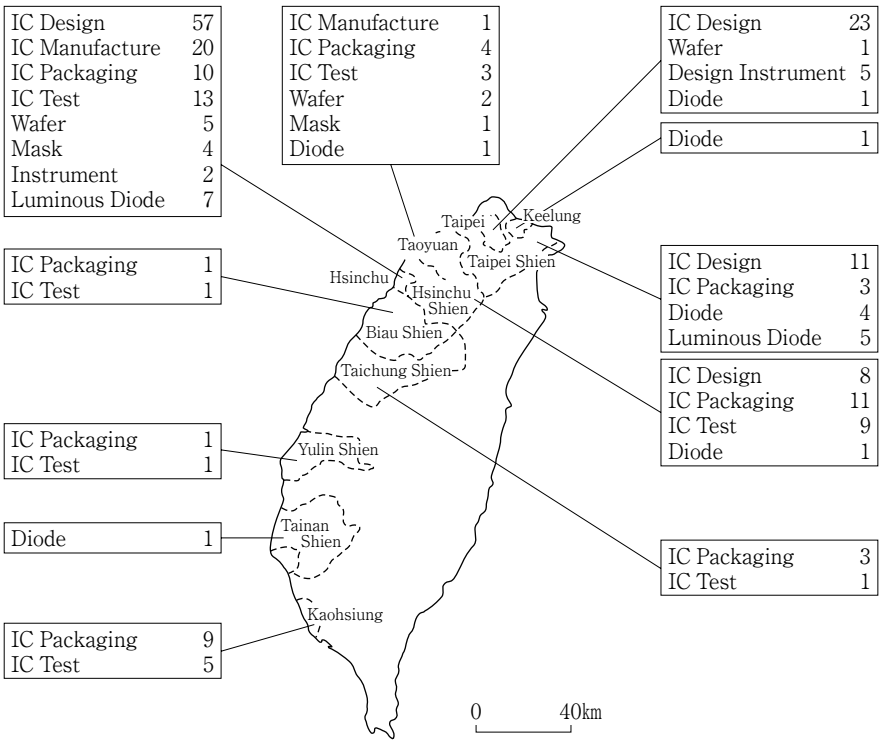
Taiwan's semiconductor industry got its start when engineers at Taiwan's government-run Industrial Technology Research Institute (ITRI) and Electronics Research & Service Organization (ERSO) began spinoff companies: UMC, which was founded in 1980, and a subsequently founded company called TSMC. Taiwan's government took advantage of its late entry into the world semiconductor industry and had the companies focus on subcontracted (foundry) work.

As explained in the previous section, foundry makers perform front-end processes under contracts from the fabless makers, which do not have their own production lines, and thus in general they do not design products. By specializing in foundry work, Taiwan got by without investing huge sums in semiconductor research and development. And because the cost of labor is 40% that

of Japan and 60% that of South Korea, Taiwan's production costs are overall 60% those of Japan and 80% those of South Korea. Currently almost 30,000 women in their 20s are working on wafer fabrication lines and performing other jobs.

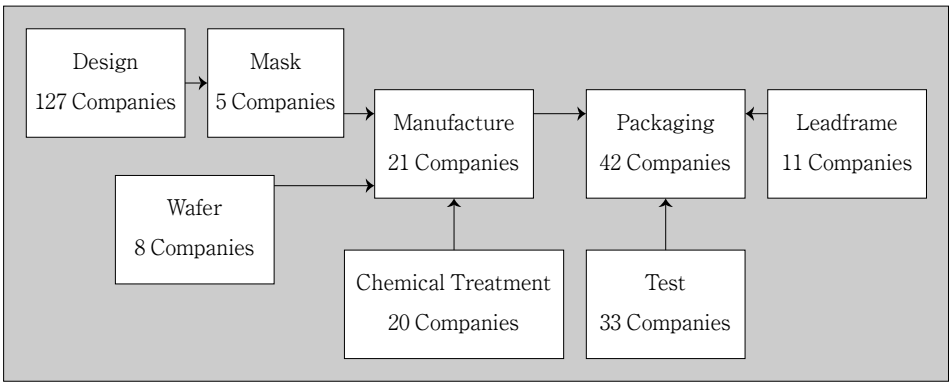
Sixteen Taiwanese companies are involved in semiconductor wafer manufacturing, while 140 companies perform design, and 34 companies were founded in the one-year period beginning in 1997 (Fig. 3).

Figure 2. Location of IC-Related Facilities in Taiwan



Source : Industial Technolgy Institute, *"2000 IC Industrial Yearbook"*

Figure 3. Number of Plants in Taiwan by Manufacturing Processes of IC



Source : *"2000 IC Industrial Yearbook"*

Reasons for the success of Taiwan's foundry industry include government tax breaks and technical support policy, under which companies got many highly capable engineers from Silicon Valley and other places, as well as having plenty of capital and affiliated small and medium enterprises.

Nevertheless, Taiwan's high-tech IT industry struggles under limitations : Because most of its raw materials are imported from Japan, the more semiconductors it exports, the more raw materials it must import from Japan, and the bigger its trade deficit with Japan. And although production in monetary terms is large, foundry production is liable to fluctuate, making for low earnings. Other problems arise from the distortion that is a concomitant of rapid growth, and from trying to bring down costs in a short time.

