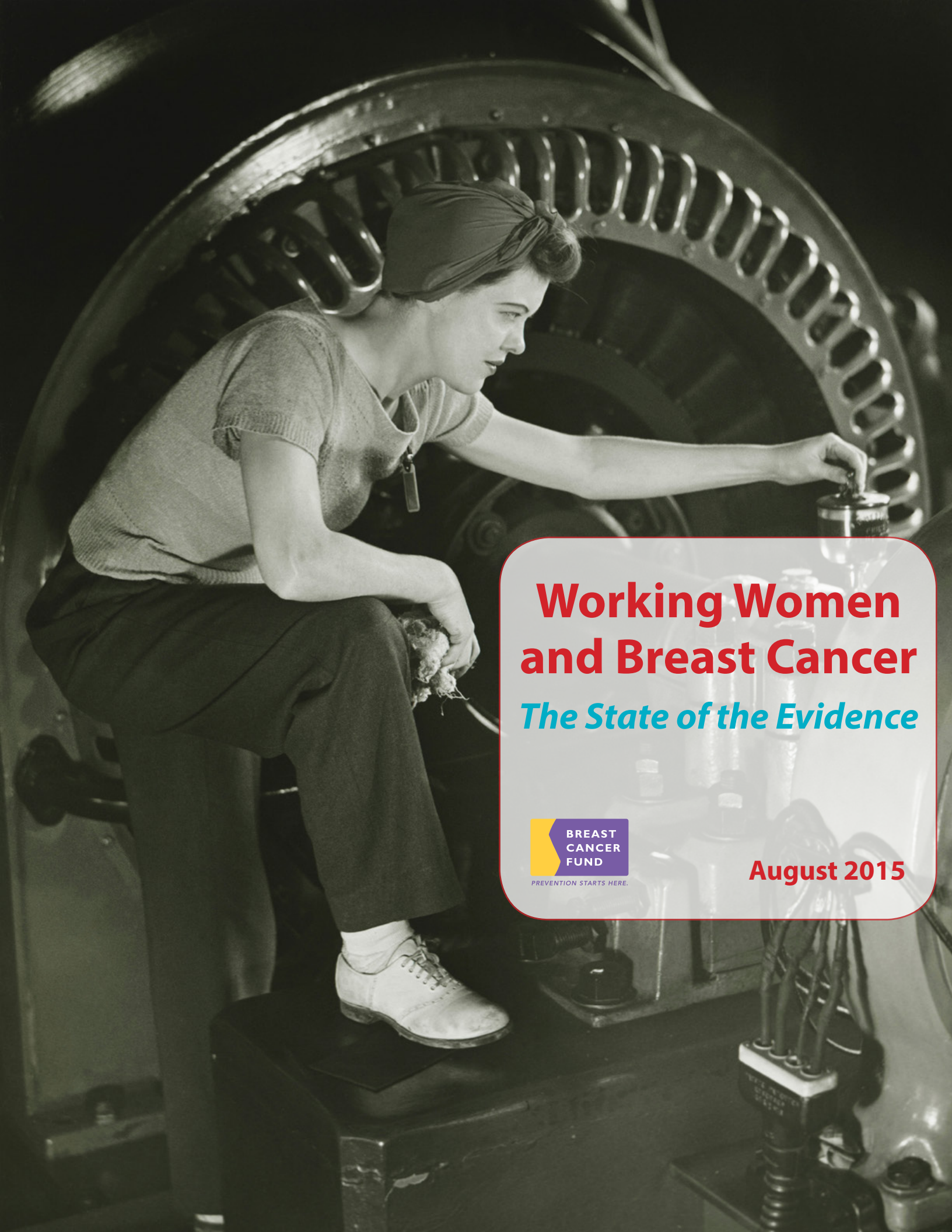

Working Women and Breast Cancer

The State of the Evidence

BREAST CANCER FUND

PREVENTION STARTS HERE.

August 2015

Working Women and Breast Cancer: The State of the Evidence

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The Breast Cancer Fund is a national 501(c)(3) organization dedicated to preventing breast cancer by eliminating our exposure to toxic chemicals and radiation linked to the disease.

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The Breast Cancer Fund thanks Kristan Aronson, Charlotte Brody, Jim Brophy, Dick Clapp, Anna Fendley, Molly Jacobs, Marg Keith, and Shelia Zahm for their review of earlier drafts of this document. We recognize the invaluable contributions of our study group participants for providing a strong foundation and context for our literature review.

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We are grateful for the generous contributions from our funders: Laszlo N. Tauber Family Foundation; The Twinkle Foundation; Cohen Family Fund; Clif Bar Family Foundation; Forsythia Foundation; The Jenifer Altman Foundation; Passport Foundation; Channaorah Meir; Cornell Douglas Foundation; The John Merck Fund; Johnson Family Foundation; Lesbians for Good of Horizons Foundation; Serena Foundation

Working Women and Breast Cancer: The State of the Evidence

Introduction

No one should face a breast cancer diagnosis because of their job. Unfortunately, workers across a wide range of sectors, from teachers to firefighters, have a significantly higher chance of facing the disease than the general population does. Which occupations, and which exposures on the job, put women at greatest risk for breast cancer? What can we do to protect workers and prevent the disease? The Breast Cancer Fund has been working to prevent breast cancer through elimination of toxic chemicals and radiation linked to the disease for over a decade.

With this report, we are making three major contributions to this effort:

1) A first of its kind scientific literature review of the research on women's work and breast cancer
2) An overview of the regulatory landscape and the U.S. government's failures to protect workers
3) Recommendations for research and policies that prioritize workers' health over industry profits or political gains

At home, work and leisure, we are all exposed to toxic chemicals and radiation. A compelling body of scientific evidence tells us that some of these exposures can increase breast cancer risk.

Because workers are often exposed to carcinogenic or toxic substances at regular doses for long periods of time, they are the modern-day canaries in the coal mine. Though research on occupational hazards provides important data, we must create a regulatory system that will ensure that workers are not exposed to these dangers in the first place.

We believe workers have these rights:

- To know what substances they are exposed to on the job
- To know the potential health impacts of those substances
- To be included in efforts to improve their working conditions

We are confident that there is a better way forward, and that a cancer-free economy is within our grasp. It's time to put breast cancer out of work.

Executive Summary

Based on the current evidence, action to reduce workplace exposures linked to breast cancer is imperative. The Breast Cancer Fund has spent nearly 15 years translating the science that links environmental exposures to breast cancer, and advocating for change. In the past several years, it has become increasingly evident that the workplace may be a substantive source of many of these exposures and of the resulting risk for breast cancer.

Occupations Linked to Breast Cancer

A well-established body of scientific evidence has identified five occupational groupings that are associated with considerably increased risk of breast cancer compared to the risk for the general population.

Our literature review confirms the scientific consensus on these occupations:

- Nurses – Up to 50% higher risk than for the general population
- Teachers – Up to double the risk
- Librarians, lawyers, journalists and other professionals – Up to 4 times higher risk
- Radiological technicians – Up to double the risk
- Lab technicians, factory workers and others who work with chemical solvents – Up to 3 times higher risk

In addition, our review uncovered a wide range of overlooked professions that deserve additional research and protections.

Professions that require additional research and protections:

- First responders (police, firefighters, military personnel) – Up to 2.5 times higher risk than for the general populations
- Food and beverage production workers – Up to 5 times higher risk
- Hairdressers and cosmetologists – Up to 5 times higher risk
- Manufacturing and machinery workers – Up to 3 times higher risk
- Doctors, physicians and other medical workers excluding nurses – Up to 3.5 times higher risk
- Flight attendants – Up to twice the risk
- Dry cleaning and laundry workers – Up to 4.5 times higher risk
- Paper and printing workers – Up to 3 times higher risk
- Retail and sales personnel – Up to 4 times higher risk
- Rubber and plastic products workers – Up to twice the risk
- Textile and clothing workers – Up to 3 times higher risk

Work Exposures Linked to Breast Cancer

Some of the strongest evidence for concerns about occupational health risks emerges from studies that examine the links between specific occupational exposures – such as benzene, pesticides and radiation – and breast cancer risk.

Workplace exposures of concern include:

Chemical Exposures

- Benzene and other solvents (Industries affected: chemicals/plastics/rubber, firefighting, health and science technology, military, printing, household services and more).
- Polychlorinated biphenyls (PCBs) (Industries affected: manufacturing, first responders)
- Polycyclic aromatic hydrocarbons (PAHs) (Industries affected: firefighting; industrial chemicals manufacture; iron and steel; metal industries; motor vehicle manufacture; nonmetallic mineral products manufacture; printing; surgeons; mastectomy personnel)
- Ethylene oxide (Industries affected: health care; medical equipment manufacturing; nurses)
- Pesticides (Industries affected: agriculture, glasswork, pottery, enamelware, wood preparation)
- Tobacco smoke (Industries affected: gambling; hospitality/food services; wholesale and retail trade; restaurants and hotels)

Other Exposures

- Ionizing radiation (Industries affected: aircraft; health and science technology; health care; lab work; nuclear power/nuclear fuel fabrication; nursing; radiological technology, radiology and medical specialties; radiation work)
- Night–shift work (Industries affected: any involving night-shift work)

Research Recommendations

Sociopolitical issues such as gender, race and economic factors must be taken into account when studying workers and breast cancer. This report provides recommendations for researchers and policymakers to incorporate these considerations into their work. For example, it is imperative that researchers and workers partner throughout the full research process, following the tenets of Community-Based Participatory Research (CBPR). This approach considers research to be a collaborative partnership that can lead to knowledge and action that benefit all partners. Since workers may be concerned about both their health (and that of their family) and their job security, it is vital that their expertise and needs be central.

Furthermore, knowledge from occupational research must be widely translated, disseminated and communicated in ways that are clear and meaningful for workers, employers, health care providers and all other stakeholders in occupational health. Ultimately, the research should support health-protective policies and activities.

We recommend a number of specific approaches that could fill gaps in the current literature on occupation and breast cancer:

1. Include workers throughout research
2. Include women in occupational studies
3. Study young working women and, when possible, follow their children
4. Measure exposures directly
5. Understand other characteristics that might affect risk
6. Include or add occupational information in studies that are already under way
7. Examine early indicators of health effects
8. Consider breast cancer subtypes
9. Bring research full circle by reporting results back to communities and individual study participants

Occupational Health Policies

The U.S. occupational safety system is broken, and the system has failed to protect the people who toil in American fields, teach our children and serve us when we're sick. The United States' complicated history of worker protections is riddled with failed attempts to meaningfully protect the workforce. The Occupational Safety and Health Agency (OSHA) and the National Institute of Occupational Safety and Health (NIOSH) are the primary federal agencies with authority to regulate and research occupational exposures. A complex history of legal challenges by industry has paralyzed OSHA in particular, and the agency admits on its own website that current regulatory limits are inadequate.

As a result of these insufficient standards, the U.S. is willing to accept far more cases of cancer resulting from occupational exposures than cases resulting from environmental exposures. The EPA offers the general public 100 to 1,000 times more protection from chemicals than OSHA provides for workers. OSHA estimates that 50,000 workers die each year as a result of past exposure to hazardous agents. Workers should never have to fight for their benefits while they fight for their lives, but oftentimes work-related illnesses go uncompensated.

Policies surrounding chemical use need to consider the full scope of product life cycles, including resource extraction, chemical production, industry utilization, consumer use and disposal.

As a result, fundamental updates to occupational health policy are indispensable to protect current workers and future generations from work-related disease, including breast cancer. These updates need to specifically take account of women in the workplace. It is past time for investment in prevention of workplace exposures and occupationally induced disease in general and breast cancer in particular.

Policy Recommendations

Policies should operate based on the fundamental principles of protecting workers and prioritizing prevention of breast cancer:

1. Research must explore breast cancer risk at work
2. Federal workplace protections must prioritize worker health via these measures:
   a. Modernize OSHA
   b. Promote and incentivize voluntary actions to protect workers
   c. Convene a Workshop on Occupation and Breast Cancer, in order to establish a national agenda on worker health and the disease
4. State OSHAs should act on their power to protect workers now, in advance of federal regulations
5. Employers should provide financial compensation to workers with illnesses related to workplace chemical exposure
6. Federal agencies, companies and researchers should collaborate with workers to develop viable methods to monitor workplace exposures
7. Health care providers should ask about work and workplace exposures
8. All stakeholders should understand and mitigate the adverse impacts of night-shift work
9. Workplaces need to fully disclose exposures of concern, regardless of trade secrets, and communicate with workers about their personal exposures when they are measured.
10. Workers should be engaged in finding solutions to reduce exposures
11. Broad coalitions and collaborations across movements and nations should be formed to improve workplace conditions globally.

Conclusions

Research is inadequate, but there is enough to raise alarm about women's work, occupational exposures and breast cancer. At the same time, policies are severely insufficient to protect worker health. Collectively, these concerns indicate it is well past the time for investment in prevention of workplace exposures and occupationally-induced disease in general and breast cancer in particular.

Methods and Guiding Principles

Breast Cancer Fund Methodology

This report is the product of over two years of work by the Breast Cancer Fund. We began by conducting a virtual study group on Occupation and Breast Cancer with more than 100 key participants, including scientists, advocates, workers, and decision-makers–both national and international experts. We held nine monthly sessions in 2013–14, each focusing on specific occupational settings. Upon completion of the study group, we evaluated what we learned and conducted an in-depth review of the scientific literature.

