HIGH-TECH POLLUTION IN ASIAN

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ABSTRACT

Technically advanced "high-tech" industries, such as semiconductor manufacturing and IT, have helped lead Japan's and Asian's economy over the past two decades and have been widely credited with helping Japan and Asian countries move toward an environmentally more benign industrial structure. Despite their clean image and their undisputed low emissions of conventionally monitored pollutants, such as sulfur dioxide into the air or heavy metals into surface waters, it has been clear since the late 1980s that high-tech industries themselves have caused serious pollution, especially of groundwater, by organic chemical compounds such as trichloroethylene. The purpose of this paper is to present representative known cases of pollution caused by high-tech industries and to refer to some problems in the clean-up system.

Key words: high-tech pollution, groundwater contamination, trichloroethylene, Hinschu, Taiwan, toxics waste

1 WHAT IS HIGH-TECH POLLUTION?

What are the features of high-technology (here, I focus mainly on the electronics industry and its associates) that relate to these new environmental problems?
1. First of all, "clean" means only "without dust", and the object is to keep "clean" the materials and parts used for making semiconductors. But the "cleanness" of its operatives and the environment which surrounds semiconductor factories is another thing.
2. Apart from the apparent waste of water, the waste of gases, the industrial waste and garbage which until now have been the focus of environmental concern, leakages from "storage" tanks of used solvents is another major cause of pollution.
3. Besides rivers and the air, therefore, groundwater plays an important role as a route for pollution.
4. The semiconductor industry uses many sorts of toxic chemicals, gases & radioactive rays, which have, even in a very small quantity, the potential of causing complex chemical pollution.
5. Because high-technology changes very fast and secrecy prevails in this field, corresponding environmental protection tends not to be forestalled.

2 THE SEMICONDUCTOR PRODUCTION PROCESS AND ENVIRONMENTAL PROBLEMS

When I analyze the environmental aspects of semiconductor production processes, two problems come to the fore: 1, why do manufacturers use so many sorts of chemicals and

gases, including toxic gas? ; 2, is it possible to make the production of semiconductors safer?

Many of the processes used in semiconductor fabrication involve chemical reactions for micro-processing and multi-layering. These reactions include plasma reactions and ion implantation, where ion and plasma coexist and the free radical of high chemical activity generates itself.

Microelectronic device fabrication used to involve the use of photoresist chemicals before biologic scientists and physicians began to learn about their toxicity. The toxicity of the plastic monomers is usually much greater than that of the finished polymers. For example, vinyl chloride monomers are much more toxic than polyvinyl chloride. Little is known of the toxicologic properties of the photo-active components.

The microscopic precision necessary for producing IC depends on several processes which utilize radio frequency and microwave radiation as well as x rays. Some investigators have wondered about the relative harmfulness of radio frequency radiation of this kind. The severe competition between semiconductor companies stimulates new processes before related technology has been developed to monitor them. Hazardous materials are often used simply because they were the first to be employed in the research laboratory.

3 ECONOMIC ASPECTS OF HIGH TECH POLLUTION

Needless to say, the competitive development of high-technology is a capitalist business activity, and the environmental problems caused by high-tech development therefore have an economic background. In my Book *The Economics of Environment and Technology* (Tokyo, Aoki Shoten Publisher, 1980), I have analyzed the relationship between business activities and environmental problems. My main conclusion were these;

1. Because of the pursuit of profit and 'cost-down' by businesses, savings on environmental protection apparatus causes environmental disruption.
2. Severe competition for new brands & chemical developments within a limited time by big companies forces them to omit the installation of safety checks of new products.
3. Therefore, it becomes a matter of urgency to devise systems to control & monitor artificially created synthetic chemicals.
4. Making use of "free natural reserves" such as groundwater leads to the ruthless exploitation of natural resources.
5. Business companies, under social pressure to attend to environmental protection, try to recover profits by pursuing 'cost-down' by recycling & reduction of waste.

I would like to analyze high-tech pollution with relation to these factors.

