

Special Contribution

Leukemia and non-Hodgkin lymphoma in semiconductor industry workers in Korea

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Reports of leukemia and non-Hodgkin lymphoma (NHL), cancers known to have a similar pathophysiology, among workers in the semiconductor industry have generated much public concern in Korea. This paper describes cases reported to the NGO Supporters for the Health and Rights of People in the Semiconductor Industry (SHARPs). We identified demographic characteristics, occupational, and disease history, for 17 leukemia and NHL cases from the Giheung Samsung semiconductor plant, diagnosed from November 2007 to January 2011. Patients were relatively young (mean=28.5 years, SD=6.5) at the time of diagnosis and the mean latency period was 104.3 months (SD=65.8). Majority of the cases were fabrication operators (11 workers among 17) and 12 were hired before 2000. Six cases worked in the etching or diffusion process. The evidence to confirm the causal relationship between exposures in the semiconductor industry and leukemia or NHL remains insufficient and a more formal, independent study of the exposure–disease relationship in this occupation is needed. However, workers should be protected from the potential exposures immediately.

Keywords: Leukemia, Non-Hodgkin lymphoma, Hematological neoplasms, Semiconductor, Republic of Korea

Introduction

Leukemia and non-Hodgkin lymphoma (NHL) are rare cancers in Korea. In 2008, the age-adjusted incidence rate in the general population was 5.8 per 100 000 people for NHL and 4.8 per 100 000 people for leukemia.¹ Age-adjusted mortality rates of leukemia and NHL were 3.1 and 2.6 per 100 000 people, respectively, in 2009.² Recently, hematopoietic cancer, especially among semiconductor industry workers, has been the object of major public concern in Korea. The leukemia death of a 22-year-old woman who had worked in Samsung's Giheung plant, generated public interest about this cancer.³

Samsung Semiconductor, which is the world's largest semiconductor manufacturer, is one of the business departments of Samsung Electronics, which employs 33 500 Koreans. Currently, Samsung operates are two semiconductor plants, Giheung and Hwasung. There are nine fabrication lines in the Giheung plant and 6 fabrication lines in the Hwasung plant.⁴ The Giheung plant, which is the largest semiconductor fabrication plant in Korea, was built in 1984. In 2008, the plant had a workforce of 24 000, including 10 000 female workers and 14 000 male

workers. Among them, 9 000 females and 10 000 males were manual workers. Samsung holds the greatest global market share (40.4%) for D-RAM semiconductors.⁵

Semiconductor fabrication involves the following processes: patterning (oxidation, photoresist application, photo exposure, developing, wet or dry etching, stripping, and cleaning), junction formation (diffusion and ion implantation), thin film, and metallization. Wet etching is a process of removing unnecessary parts from wafers is followed by stripping and cleaning photosensitive substances with various chemicals. In this part of the process, operators repeatedly dip the wafers into chemical baths composed of a combination of peroxide and BOE solution (a mixture of peroxide, hydrogen fluoride, ammonium fluoride, and some surfactant). After wet etching, workers clean wafers multiple times using various chemicals, including trichloroethylene, 1,1,1-trichloroethane, freons, isoprophyl alcohol, acetone, ethanol, hydrofluoric acid, sulfuric acid, hydrochloric acid, nitric acid, hydrogen peroxide, or ammonium hydroxide follows series of etching process (from the late 1990s, wet etching methods have been replaced by dry etching, an automatic process using plasma containing ionized particles, rather than the chemicals described above). During junction formation, diffusion

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and ion implantation are methods to complete electric currents, and involve the use of arsine, arsenic trioxide, phosphine, phosphorus trichloride, phosphorus oxychloride, boron trichloride, boron trifluoride, diborane, antimony trioxide, or antimony trichloride. In the ion implantation process, X-rays are generated from the ion sources, and workers could be exposed to X-rays.^{6–8}

Two groups of workers are involved in the wafer fabrication process: operators and engineers. Operators perform the tasks of fabrication, directly handling wafers and many chemicals. Samsung generally hires women for operator positions. Engineers maintain production facilities, repairing equipment and solving problems during the production processes.^{7,8} Therefore, they are at risk of accidental exposures. Samsung generally hires men for engineer positions.

