TRANSFERENCE OF OCCUPATIONAL CHEMICALS THROUGH BREAST MILK

By

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A Research Paper

Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
With a Major in

Risk Control

Approved: 3 Semester Credits

Investigation Advisor: Dr. Brian Finder

The Graduate School
University of Wisconsin-Stout
May 2002

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ABSTRACT

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The Transference of Occupational Chemicals Through Breast Milk
(Title)

M.S. in Risk Control Dr. Brian Finder May 2002 52
(Graduate Major) (Research Advisor) (Month/Year) (Pages)

American Psychological Association Style Manual
(Name of Style Manual Used in this Study)

The significance of this study stems from an interest in the information relating to the transference of occupational chemicals through breast milk as a job hazard for the Risk Control Specialist to consider. Three quarters of employed women are of reproductive age and more than half of United States children are born to working mothers, many of which return to work after six weeks and continue to breast feed their children until age 12-24 months. The vast number of workers of reproductive age together with the substantial number of work place chemicals suggests that a considerable number of workers are potentially at risk for adverse outcomes.

The purpose of this study is to identify the extent that industries of the 21st century that utilize high-risk chemicals are taking necessary precautions to protect their female employees. What occupational chemicals are known to transfer through breast-

milk, how does the transference occur, and what are the known toxicological implications to the breast-fed infant? What percent of the current production workforce of industries using high-risk chemicals is female and what high risk chemicals are currently being used in production? To what extent are workplace controls among high-risk industries being utilized to reduce occupational chemical exposure to females of reproductive age?

A survey was designed for this study to collect information from risk control specialists regarding the percent of women working in production in chemically high-risk areas, they types of chemicals used and the employee protection put in place by the industry. In developing the survey, the 7 questions were directed specifically to gather information on female employees between the ages of 18 and 55 years (reproductive years). The subgroup was asked to respond to generic questions on the types of jobs held by female employees, the percent on line/production workers that were female, and the total number of employees at the mailing location. The Risk Control Specialists were asked to check all the chemicals their company used in production and or cleaning and they were also asked to respond relating to the workplace controls utilized to reduce occupational chemical exposure to female employees.

All appropriate descriptive statistics will be run on the data to address the research questions for this study. The data was analyzed using SPSS software for research analysis.

ACKNOWLEDGEMENT

I would like to thank my family for their support during my pursuit of this degree and through the process of this research. I would also like to thank the risk control staff and my advisor Brian Finder for their guidance and for giving me the opportunity to further my education and career. Finally, I want to say a special thank you to my husband for the endless amount of support and love he gives me.

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Statement of the Problem

Introduction

Three-quarters of employed women are of reproductive age and more than half of United States children are born to working mothers. The vast number of working women of reproductive age (13-55 years), together with the substantial number of toxic chemicals and biological agents in the workplace, suggests that a considerable number of women are potentially at risk for adverse outcomes (NORA, 1993). The adverse outcomes discussed in this paper are the potentially detrimental effects of industrial chemical contaminants in human milk. The focus is principally the potential exposures and possible health effects to the newborn, in which a body burden of toxic chemicals may be created by breast feeding (Wolff, 1983, pp. 259).

Human milk has unique nutritional and immunologic properties and is the natural and most important foodstuff for infants. The importance of breast-feeding for healthy child growth and development has become increasingly recognized in recent decades (Jensen and Slorach, 1990, pp. preface). Psychologically, a breast-fed infant forms a maternal bond that enables adaptation more readily to a social environment (Kacew, 1993). The issue of toxic industrial chemicals present in trace quantities in human milk poses a unique occupational risk. When the exposed employee is a mother who is breastfeeding, the risk "is also taken home" and passively extended to her nursing infant via chemicals present in the breast milk (Giroux, Lapointe, Baril, 1992, pp. 472). Issues which compound this potential problem are that the information regarding the transference of occupational chemicals through breast milk is limited, occupational risk managers may not be aware of this as a risk to their employees, physicians and public health practitioners may not assess this risk during their health assessments, and the female employee may not be aware of this as a risk to her breastfed infant. Consequently, there exists a strong potential that industries which use chemicals known to transfer through breast milk are not taking the necessary precautions to minimize exposure to the associated female employees.

Purpose of the Study

The purpose of this study is to identify the extent that industries of the 21st century who utilize high risk chemicals are taking necessary precautions to protect their female employees

Research Questions

Following are three questions that serve as the basis for this study:

1. What occupational chemicals are known to transfer through breast milk, how does the transference occur, and what are the known toxicological implications to the breast-fed infant?

2. What percent of the current production workforce of industries using high risk chemicals is female and what high risk chemicals are currently being used in production?

3. To what extent are workplace controls among high risk industries being utilized to reduce occupational chemical exposure to females of reproductive age?

Background and Significance

Hazard identification from one industry in particular, the semiconductor industry, reveals that there are many sources of potential exposure to chemicals including arsenic, organic solvents, photoactive polymers, and heavy metals (Wald and Jones, 1987). The spectrum of potentially harmful substances changes rapidly with the development of new manufacturing processes within the industry, and there is frequently insufficient time to characterize potential health effects of these substances before they are brought into widespread industrial use. Technological and economic benefits associated with this industry have been accompanied by growing scientific and public concern for the health of its workers (LaDou, 1986). As the size of this industry's work force expands, the potential for adverse health effects must continue to be determined (Eldelman, 1990).

Data regarding the type of potentially hazardous work done by women, and injuries/illness women experience in the workforce is of particular value in this study. In 1984, the semiconductor industry employed over 270,000 workers in the United States, of which 74% were female and over one-third of which were production workers (BLS, 1986). Women were more likely to be employed in production than men and less likely to be employed in skilled labor, professional or managerial positions (McCurdy, Schenker and Lassiter, 1989, pp. 502). The annual incidence rate for all-reportable injuries and illnesses in the semiconductor manufacturing industry was 2.7 per 100 full-time employees for men and 3.7 per 100 full-time employees for women (McCurdy, Schenker and Lassiter 1989, pp. 499). Thus one could speculate that more women than men had potential for occupational exposure to chemicals while working in semiconductor production.

Of the 2,994 cases reported to the OHS (Occupational Health System) in 1984, the greatest total of work-loss days and restricted workdays for women occurred among production workers. Figure 1 indicates that inhalation, absorption, or other contact with chemicals and gases was the most frequently reported type of injury or illness and 69.8% of these cases occurred in production workers (Figure I, McCurdy, Schenker and Lassiter 1989, pp. 506). Based on their data analysis, McCurdy, Schenker and Lassiter (1989) indicate that the companies participating in the 1984 OHS tended to be industry leaders and large firms. Smaller companies not participating in the OHS were less likely to command comparable resources for engineering, company health clinics, and other preventive measures that would decrease hazards and favorably affect workers' health (McCurdy, Schenker and Lassiter 1989, pp. 509). Unfortunately, the data is not available for the smaller companies and therefore no way to measure the work-loss for these women.

In an additional analysis of case reports of the Bureau of Labor Statistics (BLS) from 1980-1985, data showed that 55 % of the injuries and/or illnesses reported were for females employed in the semiconductor manufacturing industry. The semiconductor incidence rate for "respiratory conditions due to toxic agents" during 1984 was five times greater than rates for private industry and all other manufacturing industries. Almost one-half of these toxic substance type injury and illness cases were due to inhalation exposures. Given the nature of the workers' compensation cases (i.e., variable and under-reporting), this frequency may be understated and may indicate that inhalation of toxic substances may be a greater health problem for workers in the semiconductor industry (Robbins, Butler and Mahaffey, 1987, pp. 12).

Figure 1. Frequency of Reported Cases and Work-Loss Days for Cases Reported to the Semiconductor Industry Association's Occupational Health System in 1984 by Source of Injury/Illness (McCurdy, Schenker and Lassiter 1989, pp. 506).