The semiconductor industry's environmental and safety problems discussed in this article are part and parcel of those limitations.

2.2 Hsinchu Science-based Industrial Park

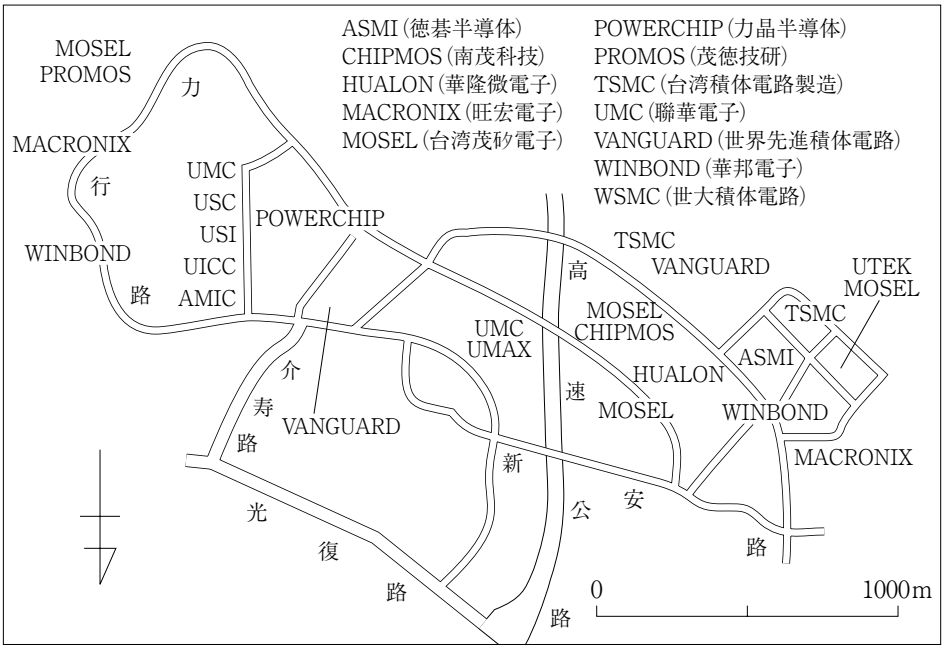
Going south from Taipei's international airport takes you past a string of semiconductor-related factories. There are so many that you might be fooled into thinking the expressway itself is a production line. The road takes you to the Hsinchu Science-based Industrial Park, a hilly area about 10 kilometers inland where Taiwan's high-tech IT industry is concentrated.

Taiwan's government founded this industrial park in 1980 to serve as an incubator for high-tech industries. At first the government leased land and buildings to manufacturers, and provided incentives to tenant companies such as tax cuts or exemptions, low-interest loans, and assistance for research and development. By 2000 about 300 companies had come to the 4,000-plus hectare area, where about 98,000 people worked (half were women). A labor force breakdown shows that the average age is 31, and that about 31% of the workers are junior high or high school graduates, 24% are junior college graduates, 21% are college graduates, 16% have master's degrees, and 1 % have Ph. D. degrees.[4)]

Taiwan's major semiconductor makers have located here. These companies include Taiwan's largest semiconductor foundry maker TSMC-Acer (6,000 employees ; recently integrated Acer's semiconductor division), which was founded in 1987, second-largest UMC (2,700 employees), and Taiwan's biggest brand maker Winbond (3,500 employees), as well as Mosel (1,400 employees), Macronix (2,600 employees), Vanguard (1,700 employees), and Powerchip Semiconductor (1,500 employees) (Fig. 4).

4) *Quarterly Statistics of Hsinchu Science-based Industrial Park.*

Figure 4 . Location of Hsinchu Science-Based Industrial Park



"Green Silicon Island" is the slogan of Taiwan's Democratic Progressive Party, led by Chen Shuibian. The intent is that an environmentally friendly semiconductor and IT industry is to be the centerpiece of Taiwan's industrial development, but Hsinchu Science-based Industrial Park itself, which was created under government policy, finds itself challenged by environmental problems.

2.3 Deteriorating Local Water Environment

First is environmental deterioration caused by effluent from the park's companies.

Local environmental NGOs claim Hsinchu's rivers, the coast, and local farmland, are polluted by the park's inadequate effluent treatment. Specifically, pollution damage affects irrigation water and water channels for park-area farmland, and oysters and other shellfish along the Hsinchu coast.[5] For a decade the park's water consumption increased 10-fold, and is currently about 95,000 tons daily. Each day the park generates 80 tons of sewage sludge, which is landfilled nearby.

A health study of the 250 people who live in the watershed that receives the park's effluent reported subjective symptoms including chemical odors,

5) Taiwan Environmental Action Network, *Environmental and Social Aspects of Taiwanese and U.S. Companies in Hsinchu Science-based Industrial Park*, 2001, Section 2.

sore eyes, nosebleeds, coughing, fatigue, headaches, and palpitation, while blood tests and urinalyses revealed that nearly half the subjects had anomalous values.[6] Further, an unofficial epidemiological study found a high cancer incidence rate among Hsinchu residents, but there has been no formal report yet.

