HIGH-TECH POLLUTION PROBLEMS
-- SILICON VALLEY AND JAPAN--

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Introduction

The semiconductor industry has become the leading sector in the information revolution, because chips are the basic building blocks with which the industries of the future will be developed. It is generally assumed without careful consideration that high-tech industries are clean, as opposed to the smokestack industries of the past. Since the production of chips requires extremely high standards of decontamination, pollution by that industry seems to be a farfetched worry. But recently the high-tech pollution problems of California's Silicon Valley have been reported in detail in Japan.

Meanwhile, several high-tech pollution-related accidents and incidents of ground water contamination have occurred in Japan. In this paper, I would like to analyze the issue of pollution by the semiconductor industry in Silicon Valley and in Japan. Through a comparative study, we may hope to reach a better understanding of the relationship between high-technology and environmental problems.

I. *High-Tech Pollution in Silicon Valley*

There are about 400 electronics companies inSunnyvale and more than 300 in Santa Clara. Six years ago, there was little fear for the quality of the Valley's tap water,half of which comes from wells. But in 1980 IBM,reported a leak of trichloroethane (TCA) from an underground tank in San Jose. Then in December 1981, Fairchild Camera and Instrument reported that it had lost a significant amount of TCA, and a week later,large amounts of TCA showed up in a Great Oaks Water Company well 200 feet away. The well contained water that was 5600 ppb TCA,28 times the maximum recommended contaminant level set by the EPA.

According to the fact sheet printed by Silicon Valley Toxics Coalition, the extent of the problem is as follows:

*80% of high risk underground solvent tanks have leaked.

*About 100 toxic chemicals have been detected in the ground water.

*The March 19, 1985 Staff report to the San Jose city council estimates that only 10% of the potential underground leaks have been discovered.

*For most of the chemicals detected, there exist no health-based drinking water standards.

*23 public wells and 43 private wells in Santa Clara county have been contaminated so far.

*25% of the public wells in the state have been found to contain toxic chemical contamination.

*Santa Clara county now has 19 EPA Superfund sites, more than any other county in the country.

*The State Health Department has reported birth defects and miscarriages as 2.5 times above normal.

*The semiconductor industry reports more than 3 times as many industrial illnesses than are found in California manufacturing industries as a whole.

*Of 140 current cases of soil and ground water contamination, only

-5% of hazardous soil removal;

-1% of ground water containment;

-0% of ground water cleanup completed;

[See Map 1. Toxic Chemical Leaks and Spills in Silicon Valley] Firms have spent $50 to $70 million on cleanup so far, but these efforts are likely to continue to be necessary far into the future.