In this review we paid particular attention to studies published in the past 25 years. Studies were drawn from Scopus and Google Scholar searches during that time frame, from pivotal reviews published in 2003[1] and 2013,[2] and from research projects cited by the experts in our study group.

Nearly 250 studies comprised our initial review. From this initial compilation, we excluded those that did not report on breast cancer specifically and those in which results from the same cohort were reported in more recent papers. The studies included in this report analyzed data linking occupational categories to breast cancer (see Figure 1) and linking specific exposures to individual occupations (see Table 1). A substantial proportion of the research is based upon large-scale record-linkage studies. These provide exceptional statistical power, given the large sample sizes, but are also prone to potential chance findings given the number of analyses. We report null findings (studies where no effects were seen) from studies from case-control and cohort studies, but exclude them from record-linkage studies because of the large number of these cases (see Appendix A).

The studies we reviewed offered various definitions and categorizations of occupational titles and categories, job roles, and work setting. This was particularly true of studies drawn from different nations, since each country has its own approach to categorizing jobs and occupations. Hence, we grouped similar job descriptions. The detailed data in Appendix A highlight the data in similar occupations and include the authors' original job descriptions.

Our review of the evidence is divided into two major sections: 1) Occupations and breast cancer risk; and 2) Workplace exposures with evidence linking them to breast cancer. We highlight those occupations for which there is sufficient evidence to suggest a precautionary approach

to reduce exposures in the workplace. In addition to specific occupations that may confer risk for breast cancer, we explore occupations with likely exposures to chemical and physical agents linked to breast cancer in human or laboratory studies. These agents include solvents, plastic chemicals, flame retardants, ionizing radiation and light-at-night/shift work. We conclude with recommendations for future research and policy activities that could both fill existing research gaps and reduce the burden of breast cancer associated with work-related exposures.

Principles of Policies Designed for Worker Health

Workers' health must be protected.

As was noted in the foundational paper on occupational cancers in women by Zahm and Blair in 2003,[1] "Work should be a place where people provide a living for themselves and their families, a place of accomplishment, and a place of satisfaction, not a place where women increase their risk of disease and injury for themselves or their family. Identifying and controlling hazardous occupational exposures should be a public health priority, particularly because these are involuntary exposures from the workers' perspective, yet these exposures are largely preventable. Society can and should ensure that harmful occupational exposures are identified and reduced."

Though there has been a strong movement historically to address work-site safety, the impacts of chemical exposures on safety and health have often been absent from these discussions. This report argues for the need for increased attention to the adverse impacts of chemical exposures on worker health, including both the personal and economic costs.

Prevention must be prioritized.

Prevention research and action is often under-resourced, despite their proven economic benefits.[3] Exposures to environmental and occupational carcinogens are often preventable.[4] Primary prevention that controls a common source of exposure to proven and probable carcinogens is far more effectual, and cost effective, than persuading thousands of people to each change their individual behavior.[4] We support the 2013 statement of the Interagency Breast Cancer and Environmental Research Coordinating committee that "Prevention is the key to reducing the burden of breast cancer."[5]

Protecting workers protects everyone.

Reducing exposures in the workplace benefits not only workers, but their families and the general public.[6]

Currently, for the few chemicals that have worker exposure limits, the Permissible Exposure Limits (PELs) established by OSHA are orders of magnitude higher than those set by the EPA for the general public, so women and men in the workplace are routinely

exposed to levels of chemicals that would not be allowed in their homes. The relatively lax requirements in some occupational settings lead to both higher levels and longer exposure periods than would otherwise occur in a commericial or residential setting.

Efforts to reduce workplace exposures could have far-reaching public health impacts. If we make workplaces safer, particularly by substituting safer chemicals in manufacturing and production, this will reduce toxic exposures not only for workers, but also for the general population. For instance, using inherently safer chemicals in industrial processes and in consumer products protects not only the industry's workers, but also the communities around the manufacturing sites and consumers in general. Reducing worker exposure also reduces the chance that workers will bring those exposures home to their families on their clothes and body. Hugging one's child at the end of a workday should not expose the child to toxic chemicals.

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The State of the Evidence: Occupations Linked to Breast Cancer

Occupations Linked to Breast Cancer

Women's occupational health risk is significantly under-studied, yet existing research suggests that some occupations entail a considerably increased risk of breast cancer. Occupations with the most consistent data for associations with female breast cancer include clerical and professional workers in legal and social services, teachers, health care providers, chemists and chemical workers, and those who work with various solvents. Most of these associations have been replicated in the past two decades, although the strength of the associations varies by study.

Occupations linked to breast cancer are reported in Figure 1. As expected from prior reviews, breast cancer risk was elevated among certain occupational groups.

For many of these associations, elevations were seen across multiple studies, with different methods, and in different global populations. Record–linkage studies conducted in France, Poland, Italy, China, Sweden, the five Nordic countries as a group, as well as the United States and different regions of Canada reveal similar results across several occupations.

For example, multiple studies identify elevated risk among women working in financial and insurance occupations. This is consistent with several prior findings of elevated breast cancer risk among professional women. Multiple studies also reveal elevations among women in managerial and administrative roles, in studies that both adjusted for reproductive patterns and other risk factors as well as record linkage studies that did not. These factors are considered likely confounders, which lead to inaccurate conclusions about the occupational risk. For example, professional women are also likely to defer child-bearing, which is itself a risk factor for breast cancer.

Consistent with prior reviews, multiple studies revealed elevated breast cancer risk among nurses. Strikingly, studies also indicate elevated risk among health professionals, including physicians, as well as among scientists and lab technicians.

Historically, radiological technologists had elevated breast cancer risk, as evidenced by research with a large cohort of registered technologists. However, reduced radiation exposures appear to have diminished this risk in more recent decades. At the same time, more recent radiation use and new technologies utilized by some medical specialists such as orthopedic surgeons and cardiologists may lead to increased breast cancer risk. For example, the use of fluoroscopy during lengthy procedures such as insertion of cardiac stents and various orthopedic operations.[3]

Also consistent with prior reviews, breast cancer risk is associated with employment as a teacher, although several occupations had notably higher risk estimates. Positive associations were found across educational levels, ranging from preschool teachers to university teachers, and in several different countries.

The International Agency for Research on Cancer (IARC) reviews the evidence linking exposures to cancer. IARC lists a handful of industries as probably or possibly carcinogenic, and the results of our review were consistent with several of these including:[4] dry cleaning, hairdressing (cosmetology), printing, and iron and steel (metal-working, metal products). IARC also lists "occupational exposure as firefighter" as possibly carcinogenic. Most investigations have included only men, but a recent study to assess breast cancer risk among female firefighters reported a risk elevation among women aged 50 to 55; however, this was based on only five cases.[5]

Several studies have also found elevated breast cancer risk among workers in food and beverage production industries including food canning, as well as various manufacturing sectors, retail and sale, clerical, and textiles and clothing.

Other occupations have mixed findings, and need more research. For instance, some studies find associations between breast cancer and work in farming and agriculture, while other studies find no effect and sometimes even reduced breast cancer risk. Pesticide exposure is an area of concern,[6] although agricultural workers' risk of breast cancer may be simultaneously mitigated by high levels of physical activity.[7]

Studies of workers in service sectors, such as food service, gambling and related fields have yielded mixed results. A major exposure of concern in some of these fields is passive smoke exposure, although recent laws banning indoor smoking in some locales may have reduced this exposure and could partially explain the mixed findings.

Conclusions

Breast cancer risk appears to be elevated for several jobs and occupations: financial and insurance workers, managerial and administrative workers, clerical workers, nurses, physicians, science and laboratory technicians, radiological technicians (historically), teachers, cosmetologists, firefighters, food and beverage producers, manufacturing, retail and sales, and textiles and clothing.

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Extensive References outlined in the tables featured in Appendices A and B

Occupational Research Methods

Case-control: *Case-control studies are a type of observational study that involves participants who either have (the cases) or have not (the controls) developed a particular health outcome, e.g., breast cancer. Efforts are made to match the two groups for variables that are known confounders (factors that may lead to spurious conclusions about associations between variables being evaluated and developing breast cancer), while leaving other factors to vary randomly and be evaluated in the statistical analysis. Researchers then work to compare the relative frequencies of the history of the cases' and the controls' exposure to the environmental factor(s) of interest through interviews, questionnaires and testing of biological samples (commonly urine or blood), while statistically controlling for numerous demographic and other potentially relevant variables.*

Cohort: *Cohort studies identify groups of people who have been subject to particular exposure(s), and a suitable control group who have not been exposed, and then follow the participants to examine later development of a health outcome or outcomes that are thought to be linked to the exposure disease. In cohort studies, researchers try to match the two cohorts closely so that the exposure is the only known difference. Cohort studies are longitudinal in nature; that is, researchers follow the study participants over time to understand the possible association between an exposure and later consequences.*

Record linkage studies: *Population level records-based studies examine health and demographic data from a well-defined population, defined by such variables as geographical area, race/ethnicity, occupation, etc. but typically do not have lifestyle variables that would require contact with the subjects to ascertain. Population-based studies can be either case-control or cohort, in basic design.*

Meta-analysis: *Meta-analysis is a statistical technique that allows researchers to combine results from multiple independent studies and to determine the robustness of a particular association (e.g., between an exposure and the increased risk of developing breast cancer) over a variety of studies that may each have been run under somewhat different conditions, but which all examine the relationship between the target variables of interest. Because meta-analyses include results from multiple studies, they may be able to determine statistically which variables have higher statistical power —when many of the studies agree in outcome, the aggregate of data from many studies means more people have been studied and the results may be considered statistically more reliable. Where there are differences in outcomes across studies, meta-analyses are also helpful in identifying relationships for which there is less agreement about how strong they really are.*

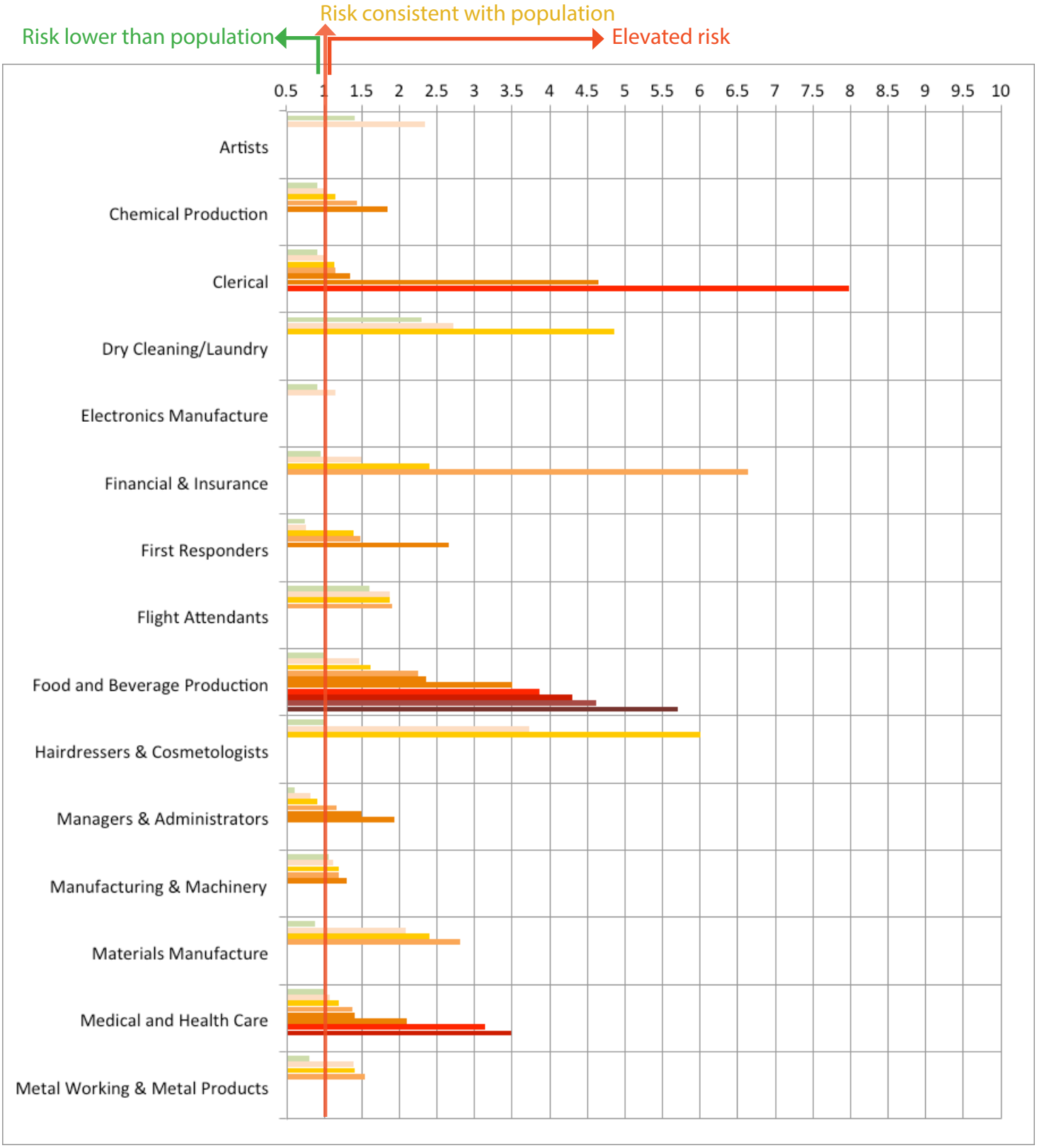
Mortality studies: *Mortality studies examine the rates of death from a particular disease, often using the U.S. Mortality files of the CDC, cancer registries, vital statistics registries, and other large databases as sources of information. These studies can also be either case-control or cohort, in basic design.*