An association between the semiconductor industry exposures and cancer has been discussed since the late 1980s. Debate over the association is rooted in analysis of cancer cases in employees from International Business Machines (IBM, USA) and National Semiconductor Ltd (UK). The standardized incidence ratios of all cancers in IBM workers were 81 (95% CI=77–85) for workers at semiconductor manufacturing facilities and 87 (95% CI=82–92) for workers at storage device manufacturing facilities.⁹ The standardized mortality ratio (SMR) for all cancers in IBM workers was 65 (95% CI=64–67).¹⁰ These results actually suggested that working in a semiconductor factory is somehow good for workers' health. On the other hand, Clapp conducted a proportional mortality ratio (PMR) study with approximately the same IBM data and found an excess of cancers.¹¹ The PMR of all malignant neoplasms in IBM workers was 106.8 (95% CI=104.8–108.8) for males and 114.6 (95% CI=110.3–119.1) for females. The PMRs of respiratory disease and cardiovascular disease were significantly lower than mortalities from other causes.

In an epidemiological study conducted by National Semiconductor Ltd during the 1980s in the UK, Sorahan *et al.* demonstrated that the SMR of all cancers was 91 (expected number=27.35, observed number=25) and that the standardized registration ratio (SRR) was 103 (expected number=47.74, observed number=49).¹² This result was updated in 1992. At that time, the SMR and SRR of all cancers were 79 (expected number=58.3, observed number=46) and 96 (expected numbers=96.9, observed number=93), respectively.¹³ According to a study in Taiwan, white blood cell counts were significantly decreased in male fabrication workers working in photolithography and ion implantation.¹⁴ The association between semiconductor industry employment and cancer remains controversial until today.

Occupational physicians and public health researchers from various countries have called for actions to prevent cancer occurrences in the semiconductor industry and called for further research, stating that, "though the earlier findings are not conclusive, it is clear that more detailed studies are urgently needed to determine whether or not there is a workplace risk, and if so, to determine its specific nature and size".¹⁵

In Korea, the Occupational Safety and Health Research Institute (OSHRI) conducted an epidemiologic study of cancer in the semiconductor industry at the request of the Korea Workers Compensation and Welfare Service (COMWEL). OSHRI evaluated SMRs and SIRs using cancer registration data from the National Cancer Center and employment data from the company and reported there was not a statistically significant increase of leukemia. The incidence of NHL in females was significantly increased. OSHRI stated that there was no definite association with work,¹⁶ but did not release the full official report or the raw data.

As the size of the industry has expanded, public interest in leukemia and lymphoma cases in semiconductor-manufacturing workers in Korea has increased. Some non-governmental organizations (NGOs) have been concerned about this issue, and some workers have reported their own cancer cases or their co-workers' cases to these NGOs as well as to COMWEL. This paper aims to describe some of the reported cases in Samsung Electronics' Giheung plant, to place these findings in the context of previous research on leukemia and lymphoma among semiconductor workers, and to consider some of the public health issues regarding occupational safety in the semiconductor industry.

Methods

We received data on the lymphohematopoietic cancer cases from the NGO, Supporters for the Health and Rights of People in the Semiconductor Industry (SHARPs), which supports workers' claims for compensation and manages an online effort to gather information about health problems among semiconductor workers. SHARPs obtained basic information about patients' disease and work history from patients themselves, family, or colleagues. SHARPs' volunteers obtained additional information through in-person, email, or telephone interviews with the patient or their family members. We classified this information by case gender, occupational history, birth date, pathological classification of disease, age at diagnosis, date of diagnosis, hire and resignation dates, death date, work division, and task. For all cases, we also identified individual workers' assigned production lines. Samsung assigned numbers to the production lines based on the order of installation, with smaller line numbers indicating older lines.

Table 1 Cases of diagnosed hematopoietic cancer from the Samsung Group

Diagnosis (ICD-10)*	Semiconductor industry						Total
	Fabrication	Assembly	White collar	Unknown	Other electronic industry		
Unclassified leukemia [†]	4	1	1	1		8	15
Acute myeloid leukemia (C92.0 or C92.4)	10	2	1	...		3	16
Acute lymphoblastic leukemia (C91.0)	2	...	...	...		5	7
Chronic myeloid leukemia (C92.1)	—	...	...	...		5	5
Unclassified lymphoma [‡]	1	...	1	...		...	3
Non-Hodgkin lymphoma (C83.0-C85.9)	4	3	3	...		1	10
Hodgkin disease (C81.2)	...	...	...	1		...	1
Multiple myeloma (C90.0)	...	...	...	...		1	1
Total	21	6	6	2		23	58

Note: *ICD-10: International Statistical Classification of Diseases and Related Health Problems 10th Revision Version for 2010.