Source of Injury/Illness	Frequency N %	Percent of cases with work-loss	Work-loss days per case (days)	Work-loss days sum (days, %)
Chemicals and gases	742 (24.8)	20.5	1.3	995 (12.0)
Containers	353 (11.8)	40.2	4.6	1,615 (19.4)
Working surfaces	347 (11.6)	49.0	6.1	2,108 (25.4)
Other	322 (10.8)	26.7	2.3	756 (9.1)
Furniture, fixtures	289 (9.7)	35.3	2.1	612 (7.4)
Not Classified	242 (8.1)	33.1	3.1	751 (9.0)
Machine or mechanical apparatus	198 (6.6)	24.2	1.7	338 (4.1)
Bodily motion	180 (6.0)	41.1	3.7	661 (8.0)
Metal items	178 (6.0)	20.2	1.3	229 (2.8)
Hand tools	143 (4.8)	16.1	1.7	245 (2.9)
Total	2,994 (100)	30.5	2.8	8,310 (100)

Exposure to and inhalation of toxic chemicals has potential to lead to systemic poisoning. The State of California gathered workers' compensation data presenting the percent of occupational illness due to systemic poisoning. Figure 2 indicates there is more occupational illness from systemic poisoning in the electric component and semiconductor industries from 1985 through 1989 than all manufacturing industries (Figure 2, LaDou and Rohm, 1992, pp. 1061).

Figure 2: Percent of Occupational Illness Due to Systemic Poisoning, California Experience (Ladou and Rohm, 1992, pp.1061).

Industry	1985 %	1986 %	1987 %	1988 %	1989 %
All manufacturing industries	21.5	20.6	17.4	17.0	16.6
Electronics components and accessories	31.6	39.7	31.4	30.7	35.6
Semiconductors	36.5	49.6	34.3	39.8	40.8

The National Occupational Exposure Survey (NOES) was a 2.5 year nationwide data gathering effort designed to develop a database which would support the development of estimates of the number of workers potentially exposed to various chemical, physical and biological agents in the semiconductor industry. Figure 3 illustrates the capabilities of the NOES to identify potential exposure agents associated with the industry, the number of people potentially exposed, and the control measures utilized. The potential exposures to arsenic were controlled with personal protective equipment PPE (59.5%), ventilation (19.8%) and other controls (20.7%) such as isolation or administrative practices and procedures. With the exception of isopropyl alcohol and 1,1,1-trichloroethane, 92.9 to 100 percent of the potential exposures to the remaining eight chemicals were controlled by PPE, ventilation, and other controls. Potential exposures to phosphoric acid were observed as controlled by PPE (62.4%) and ventilation (37.4%) (Seta and Sundin, 1987, pp. 42).

The background information relating to the occupational exposure of women to chemicals and the data from 1980s is of significance because it raises the question regarding toxicological implications to the exposed women who are now experiencing diagnoses of a chronic/terminal illness potentially relating to this earlier exposure. It also raises another question regarding the lifelong toxicological implications to the children whose chemically exposed mothers breast-fed them. The exposures to mothers who breast fed their babies during and after occupational chemical exposure also allows one to question if the children, who are now adults, carry a body burden of toxic chemicals that will affect their future health. The babies of the 1980s will soon be adults who will enter professions and they will have the ability to influence how business/industry occupationally exposes employees to toxic chemicals and justifies the importance of risk control as part of the way business is conducted in the future.

Figure 3. National Occupational Exposure Survey (Seta and Sundin, 1987 pp. 41).

Potential Exposure Agent	Total # of Worker	# of Female Worker	Percent Controlled	Respiratory Protection	Personal Protection other than Respiratory	Venti-lation	Other Control
Silica	461	234	98.3%	0.0%	0.0%	7.6%	90.7%
Ammonia	961	500	98.5%	0.0%	25.1%	24.3%	49.1%
Arsenic	98	19	100.0%	0.0%	59.5%	19.8%	20.7%
Arsine	768	294	97.9%	0.0%	0.0%	16.5%	81.4%
Isopropyl Alcohol	3440	2358	75.1%	0.0%	37.4%	27.3%	10.3%
1,1,1 Trichloro-ethane	604	384	74.0%	0.0%	40.9%	28.7%	4.3%
Nitric acid	1713	863	99.7%	0.0%	63.2%	36.5%	0.0%
Phosphoric acid	1111	712	99.8%	0.0%	62.4%	37.4%	0.0%
Sulfuric acid	1858	1036	99.9%	0.0%	65.7%	34.3%	0.0%
Trichloro-ethylene	675	471	92.9%	0.0%	46.5%	44.5%	1.9%

Assumptions

Since there is documented evidence of occupational exposure of chemicals to women via inhalation, absorption, and ingestion, and there is an increase in the number of working women of reproductive age, and more than half of the United States children are born to working women, one could assume that there is potential for transference of the occupational chemicals via breast milk to the nursing infant, thus potential for toxicological effects on these infants, that may carry on in to adulthood.

Definition of Terms

The following terms used in this paper are defined as follows:

Toxicological effects: The effects of a noxious or poisonous substance formed or elaborated either as an integral part of the cell (endotoxin) or tissue, as an extracellular product (exotoxin), or as a combination of two, during the metabolism and growth of organisms (Stedman's, 1987, pp. 763).

CHAPTER II

Review of the Literature

Introduction

The potential for injury to female workers and their babies due to chemical exposure and transference of the chemical to the baby through breast milk is a hazard in many industries. Perhaps as a result of this risk, research has been done to document the occupational chemicals known to transfer through breast milk, the methodology for infant uptake of chemicals and the toxicological implications to the infant. Research has also shown the potential for adverse outcomes from this exposure to be significant. These outcomes can include fever, allergic type skin, respiratory, eye reactions, carious teeth, jaundice, abnormal liver functions and even death (Hara, 1985).

Semiconductor Fabrication and Chemical Exposures

The semiconductor industry is an example where occupational chemical exposure to women takes place. Semiconductor fabrication plants manufacture integrated circuits that consist of miniature transistors, capacitors, and resistors on or near the surface of a semiconducting substrate such as silicon or gallium arsenide (LaDou and Rohm, 1992). In order to produce an integrated circuit, layers of micrometer-thin materials are placed on top of a silicon base through a manufacturing process called chemical vapor deposition. The deposition process works by using a gas that forms a vapor that crystallizes on the surface of the chip (Hassig, 1990). In general, these layers fall under three types of classifications; insulators (silicon dioxide), polysilicon (a form of silicon used for circuit elements) or metal (gold, aluminum, and copper), (Hassig, 1990).

After the integrated circuit layers are formed, a photolithographic process generates patterns on the deposited layers of the chip. This process involves placing a layer of light-sensitive liquid called photoresist, on top of each layer. Then, light is shown through a mask that projects a pattern onto the photoresist. Next, the areas exposed to light are removed using stripping agents, leaving the underlying layer exposed. Finally, the exposed layer is etched away using an acid or gas, thus producing the desired pattern. The final layer of protective photoresist that remains over the pattern is removed using a solution containing hydrochloric acid (Hassig, 1990, pp. 82). After photolithography is complete, the exposed areas are ready for another process called doping. This involves implanting molecular impurities into the crystal lattice structure of the silicon wafer, which produces electron potentials (excesses and deficiencies of electrons) that turn the exposed areas into a conductor or a non-conductor of electricity. The doping process involves the use of different chemicals such as arsenic, phosphorous, and boron (Eldelman, 1990). Figure 4 lists the areas of semiconductor production and some of the chemicals used in the process that are potential sources of employee exposure (LaDou and Rohm, 1992).

Figure 4: Example of Chemicals Used in Semiconductor Manufacturing (LaDou and Rohm, 1992, pp. 1052-1059).

Production Process	**Chemicals and/or Gases used in production**
Silicon Production (Wafer)	Silicon, silicon halide, trichlorosilane, galium arsenide, hydrogen gas
Etching	Nitric acid, hydrofluoric acid, acetic acid.
Polishing	Colloidal silica, sodium hydroxide.
Finish cleaning	Hydrofluoric acid and surfactants
Dopants	Slicon, tellurium, chromium, polycrystalline gallium arsenide, antimony, arsenic, phosphorus, arsine, phosphine, phosphorus oxychloride, phosphorus pentafluoride, halides of boron, boron trioxide, boron nitride, diborane, silicon tetrabromide, molten boron oxide, argon
Sandblasting	Silicon carbide, calcined alumina
Photolithography	Silicon dioxide (oxide)

The breast feeding process and methodology of chemical transference

Since the beginning of the 1970's, the percentage of working mothers who breast-feed their infants has increased from 9 % to 20 % and they start breast-feeding when their baby is 6 months old until the child reaches 32 months old (Lawrence, 1989).
The breast milk these babies feed on is produced by two different areas in the human breast, a gland called the alveoli and at the beginning of the small milk ducts. During pregnancy as these areas prepare to generate milk (a process called lactation), the breasts enlarge two to three times their normal size (Jensen and Slorach, 1990). Immediately after the infant is delivered, and during the first week afterward, breast milk is yellowish and sticky and contains protein concentrations that can reach 10% in comparison to 1% in mature milk. In addition, during breast-feeding sessions the fat concentration in human milk starts at a low concentration of 1-2% then increases to 4-6% by the end of the session (Jensen and Slorach, 1990).

