Chapter 2

Introduction to the Study

CONTENTS

Figure

Chapter 2

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INTRODUCTION

Protecting the reproductive health of male and female workers is necessary because reproductive capacity is fundamentally important, both to individuals and to the health of future generations. Because reproductive dysfunction manifests itself in and through a variety of effects, and because these effects are difficult to measure, policymakers may never have complete information regarding the full extent of reproductive health dysfunction. The management of uncertainty, therefore, stands as a central issue in the protection of reproductive health.

This chapter summarizes the nature and complexity of the issues surrounding reproductive health hazards in the workplace, outlining what is known and unknown about agents that may cause harm, the number of people potentially exposed, the nature of research on reproductive hazards, and the risk assessment process in Government regulatory agencies. The historical perspective of women in the workplace is discussed in terms of their changing fertility patterns, and the importance of occupational safety and health measures, worker education, and engineering controls is stressed,

The reproductive system involves many physiological processes, and its functioning is integrated with numerous other organ systems. Reproductive health dysfunction thus has repercussions for general health status. Alterations in sex hormone metabolism or production may, for example, increase the risk of heart disease or certain cancers in men and women. In women, alterations in sex hormone metabolism may cause premature menopause which, in turn, increases their risk for developing osteoporosis. The more immediate effects of reproductive system damage are infertility or subfertility. Reproductive impairment can also affect offspring in various ways.

Hazards to reproductive health include chemicals, drugs, infectious agents, radiation, physical factors, aspects of lifestyle such as the use of tobacco or alcohol, and stress. These hazards may be found virtually anywhere—in the home, in the environment, and in the workplace. This study is confined to reproductive health hazards found in the workplace, where most Americans spend a substantial portion of their lives.

The Federal Government is committed, through legislation, to ensuring as safe and healthy a work environment for its citizens as is administratively and technically feasible. The United States is also committed to a second important social goal, which sometimes appears to conflict with the commitment to protect the health and reproductive capacity of workers and their offspring: equal opportunity for men and women in the workplace. These commitments are complicated by the biological dependency of an embryo/fetus[1] on the pregnant woman. The embryo/fetus, an involuntary presence in the workplace, may need additional protection from exposure to harmful substances beyond that which may be required to protect the health of the worker.

A number of recent events have focused attention on exposure to reproductive health hazards, intensifying public concern over the presence of such hazards both in and out of the workplace:

- Drug= related damage to children whose mothers ingested apparently harmless drugs during pregnancy. Use of the nonprescription drug thalidomide by European women to treat minor headaches and insomnia caused major congenital malformations in their children. The thalidomide episode heightened public awareness that a drug can damage the fetus even when it is not harmful to adults.

[1]Gestation is commonly divided into three stages: 1) the blastocyst, from conception until about week 3; 2) the embryonic, from week 3 to about 8 or 9 weeks; and 3) the fetal, from 8 or 9 weeks until birth. The blastocyst stage is often subsumed within the embryonic stage in order to simplify terminology (see ch. 3).

The use of the prescription drug diethylstilbestrol (DES) by pregnant women in the United States to reduce the risk of miscarriage caused an increased frequency of a rare form of vaginal and cervical cancer in daughters born to these women. Daughters of mothers who took DES are more likely to have structural anomalies in their reproductive organs (6,24,40). Earlier evidence, which had suggested that sons of women who took DES are at higher risk for incidence of structural anomalies in their reproductive organs, has not been confirmed by a recent study (11).

- Damage to parents and offspring exposed to toxic substances as a result of industrial accidents: Minamata disease (brain damage resembling that associated with cerebral palsy) in Japan illustrated the potentially devastating effect of industrial pollution on unborn children as well as on adults. In the Japanese city of Minamata, industrial waste containing methyl mercury contaminated the fish eaten by local inhabitants, causing deaths among adults and children, and major congenital defects in children born in the area. More than 10 years elapsed before the cause of the symptoms was officially acknowledged (29).
- The potential for reproductive damage to adults and their offspring posed by exposure to toxic substances released in industrial accidents: The escape of a cloud of dioxin from a trichlorophenol plant in Seveso, Italy, and the accidental release of radioactive materials at the Three Mile Island Nuclear Power Plant in Pennsylvania have not, to date, been linked with reproductive damage. They have, nonetheless, served to heighten public awareness of the potential health hazards of industrial processes.