[†]Cases not to identify the exact diagnosis according to official medical records or cases to identify the exact diagnosis with C95.9.

[‡]Cases not to identify the exact diagnosis according to official medical records.

Older lines tend to require more manual labor, while newer lines are more highly automated.

We included in our initial analysis all cases with a reported history of working in wafer fabrication at the Giheung plant, where manual fabrication lines were in use from 1984 to 2009. We excluded non-fabrication floor workers, professional and managerial staff, and workers for whom insufficient information was available. For all cases that met our inclusion criteria, we classified case information by current mortality status (living, deceased or unknown), diagnosis, work field (engineer or operator), task, age at diagnosis, year hired, and latency; and measured frequencies and means of these variables. We defined latency as the duration from the hiring year to the year of diagnosis. In addition, we investigated whether cases had filed for compensation with the COMWEL. Where claims had been filed, we conducted qualitative, in-depth interviews with the patients or family members. In addition to our

quantitative findings, we present the details of four cases among the claimants, comprised of three operators and an engineer, because they were the first informants and their tasks were instructive for explaining the health risks of manual production processes in wafer fabrication. To examine their job characteristics, we summarized the results of these interviews.

Results

Table 1 shows all of the cases reported by SHARPs, by diagnosis and industry. Lymphohematopoietic cancer was reported in 58 people who worked in the electronics industries of Samsung Groups. We excluded six non-fabrication workers who worked in Samsung's Onyang plant, which had package or assembly lines for the semiconductor wafer, and 23 workers who worked in subsidiary companies, Samsung Electro-Mechanics or Samsung SDI, where other kinds of electronic devices such as display

Table 2 Individual occupational histories in the Samsung Electronics' Giheung plant

No.	Gender	Diagnosis (ICD-10)*	Age at diagnosis	Hired year	Latency	Job	Line	Task	Informant
1	Female	Leukemia, unspecified (C95.9)	18	1994	4	Operator	1, 2, 3	Unknown [†]	Family
2	Female	Non-Hodgkin lymphoma (C83.5)	21	1993	61	Operator	1, 8	Etching	Herself
3	Male	Acute myeloid leukemia (C92.0)	29	1987	132	Engineer	Unknown [†]	Unknown [†]	Colleague
4	Male	Acute myeloid leukemia (C92.0)	32	1989	138	Engineer	4	Unknown [†]	Colleague
5	Female	Acute myeloid leukemia (C92.0)	32	1988	168	Operator	Unknown [†]	Unknown [†]	Family
6	Female	Acute lymphoblastic leukemia (C91.0)	23	2000	44	Operator	10	Etching	Family
7	Female	Non-Hodgkin lymphoma (C84.4)	29	1995	102	Operator	1, 8	Diffusion	Colleague
8 [‡]	Male	Acute lymphoblastic leukemia (C91.0)	30	1997	89	Engineer	1, 5	Others	Family
9 [‡]	Female	Acute myeloid leukemia (C92.0)	20	2003	21	Operator	3	Wet etching	Family
10 [‡]	Male	Acute myeloid leukemia (C92.0)	46	1983	271	Engineer	1-3, 6, 7	Diffusion	Himself
11 [‡]	Female	Acute myeloid leukemia (C92.0)	30	1995	138	Operator	3	Wet etching	Family
12	Male	Non-Hodgkin lymphoma (C85.9)	30	2005	33	Engineer	Unknown [†]	Photo	Colleague
13 [‡]	Female	Acute myeloid leukemia (C92.0)	28	1999	108	Operator	2, 3	Etching	Family
14	Male	Leukemia, unspecified (C95.9)	36	2000	108	Engineer	Unknown [†]	Photo	Colleague
15	Female	Acute myeloid leukemia (C92.0)	25	unknown ^a	unknown ^a	Operator	Unknown [†]	Wafer inspection	Family
16	Female	Non-Hodgkin lymphoma (C85.9)	30	1988	151	Operator	Unknown [†]	Unknown [†]	Colleague
17	Female	Acute myeloid leukemia (C92.0)	26	1995	101	Operator	Unknown [†]	Test	Colleague

Note: *ICD-10; International Statistical Classification of Diseases and Related Health Problems 10th Revision Version for 2010

[†] Unknown; the case for the informant not to remember the information clearly.