Existing research points out the high protein and fat concentration in breast milk as risk factors for transferring chemicals from the mother to the nursing infant. Jensen and Slorach's (1990) research on chemical transference suggests that the elevated protein concentration in milk can result in excretion of protein-bound chemicals such as lead and mercury. In addition to Jensen and Slorach's (1990) research, Fleishaker, Desai, and McNamara (1987) also conducted research on chemical transference through breast milk and concluded that blood-borne chemicals prefer to excrete with fat towards the end of a breast feeding session since the milk contains the highest fat concentration. The fat is excreted as a milk-fat globule; a spherical structure with a limiting lipoprotein membrane enclosing a lipid core (Fleishaker, Desai, and McNamara, 1987).

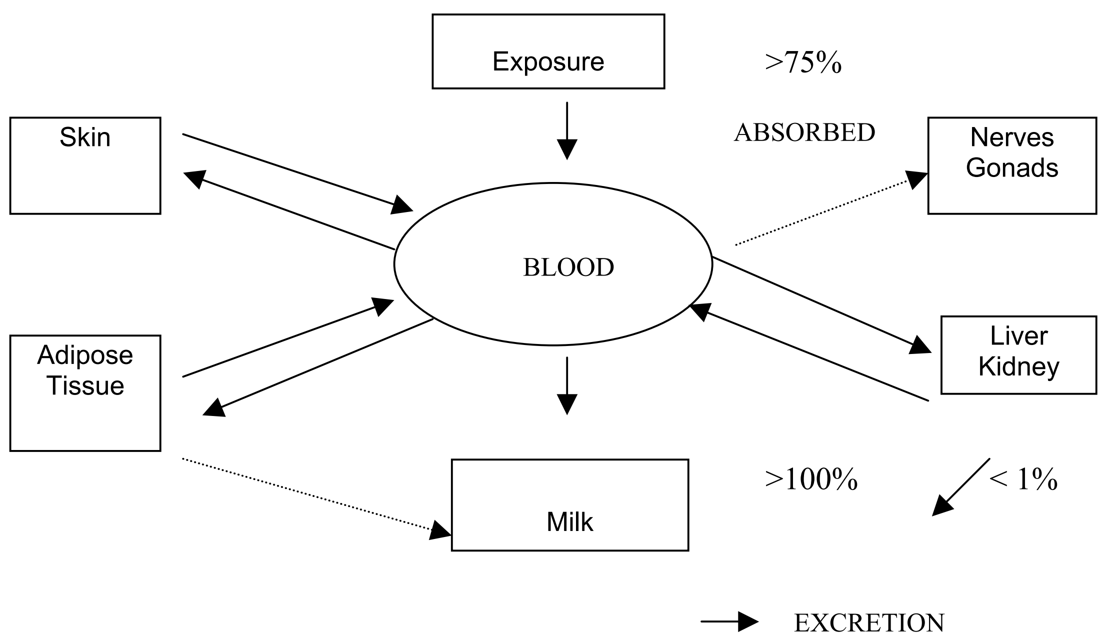
Details in research performed by Berlin, (1980) suggest that chemicals can bind to milk protein or the surface of the milk-fat globule, or with lipid-soluble compounds that equilibrate (are put in equal balance) with the lipid core of the globule. Since the molecules of these chemicals are lipophilic and un-ionized at physiological pH, they can penetrate readily into mammary gland cells and concentrate in the fat globules (Berlin, 1980). In addition, Berlin's (1980) research also suggests that by binding with the milk fat globule chemicals can be transferred in significant quantities into human breast milk if exposures are either chronic or acute. High exposures over a short time to lipophilic chemicals (e.g., organic solvents, halocarbons, and pesticides) occur in some occupations and in the general population through cases of mass intoxication (Jensen and Slorach, 1990). This suggests that female employees working in occupations with a high risk of chemical exposure have increased potential to accumulate a body burden of chemicals if accidentally exposed during work.

The literature search reveals a multitude of research on chronic exposures to low levels of lipophilic and metabolically persistent organohalogens, such as the pesticide DDT, polychlorinated biphenyls (PCBs), or polychlorinated dibenzo-*p*-dioxins (PCDDs) has also been conducted. In the blood, these chemicals bind to lipoproteins and are most abundant in the serum fraction (Birnbaum, 1985). In a pregnant woman, there is a shift in PCB distribution from the higher to very low-density lipoproteins. These are not transported to the fetus, but are a preferred source of lipid (fat) for mammary gland milk synthesis (Vodicnik, 1986, pp. 53). The metabolism and elimination of these organohalogens is very slow and as a consequence, most absorbed material is retained unchanged, resulting in a gradually increasing concentration of chemical substances in the body (Bickel and Muehlebach, 1980). Most of these organohalogens are stored in lipid-rich tissues and have biological half-lives of several years (Poiger and Schlatter, 1986). In females, lactation is the most prominent route of elimination for these chemicals (Yakushiji et al., 1978, pp. 493). Shelly, Anderson, and Fisher (1988,) developed an inhalation distribution model for the lactating mother and nursing child for organohalogens. The model supports research of earlier authors regarding the transfer of organohalogens via the breast milk and gives substantial evidence supporting the transference of inhaled chemicals through breast milk (Shelly, Anderson, and Fisher, 1988).

When organohalogens are stored in blood and adipose tissue, the concentration of these chemicals reaches dynamic equilibrium between organohalogen residues in blood and adipose tissue (Matthews and Dedrick, 1984). The organohalogen concentration in the blood depends on mobilization (movement via circulation) from body stores and the current intake of chemicals. In the general population, the intake of chemicals is most decisive for concentration in the blood, but with lactating women, the situation is different because the daily elimination of organohalogens is greater than the daily intake. In contrast, the concentration of organohalogens in human milk reflects the concentration in adipose tissue, which acts as a reservoir that is built up and mobilized during lactation (Jensen and Slorach, 1991). Chemical storage in adipose tissue may be considered a kind of protective mechanism in women, by keeping the chemical away from critical targets like the nervous system. The stored chemicals are mobilized to the blood if fat deposits diminish, which happens during lactation (Birnbaum, 1985). A model of persistent organohalogens pathways in lactating women is illustrated in Figure 5 (Jensen and

Slorach, 1990). This flowchart demonstrates the movement of a chemical through the body following an exposure by inhalation, or skin absorption where 75% of the chemical has been absorbed. The chemical is transferred to the blood and moved by the circulatory system to the nervous system, skin, liver, kidneys, and fat tissue stores and chemicals excrete at a rate of 1-100% depending on the organ.

Figure 5: Pathways of Persistent Organohalogens in Lactating Women (Jensen and Slorach, 1990, pp.12).



Occupational Chemicals in Human Breast Milk

Of the many different types of hazards that female workers are susceptible to, occupational chemicals are a threat to their health and safety (LeGrande, 1989). This is possibly due to the high number of workingwomen (50% of the workforce), the variety of occupations and the expanding use of industrial chemicals. In addition, occupational health and safety professionals are not always aware that most chemicals can be transferred from body fat or from blood into breast milk of a lactating mother and in this way expose the nursing infant to significant health hazards (Jensen and Slorach, 1991). Figure 6 is a representative list of chemicals that could present a significant threat to nursing infants. The chemicals of this list are used in different industries during production. Since literature reveals that more than 50 % of production/line workers are females and may be in close proximity to the some of the chemicals listed in Figure 6, this suggests a potential for occupational exposure to these chemicals with transference to the nursing infant.

Figure 6. Occupationally Derived Toxic Chemicals That Are Likely to Present Hazards to Nursing Infants of Exposed Mothers (Giroux, Lapointe, and Baril, 1992, pp. 473).