2.4 Soil and Groundwater Contamination

Second is soil and groundwater contamination.

Although no data have been released, documents obtained by the author in 1999 describe the results of a soil analysis inside the park showing that five of 18 samples had 1 to 2 mg of tetrachloroethylene per kg of soil, values which are 10 to 20 times the standard in Japan.

Tests of groundwater quality detected vinylidene chloride in two of nine locations, both of which exceeded Taiwan's standard of 2 ppb. Also detected were trichloroethylene, 1, 1-dichloroethylene, and trichloromethane, with one trichloroethylene sample being three times higher than Japan's standard. For the most part this contamination is thought to be caused by organic solvent leaks from semiconductor plants.[7]

In an April 2000 incident, UMC's fifth silicon plant began experimental operations in Hsinchu City's drinking water source area without conducting an environmental impact assessment. The city revoked its license and suspended operations temporarily. Later there was an investigation by the public prosecutor's office on suspicion that the mayor had demanded a political contribution in return for canceling the suspension of operations.

2.5 Illegal Dumping of Waste Solvents

Taiwan generates about 1.6 million tons of hazardous industrial wastes

Table 2. Hazardous Industrial Wastes in Taiwan

Waste water	42%	(610,000 tons)
Sludge	27%	(400,000 tons)
Precipitator ash	8 %	(120,000 tons)
Metal	7 %	(100,000 tons)
Ash	4 %	(60,000 tons)
Others	12%	

Source: *Common Wealth Magazine*, September 1, 2000 (in Chinese).

6) *China Times*, Local edition, June 15, 2000 (in Chinese).

7) For more information, see *Annual Report of Environmental Protection Team of Hsinchu Science-based Industrial Park*, 2001 (in Chinese). [http://www.hsinchu.org.tw/2000rpt.html]

Table 3. Industries that Generate Hazardous Waste in Taiwan

Electronics	43%	(630,000 tons)
Chemical	31%	(450,000 tons)
Metal	14%	(200,000 tons)
Others	12%	

Source: *Commom Wealth Magagine*, September 1, 200 (in Chinese)

yearly, but it is believed that 60% of the wastes are not properly disposed, and the island therefore has serious and continuing problems with illegal dumping. About 42% of hazardous industrial wastes are liquids, and sludge accounts for 27%. The high-tech IT industry generates about 43% of hazardous industrial wastes (Tables 2 and 3).

In the second half of July 2000 a grave incident occurred. Waste organic solvents (toluene, ethyl benzene, and xylenes) were illegally dumped in a tributary of the Kaoping River, the source of water for the Kaohsiung area of southern Taiwan, whose population is about 3 million. There was no water supply for several days.

People from a waste management company called the Sheng-li Chemical Industries Company dumped the wastes. This company specializes in disposing waste liquids and solvents, and had contracts with nearly 400 companies throughout Taiwan, including the high-tech IT industry companies in Hsinchu Science-based Industrial Park. The persons who dumped the solvents had been dumping into rivers and ditches the waste organic solvents that Sheng-li could not process. In some cases, wastes were allowed to run into the sea through buried pipes.

Behind these unscrupulous dumping incidents is an inadequate manifest system that causes inaccurate reports on the amounts of hazardous wastes generated and on how they are managed. In this incident the presidents of the Eternal Chemical Company, which was the solvent producer, and of Sheng-li Chemical Industry Company were subsequently sentenced to life imprisonment.

With reference to the illegal dumping of waste organic solvents, Taiwan University's Professor Yu Youhua (environmental engineering) observes[8] that there are problems with the ISO certification system because Shen-li had been certified under the international environmental management standard ISO 14001. He also emphasizes that "this revealed the amount of waste solvents

8) *China Times*, July 21, 2000 (in Chinese).

generated by the high-tech industry."

What is more, the Dafa Industrial Park in Kaohsiung, southern Taiwan, had practiced the open burning of cables, IC circuit boards, and other industrial wastes. The park now has a rotary furnace incinerating facility, but many wastes are waiting for incineration.

2.6 Storage and Management of Waste Solvents[9)]

Shen-li Chemical Industry Company had been managing waste solvents from Hsinchu Science-based Industrial Park, but after it lost its license, the park had nowhere to send the approximately 1,500 tons of wastes (10,000 10-gallon drums) generated each month. Fees of the few remaining waste management companies jumped to over twice their former levels, and the biggest factor aggravating the situation is the park's lack of storage space.

Taiwan's Environmental Protection Administration (EPA), which is in charge of environmental administration, is considering several options for dealing with the situation: increase the amounts that other waste management companies are permitted to handle; screen and then incinerate nonhazardous solvents; use abandoned mineshafts as temporary storage facilities; and ask the Ministry of Defense Affairs (i.e., the military) to provide land for storage. Currently Hsinchu's one company temporarily stores the wastes, which are to be incinerated.