There has also been increased attention given to the effects of such other hazards to reproduction as alcohol consumption, ingestion of illegal drugs, and smoking. These hazardous agents can impair reproductive health and sexual capacity in adults and can have adverse effects on the developing embryo/fetus. They differ, however, in that individuals can control their use and are often aware of the potential health risks posed by use or ingestion of these substances.

PREVENTION OF REPRODUCTIVE IMPAIRMENT

Reduction of preventable reproductive impairment would lessen the need for policies to deal with the consequences of such impairment, A visible, serious, and persistent commitment to safety by both management and labor appears crucial to preventing workplace impairment of reproductive function. Workplace-induced damage to reproductive function can be minimized by such specific measures as reducing exposures through engineering controls (e.g., ventilation), placing physical barriers between the worker and the source of the hazard, substituting nonhazardous materials for hazardous ones, using personal protective equipment, training workers in the safe performance of tasks, initiating repeated, systematic inspections of the workplace for emerging or previously undetected hazards, and rotating jobs or changing tasks to reduce exposure to the hazard. This latter action could, however, have the opposite effect in that greater numbers of workers would be exposed if job rotation were the only means instituted to reduce exposure. Control technologies are extensively described in the recently completed OTA assessment, ***Preventing Illness and Injury in the Workplace, 1985.***

It is important to monitor workers for evidence of reproductive health impairment prior to and during workplace exposure, and to adequately compensate those who have been harmed by such exposure. This report assesses current levels of knowledge of the causes of reproductive impairment and detection of such impairment. It also analyzes the regulatory and legal apparatus for reducing exposure to reproductive health hazards and compensating for reproductive impairment when it occurs.

THE POPULATION AT RISK

Ascertaining the extent of exposure to hazards in the workplace is crucial. How many workers are at risk? How many workers are of reproductive age, and how many of these workers are exposed to reproductive hazards? In what occupations are workers more likely to be exposed to reproductive impairment? What is the extent of reproductive dysfunction in the total population?

In 1984, the number of individuals in the American work force totaled 106.3 million, according to the Bureau of Labor Statistics (BLS). Men constituted 56.3 percent (59.8 million), and women, 43.7 percent (46.5 million) of this total. Approximately three-fourths of employed women were of reproductive age (16 to 44).[2] Reproductive age limits for men are more difficult to identify because reproductive function is less strongly correlated with chronological age.

There are no reliable estimates of the number of workers potentially exposed to reproductive or other health hazards at present. The National Institute for Occupational Safety and Health (NIOSH) is, however, now surveying industries for the purpose of obtaining these data, which will be tabulated by sex but not by age. Preliminary information will be available in late 1985 (8)26).

Estimates of the proportion of U.S. women who were employed during their pregnancies indicate that in 1980, 63.2 percent of married women over 20 years of age who had delivered a live infant were employed at some time during the 12 months prior to the birth of their children. Of these women, an estimated 17 percent, or 314)000 mothers, worked in industries and occupations in which they faced possible exposure to 10 potential teratogens (13).[3]

In humans, only one-fourth to one-third of fertilized eggs are likely to survive to term (43). Prior to the third month of pregnancy, about three-fourths of spontaneous abortions show chromosomal or other abnormalities (1)2,12). Some congenital malformation is present in 3 percent of live births in the United States. Some serious developmental defect is diagnosed by the end of the first year in another 3 percent of live births. Although rates of congenital malformation do not appear to be rising, the causes of these malformations are unknown in 60 to 70 percent of these births (10,14).

An estimated 8.4 percent of U.S. couples in which the wife is of childbearing age are infertile[4] (15). In some cases this inability to bear children appears to correct itself; in other cases the infertility persists. The causes of infertility are also unknown in a high proportion of cases.

The rates of such other manifestations of reproductive dysfunction as impotence, contaminated breast milk, or early menopause are unknown. The extent to which the chemical, physical, and biological agents to which individuals may be exposed in the workplace contribute to unexplained impairment of reproductive functioning is also unknown.

[2]Reproductive age limits for women vary according to the source. Although reproductive biologists usually define reproductive age as from 15 to 44 years, the Bureau of Labor Statistics data cover women only from age 16 onward.