Chemical Name	Chemical Name
1,1,2-Trichloro-1, 2,2-trifluoroethane	Isopropyl alcohol
Acetone	Lead (inorganic)
Antimony	Lead chromate (oxide)
Antimony oxide	Lead dioxide
Benzene	Lead tetraoxide
Butanol-1	Manganese
Butanol-2	Mercury (metal)
Butanone-2	Mercury oxide
Cadmium (metal)	Methylene chloride (dichloromethane)
Chloroprene (2-chloro-1, 3-butadiene)	Napthenic acid lead salt
Cobalt (metal)	Phenyl mercuric acetate
Cobalt chloride (2+)	Petroleum distillates (gasoline)
Copper (2+ sulfate)	Styrene
Copper (metallic)	Tetrachloroethylene (perchloroethylene)
Copper sulfate (anhydrous)	Toluene
Cychlohexane	Xylene
Dichlorodifluoromethane	Zinc (metal)
Ethyl alcohol	Zinc chloride
Ethyl benzene (sw<1mg/ml)	Zinc oxide
Fluorothichloromethane (trichlorofluoromethane)	

Case Studies of chemical transference through breast milk

In reviewing previous studies of occupationally exposed women, the theoretical risk of occupational chemicals transferring via breast milk modulated from a theoretical risk to actual occupational risk as revealed in the literature. For example, in one case study, Reed (1908) described a woman who worked in the lead industry during 16 pregnancies and nursed her 16 children while being exposed to the lead she was working with. As a result, all but one of her babies died from convulsions that occurred while the infants were being nursed. The infant who survived did so because the mother stopped breast-feeding as soon as the baby's heath began to fail. Once this step was taken, the baby recovered (Reed, 1908). In a more recent study of women occupationally exposed to lead in the Ruhr area of the Federal Republic of Germany, Prinz, Hower, and Gono, (1978) reported a correlation between lead levels in milk and blood. When the occupational blood-lead levels increased, their research determined that an even higher milk-lead concentration was reached (Prinz, Hower, and Gono, 1978, pp. 87). Thus the authors indicate that the higher milk-lead concentration was due to the occupationally exposed mothers.

Across the Pacific, in Japan, similar research has been conducted on chemical transference through breast milk. In a study of women who were exposed to Polychlorinated Biphenyls (PCB) in a capacitor manufacturing factory, Kuwabara et al., (1978) observed PCB concentrations 10-100 times higher in milk from women who were occupationally exposed to PCBs than in milk from non-occupationally exposed mothers. In addition, PCB concentrations in blood from breast-fed children were recorded up to 115 parts per billion (ppb) and were sometimes greater than the concentration of PCB's in their mother's blood. Kuwabara et al., (1978) also found a high correlation between whole blood PCB concentrations and whole breast milk PCB concentrations in the women. This suggests the possibility of estimating the concentration of PCB's in milk from the PCB concentration in blood and vice versa. This research supports the possibility of chemical transference through human breast milk following inhalation or absorption of occupational chemicals.

In addition to lead and PCB's, perchloroethylene has also been found in breast milk. For example, one case study reported by Bagnell and Ellenberger (1977) concerned a woman who, during her lunch break, regularly visited her husband while he was working in a dry-cleaning facility. Testing of the woman's breast milk indicated the concentration of perchloroethylene reached 10 parts per million (ppm) one hour after the visit and dropped to 3 ppm over the next 24 hours. (Bagnell and Ellenberger, 1977). In another example of chemical transference, the breast milk from an anesthetist was also tested for the presence of halothane, a common anesthetic. Results indicated a concentration of 0.8 to 2 ppm halothane in breast milk while air monitoring for the same chemical yielded concentrations of 0.27 to 1.5 ppm (Cote', Kenepp, Reed, and Strobel, 1976). This study indicates that the inhalation exposure to a high-risk chemical has the potential to transfer through breast milk to the nursing infant.

Benzene, another chemical used in rubber parts manufacturing, has also been found in women's breast milk. A study conducted Novikov, Kolodina, and Lipovskij (1979) in the USSR yielded concentrations of 0.5 to 0.6 ppm benzene in the breast milk. Other monitoring also yielded benzene concentrations 12-18% higher in the women's blood than in their breast milk while air monitoring yielded concentrations of 300 to 350 mg. In comparison, the permissible exposure limit (PEL) set by the Occupational Health and Safety Administration (OSHA) for benzene is 3.2 mg/m3 (OSHA, 1980). Unlike the other chemicals tested, the ability of benzene to transfer through breast milk and the extremely high air concentrations that these worker's were exposed to may be a cause for additional concern due to the carcinogenicity of benzene (American Conference of Governmental Industrial Hygienists [ACGIH], 1989).

In reviewing the literature related to chemical transference, the data collected from case studies of chemical transference through breast milk conducted by Reed (1908), Prinz, et.al., (1978), Bagnell and Ellenberger, (1977), Cote', et.al, (1976), Vozoveya, et.al., (1974) and Novikov, et.al., (1979) strongly suggest that chemicals absorbed into the body will find their way into women's breast milk. Interestingly, data from Bagnell and Ellenberger (1977) and Vozoveya, et.al., (1974) point out the ability of the body's metabolism and excretion capabilities to reduce the concentration of the tested chemical or remove it entirely after a 17-24 hour period of time. This supports that theory that infants could be exposed to occupational chemicals despite the fact that they are excreted from the mother's body in less than 24 hours.

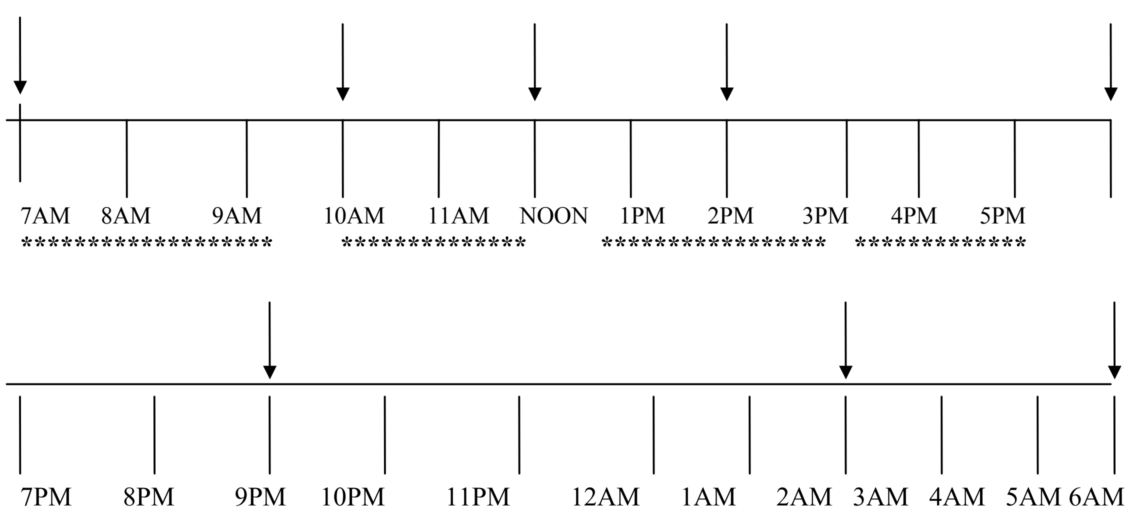
Models for Estimated Infant Uptake of Chemicals

Pharmacokinetics is the study of the uptake, distribution, metabolism and excretion of chemicals by the body and may be used along with physiologically based pharmacokinetic (PB-PK) lactation models to estimate the amount of chemical ingested by nursing infants. Starting in 1988, Shelley, Anderson, and Fisher (1988), developed a PB-PK model to estimate the lactational transfer of chemicals from mothers' occupational exposure to volatile organic compounds. Three years later, Hoover, Zeise, and Krowench (1991) also developed a pharmacokinetic model to describe the lactational transfer of 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). Two years after Hoover, et.al.,'s (1991) research, Schrieber (1993) applied a PB-PK model to estimate lactational transfer for percholorothylene. A year later, Byczkowski, Gearhart, and Fisher (1994) also developed and validated a rodent PB-PK lactation model for perchloroethylene and then adapted this lactation model for humans (Byczkowski, et.al, 1994). These PB-PK models provide additional research methods for estimating the infant uptake of the chemicals transferred via human breast milk. It is difficult to measure the infant uptake without exposing the infants to uncomfortable invasive testing which parents might not allow, thus the PB-PK models were developed to test this method of occupational exposure (Byczkowski, et.al, 1994).

A similar PB-PK lactation model (Figure 7) was developed by Fisher et al., (1997) to estimate the amount of chemical that a nursing infant ingests for a given nursing schedule and the maternal exposure to solvent vapors such as benzene and chloroform. In order to develop this PB-PK lactation model, Fisher, et.al., (1997) recruited eight lactating women who donated blood and breast milk samples for the research.