First. Formerly, environmental questions used to deal with drains, exhaust gases, industrial waste, garbage, and so on. Recent focus on high-tech pollution shows, however, that leakage from underground solvent tanks has caused groundwater pollution. This phenomenon will not have happened by accident. Why are there so many leakages from plants? The problem seems to be that many underground tanks are made of fiberglass, which is susceptible to chemical corrosion and will crack under uneven ground pressure. In Silicon Valley, today, double containment and strict monitoring are implemented. It is therefore clear that cost savings on safety management such as pressure testing and waste

treatment caused the leakages from underground tanks.

Second. New production methods, storage methods, the usage of many sorts of chemical can cause environmental problems. New high-tech products are developed one after another, and their production processes are constantly being changed. Chemicals used for these processes are also developed under conditions of "trade secrecy". These conditions necessitate a safety check system for new chemical products and the gathering and disclosure of data at the level of government & companies. Furthermore, the usage and storage of chemicals remains a problem. As I have already said, some chemical manufacturers who have newly entered into the business of semiconductor fabrication try to break into the market without equipping their factories with sufficient safety apparatuses, in an effort to keep down prices; this arises from a desire to reduce safety control costs in that industry. Small-scale business and captive manufacturers have not enough financial means to carry out "safety training" procedures.

Third. High tech pollution abuses groundwater by pumping up vast amounts of water and contaminating the groundwater which remains in the ground. Since underground microbes dissolve and absorb pollutants, groundwater has formerly been regarded as safe, and the protection of groundwater was regarded as a secondary subject. However, the pollution of groundwater draws attention to the importance of groundwater as a drinking water resource. The protection of the quality of groundwater as well as its quantity becomes urgent. One Japanese semiconductor plant uses on average 2.7 million gallons of water per day. This is because the industrial costs for groundwater are lower than those for surface water. However, because of the location of plants and the agreements for environmental protection made between plants and cities, some plants do not use groundwater (for example, Iwate-Toshiba Electronics, Iwate Pref.) and other plants adopt "closed systems" of drainage (for example, Japan Foundry, Tateyama, Chiba Pref.). Today, some plants are trying to recover organic solvents and CFCs as well as drainage. Under the pressure of regulations, citizens' movements and local agreements, semiconductor plants are trying to save materials & water with "closed systems".

Fourth. Problems are caused by those who try to "shuffle off" the duty of waste disposal. These problems are 1, soil & groundwater contamination created by drum recyclers; 2, groundwater pollution caused by leakage from the sewage drains of a special "recycle" trader of organic solvent; 3, pollution of landfill site by a "disposal" trader. While high tech companies may keep themselves clean, this could be because they transfer their duty to treat and dispose of waste to others, and this may, in turn, cause pollution beyond the boundaries of the high tech industries. This practice is the result of trying to avoid paying for the cost of environmental protection. We have also to monitor and regulate this sort of practice.

4 REPRESENTATIVE HIGH-TECH POLLUTION IN JAPAN

4.1 Case 1: Taishi City: where it was discovered

Taishi City, Hyogo Prefecture, is where groundwater pollution caused by a semiconductor plant was first discovered in Japan in 1984. A wide area of groundwater, including some that is the source of tap water supply for the city, was contaminated by trichloroethylene.

The suspected source was the Toshiba Taishi Plant, where trichloroethylene was used to clean cathode ray tubes.

Excavation of the contaminated soil was interrupted by the groundwater at a depth of 7m. Trichloroethylene concentrations measured about 8000 parts per billion (ppb) in the deep wells-more than 200 times the standard of 30ppb. The problems are caused when trichloroethylene has been stored deep underground (more than 7m) for a long time. The even more toxic *cis*-1,2-dichloroethylene was detected in nearby wells. Serious problems with cleanup were created by the long-term residence of trichloroethylene in the soil; early remediation through soil removal would have limited the damage.

After discovering the contamination in the wells, the affected area was aerated and treated with activated carbon. The water supply was converted from private wells to tap water, although some contaminated wells are being still used for bathing. Although the Toshiba Taishi Plant refused to take official responsibility for the pollution, it made a "donation" to cover the costs of converting from private wells to tap water.