Map 1. MAP KEY
Santa Clara County Spill Sites May, 1985

PALO ALTO:
1 Hewlett Packard, 395 Page Mill
2 Hewlett Packard, 640 Page Mill
*3 Hewlett Packard, 1501 Page Mill
4 Hewlett Packard, Deer Creek Rd.
5 Lockheed, 3170 Porter
6 Beckman Instruments, 1117 California Ave.
7 Watkins Johnson, 3333 Hillview
8 Fairchild Camera & Instrument, 4001 Miranda
9 Aydin Energy Division, 3180 Hanover
10 Stanford Cleaners, 2875 El Camino Real
MOUNTAIN VIEW:
*11 Teledyne, 1300 Terre Belle
12 Moffett Naval Air Station
*13 Fairchild Camera & Instrument, Ellis x Whisman
14 Siltec, 423 National Ave.
*15 Raytheon, 350 Ellis
16 NEC Electronics, 501 Ellis
*17 Intel Corp., 365 Middlefield
18 Hewlett Packard, 333 Logue
SUNNYVALE:
19 Memotronix, 1058 N. Evelyn
20 Circo, 940 Hamlin Ct.
21 Applied Technology, 645 Almanor
22 Exar-Integrated, 750 Palomar
23 Ampex, 814 San Aleso
24 Verbatim, 323 Soquel Way
25 Xidex, 305 Soquel Way
26 Zymos, 477 N. Mathilda
27 Data General, 433 N. Mathilda
28 Signetics, 730 Evelyn
*29 Westinghouse, Hendy Ave.
30 Bell Industries, 1161 N. Fair Oaks
31 AMD, 901 De Guigne Ave.
*32 AMD, 915 De Guigne Ave.
*33 Signetics, 811 E. Arques
34 Signetics, 305 Mathilda Ave.
35 Signetics, 976 E. Arques
36 Signetics, 897 Stewart
37 Signetics, 848 Stewart
38 Signetics, 830 Stewart
39 TRW Microwave, 825 Stewart
*40 Monolithic Memories, Inc., 1165 E. Arques
41 Amdahl, 1205 E. Arques
42 Inprint, 968 Stewart
43 Advanced LSI, 1195 E. Arques
44 UTC, 1050 E. Argues
45 Signetics, 740 Kifer
46 Signetics, 860 Kifer
47 KTI, 1170 Sonora Ct.
48 Intersil, 1276 Hammerwood Ave.
49 Precision Media, 1262 Lawrence Station Rd.
CUPERTINO:
50 Zilog-Bridge, 10440 Bubb
51 Tandem Computer, 19333 Vallco Parkway
52 Siemens Corp.-Litronix, 19000 Homestead
53 Hewlett Packard
54 Intersil, 10900 N. Tantau
SANTA CLARA:
*55 National Semiconductor, 2900 Semiconductor Way
56 Zycon Corp., 2981 Copper Rd.
57 Dysan Corp., 5200 Patrick Henry Drive
58 Dysan Corp., 5301 Patrick Henry Drive
59 Dysan Corp., 5440 Patrick Henry Drive

60 Monolithic Memories, Inc., 2175 Mission College Drive
61 Signetics, 3625 Petersen Way
62 Signetics, 3600 Tannery Way
63 Synertek, 3050 Coronado Blvd.
64 Synertek, 3001 Stender Way
65 Spectra Physics, 2905 Stender Way
*66 Intel Corp., 3000 Oakmead Village Rd.
*67 Intel Corp., 2880 Northwestern Parkway
*68 Applied Materials, 3050 Bowers
69 Avantek, 3175 Bowers
70 Santa Clara Circuits, 2539 Scott Blvd.
71 Magnetic Peripherals, 3333 Scott Blvd.
72 Sperry-Univac, 3375 Scott Blvd.
73 Fairchild Camera & Instrument, 3105 Alfred Drive
*74 Precision Monolithics, 1500 Space Park Drive
75 Technical Coatings, 1000 Walsh Ave.
76 Monsanto, 2710 Lafayette St.
77 A-1 Chemnetics, 2655 Lafayette St.
78 SAE Hong Kong Ltd., 350 Martin Ave.
79 Pacific Nursery Pots, 1015 Martin Ave.
80 Memorex, 1200 Memorex Drive
81 Container Corp. of America, 2500 De la Cruz Blvd.
81a Gilmore Supply, 585 Roberts
81b Western Forge & Flange, 780 Reed St.
81c Safety Kleen, 3461 Woodward Ave.
82 American Microsystems, 3800 Homestead Rd.

MILPITAS:

83 Pierce and Stevens Chemical Co., 805 Sinclair Frontage Rd.
84 Great Western Chemical Company, 941 Ames Ave.
85 Ford Motor Co., 110 S. Main St.
86 Ford Motor Co., N. Capitol Ave.
87 Jones Chemical Co., 985 Montague Expwy.
88 LSI Logic, 1601 Mc Carthy
89 Harris Microwave, 1530 Mc Carthy