Figure 7. Schematic of the Generic Lactation/Chemical Exposure Model. (The model was adapted from Ramsey and Anderson, 1984, pp. 170).

Chemical Exposure and Nursing Schedules for a 24-hour period.



Key to Figure 7:

NURSING SCHEDULE ⟶

MATERNAL EXPOSURE ***********

During the Fisher et al. (1997) model development, human blood/air and milk/air partition coefficients (PCs) were determined for 19 volatile organic compounds (VOCs), which were selected, based on the importance of high-risk occupational chemicals and availability of previous documented PB-PK models or model parameters for the VOC's. Human blood-air, and milk/blood partition coefficient (PC) values were experimentally determined and used in the PB-PK lactation model and possible adverse health outcomes of the nursing infant were characterized by comparing PB-PK predicted estimates of amount of chemical ingested by the nursing infant per day with the Environmental Protection Agency (EPA) Health Advisory guidelines for children ingesting contaminated water (EPA, 1983). Figure 8 reflects the predicted amount of chemical ingested by a nursing infant over a 24-hour period, using the EPA data.

Figure 8. ACGIH TLVs, Predicted Amount of Chemical Ingested by a Nursing Infant (AMILK, mg) over a 24-hour period, and EPA Drinking Water Health Advisory Values for Ingestion of Water (EPA, 1983, pp. 1-125).

Chemical	ACGIHTLV (ppm)	AMILK (mg)	EPA Advisory (mg/day)
Benzene	10	0.053	0.20 B
Bromochloromethane	200	2.090	1.00
Carbon tetrachloride	5	0.055	0.07
Chlorobenzene	10	0.229	-
Chloroform	10	0.043	0.1
Methylchloroform	350	3.51	40.0
Diethylether	400	1.49	-
1,4-Dioxane	25	0.559	0.4 B
Halothane	50	0.232	-
n-Hexane	50	0.052	4.0
Isofluane	50 C	0.336	-
Methylene chloride	50	0.213	2.0 B

Methyl ethyl ketone	200	12.08	-
Percloroethylene	25	1.36	1.0
Styrene	50	0.650	2.0
Trichlorethylene	50	0.496	0.6 D
1,1,1,2-Tetrachloroethane	100 C	4.31	0.9
Toluene	50	0.460	2.0
o,p,m-Xylenes	100	6.590	40.0

Key for Figure 8:

A - Adapted from EPH Health Advisory values for chronic ingestion of contaminated water by 10kg children, assuming ingestion of 1 L of water per day. These Health Advisory concentrations for chemicals in water are thought to be protective of adverse health effects for chronic exposure.
B - Adapted from 10-day Health Advisory values for ingestion of contaminated water by 10 Kg children, assuming ingestion of 1 L of water per day. These Health Advisory values for contaminated water are thought to be protective of adverse health effects for a 10-day period.
C - No threshold limit value; concentration value was assigned.
D – lifetime Health Advisory value for ingestion of 2 L water per day in adults.

Fisher et.al.'s (1997) research indicates that because the mammary tissue is so well perfused with blood and since human milk contains about 4-6% fat, preferential uptake of lipophilic chemicals into breast milk occurs. Results of the Fisher, et.al., (1997) PB-PK simulation study suggests that lactational transfer of chemical will occur from a mother's occupational exposure and the nursing infant may be most at risk from bromochloromethane, perchloroethylene, and 1,4-dioxane exposure based on EPA drinking water guidelines. However, the toxicity of chemicals in infants is not well understood and remains a challenge to the field of toxicology (Fisher et al.,1997). In addition to the PB-PK models, infant intake of chemicals via breast can be estimated by multiplying the contaminant concentration in the milk fat by the infant intake of milk fat, using the formula shown below (Jensen and Slorach, 1990). This type of formula was used in a World Health Organization (WHO) study on human exposure to organochlorine compounds. The calculated daily intake for breast fed infants is listed in the WHO study (Slorach and Vaz, 1983).

$$I(d) = \frac{C \times F \times M}{B}$$

I (d) = daily intake of contaminant (mg/kg bw/day)
C = average concentration of the contaminant in the milk fat (mg/kg
F = average concentration of fat in the milk (g/100 ml)
M = average consumption of milk (ml/day)
B = average infant body weight (kg)

PB-PK models are one method that can be used for determining the estimated infant intake of contaminants in cases where invasive testing for the true intake of contaminants would not be possible. In addition, the contaminant intake formula created by Slorach and Vaz (1983) would be another, easier, way to determine estimated contaminant intake by an infant.

Toxicological implications of chemical transference through breast milk

The contamination of human milk by chemicals has been a concern in industry and research has been done to determine the existence of chemical transference and the estimated amount of chemical that transfers to the infant. However, very few attempts have been made to determine the toxicological effect to the infant. Most available reports that correlate illness in infants with pollutants in human milk concern overt clinical illness in the infant as well as in the mother and are associated with highly contaminated food products that the mother ingested (Kimbrough, 1987). Animal studies are not relevant to the question of health risks because in rodent studies, the dose that sucklings received was usually much higher than commonly found in human milk. Investigators in most studies also did not calculate the dose the suckling received in per kg bw/day, a common measurement for chemical transference through human breast milk. In addition, some animal species are more sensitive to chemicals than others and the target organs affected by these chemicals vary in different species. Thus, it is difficult to extrapolate the results of animal studies to infants (Kimbrough, 1982).

Studies of acute poisonings by organochlorine pesticides demonstrate clinical manifestations of illness in infants. Because these infants usually have not been "followed" into adulthood, it is not known whether their development was affected by exposures during breast-feeding (Kimbrough, 1982). In one study of acute poisoning by Cam (1960), high concentrations of the pesticide Hexachlorobenzene (HCB) was identified in mothers' breast milk after exposure over an extended period and the effects to the infant's health was monitored. The nursing mothers recruited for this study-consumed grain contaminated with HCB. Cam (1960) reported what he thought to be a new disease occurring among these nursing infants. The clinical manifestations were fever, vomiting, diarrhea, and circular brown plaques on the skin. The infants were weak, lost weight and anemia was noted. The infants also developed secondary infections and all the infants in this study died. Based on the research by Cam (1960), HCB contaminated grain in conjunction with breast-feeding appeared to be a factor in accelerating the infant deaths (Cam, 1960).

Concerns of environmental health specialists worldwide relate to the over use of polychlorinated biphenyls (PCBx). In 1985, Hara conducted a study of PCB exposures in Japan. Data collected from this study indicates that clinical manifestations were found in infants nursed by mothers who were exposed to heavy exposure to PCBs. Infant symptoms included fever, red eyes, itchy skin, carious teeth, decayed nails, mottled enamel and gingival pigmentation. In addition, another study by Bagnell and Ellenberger

(1997) not only demonstrated that a variety of chemicals can be excreted in human milk, but also reported the toxicological effects to the infant. In the Bagnell and Ellenberger (1997) study, a nursing woman was exposed to perchloroethylene vapors in a dry cleaning plant for a working period of 8 hours. One hour after exposure, perchloroethylene concentrations in her breast milk reached 10 ppm. This mother nursed her 6-week-old infant who developed obstructive jaundice and abnormal liver function during this nursing period (Bagnell and Ellenberger, 1997). Similarly, Sass-Kortsak (1974) reported cases of direct-reacting hyperbilirubinemia after an infant was exposed to phenol-contaminated breast milk. Research conducted by Reed (1908), Prinz, et.al., (1978), Bagnell and Ellenberger, (1977), Cote', et.al, (1976), Vozoveya, et.al., (1974) and Novikov, et.al., (1979) suggests that human milk can become contaminated with chemicals to which the mother is exposed and other studies by Cam (1960), Hara (1985), Bagnell and Ellenberger, (1997) and Sass-Kortsak (1974) pointed out the toxicological effects to infants as a result of the chemical transference. Despite the possibly severe health effects to infants (up to and including death) from chemical transference through breast milk, no overt illness has occurred in infants from exposures to chemical concentrations in human milk that may be only slightly higher than chemical concentrations in other food sources. However, adequate studies to determine this have not been conducted for most chemicals (Kimbrough, 1987).