[‡]Cases who themselves or their family sought compensation from COMWEL.

systems, storage devices, or printed circuit boards were made using semiconductor chips.

One unclassified leukemia case and one Hodgkin's case were excluded because their exact workplaces were uncertain. Two professionals, one researcher and three white-collar workers were also excluded. An additional three leukemia patients and one lymphoma patient were excluded because their information was incomplete. Eventually, we identified 17 cases that fulfilled the criteria of this study.

Table 2 shows characteristics of the 17 cases. In the cases 8, 9, 10, 11 and 13, workers or their family members sought compensation from COMWEL. The majority (11) of the cases were female operators and all of the male cases (6) were engineers. The mean age at diagnosis was 28.5 years ($SD=6.5$, range: 18–46). Female workers were younger (mean=25.6, $SD=6.5$) than male workers (mean=33.8, $SD=4.6$). Acute myeloid leukemia (AML) was the most common lymphohematopoietic cancer. Four persons developed NHL. Eleven cases were fatal. Six cases had worked in the diffusion or etching process. Others worked in the photo, inspection, or test processes. For seven workers, no information was available on the job task. Five people were hired before 1990. Seven people were hired from 1991 to 1999, and four people were hired in or after 2000. The mean period from the hire date to the diagnosis was 128.5 months for males and 89.8 months for females. The latency

period for six people was more than 120 months and that of another six people was between 60 and 120 months. The latency period for three people was between 12 and 59 months and that of one case was less than 12 months (Table 3).

Case 10 was a male engineer who worked in the diffusion process. He started work on line 1 in August 1983 and resigned in January 2006. He worked on lines 2, 3, 4, 5, 6, and 7 for 22 years. He reported that he suffered from asthma-like symptoms while working. He was diagnosed with AML in March 2006 at the age of 46 years. He died in November 2010. His main task was the maintenance and set-up of devices in the diffusion, etching, and ion implantation processes. He performed various tasks throughout the entire wafer fabrication process. It is possible that he was exposed to chemicals such as sulfuric acid, ethylene oxide, benzene, trichloroethylene (TCE), formaldehyde, etc. We believe that exposure to radiation was also possible in photolithography or ion implantation, because the worker stated in an interview that, due to the speed of work and high work demand, he often worked without engaging the safety interlock of the ion implanter. He said that he was ignorant of the possibility of radiation exposure, and he did not receive any education about the risks.

Cases 9, 11, and 13 were female operators who worked in the wet etching process. Case 9 worked from October 2003 to October 2006 on line 3. In May

Table 3 Characteristics of leukemia and lymphoma cases in the Samsung Electronics' Giheung plant

		Male	Female	Total
Current status	Deceased	3	8	11
	Alive	3	2	5
	Unknown	0	1	1
Diagnosis	Leukemia, unspecified (C95.9)	1	1	2
	AML (C92.0)	3	6	9
	ALL (C91.0)	1	1	2
Work field	NHL (C82.0–85.9)	1	3	4
	Engineer	6	0	6
	Operator	0	11	11
Task	Diffusion/etching	1	5	6
	Others*	2	2	4
Age at diagnosis	Unknown	3	4	7
	10s	0	1	1
	20s	1	7	8
Latency (years)	30s	4	3	7
	40s	1	0	1
	Mean (SD) (years)	33.8 (6.5)	25.6 (4.6)	28.5 (6.5)
Hired year	Range	29–46	18–32	18–46
	≤1	0	1	1
	1–5	1	2	3
	5–10	2	4	6
	>10	3	3	6
	Mean (SD) (months)	128.5 (79.4)	89.8 (55.6)	104.3 (65.8)
	Range (months)	33–271	4–168	4–271
	~1990	3	2	5
	1991–1994	0	2	2
	1995–1999	1	4	5
	2000~	2	2	4

Note: *Others: two worked in photo process and two worked in test process.

2005, she experienced bruising, vomiting, fatigue, and dizziness. She was diagnosed with AML at 20 years of age and died at 22 years. Case 11 worked from January 1995 to August 2006 on line 3. She was diagnosed with AML at 30 years and died about 1 month after diagnosis. Cases 9 and 11 worked in the same manual wafer cleaning with wet etching unit on line 3. A job description given by case 9 stated that isopropyl alcohol, acetone, and sulfuric acid were used to clean the manufacturing equipment. Case 13 worked from November 1999 to February 2004. She worked in the etching process on line 2 for 5 years. She resigned due to headaches, dyspepsia, and a shift work fatigue. Her first pregnancy ended up in miscarriage in February 2005. She noted the appearance of multiple bruises started from April 2008. She was diagnosed with AML at that time, and then doctors started chemotherapy. She received her first bone marrow transplantation in October 2008. She relapsed in June 2009. She received a second transplantation but died on 24 November 2009.