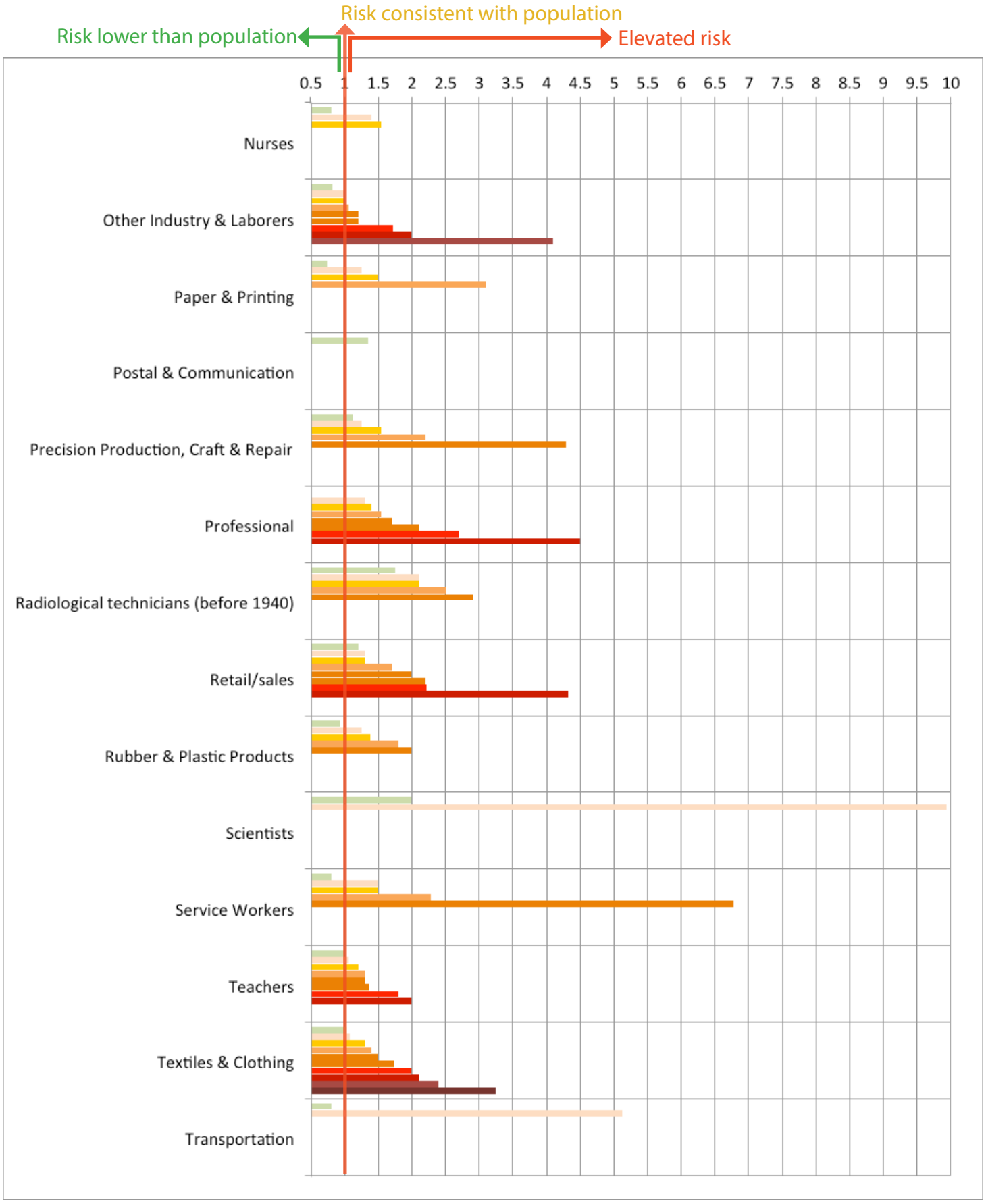
Incidence studies: *Incidence studies examine the rates of diagnosis of a particular disease and can be either case-control or cohort, in basic design. While large databases exist with information about incidence, especially cancer incidence, often these data are supplemented with examination of pathology reports and/or personal responses to surveys about health outcomes.*

Exposure studies: *Exposure studies measure, either directly or indirectly, chemicals and other exogenous agents to which humans are exposed and correlate these data with health (or other) outcomes. Exposure measurements can include bio-monitoring (sampling of people's blood, urine, breast tissue, etc. and determining chemical contamination), or measurement of the environmental chemicals through acute or chronic monitoring of air, water, soil, or dust samples. These measurements can be incorporated into either case-control or cohort studies.*

Figure 1. Summary of Occupational Risks for Breast Cancer, 1990-present *See Appendix A for Detailed Data*

Each bar represents one study.
The longer the bar, the greater magnitude of estimated risk. A value of one indicates a level of risk consistent with the population as a whole; values <1 suggest a protective effect; and values > 1 suggest elevated risk.




Risk lower than population
Risk consistent with population
Elevated risk
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7
7.5
8
8.5
9
9.5
10
Nurses
Other Industry & Laborers
Paper & Printing
Postal & Communication
Precision Production, Craft & Repair
Professional
Radiological technicians (before 1940)
Retail/sales
Rubber & Plastic Products
Scientists
Service Workers
Teachers
Textiles & Clothing
Transportation

The State of the Evidence: Work Exposures and Breast Cancer

Occupational Exposures and Breast Cancer

Occupational cohorts have functioned for decades as "canaries in the coal mine" for identifying carcinogenic substances. These workers bear a disproportionate cancer burden while acting as sentinels for the rest of society.[1]

Most environmental exposures are vastly under–studied, leaving significant gaps in what we know about the types and levels of exposures in different occupations. Some specific exposures may be higher among workers in specific occupations, but the majority of studies that assess general environmental exposures rely on population-based data, without collecting detailed occupational exposure information. This leaves significant gaps in what we know about occupational exposure levels and risk of disease.

Methods of Estimating Exposure

Few studies of occupation and breast cancer involve monitoring for exposures. Those studies that have included exposure estimates used methods including routine monitoring (especially common for radiation workers), historical records, levels of chemicals in air or dust, levels of dermal contact, and biomonitoring (measuring chemicals in human fluids and tissues).

The need to measure actual exposures is compounded because women may have different exposures than men within a given occupation, job title and work role. These variables may include:[2]

- Work in different aspects of a sector (e.g., women in smaller businesses vs. men in more industrial large-scale operations)
- Different job responsibilities, even within the same job at the same place. For instance, women may move from function to function more frequently.
- Different proximity to exposure sources (e.g., dust from a work table) and poorer fitting personal protective equipment
- Different metabolism of some substances
- Differences in work history/job duration/temporality
- Breaks (albeit often short ones) for maternity leave

As a result of these different patterns of exposure, it may be especially important to develop accurate and precise methods to measure women's exposures to chemicals, physical agents, and workplace conditions. Several methods of exposure assessment are employed in work environments:

- Health care workers with frequent radiation exposure often wear dosimeters to measure exposure.
- Night–shift work is often assessed via recall in interviews or questionnaires, and researchers can assess both the timing of shifts, the frequency of shift rotations, and the duration of shift work.
- Some studies rely on historical records, particularly for exposures that are routinely tracked to meet regulatory requirements. For these exposures, data may exist for ambient air levels in different areas of the workplace. To assess exposures to specific individuals, researchers may rely on efforts to reconstruct exposures based upon job title and/or activity.

- Exposure estimates can also be inferred via reconstruction of prior activities. Industrial hygienists use workplace diagrams, chemical use patterns, historical records, and job descriptions to provide insights into exposures for retrospective studies. In conjunction with employee records, these may even allow for estimates of the age at exposure and duration of exposure.
- A novel method employed by some researchers is space or body mapping, which uses drawings or visual maps to elicit participants' memories of chemical use, exposures, or symptoms.[3]
- Some methods precisely measure chemicals in the work setting. One study of airline crews used handwipes to identify exposures to flame retardants in airplane cabins. This study found elevated levels of Deca-BDE on handwipes, with several other flame retardants found in cabin dust.[4]

Biomonitoring

Studies that measure chemical body burdens are rare. Measuring levels of chemicals in blood or urine may allow for a more refined estimate of internal exposure, which can be useful in studies establishing associations of exposures with work roles. For instance, one study assessed phthalate levels among persons who work with or in proximity to that class of chemicals. Not surprisingly, they found that individuals who worked directly with the phthalate DINP had concentrations six to eight times higher than others, and that those who worked during a shift when it was used had concentrations 1.7 times higher than those who worked when DINP was not used.[5] Phthalates clear from the body relatively quickly. For these and other exposures with short half-lives, studies would need to frequently assess exposure levels to get an accurate picture of exposure. This would pose cost and logistical challenges. Other chemicals persist in the body and can be measured after months or years.

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Exposures in Health Care Settings

Health care providers, including nurses,[1] radiological technicians,[2,3,4,5] and orthopedic surgeons,[6] are among the occupations with elevated rates of breast cancer. Exposures and other risk factors in health care settings are notable, including night–shift work; ionizing radiation; chemotherapeutic agents; plasticizers and plastic chemicals such as phthalates; PVC and BPA; flame retardants, antimicrobials such as triclosan; sterilants such as ethylene oxide; and cleaning products, as noted in Table 2.

Union contract language for health care workers can address some of these concerns and provide recourse and power to influence policies related to exposures and resulting health concerns.[7,8] The American College of Occupational and Environmental Medicine offers guidance related to occupational health services for health care providers.[9]

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Chemical and Physical Agents at Work

Some of the strongest evidence for concerns about occupational health risks emerges from studies that have examined the potential links between specific occupational exposures and breast cancer risk. These studies can provide valuable data, but they are less common than research based upon industrial/occupational titles and breast cancer risk, described in the previous section.

Most exposure studies tend to focus on single (or a few) exposures, despite the reality that workers are exposed to mixtures at the work site and multiple chemicals across the day.

Studies have linked exposures to a number of chemicals with breast cancer risk:

- solvents (such as benzene, styrene, carbon tetrachloride, methylene chloride, formaldehyde, Freon, isopropyl alcohol, trichloroethylene, gasoline and other petroleum products)
- pesticides (such as aldrin, chlordane, dieldrin, heptachlor, lindane, captan, dichlorvos, chlorpyrifos, terburfos, malathion, 2,4,5-TP)
- polychlorinated biphenyls (PCBs)
- polycyclic aromatic hydrocarbons (PAHs)
- aromatic amines
- ethylene oxide
- tobacco smoke.

Studies have also linked night–shift work and occupational exposures to ionizing radiation with excess risk of breast cancer.

Solvents: Benzene and other solvents are among the most thoroughly studied substances with regard to breast cancer risk. Studies have found evidence that occupational benzene exposure is linked to elevated breast cancer risk[1] and that long-term benzene exposure may be linked to breast cancer mortality.[2] A 2015 study found elevated breast cancer risk among women with occupational exposures to solvents.[3]

Occupational studies suggest that breast cancer risk and outcome may vary by ethnicity and race, as black women had higher incidence and mortality rates compared to white women of the same age and solvent exposure levels.[4,5] Age may be another factor influencing breast cancer development; women exposed to solvents at work prior to the birth of their first child had an increased risk of breast cancer.[6,7] Exposure to metal–working fluids has also been linked to increased risk of premenopausal breast cancer.[8] In addition to their relationship to breast cancer mortality and incidence, solvents have been linked to increased risk of multiple myeloma.[9,10,11,12] Studies have also found that exposure to different solvents are associated with different breast cancer tumor subtypes.[13,14]

Pesticides: Approximately 32 percent of the entire global spending on pesticides comes from the United States.[15] More than 17,000 individual pesticides are registered for use in the United States,[16] although a much smaller number are widely used. As a result, assessing the full scope of occupational pesticide exposure and health effects is daunting.