[3]The results of this survey are limited because only married women who delivered a term live birth were included, only three physical agents and seven chemicals were labeled potentially teratogenic, and the exposure of the women in the sample was not measured. Instead, potential exposure was linked to the occupations that women reported. Only nonpharmaceutical, '(recognized" animal teratogens were included. Recognized animal teratogens are defined as two positive findings from at least two different laboratories and in at least two different mammalian species.

[4]This figure does not include couples in which one spouse has been surgically sterilized.

HISTORICAL PERSPECTIVE

Interest in protecting reproductive health traditionally has focused on women as bearers of children. One of the earliest references to hazards to women's reproductive health is found in the writings of Aristotle, who observed that "foolish, drunken, and harebrained women most often bring forth children like unto themselves, morose and languid" (7). And in Judges13:7 of the Old Testa-

ment the woman who is to bear Samson is advised, "Behold, thou shalt conceive and bear a son: and drink no wine or strong drink. " Only in the last 20 years has the importance of male reproductive health and its contribution to healthy children been widely recognized.

Social concern for hazards to women as bearers of children appears at several points in the history of women in the workplace. This concern has intensified during periods when women entered the workplace in relatively large numbers.

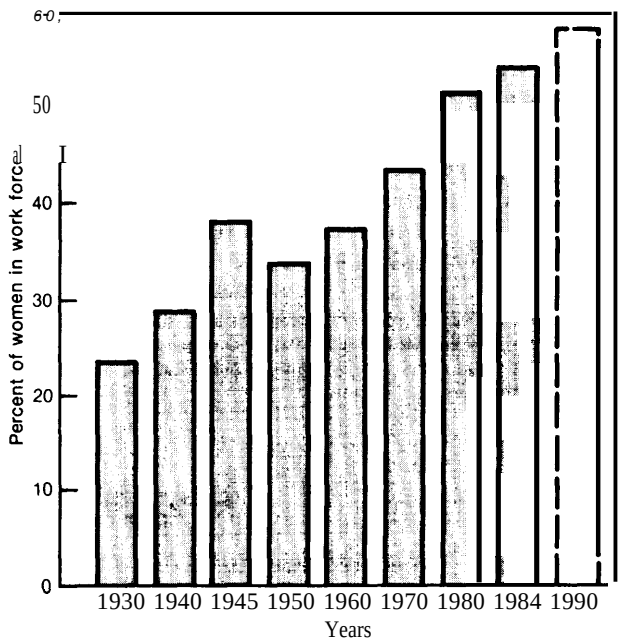
Before the Industrial Revolution women played an acknowledged role in economic life. In agrarian England, male wage earners were paid lower wages because their wives also earned wages. With the eradication of home industries during the Industrial Revolution, women were squeezed out of the economy. During this period the powerful image of woman as preserver of home and hearth flourished, obscuring the role of woman as wage earner. With the emergence of the middle class, a wage earner could make enough money to support a wife, children, and sometimes servants. Women of that era who were not married or who had been widowed had difficulty obtaining jobs that paid well because of the widespread conviction that a woman's place was in the home (28).

The view of women as lifelong homemakers has been perpetuated in the 2oth century by the misperception that fewer children and less time-consuming household chores have "pulled" women from the home into the workplace. Smaller family size has not, however, been a decisive factor in the return of women to the workplace. While the birth rate (number of children born annually per 1,000 women of childbearing age) has declined, ***more*** women today are having at least one child. From 1910 to about 1960, most American women either bore no children or had only one or two children. Until the 1950s, about one in five U.S. women who reached age 35 to 39 had never given birth to a child. Another 20 percent had given birth to only one child. Since the 1960s, the percentage of women who are childless or have only one child has fallen to about 1 in every 10 women of childbearing age.

The persistent image of woman as preserver of the home is also belied by the fact that one-fifth of U.S. women were employed outside the home at the turn of the century (an underestimate because women who labored on farms were undercounted). Before World War II, the proportion of women employed outside the home was nearly 30 percent, This proportion rose to 38 percent during the war, returned to 30 percent immediately thereafter, and has risen steadily since 1945 (28). In 1960, 38 percent of women over 15 years of age were employed; by April of 1984, this percentage had climbed to 54. Some 58 percent of American women are expected to be in the labor force by 1990 (36) (see figure 2-l).