Discussion

Leukemia and NHL cases in the Samsung Semiconductor plant in Giheung possess shared characteristics such as relatively young age at diagnosis and a short latency period. Leukemia and NHL were more frequent in early hired fabrication (FAB) operators. The latency periods of female FAB operators were relatively shorter than those of male FAB engineers. The range of latency periods were very wide.

Samsung has refused to provide information about workforce size or turnover in the plant. Therefore, we could not measure the denominator population and also could not compare the lymphohematopoietic cancer incidence rates with the general incidence rates outside of the plant.

Workers in the rubber, painting, or oil refinery industries are at increased risk of work-related leukemia and NHL.¹⁷ In the electronics industry, studies regarding the relationship between electromagnetic fields and leukemia have not been conducted, but the likely causal relationships have been proven conclusively.¹⁸ For instance, in the present study, Samsung has consistently declined to provide key information about chemical exposures or data about workers who have or have not developed cancers such as leukemia or NHL. As a result, a methodologically rigorous study to prove causal relationships between occupational exposures and such cancers has been impossible. Similarly, the risk for leukemia in semiconductor workers has not been definitively determined through research in other industrial settings. None of the cohort studies among semiconductor workers in the UK or USA found a statistically significant increase in SMRs or SRRs for leukemia or NHL.^{7,10,19,20} However, one study

reanalyzed approximately the same data as the IBM study, calculating PMR and proportional cancer mortality ratio (PCMR, ratio of the number of deaths attributed to a specific subtype of cancer to the total number of deaths caused by cancers) and showed significantly increased risks, a marked difference from other results.¹¹ According to another study of IBM Endicott plant workers from 1969 to 2001, the lymphoma risk (PCMR=220; 95% CI=101–419) was significantly increased in males.²¹

In 2010, the results of a cohort study conducted at UK National Semiconductor and IBM were published. The subjects of the IBM study were 100 081 US individuals who had worked for IBM for more than 6 months from January 1983 to 1 February 2002. The SMR of NHL was 0.86 (95% CI=0.47–1.44) for fabrication workers and the SMR of leukemia for fabrication workers was 0.69 (95% CI=0.34–1.23). Meanwhile, the SMR of all causes of death was 0.54 (95% CI=0.51–0.57).⁷ These SMR results must be interpreted in the context of the healthy worker effect, namely the underestimation of disease in a working population because they are healthy enough to work. Including workers of relatively short employment duration (shorter than a year) may have biased the study.

A follow-up study on UK National Semiconductor also demonstrated statistically insignificant results for lymphohematopoietic cancer SMR and SRR among 4388 workers who had worked there prior to 30 April 1999. The Health and Safety Executive (HSE) concluded that the occurrences of lymphohematopoietic cancers are not related to the employment in the semiconductor industries, thus additional epidemiologic studies were not necessary.²² However, this study also encountered limitations such as small sample size and the healthy worker effect.

There is very little information on the specific hazards to which workers are exposed in the semiconductor industry. The HSE conducted historical hygiene assessment in the UK and said that carcinogens including arsenic and arsenical compounds such as arsine, TCE, aliphatic and alicyclic hydrocarbon solvents, ionizing radiation, and non-ionizing radiation were used in production processes.²³ Based on a review of previous studies, statements from colleagues or patients, and an article about Samsung's environmental handbook for engineers,²⁴ we could also identify some chemicals used in the semiconductor industry that are known or suspected human carcinogens, including ethylene oxide, formaldehyde, arsenic, quartz, TCE, thinner, and sulfuric acid.

Samsung's environmental handbook for engineers confirmed the recent use of TCE in Samsung semiconductor fabrication. However, in 2010 company officials stated that TCE has not been used since

1995.²⁴ The production process renders the maintenance of 100% purity for TCE difficult. The International Program on Chemical Safety reported that the purity of commercial TCE was approximately 99.85%, and it is possible that some benzene, which is known as a definite carcinogen of lymphohematopoietic cancers, could be included in the impurities.²⁵ Thinners used as general cleaners in the semiconductor industry also contain 0.1–56.7% of benzene.²⁶ Therefore, the workers in the semiconductor industry might have been exposed to benzene. The etching and diffusion process in particular used numerous chemicals, known, or probable causes of lymphohematopoietic cancers, such as ethylene oxide, benzene, TCE, formaldehyde, and radiation.