Still, EPA's position is that a fundamental solution makes it essential that generators of waste solvents must reduce and recycle wastes. In response to this situation, Taiwan is now formulating a National Industrial Waste Management Plan, which aims to properly manage all industrial wastes by the end of 2003.

2.7 New Taiwanese Legislation to Remediate Contaminated Soil and Groundwater

About 15% of Taiwan's population depends on groundwater for drinking water, and the rate of dependence is especially high in the south. The worst soil and groundwater contamination is considered to be that caused around Kaohsiung by the state-run China Petro and by pesticide plants, but soil and groundwater contamination by the high-tech IT industry is growing in seriousness. To deal with this, the Soil and Groundwater Pollution Remediation Act was enacted in February 2000.

Enactment of this law was directly triggered by whistle-blowing in 1994 by former workers at a subsidiary of the US-based RCA company, whose plant

9) *Environmental Protection News,* July 20, 2000 (in Chinese).

(closed in 1992) in Taoyuan County, northern Taiwan, manufactured appliances and electronic products such as televisions. This whistle-blowing revealed soil and groundwater contamination and occupational illnesses caused by organic solvents. RCA admitted its responsibility and in 1998 voluntarily performed soil remediation, but groundwater remediation is not yet complete.

The remediation law's initial bill placed emphasis on soil remediation, but discussion in the Legislative Yuan, Taiwan's parliament, extended the law to cover groundwater contamination as well. Let's take a brief look at how this law works.

The state of pollution is categorized at one of three stages based on monitoring by local authorities: (1) monitoring, (2) supervision, or (3) remediation. To begin with, when pollution at the source exceeds standards, the authorities designate the site a controlled area, and tell the polluter to monitor and control the area. When ownership changes hands, the owner must investigate soil contamination and remediate it.

When authorities determine there is a threat to public health and the environment, the site is designated a remediation area, and the polluter or the party associated with the site (user, custodian, or owner) must prepare a remediation plan. Depending on geological characteristics, the pollutants' characteristics, and other factors, standards may be made flexible. When the source of groundwater contamination is unknown and contamination exceeds standards, the authorities take action and later bill the polluter for remediation costs. The sale of remediated sites is prohibited. Revenue sources including a tax levied on certain chemical substances were used to create a fund that is used for remediation. Currently there are 138 monitoring wells, but this number is to be increased to 431 by 2006.

Of special note is that the system takes some ideas from the US Superfund law and is designed to allow flexible responses.

2.8 Fires at Semiconductor Plants

The third problem that Hsinchu Science-based Industrial Park causes for the community and environment is fires and susceptibility to disasters. Because the semiconductor industry makes intensive use of many chemicals, it needs special precautions against fires and earthquakes.

Recently fires have been especially prominent accidents at Taiwanese semiconductor plants. Below is a rundown of the major fires.[10)]

In October 1996 Winbond stopped production for several months at its new 8-inch fab plant because of a fire of unknown cause, resulting in a loss of be-

10) Brian Sherin, "Comparative Risk Management for IC Fabs," in *Solid State Technology,* February 1998.

tween $ 80million to $ 100 million.

In September 1997 a semiconductor plant of the Singapore-based Chartered Semiconductor had a fire caused by an excess flow of silane gas into a combustion furnace. In the same month a fire occurred at an 8 -inch wafer plant of United Integrated Circuits Corporation (UICC), a joint-venture fab facility of United Microelectronics Corp. and US-based United Semiconductor Corp. The fire broke out in a clean room, completely destroyed production equipment, and took 36 hours to extinguish. UICC's plant was closed until 1999 and suffered damage estimated at $ 470million. That following January a fire at the 4 -inch fab plant of a smaller Hsinchu-based company, Advanced Microelectronics, caused $ 66 million in damage.

In January 1998 two fires were caused at the UICC wafer plant by sparks in a pipeline.

These examples should be sufficient to illustrate that fires causing expensive damage occur quite frequently. The main cause of semiconductor fab plant fires is thought to be the many chemicals used, which are also the cause of odor complaints from people living near plants.

Taiwan's largest semiconductor maker TSMC just happened to conduct an evacuation drill during my visit to the Hsinchu park. Young women plant workers attired in white bunny suits filed out of the plant as I watched. Apparently such drills are commonplace. It was striking to see them moving in an orderly manner while carrying large banners.

But what kind of disaster-prevention measures have administrative authorities developed ? Hsinchu Science-based Industrial Park has a staff of only five disaster-prevention specialists, and many park facilities lack proper firefighting equipment. What's more, Hsinchu City's fire department has only 80 members, who are charged with protecting 500, 000 people. One of the world's largest concentrations of industrial production has dedicated surprisingly small resources to disaster prevention.

In Taiwan the creation of a pollutant release and transfer register (PRTR) and an environmental information disclosure system is still not on the agenda, showing that safety is unfortunately not an area of prime concern. Although the government proclaims the slogan "Green Silicon Island," it is afraid of worsening its image by releasing data.[11)]

2.9 Repercussions of the Central Taiwan Earthquake

The major September 1999 earthquake in central Taiwan killed or injured 10, 000 people, caused serious damage to Taiwan's semiconductor industry, and

11) Jiin-Chyuan John Luo et al., Lung Function and General Illness Symptoms in a Semiconductor Manufacturing Facility, *Journal of Occupational and Environmental Medicine*, Vol. 40, No. 10, pp. 895−900, 1998.

had a grave impact on world personal computer production, which is closely linked to that industry. While the earthquake showed the importance of Hsinchu Science-based Industrial Park to the world, it also evinced the park's various disaster-prevention and safety problems.