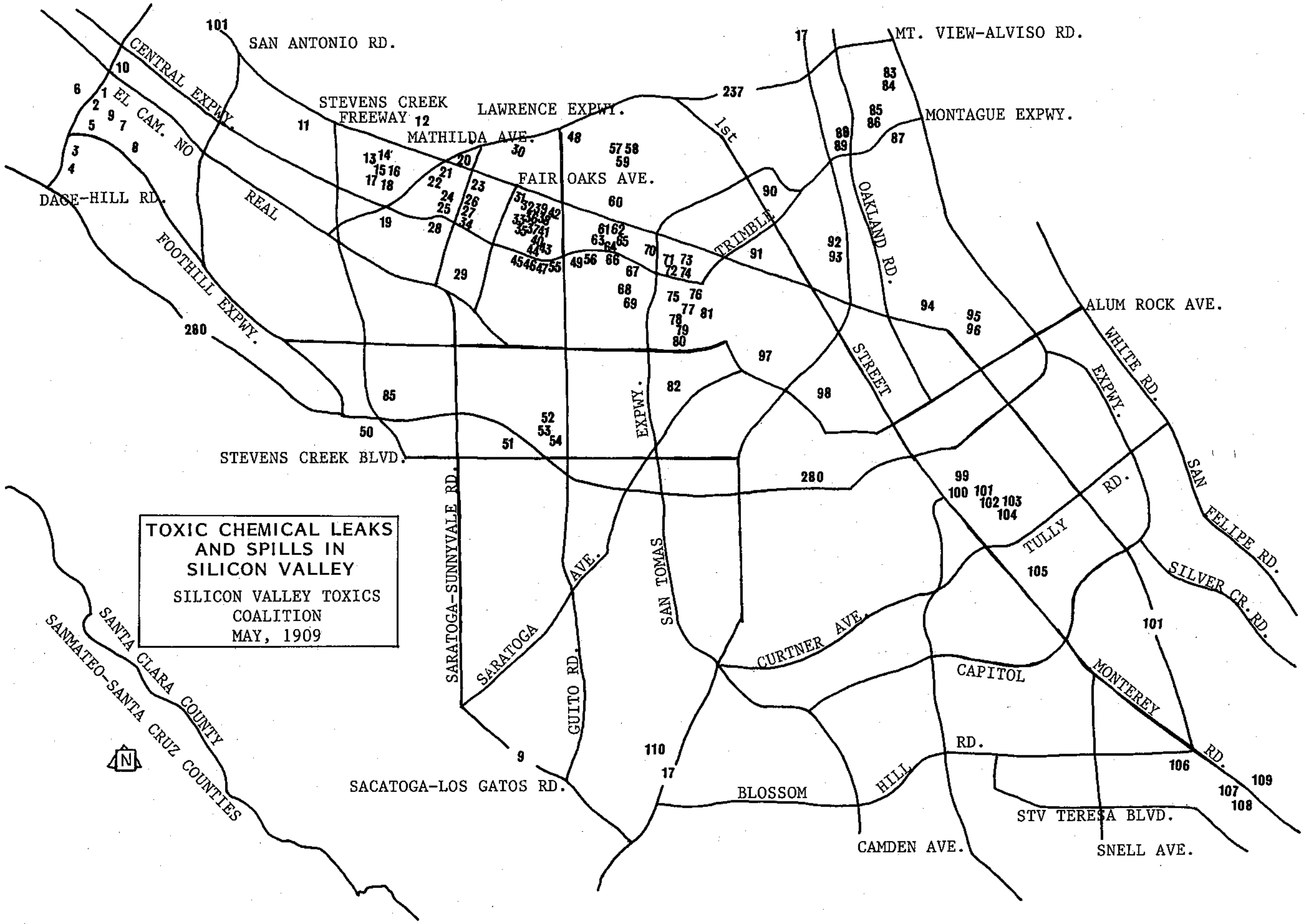
SAN JOSE:

90 IMP, 2830 N. First
91 Hewlett Packard, 350 W. Trimble Rd.
91a Amtronics, 2681 Zanker Rd.
91b Apogee Circuits, 420 Reynolds Circle
91c Haro's Metal Finishing, 439 Reynolds Circle
92 United Metal Plating, 2079 Hartog
*93 Van Water & Rogers, 2256 Junction Ave.
94 Solvent Service, 1021 Berryessa Rd.
95 Economics lab, 640 Lenfest Rd.
96 DAP Industries, 520 Marburg Way
97 FMC Corp., 1125 Coleman Ave.
98 Safe Way Chemical, 909 Stockton Ave.
*99 Lorentz Barrel & Drum, 1515 S. 10th St.
100 Micro Metallics, 1695 s. First St.
101 Spartan Plating, 275 Leo
102 Santa Clara Co. Transit Yard, 2240 S. 7th St.
103 Burke Industries, 2049 Senter St.
104 U.S. Cellulose, 520 Parrott St.
105 Hawk Manufacturing, 377 Umbarger
*106 IBM, 5600 Cottle Rd.
107 Magnex Corp., 6850 Santa Teresa Blvd.
*108 Fairchild Camera & Instrument, 101 Bernal Rd.
109 UTC Coyote Center, Metcalf Rd.

LOS GATOS:

110 Becton, Dickenson and Co., 14300 Winchester Blvd.

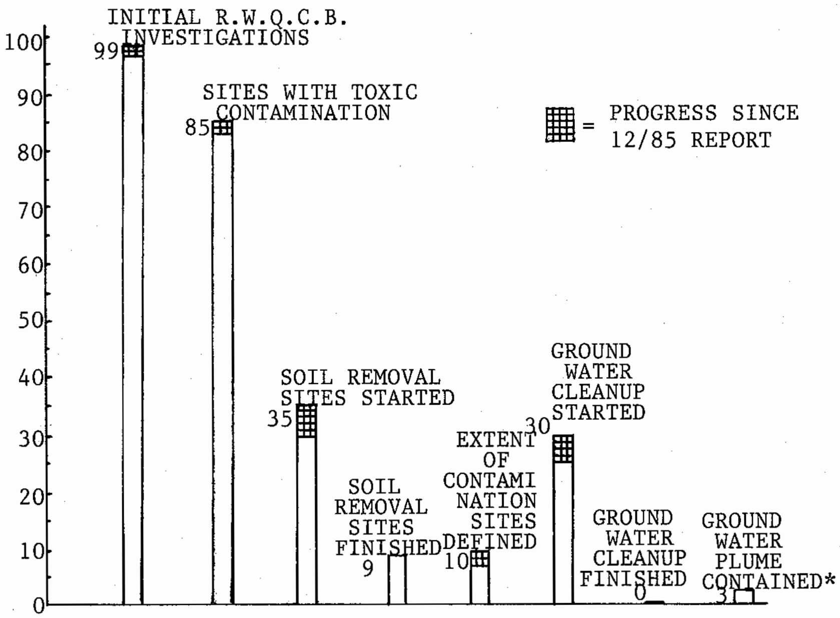
* EPA Superfund Site



TOXIC CHEMICAL LEAKS AND SPILLS IN SILICON VALLEY

SILICON VALLEY TOXICS COALITION
MAY, 1909

Table 1. Status of Silicon Valley Toxic Cleanup Cases



c prepared by J.A.R. for S.V.T.C.

Source: Regional Water Quality Control Board Report(2/86)
*Controversy Exists in Definition of "Ground Water Plume Containment".

[See Table 1. Status of Silicon Valley Toxic Cleanup Cases]

[Sources:

* *Silicon Valley Toxic News* (A Publication of the Silicon Valley Toxics Coalition).

*J. LaDou, "The Not-so-Clean Business of Making Chips" *Technology Review*, May/June 1984.

*California Department of Health Service, *Ground Water and Drinking Water in the Santa Clara Valley, A White Paper*, October 1984.

*P. Steinhart, "Warning: Drinking the Water in This State May Be Dangerous to Your Health, *California*, March 1985.

*C. Barney, "Toxic Chemicals Jar Industry", *Electronics Week*, March 18, 1985.

*L. Siegel, *The High Cost of High Tech: The Dark Side of the Chips*, 1985.

*State of California, Department of Industrial Relations,

Semiconductor Industry Study, 1981.
High Tech Pollution at East Coast, See *High Tech Toxics: Communities at Risk,* A special Report prepared for the Task Force on High Tech Toxics, 1984.]