In 2010, some NGOs published a Civil Society Report to prepare for Parliamentary Audit about the risk assessment results conducted by Seoul National University. Because the company decided not to release the official report, NGOs obtained the report through an unofficial channel. On this Civil Society Report, the NGOs stated that data on substances and the introduction dates of the chemicals in use were lacking and that there were risks of organic solvent exposure. They asserted that the chemical exposure control was insufficient and that there were errors in the working environment measurements.²⁷ For example, in the advisory report from Seoul National University, 99 chemical products were used in the Giheung plant (in line 5) but Samsung Electronics has never given notices about some of substances to workers. The risk assessment reported that there were 46 instances where the gas detector alarm was triggered 46 from February to July 2009; 25 of these were due to gases remaining after Preventive Maintenance tasks were conducted. There were 11 cases of gas detector malfunction, and 33 cases of gas leakage occurred when every other manufacturing processes was running normally. Researchers also detected benzene at 0.08–8.91 ppm in six bulk materials and ethylene glycol at 5.90–63.92 ppm in four bulk materials by qualitative assessment using gas chromatography/mass spectrometry with six photo resistors which were used in the photo process. More than 40–50 chemical solutions were used. Ethylene glycol was also detected in the etching process from regular working environment measurements carried out by Samsung in 2007.²⁸ The possibilities for exposures to these substances and subsequent risk for lymphohematopoietic cancer have not been excluded. In the meantime, the manual processes in the Samsung Electronics' Giheung plant have been halted, and those processes were rapidly substituted with automation, thanks to the development of production techniques. This means that exposure levels might have changed over time.

Colleagues of the cases reported here said that the company did not provide adequate personal protective equipments. Workers merely wore dust-free garments, arm warmers, and respiratory protectors against dust, but not against gas. In Korea, business secrecy, rapid technical change, and the closed culture of Samsung for communication of risk makes it difficult to obtain the list of chemical substances currently or previously used.

This descriptive study cannot show whether there is a causal relationship between the employment in the semiconductor industry and the development of leukemia or NHL. A limitation of this study is that we reported only those cases reported by informants; we were not able to access company or government data. We believe our study does not include all cases among the population studied. Boffetta said that, "low estimates may reflect lack of knowledge as well as lack of risk".²⁹ Risk assessments of unusual situations and follow-up studies on workers who have worked in the factory in the past are required.

We believe that a disease surveillance system and compensation for patients are also important. In June 2011, the court ruled that COMWEL must compensate for two leukemia cases among five cases which sought compensation from COMWEL. Trials on three remaining cases are in progress. In July, Environ, a US company commissioned by Samsung Electronics to investigate the relationship between semiconductor plant workers' exposures and the occurrence of leukemia, presented findings that reportedly showed no statistically significant correlations, but the corporations gave no public presentations that provided details of the data that justified this conclusion.³⁰ Samsung has also decided to establish a research institute and to compensate for cancer cases according to their own standards.³¹ Though Samsung Electronics tried to establish several long-term policies like establishment of research institute, enactment of its own compensation policy, and initiation of a stricter risk control program, they still refuse to release the hazard information for various chemicals used in the production process, citing trade secrets as the rationale.

We believed that the change in the corporation's culture and policies is necessary. The company must establish a prevention policy, respect workers' right to know by providing full information on chemical exposures, and follow the precautionary principle by avoiding the use of chemicals that may cause severe damages to the workers' health. Education about chemical hazards and understandable risk communication are required for current Samsung workers. Basic policies on adequate personal protective equipment for personnel, engineering controls, and risk management are also necessary. In addition to

providing full information about all chemicals used in semiconductor production, the corporation should facilitate access to data by independent researchers who could assess causality definitively through the comparison of workers who do or do not develop cancer after exposure to the same working conditions.

Therefore, we call for actions such as more detailed, more open, and sounder studies about workplace risk, and active prevention before more definitive evidence of excessive occurrences of cancers in semiconductor workers emerges. We should follow the precautionary principles rather than exposing more workers to potentially unhealthy work environments.

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