Summary of Precautions to Protect Employees

The best method to minimize or remove potential occupational chemical hazards is through implementing engineering controls such as substitution of toxic substances with less hazardous alternatives, using a ventilation system and enclosing the production area where toxic chemicals are used (LeGrande, 1989). Substitution removes the toxin from the product production, thus removing it from potential employee exposure. In some cases the non-toxic substitute may cost more than the toxic substance, so the risk control professional may have to do a cost/benefit analysis to justify the human benefits acquired when the toxin is removed from production. Instead of substitution, some companies enclose their processes, thus removing any employee exposure to toxins (LeGrande, 1989). Another, more permanent solution is process revision where the production is reengineered and revised to reduce employee exposure to toxic chemicals (LeGrande, 1989). Another control that companies might use include storage units specifically designed for the type of toxic chemical in use. These units are monitored for the amount of chemical in storage at any given time. Special construction of these units also reduces the chance of overexposure/explosion to the employee and community should there be an occupational incident (LeGrande, 1989). In addition to all the above mentioned methods of control, a wet method can be used in production where particulate chemicals used in the process are washed into water and in a later process, away from production areas, recycled out of the water, reused and/or disposed of (LeGrande, 1989).

In addition to engineering controls, administrative controls such as conducting air monitoring and removing employees when the chemical concentrations are too high can be used. This can also be supplemented by the employee use of personal protective equipment (PPE) such as respirators, gloves and safety glasses/goggles. Another administrative control is medical surveillance of employees in order to detect early signs and symptoms of exposure to toxic chemicals. In addition, control of employee personal hygiene may be used when dealing with chemicals such as lead, which can cling to clothing, skin, hair and shoes (LeGrande, 1989). Because of lead's ability to cling to clothing, etc., the employee may be required to shower and change clothing and shoes prior to returning home after the workday. The maintenance of all equipment used by employees, and good housekeeping of their work areas may also be used to reduce employee exposure. In addition to the engineering and administrative controls used to control chemical exposures to the employee, worker training and employee cooperation is of importance (LeGrande, 1989). Particular emphasis should also be placed upon occupational safety and health hazard recognition and control training for both workers and employers (LeGrande, 1989).

The conclusions drawn from existing research by Reed (1908), Prinz, et.al., (1978), Bagnell and Ellenberger, (1977), Cote', et.al, (1976), Vozoveya, et.al., (1974), Novikov, et.al., (1979), Cam (1960), Hara (1985) and Sass-Kortsak (1974) point out the potential for transference of chemicals through breast milk and the toxicological effects to infants. In respect to the workplace protection of vulnerable populations, (e.g., lactating women who nurse their infants), more research may be needed to add further support and knowledge to the transference of chemicals through breast milk. Increased awareness of this potential route of exposure by occupational health and safety professionals may also be needed to support a paradigm shift in exposure routes and continued vigilance towards using measures to protect women working in the semiconductor industry. Chapter III will define the methodology used to obtain information about the extent that these controls are being utilized to reduce chemical exposure to females of reproductive age.

CHAPTER III

Methodology

Introduction

Occupational exposure to chemicals is a nation-wide challenge to the health and safety of employees and of grave concern to Risk Control Specialists. This author is researching the current workplace controls utilized among industries utilizing high-risk chemicals to protect females of reproductive age from exposure. This chapter will describe how the workplace sample was selected, a description of the sample, and the instrumentation used to collect the data. A description will follow of the data collection methodology, data analysis procedures, and conclude with the research methodological limitations of this study.

Subject Selection and Description

Occupational transference of chemicals through breast milk limits the subjects to females of reproductive age who are employed in chemically high-risk industries with the potential for exposure to these chemicals while on the job. Since about half the work force is female and females tend to occupy a larger percent of the production type positions and there are literally thousands of industries using high-risk chemicals, the pool of subjects is enormous. In researching the literature, the semiconductor industry is one industry that uses a vast number of high-risk chemicals and employs many women in production. Thus the industrial group of subjects chosen for this research consisted of the companies that are members of the semiconductor environmental safety health association (SESHA). In reviewing the 2001 membership, three hundred members were employed in occupational health, safety, chemical hygiene, safety engineers or risk/loss management specialists, and this was the subgroup chosen for sampling. This sampling group responded to the survey questions as professionals in risk control and on behalf of their company regarding the use of high-risk chemicals in production and the number of female employees with potential for exposure to the identified high-risk chemicals. They also responded on behalf of the company and it's female employees regarding the controls used to protect female employees from exposure.

A systematic method of subject selection took place to choose a mailing sample of 100 names and addresses from the subgroup of 300. The formula used was $K = 300 \div 100$, with K = every 3rd member of the SESHA subgroup of 300 members within the specifically defined job titles. The mailing sample began with the second member of the subgroup and every 3rd member after that was selected for the mailing until a total of 100 names and addresses were in the mailing sample.

Of the 100 names in this subgroup, 40 were female and 60 were male. The subgroup mailing addresses were from the following 21 states: Arizona, California, Colorado, Connecticut, Illinois, Indiana, Maine, Maryland, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oregon, Rhode Island, Texas, Utah, Virginia and Washington. All were members of the SESHA and held a job title of occupational health, safety, chemical hygiene, and safety engineers, or risk/loss management specialists.

Instrumentation

This author chose to design a three-page survey specifically for this study. The survey questions were derived from the information obtained in the literature review. In developing the survey, the 8 questions were directed specifically to gather information on female employees between the ages of 18 and 55 years (reproductive years). The subgroup was asked to respond to generic questions on the types of jobs held by female employees, the percent on line/production workers that were female, and the total number of employees at the mailing location. The literature review revealed a list of 39 occupationally derived toxic chemicals that are likely to present hazards to nursing infants of exposed mothers. This list was used in the survey and the subgroup was asked to check all the chemicals their company used in production and or cleaning. Since the subgroup consisted of persons employed in the fields of occupational health, safety, chemical hygiene, and safety engineers, or risk/loss management specialists, they were questioned specifically on the workplace controls utilized to reduce occupational chemical exposure to female employees. Finally the subgroup was asked if they were aware of the transference of occupational chemicals through breast milk and given web sites to contact for more information on the subject. Since this is an instrument developed specifically for this study, no measures of validity or reliability can be documented (survey instrument, appendix 1).

Data Collection

The 7-question survey was mailed on March 10, 2002 from Menomonie, Wisconsin to all 100 persons in the subgroup. A letter accompanied it stating that a survey was enclosed with instructions for completion by April 15, 2002. Included in the information was a self-addressed, stamped envelope to be used for return of the survey. The subgroup was told that if they chose not to participate, to simply destroy the survey, and by returning the survey, they agreed to participate. This is considered a confidential survey because the respondents were asked not to identify themselves or the company where they worked. The respondents were given the survey author's name, address, daytime and evening phone numbers, along with the phone number of the advisor for the study.

Data Analysis

All appropriate descriptive statistics will be run on the data to address the research questions for this study. An ordinal scale of measurement was used for survey questions number 3,4 and 6, with frequencies, percents, mode, and median as the appropriate forms of measurement. For research question number 1, all data came from the literature review in chapter 2 and data for research questions number 2 and 3 came from the survey measurements. The data was analyzed using SPSS software for research analysis.

Limitations

Since this is an instrument designed specifically for this study, one of the limitations is the fact that there are no measures of validity or reliability. An additional limitation to the study is that only semiconductor industry risk control employees were sent the survey and there are many other industries that use some of the 39 identified chemicals in production or cleaning. The author felt that after conducting the literature review, the semiconductor industry was most representative of an industry that would use the toxic chemicals listed in the survey. The respondents may not be truthful in responding to the questions or they may not want to participate, both of which could impact the return rate, which in turn affects the results of the study.

CHAPTER IV

Results

Introduction

The purpose of this study is to identify the extent that industries of the 21st century who utilize high-risk chemicals are taking necessary precautions to protect their female employees.

Following are three questions that serve as the basis for this study:

1. What occupational chemicals are known to transfer through breast milk, how does the transference occur, and what are the known toxicological implications to the breast-fed infant?

2. What percent of the current production workforce of industries using high-risk chemicals is female and what high-risk chemicals are currently being used in production?

3. To what extent are workplace controls among high-risk industries being utilized to reduce occupational chemical exposure to females of reproductive age?

This chapter includes all results of the study on transference of occupational chemicals through breast milk. Demographic information and item analysis are presented resulting from the survey data. The chapter concludes with discussion of the research questions under investigation.