II. *High Tech Pollution in Japan*

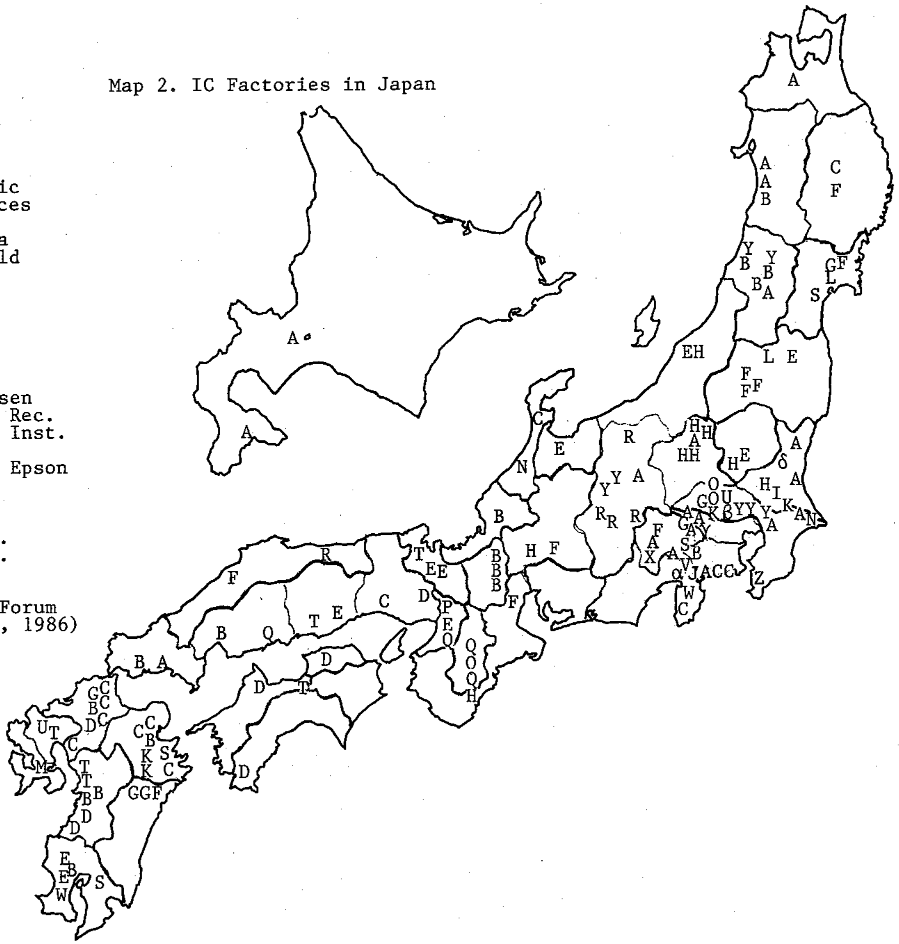
Today in Japan, there are about 130 semiconductor (IC) factories (about 30 companies), of which 72 perform either integrated processing or pre-processing (silicon ingot and wafer manufacturing). See Map 2, IC Factories in Japan

The semiconductor industry emits two sorts of pollution. One is pollution by leaks of solvents,* [See, Kenneth Geiser, Health Hazards in The Microelectronics Industry, in *International Journal of Health Services,* Vol. 16, No.1, 1986] and the other is occupational exposure of workers to toxic chemicals. Already, 13 cases of toxic gas accidents in the semiconductor industry have been reported *Officially* by the Ministry of Labour. About half of these cases involve death by suffocation after inhalation of inert gases. As we cannot acquire exact statistics on occupational injuries and illness, it seems to us these 13 cases are only the tip of the iceberg.

On the other hand,several cases of solvent leaks from IC factories have been reported. In January 1984 it was revealed that TCE (Trichloroethylene) from the Taishi Factory of Toshiba (Hyogo Pref.) had polluted the underground water supply (171 ppb and 97 ppb). Toshiba said that in February 1984,it had changed TCE to 1.1.1.TCA and had completed hazardous soil removal by May. The town of Taishi has cleaned up the polluted water by aeration. But there remains the possibility of TCA leaks, not only from the solvent tank, but also from the air ducts. [See Map 3,Table 2]

Another is the case of Fuchu City (Tokyo). In 1984, underground water contamination by TCE was detected (774 ppb-32 ppb). For example, Toshiba's Fuchu IC factory had itself contaminated private well water (774 ppb).