The proportion of married women who are employed has also increased rapidly, from 31 percent in 1960 to 55 percent in 1982. Married women with children accounted for most of this increase. Among married women with children 6 to 17 years of age, the proportion employed rose from 39 percent in 1960 to 62 percent in 1980. Among married mothers with younger children,

Figure 2-1 .—Civilian Labor Force Participation Rates 'for Women 16 Years and Over, Selected Years



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, *Handbook of Labor Statistics,* Bulletin 2175, December 1983.

the proportion employed more than ***doubled,*** from 19 percent in 1960 to 45 percent in 1980 (13). By March of 1984, BLS reported that 46.8 percent of married women with children under a year old were in the labor force, compared with only 24 percent in 1970. The sharp rise in numbers and proportion of women-workers over the past 10 years has been accompanied by growing concern for their safety. Evidence of the risk to the reproductive capacity and sexual functioning of both men and women posed by toxic exposures has continued to mount during this period.

EVIDENCE OF REPRODUCTIVE HEALTH HAZARDS

The effects of occupationally induced disease on the reproductive system were first described in 1775, when Percivall Pott detected the link between chimney sweeps and scrotal cancer. He observed that scrotal cancer occurred almost exclusively in chimney sweeps and that '(the disease in these people seems to derive its origin from a lodgment of soot in the rugae of the scrotum ." Pott thus also identified the first known carcinogen. Interestingly, a 1962 report on his work points out that:

> . . . the mechanism of action of soot or its active ingredient is not understood, even after 187 years of enormous technological development, and the easiest, most effective method to control scrotal soot cancer is the same as that available to Percivall Pott and his contemporaries: prevention by avoidance of contact (22).

Physician Alice Hamilton, a pioneer in occupational health, brought the plight of female lead workers to public attention in 1919. Although she also demonstrated evidence of negative health effects in male workers, she was particularly interested in the causes of the more severe effects observed in women. She showed that the adverse health effects in these women and the higher infant mortality among their offspring were due not to their being "the weaker sex" but to the fact that women workers came from economically disadvantaged circumstances. More women than men were suffering from lead poisoning, for example, because men were more likely to be members of strong unions (which gave them some protection from adverse working conditions), were better paid, and had better living conditions. Women were more likely to be young and unmarried or to be widows, since married women were discouraged from working, and were unorganized, underpaid, and poorly housed (9). They came to the workplace undernourished and ill and were further weakened not only by the lead but by the effects of long hours, poor living conditions, and low pay.

To date, most studies of reproductive hazards have been carried out on wives of workers and their offspring or women and their offspring (4,19). The 1977 case involving exposure to 1,2-dibromo-3-chloropropane (DBCP), a known carcinogen, was one of the first to highlight the importance of hazards that affect male reproductive function. Informal discussion among male workers in a California pesticide factory manufacturing DBCP disclosed the fact that their wives had been having trouble conceiving since the husbands began working at the plant. After considerable discussion, one worker convinced five others to submit semen samples for analysis; all samples were determined to be grossly abnormal. All of these men worked with DBCP (41,42). Soon after the discovery of abnormal sperm at this and other plants, the Occupational Safety and Health Administration (OSHA) issued an emergency temporary standard that reduced exposure levels. A final standard was issued in March 1978 (43FR; 11514). DBCP was later banned by the Environmental Protection Agency (EPA) except for specific limited uses (spraying of pineapple plantations in Hawaii). EPA banned all uses in January 1985, and stipulated that existing supplies in Hawaii must be phased out by 1987. A subsequent study (20) indicates that, except in cases of exposure greater than 100 hours, the effects of DBCP on male fertility appear to be reversible. However, there is some evidence of an altered sex ratio in subsequent births to wives of the exposed workers (21) (see chapters 4 and 7).

The policy ramifications of this incident are also significant. Male reproductive capacity was found

to be endangered by DBCP, but men of reproductive age were not removed from their jobs. Instead, the hazardous agent was banned. In cases where the potential developmental hazard is paternally mediated, male workers have not been removed. The treatment of women workers in similar circumstances has, in certain cases, been reversed: when developmental hazards to the embryo/fetus have been identified, the women, rather than the hazards, have been removed. In at least two instances female X-ray technicians were removed from their jobs because of suspected risks, and in another case, women had themselves sterilized because they believed it was the only way they could retain their jobs (see chapter 8).