Hsinchu Park is about 120km from the earthquake's epicenter, and so was spared the worst that could happen in semiconductor fabrication : the collapse of clean rooms. Nevertheless, it took nearly a month to resume full-scale production. Semiconductor products outsourced by the US and Japan to Taiwan contain the logic circuits at the heart of personal computers and communications equipment, which makes it hard to find substitutes. And because inventories were low, this interruption in production had serious impacts. Losses are estimated at over 10 billion yen.

There is a geological fault near Hsinchu Park, and while the earthquake brought increased business for Japanese construction companies to perform seismic resistance diagnoses and design earthquake-resistant buildings, this indicates how cheaply and quickly existing plants were built. Here is the secret of why Taiwanese foundry makers can deliver at low cost.

A related infrastructure problem is that of the power supply grid. Because most of Taiwan's power plants are concentrated in the south, power supply to the north was limited by damage to the grid in the island's central region. Although power to Hsinchu Park was given priority and recovered in a few days, this problem exposed the weakness of having high-tech industrial parks concentrated in the north.

To make up for the oversiting of high-tech industrial parks in the north, Taiwan is building a new park called "Tainan Science-based Industrial Park," and it may very well build on the Chinese mainland, too. In fact, conditions for investment are deteriorating in Taiwan owing to continued high land prices, shortages of power and water, and other infrastructural deficiencies, reviews of incentives, and other factors.

High-tech IT companies in the Hsinchu Science-based Industrial Park lack adequate disaster-prevention, safety, and environmental arrangements suitable for one of the world's highest concentrations of industry. In particular it must quickly enhance measures to deal with chemical contaminants in effluent, soil, and groundwater, and also improve disaster-prevention and safety measures. Such are the lessons of the 1999 earthquake, and the path that Taiwan should take to truly become "Green Silicon Island."

3. South Korea : Tapwater Contamination by Dosan Electronics

3.1 South Korea Specializes in DRAMs

A characteristic of South Korea's semiconductor industry is that it has

specialized in exporting different kinds of dynamic random access memory (DRAM) for each business group, or *chaebol*.

South Korea's semiconductor industry got its start with transistor assembly instead of developing from small-scale to large-scale integrated circuits as the industries in Japan and the West did. After quickly accelerating its development as a less-developed country, South Korea's government and private sector worked together beginning in the 1980s to achieve large-scale integrated production of DRAMs. This type of memory is very amenable to mass production and enjoys a huge market and fast growth because it is used in many kinds of electronic products. Such qualities are well suited to the character of South Korea's industry, whose strong suit is mass production of a few products. South Korea already has the world's largest share of the DRAM market. This is why South Korea is known for DRAM production, as Taiwan is known for foundry production.

The reasons for South Korea's semiconductor success are that it concentrates on the previous-generation memory type, emphasizes the Asian market, and conducts competitive and concentrated investment separately for each chaebol. South Korean manufacturers also scouted Korean engineers in the US, set up locally incorporated subsidiaries and gathered information in Silicon Valley, and brought in technology through means such as OEM partnerships, while at the same time developing channels to build its technology by means of technical help from Japan. As a result, South Korea moved to fill the market that had been partially opened because Japanese exports to the US had been limited by the US-Japan Semiconductor Agreement.[12)]

But because the chaebol had gone deeply into debt for their competitive investments in DRAM semiconductors, they were dragged into price decreases in the world market starting in 1995, and in 1997 they were buffeted by the Asian currency crisis. This situation is now forcing South Korea's semiconductor industry to reorganize. Samsung Electronics, the biggest, reorganized or divested of 72 departments in its expanded businesses, and had to dismiss 40% of its employees. Samsung now plans to revive itself with digital consumer electronics and communications (IT). And because LG Philips LCD sold its semiconductor stock to Hynix Semiconductor (Hyundai Electronics), which is South Korea's second-largest semiconductor company, that country's semiconductor industry is nearly dominated by just the two companies of Samsung and Hynix Semiconductor.

As a result of its restructuring, the earnings of Samsung alone at the end of 2000 were about 6 trillion won, or about 70% of the earnings of all South Ko-

12) Joe, J., *Corporate Strategy and Industrial Development*, Hakuto Shobo, 1995 (in Japanese).

rea's companies.

While South Korea's semiconductor industry exports 90% of its entire production, it depends on imports for about 70% of domestic semiconductor demand. Because the domestic industry has specialized in DRAM production, it must depend on imports for semiconductor parts other than DRAMs.[13] Further, South Korea supplies 45% of its semiconductor raw materials, and 25% of its own equipment, which means that it relies on Japan for most of its raw materials and equipment. The more memory it exports, the more raw materials and equipment it must import.