Women make up only about 3 percent of licensed pesticide applicators, although some women apply pesticides through their husbands' licenses.[17] As a result, it is difficult to parse direct pesticide exposure (e.g., from applying pesticides) and indirect exposures (e.g., from proximity to fields or from washing clothes worn during pesticide application). Among women farming in Iowa and North Carolina, approximately half had used pesticides at least once.[17]

Women do not need to directly apply pesticides to be exposed. The Agricultural Health Study found that the wives of farmers in Iowa and North Carolina had elevated breast cancer risk, associated with their husbands' use of several pesticides shown in Table 1. Menopausal status was also associated with breast cancer in studies of a variety of pesticides.[17] Age, breast cancer onset, and age at diagnosis are important factors for calculating breast cancer risk relative to any exposure.[18] The type of food grown can dramatically increase risk of breast cancer, as found among Hispanic women in mushroom agriculture.[18]

Other chemicals: A study of male breast cancer found associations with exposures to alkylphenols, dioxins and PCBs.[19]

In occupational studies of women exposed to PCB, the results were inconclusive, with some finding that PCBs elevate breast cancer mortality rates, and others report PCBs associated with reduced rates.[20,21]

Studies have also found associations between aromatic amines and breast cancer in exposure dependent patterns.[22] Exposures before age 36 to PAHs from petroleum have been associated with breast cancer risk,[22] as have exposures to acrylic fibers (up to a sevenfold increased risk with exposure before age 36).[14]

Workers in sterilization facilities with the highest exposure levels and longest exposure time to ethylene oxide (a chemical used to sterilize instruments) had elevated breast cancer risk. The risk increased with higher levels of exposure, even 15 to 20 years later.[23,24]

SIDEBAR: Work Stress and Female Breast Cancer

Several studies have demonstrated that experiencing a major life stressor, such as the death of a spouse or partner, is associated with an increased short-term risk for developing breast cancer.[1,2,3,4] The mechanism for this response may lie in the existence of receptors for stress hormones in breast tissue. Increased adrenal secretion of cortisol, the predominant glucocorticoid (GC) found in humans, is an important part of the normal response to environmental and social stressors. Elevated levels of cortisol and activation of mammary GCs are associated with increased proliferation and decreased apoptosis, or programmed cell death, in mammary cells.[4,5]

In addition to the ovarian steroids, estradiol and progesterone, other hormones including the GCs are important in normal development of breast tissue but may play a role in mammary cells' transition from healthy to cancerous cells.[6] GC receptors, necessary for the effectiveness of glucocorticoids in altering cellular processes, are found in both normal mammary epithelial cells and mammary tumor cells.[4,7,8]

Recent work by Pudrovska[9] and colleagues[10] uses a biosocial model to explore the relationship between chronic stress levels and breast cancer incidence in women who held professional and management positions in the 1970s. These findings are an important departure from the usual research observation that people with lower socioeconomic status are more vulnerable to many other diseases. Using data from the Wisconsin Longitudinal Study, the research indicates that the stress of job authority, especially in the early years of women rising to higher level positions, may lead to dysregulation of the glucocorticoid system and increased risk for developing breast cancer.

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Passive smoking: One study reported a 32 percent excess risk of breast cancer among those with more than 10 years of exposure to passive smoke, whether exposed in childhood, as an adult at home, or as an adult at work.[25] While a large body of research links passive smoking to breast cancer, work-related exposures have rarely been studied.

Ionizing Radiation: Occupational doses of ionizing radiation among health care workers have decreased dramatically since the first medical use of radiation.[26] However, use of some medical procedures such as fluoroscopy exposes health care workers to high radiation doses. In medical settings using fluoroscopy, technicians or physicians are in the room and near the patient during fluoroscopic procedures. The lack of studies of resulting occupational hazards represent a notable gap in the research, especially as more specialties now use fluoroscopy.[26]

Orthopedic surgeons, physicians, and radiological technologists exposed to ionizing radiation have elevated breast cancer risk.[27,28,29] Within exposed medical settings, rates of breast cancer were most notable among those who began work before 1940 and those who started work at younger ages.[29,30,31] Greater estimated cumulative exposure to radiation increases risk of breast cancer compared to minimal exposure.[29] Breast cancer subtype has also been found to be associated with age at exposure: Premenopausal women likely exposed to ionized radiation at work were significantly more likely to be diagnosed with HER2+ breast cancer.[32] Increased thyroid cancer but not breast cancer was also found among both men and women medical workers.[33] One future direction underway is examining whether individuals' variability may increase vulnerabilities to ionizing radiation.[34,35,36]

Workers in other fields are also exposed to ionizing radiation. Researchers have found that current estimates of occupational radiation exposure among nuclear workers and clean-up teams are inaccurately low. More accurate exposure estimates suggest a rate of 24 excess solid tumors of all tissues per 1,000 women (14 tumors per 1,000 men).[37]

Night-shift work: The International Agency for Research on Cancer designates shift work involving circadian rhythm disruption as probably carcinogenic.[38] Several studies have examined the relationship between night–shift work and breast cancer, with estimates of risk elevation ranging from 14 percent[39] to 109 percent.[40,41] A record linkage study of occupation and cancer in Britain estimated that night shift work may account for 4.5 percent of breast cancer cases and death.[42]

Studies have found variations of breast cancer risk correlated with duration of night–shift work,[40,43,44,45] with shift timing and patterns,[40,44] and with occupation.[39,41] Women who worked night shifts before their first pregnancy had a higher risk for breast cancer.[40]

Researchers are now investigating potential mechanisms for elevated risks of breast cancer among night-shift workers. Findings from studies examining melatonin levels in night–shift nurses[46,47] and reproductive and sex hormone levels in nightshift workers have been mixed.[46,48,49,50]

Racial differences appear to have an impact on breast cancer risk and night–shift work; studies performed on Asian women working nights found that they were able to maintain a normal circadian pattern of melatonin production compared to white women working nights,[51] and another study found that Chinese night–shift workers had no increased risk of breast cancer.[52]

Conclusions

Several job-related conditions are linked to elevated risk for breast cancer. Night–shift work and exposures to ionizing radiation appear to increase breast cancer risk. Chemicals such as solvents, some pesticides, and others likely also contribute to increased risk of the disease, although most chemicals have not been studied.

Statistics Decoder

CI (Confidence Interval): *The risk estimates that fall within a specified range based upon the study size. Researchers often report the 95% confidence interval, which is the range they are 95% will include the actual result. Studies with narrow Cis have more precision in their estimates of effect.*

HR, Hazard Ratio: *A measure of how often a particular event happens in one group compared to how often it happens in another group, over time. Used in cohort studies.*

IRR, Incidence Rate Ratio: *A measure of incidence rates in one group compared to another group.*

OR, Odds Ratio: *A measure of the odds of an event happening in one group compared to the odds of the same event happening in another group. Used in case-control studies.*

> ***MOR, Mortality Odds Ratio:*** *An odds ratio that specifically measures the likelihood of death in one group compared to another group.*

PMR, Proportional Mortality Ratio: *A ratio of observed deaths in a cohort due to a specific cause compared to total number of deaths. Sometimes compared with similar ratios for a larger population.*

> ***PCMR, Proportional Cancer Mortality Ratio:*** *A ratio of the proportion of deaths due to a specific cancer among all cancer deaths in an exposed population compared to the proportion in an unexposed or less-exposed population.*
>
> ***PCIR, Proportional Cancer Incidence Ratio:*** *A ratio of the proportion of all cases of a specific cancer among all cancer cases in an exposed population compared to an unexposed or less-exposed population.*

RR, Relative Risk: *A measure of the risk of a certain event happening in one group compared to the risk of the same event happening in another group. Commonly used in forward-looking or prospective studies.*

SIR, Standardized Incidence Ratio: *A measure of the ratio of observed to expected cases, or incidence.*

SMR, Standardized Mortality Ratio: *A measure of the ratio of observed to expected deaths.*

Table 1. Occupational Exposures Linked to Breast Cancer

Solvents	Chemical	Study	Results	Notes
	1,3-butadiene	2007, Suthiakamar[53]	RR = 2.6, 95% CI, .9-7.3	
	Aliphatic solvents	2015, Glass	OR=1.21; 95%CI, .99-1.48	
	Aromatic solvents	2015, Glass	OR=1.21; 95%CI, .97-1.52	
	Benzene	1998, Petralia	SIR = 1.3; 95% CI = 1.0–1.7	
	Benzene	1999, Petralia[54]	OR 1.95,95% CI 1.14—3.33	High exposures
	Benzene and solvents	2010, Labrèche	OR = 3.31; 95% CI, 1.07-10.20	Increased risk of ER+/PR- tumors with exposure before 36
	Gasoline and petroleum	2015, Ekenga	HR = 2.3; 95% CI, 1.1-4.9	
	Metal working fluids	2005, Thompson	OR = 1.04; 95% CI, .99-1.08	straight metal-working fluids: autoworkers
	Metal working fluids	2005, Thompson	OR = 1.02; 95% CI, 1-1.04	soluble; autoworkers
	Metal working fluids	2012, Freisen	HR = 1.4; 95% CI, .7-2.5	
	Solvents	2005, Rennix	IRR = 1.48; 95% CI, 1.01-2.07	Medium to high solvent exposures; army
	Solvents	2005, Rennix	IRR = 1.43; 96% CI, 1.01-2.07	Black women were more likely to be diagnosed with breast cancer than white women
	Solvents	2005, Rennix	IRR = 2.17; 99% CI, 1.98-2.39	Increased with age at diagnosis for all women; army
	Solvents	2009, Peplonska	OR = 1.57; 95% CI, .99-2.5	Pre-menopausal women at higher risk of breast cancer; army
	Solvents		OR = 1.4; 95% CI, 1.1-1.8	Higher risk with ER-/PR- receptor status; army
	Solvents	2014, Ekenga	HR = 1.28; 95% CI, 1.01-1.62	Increased ER+ solvent job before 1980
	Solvents	2014, Ekenga	HR = 1.39; 95% CI, 1.03-1.86	Increased ER+ with exposure before first birth
	Solvent	2006, Clapp	PCMR = 1.15; 95% CI, 1.06-1.25	microelectronics workers
	Solvents	1999, Hansen	OR = 1.40; 95% CI, 1.12-1.76	
	Solvents	1999, Hansen	OR = 1.84, 95% CI, 1.15-2.95	chemical workers
	Solvents	1999, Hansen 1999, Hansen	OR = 1.51, 95% CI, 1.10-2.04	Paper and Printing Metal products
	Solvents	1999, Hansen	OR = 1.35, 95% CI, 1.01-1.83	Chemical workers
	Solvents	1999,. Hansen	OR = 2.40, 95% CI, .97-5.99	Wood and furnitre
	Styrene	2007, Suthiakamar[53]	RR = 2.6; 95% CI, .8-6.4	
	Styrene	1995, Cantor	OR = 1.13 – 2.14	Black women had highest mortality
	Trichloroethylene	1998, Blair	RR = 3.1; 95% CI, 1.5-6.2	Low-level intermittent exposure; aircraft maintenance
	Trichloroethylene	1998, Blair	RR = 3.4; 95% CI, 1.4-8.0	Low-level continuous exposure
	Trichloroethylene	2007, Sung	SIR = 1.38; 95% CI, 1.11-1.7	Higher breast cancer among employees working prior to solvent regulations in 1974; electronics

		2010, Koutros	RSIR = 1.66, 95% CI 1.51-1.82	
		2005, Mills	OR=6.0; 95% CI, 2.0-18.0	Mushroom Farming
	2,4-D	2005, Mills	OR=2.14, 95%CI, 1.06-4.32	High use, diagnosed 1995-2001
		2005, Mills	OR = 2.16; 95%CI, .95-4.93	
	2,4,5-TP	2005, Engel	RR = 2.2; 95% CI, 1.3-3.9	Postmenopausal
	Aldrin	2005, Engel	RR = 1.9; 95% CI, 1.3-2.7	Husband's use
	Aldrin	2005, Engel	RR = 1.7; 95% CI, 1.1-2.6	Postmenopausal
	Atrazine	2011, Freeman	RR = 1.14; 95% CI, 0.47–2.50	No association
	Captan	2005, Engel	RR = 2.7; 95% CI, 1.7-4.3	Husband's use
	Captan	2005, Engel	RR = 3.6; 95% CI, 2.1=6.1	Postmenopausal
	Chlordane	2005, Engel	RR = 1.7; 95% CI, 1.2-2.5	Husband's use
	Chlordane	2005, Mills	OR=3.85, 95%CI, 1.22-12.20	High use, diagnosed 1988-1994
	Chlorpyrifos	2005, Engel	RR = 2.2; 95% CI, 1.0-4.9	Premenopausal
	Chlorpyrifos	2005, Engel	RR = 1.6; 95%CI, 1.1-2.4	Postmenopausal
	Dichlorvos	2005, Engel	RR = 2.3; 95%CI, 1.0-5.3	Premenopausal
	Dieldrin	2005, Engel	RR = 2.0; 95% CI, 1.1-3.3	Husband's use
	Hepatchlor	2005, Engel	RR = 1.6; 95% CI, 1.1-2.4	Husband's use
	Heptachlor	2005, Engel	RR = 1.7; 95% CI, 1.1-2.7	Postmenopausal
	Lindane	2005, Engel	RR = 1.7; 95% CI, 1.1-2.5	Husband's use
	Lindane	2005, Engel	RR = 1.7; 95% CI, 1.0-2.7	Postmenopausal
	Malathion	2005, Engel	RR = 1.5; 95% CI, 1.0-2.3	Postmenopausal
	Malathion	2005, Mills	OR = 2.95; 95%CI, 1.07-8.11	Medium Use, diagnosed 1988-1994
	Methyl Bromide	2005, Engel	RR = 3.2; 95% CI, 1.2-8.7	Heaviest direct use for >10 years
	Methyl Bromide	2005, Engel	RR = 2.3; 95% CI, .9-5.8	Heaviest direct use >40 days
	Terbufos	2005, Engel	RR = 2.6; 95%CI, 1.1-5.9	Premenopausal
Other Chemicals	Aromatic Amines	2009, De Vocht	RRs = 3.69-10.40	Rubber Tire Manufacturing
	Ethylene Oxide	2011, Mikoczy	3rd quartile: IRR 2.76, 95% CI 1.20-6.33; 4th quartile: IRR 3.55, 95%CI 1.58-7.93	Sterilization Factories
	Ethylene Oxice		IRR 2.75, 95%CI 1.32-5.72	Those with longest duration of employment; Sterilization Factories
	Ethylene Oxide	2003, Steenland	SIR=1.27, 95%CI, .94-1.69	For women in the highest quintile of exposure: Sterilization Factories
	PCB	2009, Silver	SIR = .81, 95% CI, 1.14-1.46	For full cohort; Electrical Capacitor Plant
	PCB	2009, Silver	HR = 1.33; 95% CI, 1.14-1.46	For non-white women; Electrical Capacitor Plant
	PCB	2009, Prince	SIRs .8; 95%CI, .7-.9	For white women; Electrical Capacitor Plant
	PCB	2009, Prince	SMR = .59; 95%CL, .33-.98	For reduced risk of breast cancer mortality
	PAHs from petroleum	2009, De Vocht	OR = 2.38; 95%CI=1-5.67	Exposure before age 36; rubber tire manufacturing