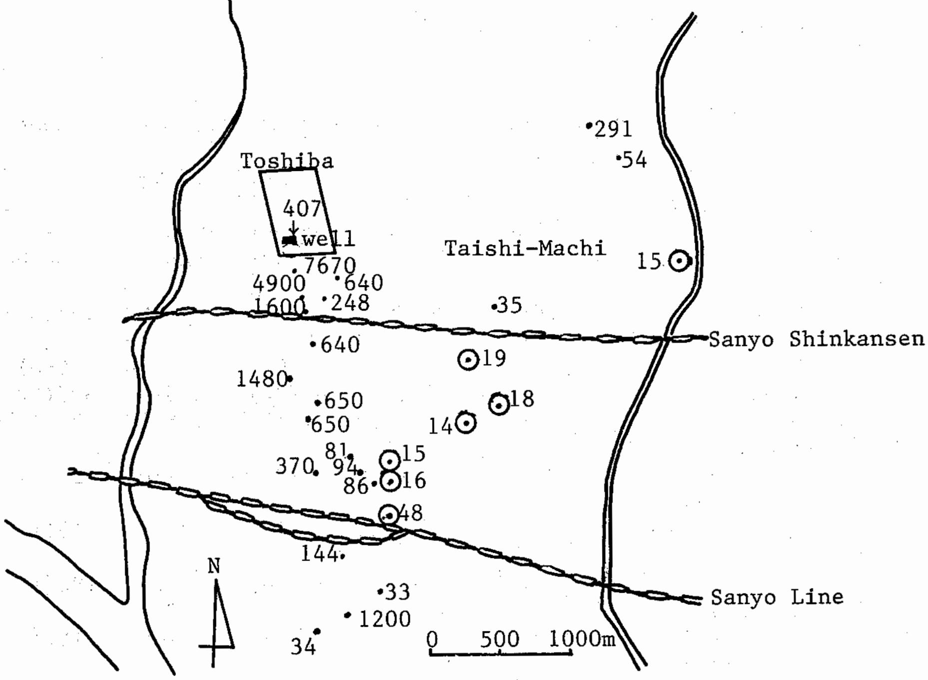
Map 2. IC Factories in Japan



A Hitachi
B NEC
C Toshiba
D Mitsubishi
E National
F Fujitsu
G Oki
H Sanyo
I Japan LSI Logic
J Analogue Devices
K Japan TI
L Japan Motorola
M Japan Fairchild
N Sanken Elec.
O Sindengen
P Ricoh
Q Sharp
R Fuji Elec.
S Sony
T Romu
U Shin-nihon Musen
V Japan Intern. Rec.
W Japan Musical Inst.
X Pioneer
Y Seiko Elec. & Epson
Z NHB Semicon.
α Meidensha
β Tamura Musen
γ Yokokawa Elec.
δ Hiyama Indust.

(Source: Science Forum *ULSI* June, 1986)

Map.3 TCE Contamination Levels (ppb) found in Underground Water at Taishi (Hyogo Pref.) (17 May 1984)



• fixed point well
⊙ pursuit point well

[Source: Kunihiro Yamada, "Warning from Underground Water," *Gijutsu to Ningen (Technology and Man)*, April 1985. p.21]

Table 2. Volume of TCE Used at the Taishi Factory (Toshiba)

Year	Volume of Use (tons/year)	Recovery (tons/year)	Rate of Recovery (%)
1970	89	21	23.6
1975	346	82	23.6
1980	181	43	23.6
1981	173	34	19.7
1982	160	43	26.9
1983	148	36	24.3

[Source: Kunihiro Yamada, op.cit., p.16]

[Source: Tatsuo Hitomi, *Ningen to Kankyo (Man and Environment)* Vol.10. No.1. 1984. p.49.]