4.2 Case 2: Kimitsu City: a pioneer in cleanup

In 1988 it was revealed that the groundwater near the Toshiba Components Plant in Kimitsu City, Chiba Prefecture, was polluted by organic compounds. This plant, which produces semi-conductors and employs about 500 workers, used trichloroethylene as an organic solvent to clean the silicon chips. Neither the central government nor the local government had carried out a systematic investigation of the trichloroethylene problem at this site, so the initiative rested by default with Kimitsu City and the Chiba Geological Environment Research Laboratory. By boring in 34 places, they mapped the aquifer and delineated seven highly polluted "hot spots." They then developed a new cleanup technology to address the problem.

First, waste substances and contaminated soil were removed and then subjected to heating and air drying treatment. Second, a shield of steel-tubing sheet pile was installed to create a barrier well system. Third, to remove the contaminated substances, the cleanup operation sought to pump, aerate, and use the water of public wells. The total cost of the investigation and the cleanup operation has so far amounted to less than 1.2 billion yen, of which only 50 million yen has been supplied by the city.

The Kimitsu groundwater pollution case gave impetus to an amendment of the Water Pollution Control Law in 1989 and had a great influence on handling high-tech pollution all over Japan. The relation of cause and effect of high-tech pollution was disclosed for the first time in this case, and the cleanup technology developed by Kimitsu came to be known widely in Japan.

4.3 Case 3: Yamagata Prefecture industrial park pollution

Both Kyushu in Japan's south and the Tohoku (northeast) district are scenic with abundant water; but they are economically lagging, with a ready supply of relatively low-wage labor. These two factors, combined with accommodative local governments, make it attractive to locate high-tech industries there. Many semiconductor manufacturing plants have been built in the Tohoku district. The government of Yamagata Prefecture developed the Omori Industrial Park, where 16 companies have located, including a number of high-tech manufacturing factories, A local government survey in 1992 detected trichloroethylene near the industrial park in concentrations as high as 2000ppb.

The five plants that used trichloroethylene as an organic solvent were the suspected

sources: Yamagata Casio, Higashine Shin Dengen, Yamagata Sanken, Yamagata Fujitsu, and Yamagata Kinseki. With a total workforce exceeding 3000, these plants have a large impact on the local economy. Although the local government has already confirmed contamination of soil strata at the sites of three of these business establishments, it has not yet revealed how the contamination was caused or to what extent corrections have been made.

4.4 Case 4: Takefu City: chrysanthemums and high-tech pollution

Takefu City in Fukui Prefecture is famous for its "chrysanthemums and high-tech." A 1989 survey by the local government detected groundwater pollution from trichloroethylene in the city. At first the source of the pollution was not identified, as there was no plant in the area that used trichloroethylene. Professor Tsugo of the Fukui Industrial Vocational High School, who investigated at least 200 wells, suspected that the pollution source might be a large ceramic condenser manufacturer, the Fukui Murata Plant (2600 workers), located upstream of the groundwater. The pollution had spread nearly to the tap water source of a neighboring city.

When, at the behest of the prefecture, the Fukui Murata Plant did borings at 25 sites on its grounds, it detected trichloroethylene in all of them. Professor Tsugo's investigations revealed that the plant had been careless in the way it stored trichloroethylene, and that it had even spread the chemical as a herbicide.

4.5 Case 5: Yokaichi: the worst case

The outskirts of Yokaichi City in Shiga Prefecture are thought to be the most extensive area (40km^2) in Japan affected by trichloroethylene pollution, with a point maximum of 1770ppb within the city proper. Nine plants using trichloroethylene are located in the most heavily polluted district, near the Meishin Yokaichi interchange, along the Nagoya-Kobe transportation route. As Shiga Prefecture found it difficult to identify the specific sources of pollution, it gave "administrative guidance" (legally non-binding instructions) to the plants on how to reduce the seepage of organic solvents into the soil and groundwater.

Although a group of plants near the interchange of the Meishin expressway are the primary suspects as a pollution source, Dr. Kunihiro Yamada has proposed that the Yokaichi branch of Murata might be the primary source, as the factory seems to have been a major user of the organic solvent. According to a survey by Shiga Prefecture in 1994, trichloroethylene was detected in 15 of 20 locations at above-standard levels, with particularly elevated concentrations in six places. Because the sources of the pollution have not been removed, even in the most seriously affected area the problem has yet to be fundamentally addressed.