Ionizing Radiation	Occupation (if reported)	Study	Results	Notes
		2013, Buitenhuis	OR = 1.16; 95% CI, .87-1.56	
		2013, Buitenhuis	OR = 2.57; 95% CI, 1.09-6.03	Premenopausal, HER2+ breast cancer
	Physicians	2009, Pukkala	SIR = 1.71; 95%CI, .91-2.91	Monitored physicians
	Physicians	2009, Pukkala	SIR = 1.24; 95% CI, 1.12-1.35	Unmonitored physicians
	Physicians	2009, Pukkala	RR = 1.7; 95%CI, 1-3.1	Monitored compared to unmonitored
	Radiological Technologists	2006, Doody	RR = 1.7; 95%CI, 1.1-2.5	
Night-shift Work	Flight Attendant	2005, Megdal	RR = 1.79, 95%CI, 1.25-2.57	
	Nurses	2005, Megdal	RR=1.14, 95%CI, 1.01-1.28	
		2013, Grundy	OR = 2.21, 95%CI, 1.14-4.31	Risk for breast cancer of nightshirt work >30 years
	Nurses	2011, Lie	OR = 2.4; 95%CI, 1.3-4.3	Working >6 consecutive nights for >5 years
		2011, Grundy	OR = 1.47, 95%CI, 1.02-2.12	Worked night before first full-term pregnancy
		2011, Grundy	OR = 1.95, 95%CI, 1.13-3.35	Worked nights for >4 years before first pregnancy

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Occupational Breast Cancer in Men

Breast cancer is relatively uncommon in males, with incidence of diagnosis being less than 1 percent the incidence for females. For 2015, the American Cancer Society estimates there will be 2,350 new cases of invasive breast cancer in U.S. men compared with an estimate of 231,840 new cases of invasive breast cancer in U.S. women.[1] *Mutations of BRCA2 and, to a lesser extent mutations in BRCA1 (genes associated with breast cancer susceptibility), have been associated with increased risk for developing male breast cancer.*[2,3] *In addition, some of the strongest links between exposures and development of breast cancer have been demonstrated in male workers.*

For example, numerous studies have pointed to a connection between development of breast cancer and occupational exposures to electromagnetic fields in men working in office settings and in outside jobs that entail elevated exposures to electrical fields.[4,5,6,7]

The largest studies implicating benzene and associated chemicals with increased breast cancer risk are studies of men who were exposed to gasoline fumes and combustion while on the job. For these men, there was a significant increase in rates of breast cancer,[8] *and the effect was most pronounced among men who started their jobs before age 40.*[9]

Preliminary data also indicate increases in breast cancer among men who serve as first responders, including police[10] *and firefighters.*[11]

Camp Lejeune

Over the past several years, former marines and family members of marines stationed at Camp Lejeune in North Carolina have come forward, documenting development of male breast cancer decades after exposures to trichloroethylene (TCE) and other toxic industrial solvents that were found in the water supplies on the base. By the middle of 2014, some 84 cases of breast cancer had been documented among men who were exposed to the solvents at Camp Lejeune.[12] *This extraordinarily high rate of male breast cancer is further evidence of the link between exposures to environmental toxicants and increased risk of developing breast cancer.*

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Hazardous Exposures at Work

Most agents have not been specifically measured in work settings, and even fewer have been assessed for their links to breast cancer. Nevertheless, laboratory research raises concerns that many of these phsyical and chemical agents may contribute to breast cancer risk.

Several reviews and record–linkage studies have broadly defined the scope of potential exposures within different occupations. Table 2 highlights these exposure/occupation pairings, along with the links of those exposures to cancer in general, mammary gland tumors, endocrine disruption and reproductive toxicity. Combined, the results suggest that extensive occupational exposures to chemicals, physical agents and work circumstances are linked to breast cancer. Workers in multiple occupational settings may be exposed to one or more of these agents, as indicated in the far right column.

Table 2. Occupations with Exposures to Breast Cancer Chemicals of Concern

Carcinogenicity evidence key:
International Agency for Research on Cancer (K=known; Pr=Probable: Po=Possible
National Toxicology Program Report on Carcinogens (K=Known; RA=Reasonably anticipated)
EPA IRIS Carcinogen classification (A=Known; B1=Probable; B2=Possible)

Endocrine Disruption evidence key:
1=Evidence of endocrine disruption in living organisms (European Chemicals Agency, ECHA)
2=Evidence of potential to cause endocrine disruption (European Chemicals Agency, ECHA)
•=evidence listed by the Endocrine Exchange

Exposure Linked to Breast Cancer ***For details on health effects for individual chemicals from classes (underlined), see Appendix C.***	**International Agency for Research on Cancer**	**Nat'l Toxicology Program Report on Carcinogens**	**Prop 65 Carcinogen**	**Mammary gland tumors**	**Endocrine Disrupting Compounds**	**Developmental Toxicant**	**Occupations Exposed**
1,3-butadiene	K		●	●		●	Chemical, plastics and rubber industries;[1] manufacture of industrial chemicals and other chemical products;[2] plastic products[2]
Acrylamide	Pr	RA	●	●		●	Health & science technicians;[3] manufacture of industrial chemicals and other chemical products;[2] manufacture of rubber products;[2] paper;[4] research and scientific institutes[2]
Acrylonitrile	Po	RA	●	●			Plastics industry[5]
Alcohols (methanol, ethanol, isopropyl)						●	Aircraft maintenance workers;[6] military/army[7]
Aromatic Amines	K Po	K RA	●	●			Iron and steel industries;[2] manufacture of textiles;[2] manufacture of leather and leather products;[2] personal household services;[2] rubber[8]
Benzene	K	K	●	●	●	●	Chemicals/plastics/rubber;[1] firefighters;[10] health & science technicians;[3] industrial chemicals;[11] iron & steel;[11] land transport;[11,12] leather & tanning workers;[12] manufacture of industrial chemicals;[2] military/army;[7] personal and household services;[11,12]printers;[31] wholesale and retail trade[11,2]
Benzidine	K	K	●	●			Health and science technicians;[3] textiles: dyes based on benzidine[14]
Bisphenol A					1		Food packaging;[15] Plastics industry;[5] rubber and plastic products manufacture[16]
Cadmium	K	K	●			●	Electrical machinery manufacture;[2] firefighters;[10] industrial chemicals manufacture;[2] metal industries[2]
Carbon Tetrachloride	Po		●	●	●		Aircraft maintenance workers;[17] printers[13]
Chemotherapy agents/ Antineoplastic drugs/ Cytotoxic and cytoplastic drugs	K Pr Po	K RA	●	●		●	Health care providers;[21,1] Nurses[16,18]
Diesel exhaust	K		●	●[1]			Construction;[2] firefighters;[10] land transport;[2] personal and household services[2]
Dioxins **(2,3,7,8-Tetrachlorodibenzo-*para*-dioxin)**	K	K	●		1[2]	●	Agriculture and forestry;[2] farming;[2] firefighters: polybrominated and polychlorinated dioxins and furans;[20] Glass workers;[2] horticulture;[2] iron and steel;[11,2] manufacture of industrial chemicals;[11] non-ferrous metal industries;[11] potters, enamelware and porcelain: in dust;[12] restaurants and hotels;[11] wholesale and retail trade[11]

[1] 1-nitropyrene, 2-nitrofluorene, benzo[a]pyrene, 1,3-dinitropyrene, 1,8-dinitropyrene, 4-nitropyrene, 6-nitrochrysene
[2] 1,2,3,7,8-Pentachlorodibenzodioxin is also rated a level 1 EDC; several related furans are rated level 2

Exposure Linked to Breast Cancer *For details on health effects for individual chemicals from classes (underlined), see Appendix C.*	International Agency for Research on Cancer	Nat'l Toxicology Program Report on Carcinogens	Prop 65 Carcinogen	Mammary gland tumors	Endocrine Disrupting Compounds	Developmental Toxicant	**Occupations Exposed**
Dyes/pigments	K Po	K RA	●	●			Paper;[4] printing;[13,1] textiles[4,14,16]
Ethylene oxide & other sterilizing agents	K	K	●	●		●	Health care providers;[12] medical equipment manufacturing;[21] Nurses[16]
Flame retardants	Po	RA	●	●	2	●	Firefighters;[20] flight crews: pilots, flight attendants, cabin cleaning crews, aircraft mechanics;[22] plastics;[3] textiles[14]
Ionizing Radiation	K	K	n/a	●			Aircraft crew;[2].[23] general industry;[2] health & science technicians [radioactive substances];[3] health care providers;[1,2,3] jobs requiring frequent air travel;[23] laboratory workers;[23] nuclear power/nuclear fuel fabrication;[2] nurses;[16] radiological technicians;[1,24] radiologists and medical specialties (e.g., cardiologists using fluoroscopy);[24] radiation workers (e.g., nuclear power plants, chernobyl clean-up crews)[25]
Job Stress			n/a				Health care;[12] professional/managerial roles[26,27]
Methylene Chloride/ Dichloromethane	Pr	RA	●	●	●		Aircraft maintenance workers;[6,17] firefighters;[10] furniture stripping;[14] military/army[7]
Non-ionizing radiation/ electromagnetic fields			n/a	●[3]			Electrical workers;[28] physiotherapists;[29] telephone and telegraph workers,[12] textile workers[16]
Other solvents	Pr Po	RA	●	●	●	●	Chemical, plastics and rubber industries;[1] computer manufacture;[1] electrical;[4] electrical components and accessories;[13] leather and tanning workers: chlorinated solvents;[12] military/army: paint solvents, stoddard solvent, petroleum distillates;[7] motor vehicle manufacture;[1,31] plastics;[5] rubber manufacture: heptanes and methyl ethyl ketone;[4] rubber and plastic product manufacture;[16] textile workers;[4,14,16] wood preparation workers[12]
Perchloroethylene (Tetrachloroethylene)	Pr		●		2		Aircraft manufacture;[17] aircraft maintenance workers;[6] apparel manufacture;[2] construction;[2] dry cleaners/laundry;[32] firefighters;[10] Land transport;[2] machinery manufacture;[2] personal and household services;[2] printing, publishing and allied industries[2]
Pefluorooctonoic acid (precursor to many fluorinated compounds)	Po			●	●	●[4]	Firefighters[20]
Pesticides	K Pr Po	RA	●	●	1 2	●	Agriculture;[1] farmers;[12] glass workers, potters, enamelware and porcelain: in dust;[12] wood preparation workers[12]
Phthalates		RA	●		1 2	●	Firefighters: dehp;[33] nail salon work;[34] phthalate manufacturing;[34] plastics industry;[5] pvc film and compounding workers: dinp;[35] pvc film manufacturing/pvc compounding;[34] rubber and plastic products;[16] rubber hosing/boot/gasket manufacture;[34] vehicle filter industry;[34]

[3] Weak evidence, mixed
[4] PFOA, ECHA candidate list of substances of high concern

Exposure Linked to Breast Cancer *For details on health effects for individual chemicals from classes (underlined), see Appendix C.*	International Agency for Research on Cancer	Nat'l Toxicology Program Report on Carcinogens	Prop 65 Carcinogen	Mammary gland tumors	Endocrine Disrupting Compounds	Developmental Toxicant	**Occupations Exposed**
Polychlorinated biphenyls (PCBs)	K	RA	●		1[5] 2[6]	●	Manufacture of electrical components and accessories[13] World trade center first responders[36]
Polycyclic Aromatic Hydrocarbons	K Pr Po	RA	●	●	●		Firefighters;[10,33,37,38,39] industrial chemicals manufacture;[2] iron and steel;[2] metal industries;[2] motor vehicle manufacture;[31] non-metallic mineral products manufacture;[2] printers[13] surgeons/ mastectomy personnel[40]
Shift work	Pr		n/a				Health care providers;[1] world trade center first responders[36]
Styrene	Po	RA		●	1		Aircraft manufacture;[17] military/army;[7] plastics industry;[5] Rubber manufacture[47]
Tobacco Smoke (passive)	K	K		●[7]		●	Gambling;[5] hospitality/food services;[1] wholesale and retail trade, restauarants and hotels[2]
Toluene					●	●	Aircraft maintenance workers[6] and manufacture;[17] Beauty technicians;[48] firefighters;[10] printers;[13] rubber manufacture[4]
Trichloroethylene	K	RA	●			●	Aircraft maintenance workers[6,49]and manufacture;[17] Firefighters;[10] machinery manufacture;[2] metal products;[2] military/army;[7] personal and household services;[2] printing and publishing;[2] transport equipment manufacture[2]
Vinyl Chloride	K	K	●	●			Chemical, plastics and rubber industries;[1] chemical products and industrial chemicals manufacture;[2] plastics industry;[5] plastic products manufacture, transportation[2]
Volatile organic compounds	Po	RA	●	●		●	Beauty technicians;[48] military/army[7]
Xylene					●		Firefighters;[10] printers[13]

[5] PCB, PCB 153 (2,2',4,4',5,5'-Hexachlorobiphenyl), PCB 169 (3,3',4,4',5,5'-Hexachlorobiphenyl), PCB 47 (2,2',4,4'-Tetrachlorobiphenyl), PCB 77 (3,3',4,4'-Tetrachlorobiphenyl), PCB Aroclor 1242, PCB Aroclor 1248, PCB Aroclor 1254, CB Aroclor 1260 (Clophen A60)
[6] PCB 136 (2,2',3,3',6,6'-Hexachlorobiphenyl), PCB 156 (2,3,3',4,4',5-Hexachlorobiphenyl), PCB 48 (2,2',4,5-Tetrachlorobiphenyl), PCB 61 (2,3,4,5-Tetrachlorobiphenyl), PCB 75 (2,4,4',6-Tetrachlorobiphenyl)
[7] Several compounds found in tobacco smoke are mammary carcinogens: ortho-toluidine hydrochloride, acrylamide, benzene, benzo[a]pyrene, dibenz[a,h]anthracene, dibenzo[def,p]chrysene, ethylene oxide, isoprene, styrene

Carcinogenicity evidence key:
International Agency for Research on Cancer (K=known; Pr=Probable: Po=Possible
National Toxicology Program Report on Carcinogens (K=Known; RA=Reasonably anticipated)
EPA IRIS Carcinogen classification (A=Known; B1=Probable; B2=Possible)

Endocrine Disruption evidence key:
1=Evidence of endocrine disruption in living organisms (European Chemicals Agency, ECHA)
2=Evidence of potential to cause endocrine disruption (European Chemicals Agency, ECHA)
•=evidence listed by the Endocrine Exchange

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Research Gaps & Recommendations

Research Gaps

Several gaps exist across the literature on occupation and breast cancer. Over time, more studies have accounted for social and reproductive factors that are likely to correlate with occupation and confound results, but it is still the case that far too few studies stratify results by race/ethnicity, tumor subtype and menopausal status.