South Korea's high-tech IT industry, including semiconductors, is a key industry that accounts for about 20% of manufacturing output and about 30% of exports. Many of the companies are small and medium-sized, and are located in places such as the Panwol National Industrial Park (Ansan City, about 500 companies) near Seoul, Shihwan National Industrial Park (Shihwan City, about 800 companies), and, in the south, Kumi Industrial Park (Kumi City, about 150 companies).

South Korea's high-tech IT industry is dependent on technology from Japan and on copying Japanese technology, while Southeast Asia and China are quickly closing in from behind. At the same time, environmental problems are getting more attention because of, for example, restrictions on the use of CFCs.

3.2 Contamination of Taegu City Tapwater

The connections between South Korea's semiconductor industry and environmental problems are still not fully understood. The only well-known incident is the phenol contamination of the public water supply in Taegu, South Korea's third-largest city, by Dosan Electronics in March 1991. This company, a member of the Dosan Group, has a monopoly in South Korea in the production of laminated circuit boards and printed circuit boards.

At that time Taegu got 90% of its public water supply from the Naktongan River, South Korea's longest. Dosan Electronics was located in the industrial park at Kumi City on the upper reaches of the river. Taegu Metropolitan City's Korean-language report, *Ninety Years of Waterworks in Taegu City* (1993, p. 187) includes this passage about industrial effluent from Kumi Industrial Park.

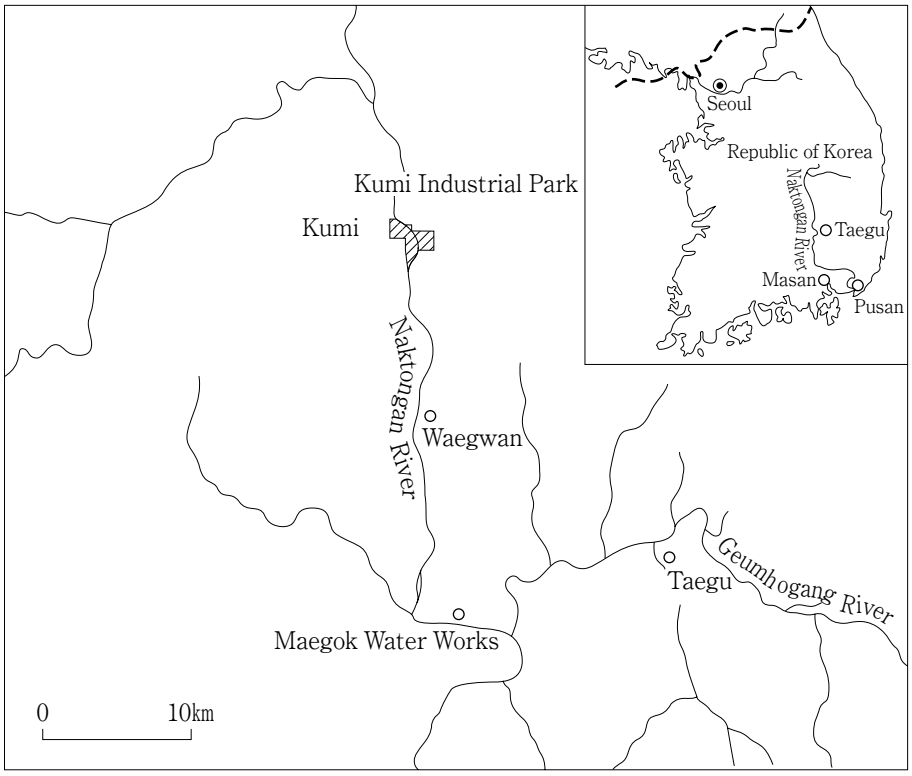
"Before full-blown work on the industrial park, the raw water for the public water supply was class 1, and so clean that people living by the river used it for drinking water... In the early 1970s when Kumi Industrial Park was built, PR communications promised that the park would emit no toxic effluents. It

13) L. Kim, *Imitation to Innovation*, Harvard Business School Press, 1997.

was thought that a little industrial effluent would be easily remediated by the river's self-purification mechanism, but that was a big miscalculation."

That miscalculation developed into a serious matter of public concern. On the night of March 14, 1991 Dosan Electronics' phenol concentrate storage tank burst due to an unknown cause, instantly liberating about 30 tons of the concentrate, which flowed into a Naktongan River tributary via sewerage. The phenol reacted with the chlorine used as a tapwater disinfectant and produced chlorophenol, whose strong odor caused panic among nearly 2 million Taegu residents. (Fig. 5)

Figure 5 . Kumi, Taegu, and the Naktongan River Watershed



Source : Tamio Hattori "Korea-Accident of Water Pollution at Taegu"

People complained that tapwater was undrinkable, and that rice and kimchi smelled. Pregnant women were having abortions because they feared health damage to their unborn children. An investigation found that administrative authorities had dealt poorly with the situation and that institutional provisions for environmental protection were weak. As these facts came to light the citizen backlash grew stronger, and the situation became a political issue that was aggravated by another phenol concentrate spill in April. The di-

rector of the Environment Agency took responsibility and resigned, and there were consumer boycotts on Dosan Group products such as beer and cola.