Fuchu City, Hachiohji City (Tokyo), and Kawasaki City (Kanagawa Pref.), located along the Tama River, have reported many TCE cases of contaminated ground water. Near the Tama River,there are many IC plants (Fujitsu, Toshiba, NEC, Oki, etc.).

Table 3. Levels of Ground Water Contamination (EPA of Japan, 1982)

Number Sampled Chemicals	Shallow Well 1083 Detect Number(%)	Limit μg/ℓ	Deep Well(30 m-) 277 Detect Number(%)	Limit μg/ℓ	Total 1360 Detect Number(%)	Limit μg/ℓ
nitrate	980(90)	20-80000	202(73)	20-12000	1182(87)	20-80000
methyl chloride	2(0)	2	0(0)	-	2(0)	2
dichloromethane	5(0)	2-6	1(0)	6	6(0)	2-6
chloroform	240(22)	0.5-28	65(24)	0.5-31	305(22)	0.5-31
carbon tetrachloride	84(8)	0.05-2200	47(17)	0.05-17	131(10)	0.05-2200
1.1. dichloroethane	20(2)	1-175	9(3)	1-30	29(2)	1-175
1.2. dichloroethane	14(1)	1-33	2(1)	3-13	16(1)	1-33
1.1.1. trichloroethane	142(13)	0.2-1600	44(16)	0.2-70	186(14)	0.2-1600
1.1. dichloroethylene	10(1)	1-7	3(1)	1-5	13(1)	1-7
cis 1.2. dichloroethylene	88(8)	1-537	31(11)	1-338	119(9)	1-537
trams 1.2. dichloroethylene	15(1)	1-15	5(2)	2-10	20(1)	1-15
trichloroethylene	289(27)	0.5-4800	90(33)	0.5-210	379(28)	0.5-4800
tetrachloroethylene	289(27)	0.2-23000	83(30)	0.2-190	372(27)	0.2-23000
benzene	3(0)	4-11	0(0)	-	3(0)	4-11
toluene	12(1)	2-42	8(3)	3-5	20(1)	2-42
xylene	5(0)	3-17	0(0)	-	5(0)	3-17

Another case is the area of Yohkaichi City, Azuchi Machi and Ohmi-hachiman City in Shiga Pref. Near Lake Biwa along the Tokaido Shinkansen,there are many semiconductor-related factories(National,NEC,Murata). Shiga Prefecture's research has disclosed that there are 27 states, at which TCE levels are over 30 ppb.

[Sorce: Kunihiro Yamada, op.cit., p.23]

In 1982, Japan's EPA released statistics on ground water contamination levels. According to Table 3, we can see that:

(1) many sorts of chemicals have been detected;

(2) contaminated solvents (especially TCA, TCE) are becoming more acute; and

(3) contamination has reached down to deep wells.

Table 4 shows the production and waste levels of organic chloride chemicals in Japan. These chemicals are used in the metal processing industry, and in the laundry industry, in addition to the semiconductor industry.

Table 4. Production and Waste Levels of Organic Chloride in Japan

Chemicals	1982 tons/year	1983 tons/year	Waste tons/year
chloroform	8424	9618	
carbon tetrachloride	39622	39390	
dichloroethane	1547585	1735800	
1.1.1.trichloroethane	91583	95701	about 90000
1.1.dichloroethylene		about 33000	
1.2.dichloroethylene		about 8000	
trichloroethylene	67474	66693	about 70000
tetrachloroethylene	59894	59830	about 50000

[Source: Kohei Urano, *Suishitsu Odaku Kenkyu (Japan Journal of Water Pollution Research)* Vol.8, No.5, 1985. pp.269-270.]