Since the regulation of DBCP in 1978, only two other standards, those for lead and for ethylene oxide, have been developed to protect workers from reproductive health hazards as well as other health hazards. These standards reduce allowable exposure levels and require mandatory posting of signs warning of risks to health and the reproductive system and mandatory employer education of employees with regard to health risks. In the case of ethylene oxide, regular physical examinations with attention to reproductive function are required, and in the case of lead, counseling with a physician is recommended if a pregnancy is planned (49FR 25734; 50FR64; 43FR 52952).

WORKER PERCEPTION OF RISK

Even if all risks could be accurately estimated and all workers fully informed and free to reject risks without other economic or social constraints, workers' actions would still be guided by personal perceptions of risk. The element of risk is a cost that is weighed against other costs and benefits in the personal decisionmaking process. Several features motivate an individual's acceptance of risk (3,5,27):

- the seriousness of the consequences,
- the perceived probability of personal impairment or misfortune,
- the voluntariness of the dangerous activity,
- the familiarity of the risk, and
- the availability/awareness of alternatives.

The inability of an individual to obtain information on which to base a decision is a source of stress. Among the coping mechanisms individuals use when faced with uncertainty is denial. When the safety of an activity is unclear, they may reduce or exaggerate the risk in order to support their choices. Another mechanism is to consider oneself immune from risk: "I am a safe driver; I won't have an accident." Others seek information from external sources, relying on "experts)" or the media. A consequence of this tendency is often a distorted sense of the risk inherent in some of the dangers people face. They tend to overestimate the likelihood of highly publicized events while underestimating more common events that elicit less public notice (5,27).

Although there is some evidence that workers mistrust employers, believing that they put profits before safety, evidence from the 1977 Quality of the Workplace Study (23) indicates that 84 percent of the workers questioned believe that their employers do inform and will continue to inform them of any dangerous or unhealthy conditions to which they are exposed on the job. There has been little quantitative analysis of employee risk perception, however. A recent qualitative study (18) describes worker perceptions of risk, fears of being harmed, and perceptions of employer neglect with regard to potential exposure, but provides no representative sampling of worker attitudes.

RISK ASSESSMENT AND MANAGEMENT OF HARMFUL AGENTS

The practices of risk assessment and risk management are changing, as are their underlying concepts. The protection of workers and others from the harmful effects of ionizing radiation emitted at nuclear powerplants was until recently a major focus of concern. As more and more chemicals have been produced, the emphasis of risk assessment and management has turned to the effects of chemicals that maybe toxic. Attention has shifted from protecting the human genome from the mutagenic effects of X-rays and radiation to protecting the population from the specific disease effects of often proprietary chemicals produced by individual companies.

Assessing and managing the risks of chemicals and other agents are complex undertakings. Most of the 5 million chemicals now in existence are probably not harmful at typical exposure levels. The National Academy of Sciences (17) estimates that there are about 53)500 chemicals to which individuals in the population potentially could be exposed. This total includes everything from industrial solvents to food additives, however. Many chemicals are manufactured in small quantities or are used in small amounts in research Laboratories. Of the more than 48)000 chemicals listed in the Toxic Substances Control Act (TSCA) inventory, only about 12,800 are manufactured in quantities of more than 1 million pounds per year, 13)900 are manufactured in quantities of less than 1 million pounds per year, and 21,700 are produced in unknown amounts (17). It is therefore unlikely that many people will be exposed to more than a few of these chemicals. But because no publicly available toxicity information exists for more than 70 percent of the chemicals included in the TSCA inventory, it is not possible to evaluate their health effects (17). In the case of chemicals for which there is sufficient information to undertake a health hazard assessment, factors such as dose, number of people exposed, conditions of use, and costs of testing must be taken into account in establishing priorities for health hazard evaluation and risk assessment.

'1982 estimate: this figure now exceeds 63,000.

The manufacturer is responsible for testing new chemicals when testing is required. Manufacturers must submit a Premanufacture Notification to EPA for substances included under TSCA, for example. But because TSCA requires no standard tests, the data need be only those that the company has available (30)31,32) (see chapter 7). For chemicals in commerce, EPA can issue a rule requiring that certain tests be undertaken by the manufacturer if EPA officials believe that the chemical poses a potential hazard.