4.6 Case 6: Hadano City: Japan's superfund

Hadano City, with 160,000 residents, is located at the foot of the Tanzawa Mountains in Kanagawa Prefecture. Most of its tap water, (now nearly 65 % of it), has been supplied by groundwater since the city set up a water supply company in 1890. Since the discovery of groundwater pollution in 1989, the city has installed aerators in four places in its water distribution system.

Hadano's industrial park, where many business establishments continue to use chlorinated chemical substances, is located directly over the center of the city's groundwater recharge

basin, spreading pollution over an area of 12km^2, In 1992 it was reported that 60-m deep wells were polluted by trichloroethylene (95-866ppb) and tetrachloroethylene (19-143ppb).

The local authority conducted a basic survey of 63 companies, occasionally using test borings, from 1991 to 1994. In response, 44 of the 63 companies undertook detailed investigations at their own expense and subsequently initiated cleanup activities on their own. Approximately 9 tons of organic solvents were obtained from 22 companies, including two drycleaners.

Hadano has established a Groundwater Use Cooperative Fund System for the preservation of groundwater and has taken the opportunity to check groundwater pollution. It has led the country in enforcing the Groundwater Contamination Control Cleanup Ordinance, also known as the "Japanese Superfund," established in 1993.

4.7 Case 7: Fukushima and Tochigi: pollution at all levels

Generally speaking, high-tech products are made up of many parts that are manufactured by widely dispersed sub-contractors. Many of these firms appear to be polluting the groundwater outside the big cities throughout Japan and in much of the rest of Asia. Within Japan, evidence comes from Fukushima Prefecture, where sub-contractors of precision machinery for optical lens production have been the object of a groundwater cleanup enforcement operation covering 36 cases. In addition, tetrachloroethylene leaks into the groundwater appear to have occurred at the large (1500 workers) Canon Fukushima plant.

Tochigi Prefecture offers additional examples. The groundwater of Tochigi City and Tsuga Town is partially contaminated by trichloroethylene, and the same chemical was detected at concentrations up to 4400ppb in a drain from a ditch running alongside the Electrolysis Condenser Company. In 1990 trichloroethylene was detected in groundwater at Kanuma, also in Tochigi, whose local product, Kanuma Soil, is prized for gardening use. According to an investigation by the prefecture, the relatively small Canon Kanuma Plant (220 workers), located upstream of the aquifer, was identified as the suspected pollution source.

The plant used 240 tons of tetrachloroethylene per year as an undiluted solvent for grinding lenses for copy machines and cameras. The used solvent was stored in six underground waste liquid tanks and was collected by an industrial waste disposal business. Leaks from both the cleaner waste liquid tank and the distillation reprocessing apparatus seem to be a cause of the pollution.

4.8 Summary of High-tech Pollution in Japan

The above cases illustrate the worrisome levels of pollution from high-tech plants. including subcontractors, that has spread throughout Japan. Of special concern is that most of the known groundwater pollution incidents have not yet been made public. One reason for this is that local authorities have responded to the pollution cases in different ways. Some are active in identifying polluters and enforcing cleanups, whereas others are reluctant to explore or reveal pollution sources. These differences may be due to a number of factors, including the nature of relations between authorities and the relevant enterprises, variations in the degree of public dependence on groundwater, and local legal provisions exemplified by groundwater pollution control ordinances.

It will be crucial in the future to proceed with groundwater cleanups according to the amended Water Pollution Control Law (amended in 1996), although enforcement is likely

to be costly and difficult. Some enterprises refuse to admit responsibility for pollution officially but pay some of the cleanup expenses as a "contribution." Although some local authorities have raised funds to provide companies with loans for cleanup, this money is derived from public funds, in violation of the polluter-pays principle. It is indispensable to make clear the cleanup responsibility of an enterprise identified as a pollution source. It is also vital that information regarding pollution sources and purification measures be made available to the public.