Research recommendations are explored on page 48 to address gaps such as the following:

- **Few studies explore risk stratified by race, ethnicity or socioeconomic status.** The small number of studies that have done this have frequently found differences in risk between black and white women. Studies that report results for women of any other ethnicities are strikingly rare. Even if other ethnicities are present in the cohorts, their numbers are too low to draw statistically valid conclusions.
- **Few studies explore risk based upon tumor receptor status.** Those that have done this have found different patterns of risk depending on receptor status. This may be a particularly important factor to consider, since it is plausible that different exposures could be associated with different tumor subtypes. (See www.breastcancerfund.org/clear-science/biology-of-breast-cancer/breast-cancer-subtypes)

- **Few studies explore risk based upon menopausal status or age.** Studies that parse data by menopausal status or age at diagnosis glean new information. Premenopausal breast cancers are often more aggressive and could plausibly be linked to different exposures, but premenopausal breast cancer is less likely to be studied than postmenopausal breast cancer.
- **Few studies assess the duration of exposures or the age at which exposures began.** However, we know from the larger body of research on environmental exposures and breast cancer that the timing of exposures can be quite significant, and in some occupations, the worst exposures may occur in entry-level or temporary roles. The findings from some studies suggest that earlier-life occupational exposures may be of greatest concern, as in the case of radiological technologists employed very early in adulthood, and at a time when exposures were highest due to less sophisticated equipment and less stringent safety precautions.[1] Farmworkers in particular may begin work as children or young adults and their early exposures may be of particular importance.[2]

- **Most record-linkage studies and some cohort studies do not account for reproductive history.** However, there are associations among childbearing patterns and occupation. Women in some occupations are more likely to delay having children, or choose not to have them, as a result of education, work demands, and work cultures. Since giving birth at a younger age is associated with reduced risk of breast cancer, this is an especially important potential confounder. In addition, hormonal influences can affect the biologically active dose of an exposure.[3]

- **Physical activity may be a key confounder.** Physical activity is demonstrably protective for breast cancer, and may ameliorate some chemical risks in highly active occupations (for example, agriculture or firefighting), but this has rarely been explored.

- **Comparison group selection can be complicated.** The relationships among poverty, breast cancer risk, and breast cancer subtype are complicated, which means that occupational cohort studies should thoughtfully select a comparison group with similar characteristics. In cohort studies, the best comparison group would be composed of those with similar education, occupational attainment and income, within the same region. Poverty is a strong predictor of overall health, but overall breast cancer risk is highest among white women, who are middle class and higher. At the same time, more aggressive tumors are more common in young black and Latina women. Some regions may have heavy sources of environmental pollutants from industry, which could drive elevated risk for a region, including, but not limited to, workers in that industry. Comparisons among groups within the same region, then, would provide the most accurate estimates of occupational risks.

- **Exposure assessments take a one-size-fits-all approach.** However, even within a given job title, the work that women do may lead to different exposures than those experienced by men. As a result, when possible, engaging workers about their experiences, activities, patterns and work cultures may be vital.[3] Observing work settings, ergonomics and activities, as well as direct monitoring or biomonitoring, could help fill in some of the substantial gaps here.

- **Sample sizes can be too small to find a statistically significant effect.** Many studies showed elevated risk calculations that approached but did not attain statistical significance, and it can be difficult to know how to interpret these studies. Scientific prudence would require statistical significance, but public health precautions might rely more on apparent elevated risk. Replicating studies with larger samples would help resolve the questions.

- **Record–linkage studies have unique strengths and weaknesses.** They make use of existing data and are therefore economical to conduct. Large records-based studies may reveal previously unidentified concerns that can be examined with more robust methods. A major issue with these studies is the lack of individual exposure information. In addition, these studies often conduct dozens or even hundreds of risk calculations. While many studies make the appropriate statistical corrections for multiple analyses, those that do not should be interpreted with caution.

- **Few studies consult workers about their needs, exposures and concerns.** Workers are likely to be the best informed about their job roles and activities, their proximity to exposures of concern, and health issues among their colleagues. Their own experiences of sights, smells and physical responses can inform an understanding of exposures. At the same time, research could help empower workers to demand safer conditions. Worker engagement should be included as a critical aspect of occupational research.

Conclusions

Notable gaps still exist on the research related to occupation and breast cancer. The research community needs to collect and analyze data on breast cancer subtypes, menopausal status, race, class, ethnicity, and reproductive history. Gaps also exist related to the collection of exposure data, such as details on timing and duration.

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Research Recommendations

To achieve the goal of reducing occupationally–related breast cancer risk, we need significant investment and commitment to research on breast cancer, exposure, and occupation. Based on discussions within our Study Group series on Occupation and Breast Cancer and our review of the literature, the Breast Cancer Fund recommends nine directions for future research examining relationships between occupations, exposures, and risk for developing breast cancer.

1. Include workers throughout research

Most occupational studies do not include the workers in the design or implementation of studies. Often that is because researchers do not think to involve these important partners. In other cases, especially when studies involve people with many different occupations or data drawn from large databases (e.g., cancer and other health registries), or from the general population, it is impractical to involve workers in the research process. And sometimes, even when researchers want to include workers in their projects, workers may not engage in the process for fear of retribution including possible loss of their jobs, or conversely, may feel forced to participate by their employer, violating the principle of informed consent. However, in rare instances when workers have been engaged in the research process, worker participation has been key in shaping the research agenda. Worker participation also reinforces the importance of nesting research objectives within the context of workers' everyday concerns.[1]

Worker input into the research agenda can also help balance theoretical objectives with practical realities, and hence must be a priority. In one project, nail salon workers urged that policy changes for safer workplaces incorporate economic considerations for workforce members.[1] This program engaged a diverse group of stakeholders including Vietnamese salon workers, owners, researchers, advocates and regulators.

Community-based participatory research (CBPR) provides a principled framework for these studies. CBPR involves a partnership among community members; representatives from community-based organizations, service and regulatory agencies; and academic researchers. Ideally, the partnership equitably involves all members in all aspects of the research process. All members contribute their varied expertise and share decision-making and ownership in projects aimed at simultaneously enhancing knowledge and improving the health of community members through interventions and policy and social change.[2]

CBPR can offer actionable information for affected communities.. Workers have the best understanding of their environment and the politics of their workplace and can offer an entrée into professional organizations, which can work with employers and regulators to achieve real and lasting change in workplaces and practices. It is important to engage the workforce, to find out what is important to its members. This can help researchers ask more realistic and meaningful questions. Beyond these practical considerations, there is a moral imperative to involve workers in occupational health studies. Research on work-related exposures should lead to better understanding of occupational conditions, on the part of both workers and management.

This is not a trivial undertaking. Academic-community collaborations are complex endeavors that require significant investment in building relationships to ensure that the goals, objectives and needs of each partner are clearly addressed.[3]

There are several different models for CBPR that have been described in the literature[4] and also within the Study Group that informed this report. One particularly important model described was the work of the CDC's Agency for Toxic Substances and Disease Registry's (ATSDR) with the marines of Camp Lejeune. This project included the development of a Community Assistance Panel (CAP) comprised of members of the affected community. CAPs are especially important in cancer studies, due to the long latencies between exposures and emergence of the disease. CAPs can help affected workers find financial, medical and emotional support. Community collaborators are uniquely able to provide information about long-term exposures, work conditions, and other factors that may be relevant.[4]

It is important to recognize that workers can be concerned about threatened job loss for participating in research studies or for raising concerns about workplace procedures. This is especially true if workers' concerns motivate the study or precipitate an active intervention. Researchers should be aware of and account for the power imbalance that exists between workers and employers, especially if workers are not unionized.

Where such concerns are prevalent, researchers will have a harder time getting into the workplace to conduct studies, but it is still possible for researchers to meet workers in safe place, outside of work (e.g., faith-based centers, community centers, etc.) where they may feel more comfortable acting as full participants in project planning and development. A good example is Lipscomb's study of poultry workers,[5] in which the workers were immigrants with few protections and many barriers to break down. In this study, community–based staff were responsible for coordinating many aspects of the study, including managing local activities of a community-based project office, and recruiting and collecting data from study participants. Workers were paid to participate and were included in all aspects of project.

When true CBPR approaches are impractical because of study size or a wide range of occupations, one approach for informing the research and interpreting the data is to conduct intensive focus groups with a subset of the participants in the study, or with local workers. An example where this approach was successful was the research by Brophy and colleagues[6,7] involving paired quantitative

(large) and qualitative (smaller) studies examining occupational exposures and breast cancer incidence in women working in plastics manufacturing. The focus groups helped the researchers to achieve a deeper understanding of the chemicals to which the women were exposed, the adverse conditions the women were working in, and the negative health effects —both acute and chronic—that resulted from workplace exposures to toxic chemicals.

Workers should be involved at all stages of the research process, from project inception through planning, execution, result dissemination and implementation of solutions. Community-based participatory research (CBPR) provides a principled framework for these studies.

2. Include women in occupational studies

Women have historically been excluded from occupational studies, which means that health issues that predominantly affect women, including breast cancer, have been at best under–studied and at worst ignored. Issues that need to be addressed when studying women in the workplace:

- There are fewer women than men in some fields (e.g., firefighting, microelectronics), though others (e.g., medicine) are starting to equalize
- Women often have non-traditional work patterns (e.g., they are often employed part-time and may have career breaks before returning to employment)
- Many women change their last names at marriage, making it more difficult to gather longitudinal data from registries and other databases.

Women's occupational exposures and work–related disease risk need to be studied, and this research must acknowledge women's historical work histories. More studies of breast cancer in men are also needed in some historically under–studied work settings such as the military.

Women' occupational risks should be specifically studied. Women do not always have the same exposures as their male counterparts and may have different physiological responses to similar insults. Specific research is required.

3. Study young working women and, when possible, their children

Breast cancer is diagnosed much more often in post-menopausal women, but exposures early in life can impact risk of its occurrence later. It is therefore important that we study young workers in order to capture these exposures and, ideally, include enough follow-up time within study designs to observe effects later in life. Women at younger ages may be more vulnerable to effects of toxic exposures, as has been seen in occupational studies of ionizing radiation[8] and solvent exposure.[9]

Young women are also of childbearing age, which presents a particular set of considerations. A growing body of research supports the theory of developmental origins of health and disease (DOHaD), meaning that exposures in early life, within the womb, can have significant effects on later–life health and susceptibility to disease.[10] We must be concerned for the effects of women's occupational exposures on health outcomes for their fetuses and children, as well as for themselves.

Women of childbearing age have particular vulnerabilities both for their own health and for that of their future children.

4. Measure exposures directly through biomonitoring and workplace monitoring

Without direct monitoring of occupational exposures, it is exceedingly difficult to capture the environment of the workplace or the level and type of toxicants to which women have been exposed. This is especially an issue for studies of diseases like breast cancer, where the latency between exposures and diagnosis may be several years or even decades. Good exposure measurements need to be made and retained for long periods of time.

Often workers are exposed to several toxicants concurrently, and many chemicals may become more toxic during the process of manufacturing products, or the heating or application of chemicals.

Although sometimes difficult, and always expensive and time-consuming, it is critical that accurate measurements of occupational exposures.

This is important not only for better research designs, but for serving as the basis for worker and management education, workplace remediation, and revision of standards and policy change.

Workers, unions and employers should all be involved in this process, to ensure all are informed and supportive. Once agreed upon, the following would be best practices:

- Measure the levels of workplace chemicals and their metabolites through biomonitoring of workers. This involves taking biosamples from workers (serum, urine, etc.) and testing for chemicals and the products of their metabolism in the body.
- Measure chemicals and radiation exposure in the workplace (e.g., through dust, air and water sampling)
- Use subsampling, and effective way to use limited resources.
- Ensure full consent from workers asked to participate, return biomonitoring results to participants requesting the information, and fully protect biomonitored workers from retribution by their employers.