The owner and chairman of the Dosan chaebol was forced to resign, and Dosan was required to pay huge compensation of over 100 million yen each to the city and citizens, including compensation to 28 women who had gotten abortions.

3.3 The Accident

Dosan Electronics was located in the Kumi City national industrial park, which was planned in the 1970s during the Park Chung Hee government to attract the electronics industry, which people perceived as causing little air and water pollution. Construction on the park's common effluent treatment facility began after the park was opened, and was still under construction when the accident happened.

This accident raised the Korean people's environmental consciousness, and served as an occasion that made the government adopt new environmental policies, especially for measures to protect water quality. Even the Dosan Group changed its stance to one of positive environmental action.

Ten years after the accident the author had an opportunity to visit the scene of the accident, which had brought about major changes in Taegu City's water utility. Dependence on the Naktongan River had dropped from 90% to 70%, and the utility had installed advanced water treatment equipment using ozone and activated carbon. Management of water quality in the Naktongan River watershed had been beefed up. I visited a very modern tapwater purification facility in which the utility had invested much money. As the administrative authorities' responsibility had been severely called into question 10 years before, the water intake had an emergency warning device to detect the presence of chemicals in the water, and the facility was strictly guarded. Additionally, because Kumi Industrial Park's common effluent treatment facility was operating, factory effluent treatment was basically no longer a problem.

3.4 Soil and Groundwater Contamination in South Korea

South Korea's *Environmental White Paper* says that although ground water use has begun to increase recently, as yet only about one-fourth of available groundwater is being used. Yet a 1998 nationwide groundwater quality survey showed that 8 % of the country's groundwater is polluted over the standards. Especially in the most polluted areas, the standards were exceeded by 10% in industrial parks, waste landfills, and places with many storage tanks, leading to concerns about spreading pollution.

Of the 15 water quality survey items, there were many locations that ex-

ceeded the standard for nitrate nitrogen, especially waste landfill sites and blackwater treatment plants. This pollution is the result of percolation into the ground of graywater, livestock effluent, and other pollutants. Behind this comes pollution by metal cleaners and other substances, while trichloroethylene exceeded the standard at industrial parks.

As far as one can see from the *Environmental White Paper*, even though South Korea's high-tech IT industry is central to the country's export industry and considered the most important sector, its environmental impacts are not clear. The only well-known incident is the contamination of drinking water by phenol, described above. My own visit to Kumi Industrial Park showed that the factories of semiconductor and electronics companies such as Samsung, Hynix, and LG-Philips LCD are crammed into a park that is not very big, and local government administrators say that no special measures are taken within the park to deal with chemicals or groundwater contamination. Companies are concerned mainly with price competition and restructuring, and they fear that if data on worker safety were released, they would be used in labor disputes.

South Korea's environmental administration and institutional arrangements for protecting water quality made big progress because of the phenol accident 10 years ago. Nevertheless, insufficient efforts have been made to manage the chemicals characteristically used by the high-tech IT industry, or to control soil and groundwater contamination. Dealing with these problems is unavoidable if South Korea is to build its economy on IT.

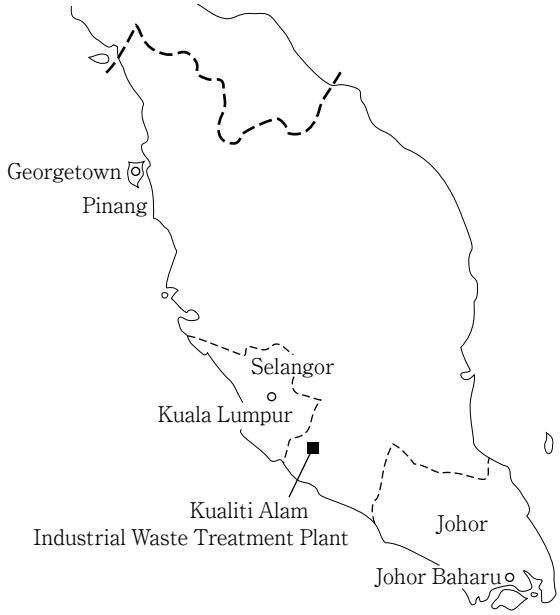
4. Malaysia : Overdue Action on Wastes

4. 1 A "Silicon Valley" by Transnational Corporations

In the second half of the 1980s Malaysia relaxed its conditions for letting foreign capital into exporting industries and encouraged foreign-capital companies to locate in Malaysia, and in particular gave preferential treatment to the high-tech industry. Prime Minister Mahathir saw Pinang and Peninsular Malaysia as "Malaysia's Silicon Valley," and brought in foreign high-tech companies with cutting-edge technology. Malaysia is a major exporter whose value of exports nearly equals its GDP, and electronics products account for over half of that.

Malaysia's electronics industry is found in three peninsular states : on the west side in Pinang state, and the state of Selanagor, which includes the capital, Kuala Lumpur, and the southern state of Johor (Fig. 6).

Figure 6 . Three Concentrated Wards of IT Industries in Malaysia



Rapid industrial development in these areas recently has maintained a continuing seller's market for labor. Factory laborers' wages have increased fourfold in 20 years, and there is a high job-switching rate. Malaysia must do something to compete against China, which is approaching fast from behind.