5 HIGH-TECH POLLUTION IN TAIWAN

5.1 Hinschu Science Park, Taiwan and High-Tech Pollution

Now Taiwan is becoming the biggest in producing laptop PC of the world as the foundry manufacturing. There are about 20 fabs in Hinschu Science Park, Taiwan; for example, TSMC, UMC, Winbond, Mosel Vitelic, Macronix, Vanguard, Power Chip etc.
However, Hinschu Science Park has serious contaminated sites by organic solvents: soil contamination of tetrachloroethylene 5 of 18 samples were 1-2 mg/kg (10-20 times of the Japanese standard) in 1999. Also groundwater contamination of trichloroethylene is detected over the standard.

5.2 River Pollution by dumped wasted solvents

On July 14, 2000, a major source of drinking water for Kaohsiung area suffered hazardous waste contamination when treatment firm illegally dumped waste solvents into the Chi-Shan River in southern Taiwan. The EPA of Taiwan reported that the contamination impacted the operations of three water treatment plants in the area. The EPA has determined that the waste solvents originated from the Eternal Chemical Company and were illegally dumped by the Sheng-Li Chemical Company. Sheng-Li was one of Taiwan's only legal waste solvent treatment firms. The EPA reported that every year Taiwan produces 52,315 tons of hazardous spent solvents including those from high-tech fabs. With Sheng-Li operations shut down, pressure on the island's treatment will rise dramatically.

5.3 Soil and Groundwater Pollution Remediation Act Passes

On January 13th, 2000, a full meeting of the Legislative Yuan, Taiwan completed the second and third reading of the Soil and Groundwater Pollution Remediation Act, officially bringing the new Act into law. The Legislature confirmed that the new Act will fully address groundwater pollution remediation, and established a system where soil and groundwater pollution sites will be divided into two categories. When levels of soil or groundwater pollution exceed set control standards, the site will be listed as a "control site", and the competent authority will be charged with taking steps to prevent further spread of pollution. Control sites assessed to be high risk will then be listed as "remedial sites", and the polluter or person involved with the land must remediate the site in accordance with regulations. Sales of the polluter or involved person's land will also be prohibited.

5.4 Too many semiconductor fab accidents in Hinschu,Taiwan

There happened too many semiconductor fab accidents in Hinschu, Taiwan. According to an article by Brain Sherin, "Comprehensive risk management for IC fabs",(Solid State Technology, Feb,1998):
In October 1996, fire of unknown origin at Winbond's new 8-inch wafer fab facility in Taiwan. Total damage estimated between US$80-100 million and production delays for several months.
In September 1997, fire from excessive silane flowing into burn box at Chartered Semiconductor Manufacturing in Taiwan closed fab for one day.
In October 1997, fire(cause not released) at United Integrated Circuit Corps (UICC) 8-inch wafer fab facility in Taiwan, completely destroying the plant's production equipment. Fire quickly spread to the clean-room and took 36 hours to completely extinguish. Fab shut down until at least 1999, could cost company more than $470 million.
In November 1997, fire at Advanced Microelectronic Products, Inc. four-inch wafer fab in Taiwan. Damage costs initially at $66 million, but may have been adjusted down to $10 million.
In 1998, second fire at UICC wafer fab may have been caused by sparks in a pipeline under the fab.
Safety facilities at Hinschu have many problems:

Apparent lack of infrastructure to deal with emergency situations.

Hinschu industrial park has five people on staff.

Private emergency response do not have equipment and adequate training and do not coordinate activities with the fire department.

Many of the facilities at the Hinschu Park lack adequate fire protection.

City fire department is not equipped or trained in hazardous materials response.

Has 80 members to protect a population of 500,000.

Because of heavy city congestion, response times are also slow.

5.5 Occupational Health Problems of Semiconductor Factory in Taiwan

Recently the occupational health problems at semiconductor fab have attracted much attention.
A Study was done by researchers of Chang Gung Medical College, Taiwan("Lung function and general illness symptoms in a semiconductor manufacturing facility," *Journal of Occupational & Environmental Medicine*, Vol.40(10) 1998 Oct.).
The study is part of a clinical survey conducted on 926 workers in a semiconductor plant in Taiwan in July 1995. The study items included a standard self-administered questionaire, chest x ray, pulmonary function tests, and physical examination in 249 workers. This study suggests that restrictive lung abnormality is a potential health effect in male silicon-wafer fabrication workers in the semiconductor industry. The tasks of male process, maintenance, and equipment engineers put them at risk for intermittent short-term peak exposure. This may account for a higher prevalence of mild restrictive lung abnormality among male engineers of photolithographic and ionimplantation sections.