- Measure the same chemicals in workers' homes and communities, to ascertain more complete exposure patterns and to determine whether community controls are indeed unexposed, since some industries may also pollute local air and water.
- Use controls from the same community, where appropriate.
- Collect qualitative data that can inform exposure assessment, with or without biomonitoring. Brophy and colleagues[6,7] used such methods to collect experiential data through individual and group interviews with workers. Facilitated discussion included open-ended questions about the participants' working conditions, job tasks, plant layout, chemicals used, protective controls, changes that occurred over time, exposure concerns, improvements needed, and perceived barriers to gaining improvements.

We must know which exposures are contributing to breast cancer risk in particular occupations in order to develop workplace solutions. Direct measurements are needed to provide this information.

5. Understand other characteristics that might affect risk

Breast cancer is a disease (or rather, a set of diseases) of complex etiology. A woman's risk for developing breast cancer is a reflection of the intersection of many biological, social, lifestyle and environmental factors. Understanding possible links between workplace exposures and breast cancer risk will require sophisticated modeling exercises and collection of detailed personal and health histories for study participants.

It is important to account for other characteristics relevant to breast cancer risk while recognizing that some of these may also be influenced by occupational exposures. These other characteristics include socioeconomic factors, race/ethnicity, geography of origin, other exposures (e.g., in the home or ambient environment), work history, physical activity, diet, breast density, age at menarche (first period), menopausal status, parity (number of births), genes relevant to breast cancer risk, night–shift work and sleep patterns, and psychosocial stress measures.

In examining so many factors, identifying direct cause–and–effect relationships between single variables and development of breast cancer may become almost impossible. Researchers and public health policymakers need to become more comfortable with models based on probability and uncertainty, which emerge as a result of incorporating greater complexity, and they must be willing to act to protect worker health even in the face of these uncertainties.

Non-occupational risk factors for breast cancer, such as reproductive history, should be included in studies of workplace exposures and occupationally–related risk.

6. Collect occupational histories in cohort studies

Several ongoing cohort studies explore breast cancer risk and other diseases among women. Many of these studies are longitudinal, and some are prospective studies with ongoing data collection including biomonitoring. Cohort studies can require considerable resource investments to support both data collection and participant retention. Yet many of these studies do not collect adequate data on occupation as a factor. We propose that studies add questions about occupational history, which could greatly enhance the scope of knowledge in this field.

Since many chemical exposures are short-lived, and because exposures at critical life-span time periods can have profound effects on later-life health, prospective studies are particularly important for understanding environmental links to breast cancer.

It is important that occupational history be included in large longitudinal cohort studies. Examples of existing studies are the Nurses' Health Study, the Agricultural Health Study, CHAMACOS (if extended into adulthood) and the Breast Cancer and Environmental Research Program (BCERP; if extended into adulthood). One large cohort study, The Sister Study, has integrated occupational exposures into its data collection and analysis, and thus far has found associations with several exposures.[9,11]

New longitudinal cohort studies of women and breast cancer should include occupational histories. If they do not already, existing studies should collect this data for future analyses.

7. Examine early indicators of health effects

Chemical exposures result in disease outcomes through a variety of mechanisms. Studies of occupational exposure and breast cancer should, where possible, examine the early indicators of damage caused by exposures.

These include DNA methylation and other epigenetic effects, telomere length, melatonin levels, DNA damage and hormone levels. Examining such effects can give more information about the mechanisms of action and likely outcomes before diseases are manifest.

The long latency of breast cancer requires that upstream indicators and early physiological changes be studied as signals for risk of the disease.

8. Consider breast cancer subtypes

Breast cancer is not a single disease. There are several subtypes different profiles and prognoses. This is important because the risks of certain subtypes of breast cancer may be influenced more strongly by certain specific exposures. These subtleties may be missed if researchers consider overall breast cancer incidence or mortality.

Studies must recognize the complexity of breast cancer, then evaluate etiology and monitor outcomes accordingly including: breast cancer subtype/clinical profile; tumor characteristics and gene sequences; incidence; metastases; recurrence; mortality; age at diagnosis; and time to from diagnosis progression of disease.

Breast cancer is a complex collection of diseases with different diagnostic criteria. Specific exposures may have different effects on each of these different diseases. Detailed information on breast cancer diagnoses should be collected to enable richer analysis of the effects of specific workplace exposures.

9. Bring research full circle

It is critical to keep the community of workers fully involved in all aspects of the research process, including full report-back on findings from biomonitoring studies. All participants and researchers should be included in communication strategies, and time, staff and budget allocated to these activities from the start.

Participants have a right to know what is in their bodies and what current science interprets that to mean for their health, even if uncertainty persists.[12]

A recent review found that participants and researchers who have taken part in report-back identified significant benefits: increased trust in science, retention in cohort studies, environmental health literacy, individual and community empowerment, and motivation to reduce exposures. Researchers and participants gained unexpected insights into the characteristics and sources of environmental contamination. The review concluded that ethical considerations and empirical experience both support study participants' right to know their own results if they choose, so report-back should become the norm in studies that measure personal exposures.[12]

Finally, research results should not be an end in themselves. Policy implications that may emerge from the research outcomes should be considered and translated into workplace, occupational, local, state and federal policies such as regulation of industrial chemicals, pesticides and agricultural practices.

Individuals have the right to know what they are exposed to. All participants and researchers should be included in communication strategies, and time, staff and budget should be allocated to these activities from the start.

Conclusions

Ongoing and future research can fill critical gaps in what we know about work and breast cancer by including working women, measuring exposures more precisely, and accounting for variations in risk by factors such as menopausal status, reproductive history, and race/ethnicity/income.

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The State of the Policy

The State of the Policy

The U.S. occupational safety system is broken, and our nation's complicated history of worker protections is fraught with failed attempts to meaningfully protect the people who toil in our fields, teach in our schools, and serve us when we're sick. Historical, legal and political factors have made regulations to guard workers inadequate. To address these failings, the Breast Cancer Fund is calling for a shift in the paradigm of occupational health regulation from a chemical-by-chemical approach to a system that requires and incentivizes the use of inherently safer chemicals. While this paradigm shift is taking place, Congress, states and federal agencies should also act now to efficiently set and enforce exposure limits at truly health–protective levels.

Regulatory Overview

In our federal regulatory system, two federal agencies work together to protect worker health and safety: The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA).

NIOSH conducts research and scientific analysis of the potential harm to workers from chemical exposure, but does not have enforcement power, whereas OSHA, a division of the Department of Labor, sets exposure levels intended to protect workers.

Occupational Exposure Levels, for example, reflect the level at which an employee may be exposed to a particular substance averaged over an eight-hour work shift. NIOSH produces Recommended Exposure Limits (RELs), which are scientific evidence-based exposure limits intended to prevent occupational injury and illness from chemical and radiation exposures; OSHA uses these recommendations as a basis for legally enforceable workplace regulations called Permissible Exposure Limits (PELs).

This regulatory system fails to protect workers, and OSHA's current leadership recognizes the agency's own failure. OSHA states on its website that the current federal hazard exposure limits are "inadequate for ensuring protection of worker health."[1] The website recommends that employers use alternative standards to protect workers, because at present the legally permissible levels are "hazardous to workers" and "not sufficiently protective of worker health." The site refers to scientific data and the reduction in allowable exposure limits recommended by many technical, professional, medical, industrial and government organizations inside and outside the United States. OSHA allows for much higher exposures than the limits recommended by NIOSH.[1] For instance, for the breast carcinogen acrylamide, the permissible level of 0.3 mg/m^3 is an order of magnitude higher than the recommended level of 0.03 milligrams per cubic meter (mg/m^3). A complicated and contentious history underlies these significant gaps in worker protections.

OSHA: A Brief History

Factors contributing to OSHA's failure to protect the long-term of health of workers include:

1) The agency's inability to require safer chemicals to replace hazardous substances,
2) Undue industry influence over the regulatory process through court challenges and political influence, such as lobbying Congress
3) Burdensome statutory requirements that effectively bar regulation

When OSHA was formed in 1970 by authority of the Occupational Safety and Health Act, the agency initially set approximately 425 Permissible Exposure Limits (PELs) based on the 1968 Threshold Limit Values (TLVs) standard set by the American Conference of Governmental Industrial Hygienists (ACGIH) and consensus standards from the American Standards Association.[1,2] These standards were based on science from the 1950s and 1960s. Today, the vast majority of these nearly 50-year-old exposure limits have never been updated. In fact, since 1971, OSHA successfully established and implemented PELs for only about 30 chemicals, though not for lack of trying.[1] The agency has set only one new exposure limit since the year 2000.[1]

OSHA attempts to regulate carcinogens

In 1973, in response to a petition from the Oil, Chemical, and Atomic Workers Union (now part of the United Steel Workers and the Public Citizen Health Research Group) OSHA passed an emergency measure known as the 13 Carcinogens Standard,[3] which required worker safety mechanisms such as protective gear, air ventilation systems, respirators and decontamination procedures in facilities where these 13 chemicals were manufactured, processed and handled.[4]

OSHA issued the Generic Carcinogen Policy in 1980, which was designed to significantly strengthen its regulatory authority over carcinogens in the workplace. The landmark policy represented a major shift away from a chemical-by-chemical analysis to a regulatory framework that had the potential to address the safety of hundreds if not thousands of substances by "fast tracking" known or suspected carcinogens for immediate regulatory action.[5]

This policy emerged from the agency's belief that "to follow the past system and procedure for each and every individual substance and hazard would be, we believe, beyond the abilities of an agency, no matter how large a staff it may have."[6] OSHA's Generic Carcinogen Policy articulated a highly protective goal that "the only safe exposure to carcinogens was no exposure, and that the only factor that should limit efforts to reduce exposure was technological feasibility."[7]

The policy set out a rule-making process based on prevention, prioritized high-risk chemicals, and also accelerated the regulatory process by allowing OSHA to set comprehensive standards for a category of chemicals, rather than regulating one chemical at a time.

The Benzene Decision

The 1980 U.S. Supreme Court case, Industrial Union Department v. American Petroleum Institute, known colloquially as the "Benzene Decision," brought a major setback for OSHA. The court rejected the Generic Carcinogen Policy's standard for exposure reduction at "the lowest feasible level" and instead required that future OSHA standards must first establish a "significant risk" to workers before the agency can take action.[8]

The Supreme Court deferred to OSHA to define "significant risk," providing general guidance that while one cancer death in one billion is not "significant" risk, one fatality in 1,000 is clearly significant. However, the Court went on to note, "the requirement that a "significant" risk be identified is not a mathematical straitjacket."[8] Despite this broad authority issued by the court, the Reagan Administration's OSHA adopted the least protective standard — one in 1,000 — to "protect" workers. As a point of comparison, the EPA uses a standard that is orders of magnitude higher for the general public — in the range of one cancer case in 100,000 to one in 1 million.

OSHA's interpretation of the Benzene Decision drastically impacted the agency's subsequent ability to regulate hazards in the workplace. In response to the Benzene Decision, the agency issued a revision of the Generic Carcinogen Policy. Combined with the chilling effect of the Reagan Administration's Task Force on Regulatory Relief, which challenged OSHA's cancer policy due to its economic costs, the Generic Carcinogen Policy became defunct. Still, it remains on the books as OSHA's official policy.[5]

AFL-CIO vs. OSHA

In 1989, OSHA attempted to implement 212 new PELs and update 164 existing PELs. The labor organization, AFL-CIO sued OSHA, claiming that the new permissible exposure limits did not sufficiently protect workers. The 11th Circuit Court decision (referred to as the Air Contaminants Standard case) rejected the AFL-CIO's call for more stringent standards. The court also vacated the new PELs based on OSHA's failure to complete sufficient analyses for each chemical individually, a decision based upon the requirement for chemical-by-chemical analysis put forth in the 1980 Benzene Decision. With this disastrous ruling, the existing PELs returned to inadequate 1971 limits,[2,9,10] and OSHA was left with an impossibly high burden to meet in order to take regulatory action. This narrowing of the agency's authority slowed the regulation of chemical substances to a crawl.

Since 1980, OSHA has set health standards for only 30 toxic substances out of tens of thousands of chemicals used in commerce today.[7] Even for the few PELs that do exist, OSHA's enforcement is virtually non-existent largely due to lack of resources. When enforcement actions do take place, the penalties for violating the OSHA standards are so low as to provide little or no incentive for companies to comply with the law.

NIOSH

Before 1995, the National Institute for Occupational Safety and Health (NIOSH, the research arm advising OSHA, recommended that "exposures to chemical carcinogens be reduced to the lowest feasible level."[11] Starting in 1995, NIOSH began to quantify the risk of disease at an array of exposure levels. However, a "target risk level" (such as 1/1,000 cancer cases) was not set, although this policy is currently under review by the agency. NIOSH continues to propose reducing exposure to cancer-causing chemicals to the lowest possible level given the current technology.[5,12]

NIOSH's recommended exposure levels are just that—recommendations—not mandates. OSHA's permissible exposure levels, while informed by the recommended levels, also take into account economic and technical feasibility, usually resulting in "permissible" exposures that are much higher than truly health–protective levels. Additionally, neither the recommended levels nor the permissible levels address mixtures of chemicals or aggregate exposures to a single chemical or class of chemicals.