Demographic Information

The 100 subjects randomly selected for this study consisted of 40 females and 60 males. These subjects were all members of the Semiconductor, Environmental, Safety and Health Association (SESHA) and held the title of occupational health, safety, chemical hygiene, and safety engineers or risk/loss management specialists. They answered the survey on behalf of their company regarding the use of high-risk chemicals in production, the number of females with potential for exposure to the high-risk chemicals and the controls used to protect female employees from exposure. One hundred surveys were mailed with a request to return by April 15, 2002. Thirty-six (36) out of one hundred (100) surveys were returned for a response rate of 36%.

Item Analysis

This survey on the transference of occupational chemicals through breast milk consisted of 7 questions. Each item measured in the survey is represented in this chapter along with the statistical results following data analysis using SPSS software for windows. Data analysis consisted of either nominal scale of measurement (when the variable is an either/or situation) or ordinal scale of measurement (when the variable is put into a logical order). The “n” is the number in the group, which consisted of 36 respondents. Mode refers to the most frequent score in the data set or the score that occurs most frequently. Median refers to the point at which 50% of the scores fall above and 50% of the scored fall below this point in the data set. The survey questions 1-7 along with item analysis are presented as follows:

Question 1: Does your facility employ female workers age 18-55 years? The nominal scale of measurement was used with the following response:

n = 36
Mode = 1 (yes)

Response	Frequency	Percent
Yes = 1	36	100%
No = 0	0	0%

Question 2: What jobs do the female workers hold in your facility, with the respondent choices of clerical, line/production, sales, design, marketing, executive, and other? The ordinal scale of measurement was used with the data analysis as follows:

n = 36
Mode = 19
Median = 52.8%
Highest frequency = 35
Highest percent = 97.2% (line/production)

Response	Frequency	Percent
Clerical	28	77.8%
Line/Production	35	97.2%
Sales	19	52.8%
Design	19	52.8%
Marketing	17	47.2%
Executive	19	52.8%
Other	6	16.7%

Question 3: What percent of line/production workers are female in your facility, with the respondent choices of 1-20%, 21-30%, 31-40%, 41-50%, 51-60%, 61-70%, 71-80%, and 81-90%? The ordinal scale of measurement was used with the data analysis as follows:

n = 36
Mode = 2
Median = 5.6%
Highest frequency = 13
Highest percent = 36.1% (41-50%)

Response	Frequency	Percent
1-20%	2	5.6%
21-30%	2	5.6%
31-40%	9	25%
41-50%	13	36.1%
51-60%	6	16.7%
61-70%	1	2.8%
71-80%	1	2.8%
81-90%	2	5.6%

Question 4: How many total employees are at your location, with the respondent choices of 10 or less, 11-50, 51-110, 100-250, 251-500, 501-1000, and over 1000 employees. The ordinal scale of measurement was used with the data analysis as follows:

N = 36
Mode = 7
Median = 19.4%
Highest frequency = 13
Highest percent = 36.1% (companies of 251-500 employees)

Response	Frequency	Percent
10 or less	0	0%
11-50	0	0%
51-100	2	5.6%
100-250	7	19.4%
251-500	13	36.1%
501-1000	4	11.1%
Over 1000	9	25%

Question 5: How many chemicals are used in production, with the respondent choices of 39 chemicals listed in the following table. The ordinal scale of measurement was used with the data analysis as follows:

N = 36
Mode = 6
Median = 16.7%,
Highest frequency = 31
Highest percent = 86.1% (Acetone, Isopropyl alcohol)

Response	Frequency	Percent
1,1,2 Trichloro-1,2,2-trifluoroethane	10	27.8%
Acetone	31	86.1%
Antimony	7	19.4%
Antimony oxide	6	16.7%
Benzene	8	22.2%
Butanol-1	4	11.1%
Butanol-2 (sec-butyl alcohol)	7	19.4%
Butanone-2 (methyl ethyl ketone)	6	16.7%
Cadmium (metal)	5	13.9%
Chloroprene	2	5.6%
Cobalt (metal)	2	5.6%
Cobalt chloride	3	8.3%
Copper (2+sulfate)	12	33.3%
Copper (metallic)	15	41.7%

Copper sulfate (anhydrous)	7	19.4%
Cychlohexane	4	11.1%
Dichlorodifluoromethane	6	16.7%
Ethyl alcohol	17	47.2%
Ethyl benzene	12	33.3%
Fluorothichloromethane	7	19.4%
Isopropyl alcohol	31	86.1%
Lead (inorganic)	16	44.4%
Lead chromate (oxide)	9	25%
Lead dioxide	5	13.9%
Lead tetraoxide	3	8.3%
Manganese	2	5.6%
Mercury (metal)	4	11.15
Mercury oxide	3	8.3%
Methylene chloride	7	19.4%
Napthenic acid lead salt	1	2.8%
Phenyl mercuric acetate	2	5.6%
Petroleum distillates	5	13.9%
Styrene	2	5.6%
Tetrachloroethylene	3	8.3%
Toluene	8	22.2%
Xylene	9	25.0%
Zinc (metal)	12	33.3%
Zinc chloride	6	16.7%
Zinc oxide	8	22.2%

Question 6: To what extent does management provide protection of female employees from occupational exposure to chemicals, with the respondent choices of either engineering out the exposure, providing personal protective equipment, rotating female employees to minimize exposure, or excluding breast-feeding women from the chemical work area until they complete breast-feeding their child? The ordinal scale of measurement was used with the data analysis as follows:

N = 36

Engineering

Highest frequency = 14

Highest percent = 38.9% (often)

Personal Protective Equipment (PPE)

Highest frequency = 25

Highest percent = 69.4% (always)

Rotate females to minimize exposure

Highest frequency = 20

Highest percent = 55.6% (seldom)

<u>Exclude breast-feeding</u>
Highest frequency = 16
Highest percent = 44.4% (seldom)

Response	**Frequency**	**Percent**
Engineer out **seldom**	9	25%
Engineer out **often**	14	38.9%
Engineer out **always**	13	36.1%
Engineer **N/A**	0	0%
PPE **seldom**	1	2.8%
PPE **often**	8	22.2%
PPE **always**	25	69.4%
PPE **N/A**	2	5.6%
Rotate females **seldom**	20	55.6%
Rotate females **often**	9	25%
Rotate females **always**	3	8.3%
Rotate females **N/A**	4	11.1%
Exclude breast-feeding **seldom**	16	44.4%
Exclude breast-feeding **always**	9	25%
Exclude breast-feeding **seldom**	6	16.7%
Exclude breast-feeding **N/A**	4	11.1%

Question 7: Were you aware that occupational chemicals could potentially pass through breast milk to the nursing infant, with the respondent choice being yes or no? The nominal scale of measurement was used with the following response:

N = 36
Mode = 1 (yes)

Response	Frequency	Percent
Yes	34	94.4%
No	2	5.6%

Research Questions

Research question #1 – What occupational chemicals are known to transfer through breast milk, how does the transference occur and what are the known toxicological implications to the breast-fed infant? The data for this question came from the literature search of chapter II presenting research by various authors indicating that occupational chemicals do transfer through breast milk most often via the milk fat and that more research needs to occur to document the affects upon the nursing infants. The literature search provided the list of occupationally derived toxic chemicals that are likely to present hazards to nursing infants of exposed mothers used in the survey for this study.

Research question #2 – What percent of the current production workforce in industries using high-risk chemicals is female and what high-risk chemicals are currently being used in production? The data for this question came from the statistical analysis of responses to survey questions number 2, 3 and 5. In response to the type of jobs female workers hold, 97.2% of the respondents indicated the women work in the line/production areas and 77.8% worked as clerical. When questioned on the percent of line/production workers that are female in a high-risk chemical industry, the highest response was 41-50% of line/production employees were female. The literature search supplied the list of high-risk chemicals used in this survey with the respondents indicating that 86.1% of the companies used acetone and isopropyl alcohol, 47.2% used ethyl alcohol, 44.4% used inorganic lead, 41.7% used metallic copper and 33.3% used copper (2+sulfate), ethyl benzene and zinc (metal).

Research questions #3 – To what extent are workplace controls among high-risk industries being utilized to reduce occupational chemical exposure to females of reproductive age? The respondents could choose from seldom, often, always and not applicable. The data for this question came from the statistical analysis of responses to survey question number 6. Engineering out the exposure resulted in 38.9% of the respondents indicating that the company "often" engineered out the exposure. Provision of personal protective equipment (PPE) was “always” the choice for 69.4% of the respondents. The response for rotation of female employees to minimize exposure was “seldom” for 55.6% of the respondents. Exclusion of breast-feeding women from the chemical work area until they completed breast-feeding was also “seldom” the choice for 44.4% of the respondents.