Conclusion: To Forestall High-Tech Pollution

When I look at a high-tech plant operation from the backyard, I see that high-tech facilities use and store many sorts of toxic chemical and gas in on-site storage tanks and

cylinders. This is my impression during field research of high tech pollution in Japan and USA.

When I visit such places, I notice that many sorts of high-tech pollution have occurred and agreements for environmental protection between cities and semiconductor plants have been drawn up. We have to pay attention to what they express in common, rather than their variety.

First. An uncontrolled "High-Tech Industry" is an essentially dangerous process. We should note, too, that factories which manufacture watches, commutator and electric automobile parts, which at first sight are not related to high-technology, sometimes fabricate semiconductors and therefore use organic solvents and toxic chemicals. If local government and citizens plan to attract factories, it is indispensable to know what they manufacture and how the plant will be used. Needless to say, it is not only necessary for the local government to draw up an agreement for environmental protection, but also for the agreement to include specific regulations regarding toxic chemicals. In cases where "regional development policy" aims to attract factories, local government and the citizens tend to be submissive. Now that, as a last resort to vitalize local economies, high-tech industry is welcomed from all quarters, this need becomes ever more urgent.

Second. Groundwater pollution and the disposal of toxic chemicals have reached an emergency level. In Japan, despite the continuation of groundwater contamination, the analysis of causes and routes is too protracted. In the USA, before the clean up begins, much time and money is spent on the research into the causes and routes of pollution. If the investigation is inadequate, pollution will only grow worse, and the delay in taking action will cause even greater damage and even higher costs.

Japan has many legal problems to sort out. In Japan there are only 11 substances which are regarded as harmful to human health (CN, R-Hg, Or-P, Cd, Pb, Cr, As, Hg, PCB, Trichloroethylene, Tetrachloroethylene). Even the Basel Convention on the control of transboundary movement of hazardous waste and their disposal designated only 47 substances. On the other hand, in the USA, SARA has listed 406 hazardous substances (1988), while CERCLA listed 721 hazardous substances (1988). Japanese regulations on waste disposal in the sea are also inadequate. Nor are regulations on organic solvents and CFCs anything like strict enough. If we fail to control each chemical until "accumulation" in the environment has been confirmed, or if we say that the suspicion that a product is "carcinogenic" is not sufficient reason to regulate its use, we are, in fact, approving "experiments on the human body" on a very large-scale. It is high time for us to remember the lessons we ought to have learned from the Minamata Disease.

Third. Information about chemicals used as materials or industrial commodities should be collected, centralized and disclosed to the public. Citizens are anxious about what is done at factories and how it is done. Yet as businesses themselves are so nervous about "high-tech", they try to keep the details "secret", which is common sense in a ruthless business world. In this respect, the US legal system and the citizens' movement of the "Right-to-know" offer a model. At the same time, the government should change its policy that "data about chemicals are the property of the companies". This is necessary because the use of these chemicals mostly affects the public. It is a matter of urgency to set up legal systems that control the whole process of manufacturing, circulation and disposal of industrial chemicals.

Last. To cope with high-tech pollution, local governments should have a right to "watch" and should strengthen citizens' involvement. Although "high-tech" is somehow difficult to understand, local government and citizens should nevertheless analyze and reconsider the policy of attracting companies, to forestall high-tech pollution. In some cases, local governments tend to blanket all environmental information, because the partial release of information would only make citizens uneasy. Yet, if the citizens come to know of the situation later, their anxiety and confusion will be much greater. Early feedback from citizens would be helpful for the taking of initial all round measures.

Because of the endemic problems of trade friction, the safety standards fixed for commodities imposed by each country have been criticized as forming a non-tariff-barrier. Because of the competition between countries, information about chemicals tends to be kept secret and investment on safety is thus saved. Confrontation between nations then tends to be stirred up. It is high time that we should move beyond national borders and the restrictions imposed by individual companies, and that all the citizens of the world should be able to exchange information, especially where it concerns safety and health.