Occupational Health Effects of the Semiconductor Industry: Toward a policy analysis

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What do we know about the occupational health of workers in the semiconductor industry?

In spite of a 50 year history and increasing concern about the hazards faced by the workers in the semiconductor industry, surprisingly little is known about the long-term health effects associated with such work.

1. Exposure assessment.

One of the earliest assessments of the hazards of the semiconductor industry was assembled by the California Department of Industrial Relations in 1981, by Richard Wade and associates[1]. They surveyed 53 semiconductor companies to provide information on their use of chemicals. 42 responded. Solvents, caustics and acids were the most common chemicals used. The companies reported handling 1.5 million cubic feet of cylinder gases, including arsine, phosphine and diborane gases. Two additional surveys were conducted in the early 1980's, one by Brookhaven National Laboratory and one by Batelle Labs. Maintenance workers were found in the latter study to be at highest risk of exposure, particularly during handling of toxic gas lines and pumps.

Most of the published material has focussed on various metal (arsensic, gallium, indium, chromium and other chromates, nickel salts) exposures in relation to cancer risk.

One engineer from a major disk drive manufacturer in the Bay Area was recently interviewed to find out additional information about potential chemical exposures in that segment of the industry. In addition to metal exposures, disk drive manufacture involved reported exposure to:

- di-iso-octyl-ester of phthalic acid
- plasticizers
- substituted phenols
- creasol
- potential radiation exposure from depleted plutonium to ionize air and prevent electrostatic charges in clean rooms in the 1980's
- organochlorophosphates in foams for gaskets
- Boron fluoride used in etching
- Acrylates
- Epoxies, amines
- Organotin compounds as fungicide
- Oil base paints containing benzene

The abstracts for articles on this industry that have been reviewed did not identify many of the possible carcinogens that were obtained simply from interviewing one engineer. Perhaps, these compounds were not widely used or just not known or considered by the authors?

2. Health effects reported

There have been reports since the 1980's from university researchers that illness-associated absenteeism (as distinct from acute injuries) among semiconductor workers reported to the Department of Industrial Relations is unusually high and that problems in this industry where air is filtered and reused many times may still exist. The industry responds that total absenteeism (illness +accidents) is lower than average and that measurements of chemicals known to be used in fabrication are extraordinarily low when measured in fabrication room air.

Joe Ladou has published a series of analyses of injury and illness data suggesting that despite the "clean" reputation of this industry, the semiconductor industry has been troubled by an unusually high incidence of occupational illness (rate 3 x higher than workers in general manufacturing 1.3 vs. 0.4/100 FTE's). Lost time injuries were even more dramatic: from 1980-84 he found that California Workers Compensation statistics indicated that occupational illnesses accounted for 19% of all lost-time work injuries compared with 6.5% of all manufacturing industries. The proportion of all injuries caused by toxic or systemic poisoning was 46.7% compared with 21% for all manufacturing. Unfortunately, California stopped publishing industry-specific occupational disease data after 1991.

What are the types of illnesses previously reported:

1. Skin rashes – associated with epoxy resins.
2. HF burns
3. Solvent-related headaches
4. Memory loss, difficulty concentrating, fatigue, mood dysfunction consistent with solvent intoxication and encephalopathy.

Neurological disease

I initially became interested in the health effects of semiconductor work in the early 1980's when I was consulted by a series of patients with these symptoms who worked in the industry. Then, in 1988-91 I was a co-investigator with Bob Harrison in a series of studies of electronics workers at an electronics plant (telecommuncations equipment manufacture) in Albuquerque, New Mexico. The workers in this study were employed by a microelectronics firm that had opened in 1971 and had employed 3371 workers between 1971 and 1984. We examined over 180 workers who had filed workers compensation claims for injuries in a plant where they were exposed to solvents primarily. Neuropsychological function comparing their performance with carefully matched controls were clearly reduced[2]. We found psychological and mood dysfunction as well as visual dysfunction among the exposed workers[3]. Since these workers were involved in various lawsuits, their claims had been consistently discounted and denied. They were ultimately successful in obtaining workers compensation. An independent group of investigators have recently confirmed these findings in another group of solvent-exposed workers we have examined at Sandia National Labs.

Reproductive Hazards

Elevated miscarriage rates were also found in our cohort of electronics workers in Albuquerque[4]. The results of this study indicated that the frequency of spontaneous abortions occurring while working in this microelectronics facility was significantly higher than the frequency of spontaneous abortion in the absence of this employment. The increased frequency of miscarriages seems to be associated with employment in the assembly part of the facility.