As of 1997 Malaysia had 31 semiconductor companies (mainly back-end), whose breakdown is 10 US companies, nine Japanese, five European, and four Malaysian, making the ratio of foreign-capital companies very high. These companies' semiconductor production is mainly back-end, i.e., assembly, which means low added value.

A major challenge for the current Seventh Plan is bringing in electronic component design and development work, and wafer fab plants. Malaysia wants to set up a total, integrated production system that includes front-end processes, and to build an advanced system like that of Taiwan. The first step toward realizing this plan was taken in March 2001 when Malaysia's first front-end semiconductor maker, First Silicon, began production in Sarawak with technology provided by Sharp.

4.2 Centralized Treatment Plant for Hazardous Wastes

But industrial wastes constitute a major obstacle for Malaysia in its quest to bring in front-end work and conduct integrated production. This is because the country at present cannot provide final disposal for its growing amount of "specified industrial wastes" (hazardous wastes), a problem that is crimping

its industrial development.

In 1989 a series of regulations and orders in Malaysia required that specified industrial wastes be disposed at final disposal sites, but not a single such facility was created until 1997. Companies that wanted to manage their wastes according to the law had no choice but to store their specified industrial wastes at their factories for nearly 10 years.

Although a final disposal facility was finally completed in 1997 (by Denmark-based Kualiti Alam Sdn. Bhd. in the state of Negeri Sembilan; it began full operation in June 1998), it is still the only one in the country. And because its disposal fee is rather high, illegal dumping continues unabated, and the press often carries reports on it. For example, in May 1999 a Japanese metal surface treatment agent company illegally dumped specified industrial wastes containing heavy metals on its own grounds. A court ordered the company pay a fine and dispose of all the involved wastes by taking them to Kualiti Alam.[14)]

Over the decade until 1997 many Japanese companies exceeded the limit of specified industrial wastes they could store at their factories, and it was common to see large numbers of waste-containing barrels in vacant areas of their grounds. Some companies disposed of wastes by exporting them to the US or Japan for the ostensible purpose of recovering valuable metals, but this is restricted by the Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal. This has induced some companies to reduce the weight of their wastes by installing sludge dryers or innovating to reduce the amounts of wastes generated.

Malaysia's standards for industrial wastes and factory effluent are more stringent than those of Japan. Because industrial parks lack centralized effluent treatment facilities, each company must treat its own effluent.

In relation to the semiconductor industry, Malaysia currently has no specific standards on organochlorines or soil contamination, but as noted previously, it will probably create regulations with the increase in integrated production, including front-end processes.

Malaysia's industrial waste policy has gained a proactive aspect by creating a series of regulations and orders in parallel with its policy, implemented in the latter half of the 1980s, for building the high-tech industry, but its shortcoming has been that construction of physical facilities has not kept up, and that has restricted industrial development. Yet, businesses have to deal with wastes because of the stringent regulations. If environmental regulations are complied with, Japanese companies that came to Malaysia to achieve low costs

14) Global/Human Environment Forum, *Environmental Countermeasures of Japanese Affiliates* (*Malaysia*), 2000 (in Japanese).

will naturally have to pay the associated costs.

5. Conclusion : Asia's IT Industry and the Environment

The foregoing discussion shows that as the IT industry expands throughout Asia, it brings a host of environmental problems that arise from IT production. Because each Asian country or region is at a different stage of development, environmental problems too differ according to the place.

In Taiwan, which has a concentration of advanced semiconductor industry companies, pollution and disaster have already occurred at Hsinchu Science-based Industrial Park in forms including the deterioration of the water environment, contamination of soil and groundwater, fires, and earthquakes. Immediate action is needed to beef up measures to address soil and groundwater contamination, and measures for disaster prevention and safety.

South Korea, whose IT industry is specialized in DRAM production, has made considerable progress in its environmental administration and its program for preserving water quality as a result of what it learned from the phenol spill of 10 years ago, but efforts are still wanting in the safe management of chemicals unique to the high-tech IT industry and in addressing soil and groundwater contamination. Taiwan and South Korea must clear these hurdles if they are really going to base their economies on IT.

Although progress has been made on regulating waste disposal in Malaysia, which has many semiconductor back-end plants, this country's small number of waste management facilities could hamper the development of its semiconductor industry.

Thailand still has no semiconductor industry, and its high-tech industry is strongly characterized by IT assembly subcontracted from Japan, South Korea, and Taiwan. Many Japanese companies have located there because of the cheap labor, but Thailand's overdue action on worker safety and health and on waste management is creating risks for businesses. The undisposed industrial wastes accumulating on plant grounds is symbolic of this. Problems in these countries are indicative of the behind-the-scenes reality of globalized IT production.

There is a positive side to the price deflation of recent years because it affords an opportunity to reevaluate the irrationality of production and distribution to date. Yet because of ever more severe competition, companies try to make products as cheaply and as quickly as possible by skimping on labor costs and the needed equipment, which results in health and environmental damage. Consumers in Japan should give more thought to this problem.

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