III. *Characteristics of High-Tech Pollution*

Having reviewed the cases of Silicon Valley and Japan, I would now like to analyze these problems theoretically. In terms of the environment, high-tech pollution has two sides. One is occupational exposure to toxic chemicals and the other is contamination of local communities by solvent and gas leaks. As the semiconductor industry uses many sorts of toxic chemical gases, it is one of "the most dangerous industries in the history of manufacturing". [Source: Hiroshi Yamaguchi M.D., *Rodo no Kagaku (Science of Labour)* Vol.40, No.9. 1985. p.4]

The IC industry uses many gaseous phase and flash processes, so that it requires chemicals which have high level chemical activities. Therefore, high-tech pollution is essentially a *Chemical Hazards* problem. The usual environmental problems caused by manufacturing industries take the form of poor waste disposal. But in this case,not only waste products, but also leaks of materials and chemical agents themselves may become sources of pollution. We must therefore examine the whole process of the transport, storage, production, exhaust,and recovery of the materials and chemical agents.

In general,information on the exact processes used in the semiconductor industry is not easily obtained, because microeletronics is an industry where secrecy prevails. Furthermore,the technology advances so rapidly that processes and materials are constantly changing. [Source: J. LaDou, op.cit., p. 24]

Incidentally,the IC industry requires much more superdemineralized water than usual manufactures do. According to the data released by the National Land Agency (July 1984),one IC factory uses 2400 tons per day on the average, 5 times as much as traditional industry. Besides,about 40% of its water comes from underground sources. This fact accelerates the exhaustion and contamination of underground water.

In the case of Japan,many sorts of chemical gases for the semiconductor industry come from the U.S.and accidents have occurred in the process of transporting these gases and waste solvents. Many IC manufacturers leave responsibility for their waste matter to the waste disposal subcontractor.

IV. *What Must Be Done?*

To prevent high-tech pollution in advance, it is necessary to counteract chemical hazards by the following means:

*Decrease waste production at its source(Source Reduction).
*Recycle materials which remain in use (Recovery and Recycling).

*Treat the contaminants found in various plant discharges, such as air, water, and liquid/solid hazardous wastes (Treatment).
*Minimize risks associated with the disposal of hazardous waste(Disposal).
*Safely store hazardous materials so that leaks and spills are prevented(Storage).

Adequate technologies and practices to reduce chemical hazards currently already *do exist*. [Source: Golden Empire Health Planning Center, *High Tech and Toxics: A Guide*

Table 5. Legislation Relating to Toxic Chemicals Used in the Semiconductor Industry of Japan

Name of Gas	Legislation Act on High Pressure Gas (o applicable, x inapplicable)	Legislation Act on Toxic Material (o applicable, x inapplicable)	Labour Standard Act(specified chemicals)	Fire Defense Act
Ar	o	x	-	
CO	o	x	-	
Cl	o	x	o	o
H	o	x	-	o
HCl	o	o	o	o
He	o	x	-	-
N	o	x	-	
N O	o	x	-	
NH	o	o	o	o
AsH	o	o	-	o
BBr	x	x	-	o
BCl	o	x	-	o
B H	o	x	-	o
PH	o	x	-	o
POCl	x	x	-	
SiCl	x	x	-	-
SiHCl	x	x	-	-
SiH	o	x	-	o
SbH	o	o	-	o
O	o	x	-	o
SiF	o	x	-	-
BF	o	x	-	o
C ClF	o	x	-	-
CBrF	o	x	-	-
CClF	o	x	-	-
CHF	o	x	-	-
C F	o	x	-	-
C H	x	x	-	-
CF	o	x	-	-

[Source: Science Forum, *Handoutai Gasu Anzenka Souran*, 1984 Edition, p.34] *for Local Communities,* 1985. p.170, 175, 231.]

Ultimately, it would be better not to use many sorts of toxic chemicals for the production of semiconductors. The semiconductor industry should seek to replace hazardous processes and materials with safer ones. Hazardous materials are often used simply because they were the first ones used in the research laboratory. [Source: J. LaDou, op.cit., p.36.] But in Japan, legislation relating to toxic chemicals is inadequate. The existing law covers only about half the relevant chemicals. [Table 5]

In Japan, about 40% of IC factories have agreements on pollution prevention with local communities. Some of these agreements have clauses relating to water recycling systems and citizen inspections (for example, Tateyama City). But in fact, many such agreements do not function well. Furthermore, it is especially necessary to control the usage and contamination of underground water, because damage to these resources could be irreversible.

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