Continuing concern about anecdotal reports of miscarriages among women working in fabrication rooms of the semiconductor industry led to a series of studies of this issue. Although the routine industrial hygiene measurements of the air in typically highly controlled areas of semiconductor plants (not true of the Albuquerque plant) suggested that there should be no effects, three separate large studies, including one sponsored by the Semiconductor Industry Association, confirmed that increased rates of miscarriages was occurring.

1. In 1988, a reproductive study was performed by the U of Massachusetts among semiconductor workers at the Digital Equipment Corporation. Elevated spontaneous abortion was reported, with RR=2.18 for women working in cleanroom diffusion jobs, and 1.75 for women working in photolithography.
2. IBM commissioned a study of workers in New York and Vermont, in 1992, showing an increased rate of spontaneous abortion in women working in two cleanroom areas. Lack of biological monitoring data limited the ability to pinpoint the cause.
3. The SIA study in California, published in 1995, was performed by UC Davis and UC Berkeley researchers along with CA DHS staff. It included an ambitious retrospective study that also showed an increased risk of spontaneous abortion, with RR = 1.45. Exposures to glycol ethers and fluorides were implicated, although industrial hygiene data failed to demonstrate any significant glycol ether exposure (it is not very volatile in air). Fluoride similarly is generally not measurable on IH surveys. Other potential chemical hazards were not mentioned. A prospective study was also conducted showing an increased RR of 1.34. Sample size was inadequate, however. Urine specimens were obtained but not analyzed. NIOSH and European investigators offered to complete the study by analyzing urine values for metabolites of glycol ethers, but these offers were rebuffed by both IBM and the SIA, according to an article published by Joe Ladou in 1998.

Several glycol ether solvents, the class of chemicals associated with the highest risk tasks in the fabrication room, have been removed, since they were known to cause reproductive abnormalities in animals. Some critics were concerned that this may not have been the responsible agent.

Cancer

Studies of electronics workers have consistently found an elevated risk of malignant melanoma, a cancer of the melanin-producing cells in the skin. One Swedish study of telecommunications workers found a RR of 2.6, with an especially high risk in soldering departments (RR=3.9). This was not felt to be due to sunburn[5]. A study of cancer in England similarly

found an excess of malignant melanoma. Known UV exposure at work was noted for one of the reported cases. Recent case-control studies have implicated semiconductor and electronics work in particular as associated statistically with malignant melanoma. These cases are reminiscent of the increased rate of malignant melanoma among chemists at Lawrence Livermore National Laboratory, associated with exposure to solvents, plastics, pesticides, benzoyl peroxide and ionizing radiation.

In the mid-1990's, a group of worker in IBM's Fishkill NY semiconductor plant reported a potential cluster of several types of cancers (including brain cancer and testicular cancer) among technical workers. More recently, in the late 1990's anecdotal reports about cancers in British semiconductor factories were featured in the press. A similar cluster has now been reported from IBM workers in Silicon Valley. A Proportionate Mortality study has been conducted by the Santa Clara Committee on Occupational Safety and Health using data obtained from IBM in the course of workers compensation litigation. It suggested an overall increased risk of cancer, as well as statistically significant increases in specific types of cancer (breast, brain, testicular) among IBM workers nationwide who had died and on whom a death certificate was available to IBM.

The industry points out that industrial hygiene data once again does not suggest that there should be any problem. A few years ago a United States Environmental Protection Agency (USEPA) working group of environmentalists and industry tried to come up with actions for which a consensus existed (as part of the "Common Sense Initiative"). A study to follow semiconductor employees to determine rates of cancer was proposed by the Department of Health Services, but opposed by some of the industry participants. This opposition to any study was reported in the Wall Street Journal and other media.

III. Policy Alternatives

Staff from the State of California's Attorney General's office became aware of this issue through media reports. In meetings convened by the Attorney General's office, it was expressed by industry representatives that the industry would rather not have a study. They are concerned that any initially positive results would require many follow up studies and would cause them bad press. They point out many technical difficulties in carrying out such a study. They repeat that industrial hygiene studies suggest that their environment is risk free. DHS staff remind them of their recent experience with the miscarriage cluster in which the same arguments were raised, and there was, nonetheless a problem.

It is clear that there is sufficient information to suggest that the semiconductor industry is not the 'clean' industry that spokespersons for the industry suggest. The types and amounts of toxic chemicals used by the industry is sufficient indication of a potential hazard. This combined with epidemiological studies reporting relatively higher rates of occupational illnesses, case reports of illnesses consistent with exposures, and studies sponsored by industry confirming elevated rates of miscarriages all point in the same direction. Of public health concern are the increasing number of studies suggesting an elevated rate of cancer, particularly malignant melanoma, among semiconductor and other electronics workers.