In risk assessment, scientists evaluate the risk to find out whether the suspected hazard is real, and if so, the extent of risk to humans from exposure to the hazard (16,39). Scientists use epidemiological and toxicological evidence to predict the health effects of exposure of individuals or populations to hazardous materials and situations. Risk assessment includes: 1) hazard identification, 2) dose-response assessment, 3) exposure assessment, and 4) risk characterization (16; chapter 6):

- Hazard identification is the determination of whether a particular agent is or is not causally linked to particular health effects. In order for a substance to be identified as a reproductive or developmental hazard, it must be causally linked to reproductive or developmental impairment.[G]
- Dose-response assessment is the determination of the relationship between the dose or magnitude of exposure to an agent and the probability or incidence of the health effects in the population. Estimating human reproductive health effects is difficult because data are most often available only for animals.
- Exposure assessment is the determination of the extent of human exposure before or after application of regulatory controls. Exposure can occur in different patterns over time (chronic or acute); it can occur by different routes (inhalation or through the skin); and particular groups of workers may be more likely to be exposed.

'Developmental toxins may act from the time of conception until puberty, while reproductive toxins may interfere with reproductive or sexual functioning from puberty through adulthood (see ch. 3).

- Risk characterization is the description of the nature and often the magnitude of human risk, including attendant uncertainty. All of the issues in the risk assessment process are summarized and evaluated in order to determine the potential risk of the hazard.

Risk management, which follows risk assessment, involves deciding what to do about problems that have been identified in the assessment process. The goal of risk management is to control the risk. Decisionmakers must be able to demonstrate that when a regulation is enacted, there will, for example, be fewer deaths, or less sickness. The policy alternatives are weighed in order to select the most appropriate regulatory action. A host of legal, scientific, economic, and ethical issues attach to risk management (16,38) (see chapters 7 and 11).

Despite a growing body of information concerning the effects of reproductive health hazards and the risks they pose, legislators, regulators, industrial scientists, and managers are confronted by differing levels of uncertainty in efforts to manage potential risks. What is uncertain is likely to differ with each situation. There may be uncertainty as to which agents are harmful because workers are exposed to more than one hazardous agent in the workplace, or there may be synergism among a number of factors (including nonoccupational factors) that cause reproductive impairment. The evidence of toxic effects may come only from animal data, making extrapolation to humans difficult, or there may be a substantial time lag between cause and effect. Decisions regarding the management of reproductive risk must be made within the context of two important Federal statutes:

1 the Government's authority to protect workers, so far as is feasible, from exposure to hazards that could damage their reproductive systems (Occupational Safety and Health Act); and
2. the right of women and men to have equal access to employment opportunities, working conditions, and wages (Title VII of the Civil Rights Act).

The complexity of this decisionmaking is increased by the potential for harm to an embryo/fetus, which can come from either or both parents' exposure to toxic substances in the workplace or from exposure to substances parents may bring home on clothing and equipment.

THIS ASSESSMENT

This study examines the issue of reproductive health hazards in the workplace from three perspectives: scientific, legal, and ethical. Chapter 3 describes the fundamentals of reproductive biology, the mechanisms of action of reproductive and developmental toxins, and reproductive dysfunction in the population as a whole. Chapter 4 presents the scientific evidence for reproductive health hazards in the workplace, including chemical, physical, and biological agents. Chapter 5 reviews technologies for assessing human reproductive function. Chapter 6 describes the nature of the complexities in data collection and evaluation, and discusses the risk assessment process and regulatory agency activities with regard to guideline development for reproductive risk assessment.

The legal issues are discussed in chapters 7 through 10. Chapter 7 covers the prevention of injury; chapters 9 and 10 cover compensation for injury. Chapter 7 analyzes the regulatory process as it affects reproductive risk assessment and regulatory policy in a discussion of activities at OSHA, EPA, and the Nuclear Regulatory Commission (NRC). It also discusses landmark court decisions that bear on the Government's ability to regulate exposure to reproductive health hazards. Chapter 8 continues the discussion of relevant legal issues with an analysis of sex discrimination in employment under Title VII of the Civil Rights Act of 1964, as amended. Chapter 9 deals with workers' compensation systems, Legal liability for causing reproductive damage is assessed in chapter 10, which looks at theories of liability and

proof of causation. The issues covered in chapters 9 and 10 are of central importance because of the lack of uniformity in State workers' co--pensation laws, and the possibility of tort liability of employers if an embryo/fetus is damaged through exposure of the parent to hazards in the workplace.

Chapter 11 is devoted to an analysis of the ethical considerations surrounding the protection of workers and their offspring from reproductive damage.

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