CHAPTER V

Discussion, Conclusions, and Recommendations

Introduction

Chapter V will include discussion regarding the findings of this study on the transference of occupational chemicals through breast milk, compare and contrast the author's findings with those found in the literature review of Chapter II. The author will identify conclusions developed as a result of this study. The chapter will conclude with the author's recommendations for futures occupational health and safety strategies for workplace protection.

Discussion

The literature search in Chapter II provided documentation of the occupational chemicals known to transfer through breast milk, the methodology for infant uptake of chemicals and the toxicological implications to the infant. The literature revealed that 75% of women employed in the USA were of reproductive age, which was comparable to survey resulting in 100% of the respondents stating they employed females of reproductive health age. Chapter II literature suggested that one-third of female workers employed in chemically high-risk companies worked in production, which compared to survey results of 97.2% of the respondents stating women held production/line positions and of all the employees working in production, 36.1% of the respondents stated that 41-50% of these employees were female. Of the companies responding to the survey, 36.1% employed 251-500 employees. This study used the list of chemicals in the survey that were obtained via the literature review of chemically high-risk industries. The survey resulted with a positive response for the continued use of the same high-risk chemicals such as acetone, isopropyl alcohol, ethyl alcohol, lead, copper, benzene and zinc in production, and is comparative to the Chapter II literature review.

In contrast to the literature review on employee protection that suggested companies where most likely to engineer out the risk, only 38.9% of the survey respondents stated they "often" engineered out the risk to employees, and 69.4% responded that they "always" provided personal protective equipment. The most popular response was " seldom" from the respondents for rotation of females to minimize exposure or excluding breast-feeding women until they complete breastfeeding their infant. At the beginning of this study, the author speculated that there would be little awareness of chemical transference through breast milk, although in contrast to 94.4% of the respondents stating they were aware of this occupational risk.

Conclusions

As a conclusion of this study, the author believes enough previous research exists to support transference of occupational chemicals through breast milk as a risk in the chemically high-risk industries. Women of reproductive age are employed more than men in the production area for chemically high-risk industries and therefore if they are breast-feeding an infant, they are "at risk" of transferring the occupational chemicals to their infant. The use of high-risk chemicals is a reality in 21st century industries and this survey indicates that the majority of health and safety specialists know that the transference of chemicals through breast milk is an occupational hazard. Survey respondents chose personnel protective equipment "most often" as the method of protecting employees from this work site hazard.

Recommendations

This author recommends that chemically high-risk industries gather their risk control specialists, engineers, supervisors, management, industrial hygienists, vendors and female production employee representatives to discuss ways to engineer out the risk as the first priority to reduce this risk. When the risk cannot be engineered out, then job rotation and personnel protective equipment are second choices when it comes to protecting employees from workplace exposures. The same group of individuals should discuss and agree upon the importance of rotation and personnel protective equipment when it comes to protecting females from high-risk chemical exposure and the possibility of transference of these same chemicals to their nursing infants. This is a topic that could lead to highly emotional discussions among all involved and may take time and honest commitment on the part of management to make the employees feel protected from exposures. Through discussion regarding the importance of protecting employees as well as management support throughout the process and employee cooperation, it is hopeful that the risk control specialists would gain the financial support needed to successfully reduce the risk and produce the product in a cost effective manner. Reducing workplace risk requires that everyone involved in the process believe there is a win-win conclusion to the reduction of the identified risk.

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APPENDIX 1

SURVEY LETTER and SURVEY

Karen Levandoski

1221 Evans Lane
Menomonie, WI 54751
715-232-2388

March 2002

Dear Survey Participant;

I am a graduate student in the **Risk Control Program at the University of Wisconsin Stout** in Menomonie, Wisconsin. My research topic is the Transference of Occupational Chemicals Through Breast Milk. I have an extensive background in Public Health that inspired my interest in this potential occupational risk.

I have enclosed a survey requesting information about the employment of women, the type of work they do, the chemicals used at your facility and the types of employee protection your female employees experience.

Instructions: Please complete the survey and return by April 15, 2002 it in the self addressed, stamped envelop with **no return address**. The information from this survey is anonymous, and by your return of the survey results, you give me permission to use the data in my research project.

Freedom to withdraw: If you choose not to participate, simple destroy the survey.

Risk/safeguards: Since this is an anonymous survey, there will be no means of identifying who returned survey and personal names and/or names of facilities will not be published in my paper.

Inquiries: If you would like to contact me, you may call 715-232-2388 during the day and 715-235-0943 after 5 PM. If you would like to contact my advisor, Dr. Brian Finder, UW Stout Risk Control you may call 715-232-1313.

Thank you very much for your time, I appreciate your input.

Sincerely,

Karen Levandoski

Transference of Occupational Chemicals Through Breast Milk

A survey by Karen Levandoski, graduate student in Risk Control at the University of Wisconsin Stout in Menomonie, Wisconsin.

Instructions

Answer questions as they relate to women (age 18-55 years) working in areas where there is a potential for occupational exposure to chemicals.

About working women age 18-55 years of age.

1. Does your facility employ female workers age 18-55 years?
   (Select only one.)
   - Yes
   - No
2. What jobs do the female workers hold in your facility?
   (Select all that apply.)
   - Clerical
   - Line/Production
   - Sales
   - Design
   - Marketing
   - Executive
   - Other, specify____
3. What percent of line/production workers are female in your facility?
   (Select only one.)
   - 1 - 20%
   - 21 - 30%
   - 31 - 40%
   - 41 - 50%
   - 51 - 60%
   - 61 - 70%
   - 71 - 80%
   - 81 - 90%

About your facility/company

4. How many total employees are at your location?
   (Select only one.)
   - 10 or less
   - 11-50
   - 51-100
   - 100 - 250
   - 251 – 500
   - 501 – 1000
   - Over 1000 employees

About your production

5. How many chemicals (approximate) are used in production/cleaning?
(Select all that apply.)

	Chemical Name	**√all that apply**
1	1,1,2-Trichloro-1, 2,2-trifluoroethane	
2	Acetone	
3	Antimony	
4	Antimony oxide	
5	Benzene	
6	Butanol-1	
7	Butanol-2 (sec-buyl alcohol)	
8	Butanone-2 (methyl ethyl ketone)	
9	Cadmium (metal)	
10	Chloroprene (2-chloro-1, 3-butadiene)	
11	Cobalt (metal)	
12	Cobalt chloride	
13	Copper (2+ sulfate)	
14	Copper (metallic)	
15	Copper sulfate (anhydrous)	
16	Cychlohexane	
17	Dichlorodifluoromethane	
18	Ethyl alcohol	
19	Ethyl benzene	
20	Fluorothichloromethane (trichlorofluoromethane)	
21	Isopropyl alcohol	
22	Lead (inorganic)	
23	Lead chromate (oxide)	
24	Lead dioxide	
25	Lead tetraoxide	
26	Manganese	
27	Mercury (metal)	
28	Mercury oxide	
29	Methylene chloride (dichloromethane)	
30	Napthenic acid lead salt (cyclohexanecarboxylic acid lead salt)	
31	Phenyl mercuric acetate	
32	Petroleum distillates (gasoline)	
33	Styrene	
34	Tetrachloroethylene (perchloroethylene)	
35	Toluene	
36	Xylene	
37	Zinc (metal)	
38	Zinc chloride	
39	Zinc oxide	

6. To what extent does management provide protection of female employees from occupational exposure to chemicals?

(Select one in each category.)

Engineer out the exposure

- Seldom
- Often
- Always
- Does not apply

Provide personal protective equipment (PPE)

- Seldom
- Often
- Always
- Does not apply

Rotate female employees to minimize exposure

- Seldom
- Often
- Always
- Does not apply

Exclude breast-feeding women from the chemical work area until they complete breast-feeding their child

- Seldom
- Often
- Always
- Does not apply

7. Were you aware that occupational chemicals could potentially pass through breast milk to the nursing infant?

(Select only one.)

- Yes
- No

8. Would you like more information on this potential exposure?

Web sites: http://www.epa.gov.htm
http://www.cdc.gov.htm
http://www.nrdc.org/breastmilk

Thank you very much for the time you took to help me with my research project.
Please return the survey by April 15, 2002.

Sincerely,

Karen Levandoski
Graduate Student
University of Wisconsin Stout