What should be done to address these concerns? Is there enough information to proceed to developing policy directed at reducing these risks?

The policy alternatives can be summarized as follows:

1. Do nothing. Accept industry assurances that the rates are actually normal, and exposure levels not unusual, thus there is nothing to be concerned about.

2. Perform improved studies of both exposure and health outcomes to evaluate for potential causes. Once identified, pursue regulatory options to reduce the hazards. Questions to be addressed: What is the threshold for action? What level of proof is necessary before action is undertaken? Who should pay for these studies? Who is likely to pay for such studies? Are further industry-sponsored studies warranted if credibility may be questioned?

3. Proceed to regulatory action immediately. This is based on the assumption that risks are already sufficiently proven, and suggest that waiting for more studies will only delay preventive action. Reduce exposures to lowest feasible level, using a combination of voluntary toxic use reduction and mandatory regulatory initiatives. Encourage through incentives and/or mandate substitution of water-based technologies for hydrocarbon solvent-based cleaning. Enforce ddouble-containment methods for storage of chemicals, piping, and other potential sources of leaks, zero tolerance

for spills or 'accidental releases'. Strengths: Application of precautionary principle. Weaknesses: Subject to political winds of regulatory agencies.

I. Proposed Research Agenda

We in California are in a unique position to address these issues due to the large scale of this industry in California with adequate latency to examine delayed health effects, our public health mandates and access to data sources, and the existing technical expertise both at the State and Universities to assist in this effort.

Proposed steps:

1. To evaluate the reports of increased illness among semiconductor workers it would be useful to review the more recent available data from the Bureau of Labor Statistics (BLS), perform a "call-in" of all OSHA 200 logs for specific SIC coded industries involving electronics workers in California, pull Doctor's First Reports, and request available workers compensation data from State Compensation Insurance Fund (SCIF) and other sources.
2. To evaluate the cancer risk it is would be necessary to obtain a roster of employees who have ever worked the major electronics manufacturing companies in California and then perform a Standardized Incidence Ratio (SIR) study of these electronics industry workers matched with the California Tumor Registry.

Other potential steps might include:

1. What are the current types and levels of chemical or other hazardous exposures in the Semiconductor Industry? Discussion with industrial hygienists from the industry who were working during the 1970's and 1980's may provide additional clues, as well as interviews with other technical workers in the industry. Perhaps it would be useful to convene another task force on the Semiconductor Industry to assess the current exposures and controls. A repeat of the 1980 survey might be useful as a starting point, followed up by random plant visits and air sampling, urinary monitoring, or other exposure assessment.
2. What is the degree of compliance with environmental and occupational health regulations by the semiconductor industry? What are the barriers to compliance? Are the regulations themselves sufficiently health-protective?
3. What are the current level of symptoms or other health indicators of semiconductor workers? An anonymous mailed symptom and medical history survey to a random sample of current workers in this industry in California would be feasible and may give us clues to the current level of problems.
4. Are reproductive effects (eg. Miscarriages) continuing or increasing in this industry? What is the cause of the previously observed excess reproductive abnormalities if not glycol ethers or fluoride exposures? Follow-up reproductive surveys may be needed to determine if previous excesses are continuing.

Although several feasibility steps may be possible to fund out of existing resources, many of the above steps will require significant additional funding. Potential sources of funding for this research include:

1. NIOSH RO1 or R03
2. NIH RO1 or small grant
3. EPA
4. Industry
   Fee – based program
   Industry-based Foundation
5. State of California – General Fund – not likely in the current economic climate!

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[1] Wade R, Williams M. Semiconductor Industry Study. California Dept. of Industrial Relations, DOSH, Taskforce on the Electronics Industry, San Francisco, CA

[2] Bowler, R. M.; Mergler, D.; Huel, G.; Harrison, R.; Cone, J. Neuropsychological Impairment among Former Microelectronics Workers. Neurotoxicology. 12:1991; pages 87-104, 72 references.

[3] Bowler, R. M.; Mergler, D.; Rauch, S. S.; Harrison, R.; Cone, J. Affective and Personality Disturbances among Female Former Microelectronics Workers. Journal of Clinical Psychology. 47: 1991; pages 41-52, 59 references.

[4] Huel, G.; Mergler, D.; Bowler, R.Evidence for Adverse Reproductive Outcomes among Women Microelectronic Assembly Workers. British Journal of Industrial Medicine 47:1990; 400-404, 16 references.

[5] Vagero, Ahlbom A, Olin R, et.al. Cancer morbidity among workers in the telecommunications industry. Br J Ind Med 19985;191-195.