Chemical-by-chemical assessment: Destined to fail

While a great deal of criticism on the shortcomings of OSHA and NIOSH has focused on Occupational Exposure Levels (OELs), the setting of individual levels of "acceptable" exposure chemical by chemical is destined to fail. With tens of thousands of chemicals available for use in commerce, overcoming the regulatory barrier for each chemical individually is unachievable.

OELs also do not address the potential dangers of chemical mixtures and the increasing scientific evidence that for some chemical categories, such as carcinogens and endocrine–disrupting compounds, there may be no safe or acceptable level of exposure.

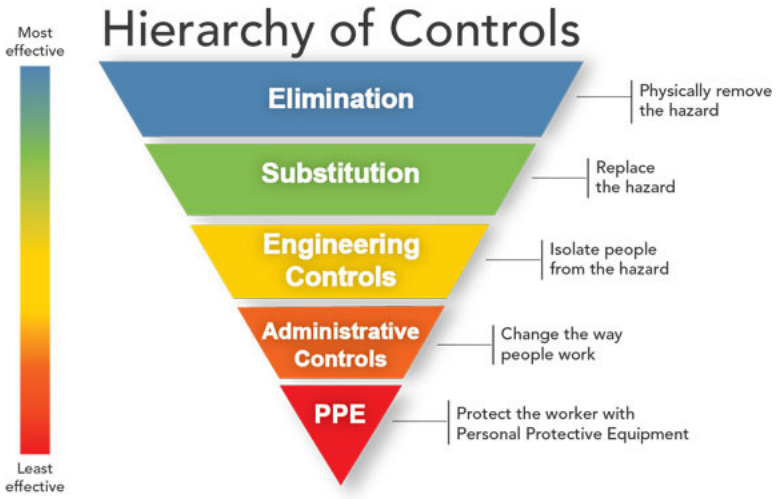
Instead, OSHA and NIOSH should shift their focus to finding inherently safer substitutes for hazardous chemicals. The "hierarchy of controls" for hazardous exposures in the workplace acknowledges that the most effective way to protect workers is to eliminate the hazard or replace it with a less hazardous option. Placing the burden on workers to use personal protective equipment (PPE) is recognized as the least effective, most burdensome way to protect workers.[13]

As OELs are the only legally enforceable protections currently available, the Breast Cancer Fund continues to call for the PELs to be set in an efficient and health protective manner and to be fully enforced. However, the use of inherently safer chemicals is a much more effective way to protect workers and the general public, and our regulatory system should move toward that approach.

Critical Gaps

Six key policy gaps leave American workers' health unprotected from unsafe occupational exposures:

1. U.S. regulations focus on setting specific exposure levels vs. removing the hazard altogether to protect workers. Worker protection policy is based on a chemical-by-chemical risk-analysis approach, rather than focusing on hazard reduction for classes of chemicals, as was done by OSHA's now defunct Generic Carcinogen Policy.
2. Legal exposure limits are inadequate to protect workers. The troubling reality is that OSHA fully admits to failure in setting adequate limits to protect workers from chemical exposure. OSHA standards are outdated and inadequate to ensure protection of worker health. The agency issued standards shortly after adoption of the Occupational Safety and Health (OSH) Act in 1970, and has updated only a small fraction of them since that time.



from National Institute of Occupational Safety and Health

3. The process for setting standards is broken. Even when OSHA attempted to update existing standards, as it did in 1989, the agency was overridden by the 1992 11th Circuit Court in the Air Contaminants Standard case. Now it can take OSHA over a decade to regulate a single chemical.[14]
4. OSHA's Permissible Exposure Levels allow an unacceptably high risk of cancer. It is currently acceptable for up to one in 1,000 workers to be diagnosed with cancer.[15] NIOSH is also currently considering adopting this standard. By contrast, the Environmental Protection Agency's regulations limit excess cancer risks to the general public in the range of between one per 100,000 to one per million."[16] This means the EPA offers the general public 100 to 1,000 times more protection from chemicals than OSHA provides for workers.
5. Women's health, in particular, is not included in the literature used to set exposure limits. As indicated in this literature review, most of the research on occupation and breast cancer has been conducted in the past two decades, well after the time when most exposure levels were set.
6. Technological and economic feasibility assessment requirements undermine worker health. OSHA's ability to utilize NIOSH recommendations is not strong enough to effectively protect workers, given that OSHA must also consider technological and economic feasibility, which further erodes the already high risk standard afforded by the agency's PELs.

Conclusions

Workplace and governmental policies should protect workers from occupational exposures to unsafe chemicals that adversely affect quality of life, shorten workers' life spans or otherwise lead to physical or emotional harm.

Existing policies are inadequate to protect workers, as the agency responsible for worker health and safety acknowledges. There is a significant need for a paradigm shift in how chemicals are regulated in work settings.

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Policy Recommendations

Policy Recommendations

The Breast Cancer Fund has identified the following policy recommendations to protect workers across industries and workplaces from chemical exposures linked to breast cancer and other diseases and chronic conditions.

1. Research must explore breast cancer risk at work

Federal agencies should recognize and prioritize research on occupational exposures linked to breast cancer. Occupational links to breast cancer are under–studied, largely due to underfunding. In a worrisome trend, the last decade has seen a decrease in the number of studies of occupational cancer. A 2013 review of the literature found a decrease in the number of occupational cancer epidemiology articles published annually from 2003 on.[1] The authors highlight that the results of these previously published articles had helped determine the carcinogenicity of workplace exposures and permissible exposure limits. We must repeat the calls for increased funding directed to research on occupational exposures linked to cancer, especially breast cancer.[2]

The Breast Cancer Fund calls for a comprehensive federal research agenda to examine breast cancer incidence in the workplace. Such research could utilize existing cohort studies, records-linkage studies or transdisciplinary research approaches.

2. Federal workplace protections must prioritize worker health.

Congress should empower and fund OSHA and NIOSH to identify, implement and enforce truly health–protective regulation of chemical exposures in the workplace. OSHA, workers and worker advocates have all acknowledged that the current system of controlling chemical exposures in the workplace has failed to protect workers. The Breast Cancer Fund recognizes the enormous, decades–long efforts by worker advocates to change this failed system, and we add our voice in support of those efforts, understanding the political challenges facing these policy changes. The Breast Cancer Fund has identified several areas where action is need.

Congress should pass legislation to change the paradigm on how chemicals in the workplace are managed. In place of a chemical-by-chemical risk assessment model, OSHA should focus on reducing the presence of hazardous chemicals in the workplace by requiring safer alternatives, where available, and incentivizing innovation when alternatives are not available.

For carcinogens, OSHA should re-adopt the Generic Carcinogen Policy, which would require immediate regulatory action to protect workers from occupational exposures to known or probable carcinogens. This approach of reducing exposures to categories of chemicals known to be toxic should be extended to other chemicals of concern, including chemicals exhibiting endocrine disruption, reproductive toxicity, neurotoxicity and mutagenicity. The European Union has instituted a system that can serve as a model for the U.S. The "EU Directive 2004/37/EC – carcinogens or mutagens at work" ordains that if there is a safer alternative to a carcinogen, it must be used. Only if an alternative is not available, are exposure limits to be set and enforced. The Directive states: "The employer shall reduce the use of a carcinogen or mutagen by replacing it with a substance not or less dangerous."[3]

Recognizing that this shift to a hazard–reduction policy is a long-term goal, OSHA, NIOSH and Congress should also take regulatory and statutory steps to improve the current process of setting RELs and PELs. In the case of many exposures, we already have ample scientific information, in the form of major reviews of the scientific literature, to take a more aggressive and proactive approach toward the protection of workers.

American Public Health Association Statement on Breast Cancer and Occupation

In November 2014, the American Public Health Association called for action to prevent breast cancer resulting from workplace exposures. It stated hat "It is increasingly clear that primary prevention of breast cancer focusing on elimination of work-related and other environmental carcinogens needs more attention, funding, and political, regulatory, and workplace action."

APHA cited the findings of multiple peer-reviewed studies that have found elevated risk of breast cancer among workers in certain occupations or facing specific exposures. The APHA statement underscored the 2010 President's Cancer Panel finding that environmentally (including occupationally) "induced cancer has been grossly underestimated," and cited the 2013 Interagency Breast Cancer and Environmental Research Coordinating Committee report's conclusion that environmental factors provide a notable opportunity to prevent breast cancer.

APHA recommended six actions to address work-related breast cancer:

- *A declaration by the U.S. Surgeon General acknowledging an association between chemicals and breast cancer and underscoring the importance of identifying workplace contributions to risk.*
- *Enhanced federal research funding on work-related exposures and breast cancer, including community-based participatory methods, alternatives assessment and green chemistry.*
- *Efforts to replace chemicals of concern with non-toxic alternatives or changes in processes to eliminate the need for hazardous chemicals.*
- *Efforts by the National Institute of Occupational Safety and Health to investigate sectors and workplaces with excess risk of breast cancer or exposure to chemicals linked to the disease, along with efforts to disseminate research findings and occupational health information.*
- *Initiation of OSHA surveillance programs to identify sectors and workplaces with hazards linked to breast cancer, as well as the capacity to implement recommendations and trainings that would reduce exposures.*
- *The integration of green chemistry, toxics use reduction, and informed substitution into analysis of the full product life cycle (from manufacture to disposal) and consideration of these principles in purchasing decisions by government agencies and foundations.*

Read the full statement here: www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2015/01/07/14/55/breast-cancer-and-occupation.

Congress should acknowledge the current compelling science, pass legislation to remove the existing barriers, and reverse the court decisions that have brought the regulatory process to a virtual standstill.

Congress should also appropriate sufficient funding to ensure the agencies have the resources they need to accomplish their missions and, at minimum, enforce the few protections currently in place. NIOSH should be provided the necessary funding to conduct more and better research on workplace safety, particularly as it applies to chemical exposures linked to breast cancer.

At the same time, OSHA should take full advantage of its current authority. An example of an action that OSHA can and should take would be to set PELs at a more protective level than those that allow one additional cancer case for every 1,000 workers. Contrary to OSHA's interpretation of the Benzene Decision, the court did not define "significant risk" as one in 1,000, but rather gave OSHA flexibility in setting risk levels it determined to be "significant." OSHA should use that flexibility to decrease the allowable risk to a level similar to protections afforded the general public by the EPA, such as one in 100,000. OSHA also has the opportunity to use the "technical feasibility" requirement in the law to push industry to find and implement safer alternatives.

In the absence of legislative and regulatory mandates, OSHA should also promote and incentivize voluntary programs. Effective resources are available, such as *Transitioning to Safer Chemicals: A Toolkit for Employers and Workers*,[4] to help responsible employers protect their workforce. OSHA should make these tools available through a broad–based dissemination strategy and assist and incentivize employers with effective implementation plans.

Congress should enact comprehensive OSHA reform legislation to provide a higher level of protection to workers by requiring the use of safer alternatives where available; update the safety level of one in 1,000 to one in 100,000; require the use of inherently safer chemicals; remove barriers to effectively set permissible exposure limits; and create enforcement mechanisms and adequate penalties to ensure the implementation of those levels.

a. *Modernize OSHA.*

Comprehensive OSHA-reform legislation would take these steps:

- Ban chemicals linked to breast and other cancers from the workplace to the greatest extent possible.
- Replace problem chemicals with safer alternatives.
- Consider exposures to mixtures of chemicals and possible low–dose effects of endocrine disruptors when assessing hazards.
- Require transparent, accessible and clear disclosure of chemicals—related safety data—in products and materials used by all workers.
- Prevent federal pre-emption of states' abilities to pass more stringent regulatory requirements.
- Provide higher penalties for violations of OSHA standards.
- Provide adequate funding to NIOSH and OSHA.

In addition, workers need to be included in definitions of "vulnerable populations" in all legislative, regulatory and research initiatives, as done in the Ban Poisonous Additives (BPA) Act of 2014 and the Safe Cosmetics and Personal Care Products Act of 2013.

b. *Promote and incentivize voluntary actions to protect workers.*

Much can be done to better protect workers and their families by promoting tools that currently exist to help employers voluntarily make needed changes to the workplace to protect workers from harmful chemical exposures.

Safer alternatives to problem chemicals are key, providing a real opportunity for green chemistry solutions. The publication and promotion of resources such as the *Transitioning to Safer Chemicals: A Toolkit for Employers and Workers* would aid good actors in making positive changes. OSHA should incentivize employers to implement these voluntary changes with recognition and possible tax benefits.

c. *Convene a Workshop on Occupation and Breast Cancer, in order to establish a national agenda on worker health and the disease.*

NIOSH should convene a 2- to 3- day workshop to discuss the current understanding of the links between occupation and breast cancer and to create a national agenda for research and action to reduce risk for, and incidence of, breast cancer in the workplace. Participants should include workers, federal agencies (NIOSH, NIEHS, OSHA, CDC, etc.), academics, breast cancer advocates and industry stakeholders.

3. State OSHAs should act on their power to protect workers now.

In the face of an ineffective OSHA, which acknowledges its own inability to provide meaningful protections, some states, such as California have stepped up to more fully protect workers within their borders. State Plans are OSHA-approved job safety and health programs operated by individual states instead of federal OSHA. Twenty-two states have State Plans which must be at least as protective as the federal standards and can implement stronger protections.[5] While most states have not taken more protective action, the ability to set safer exposure levels does exist. States should take advantage of such opportunities to implement more health–protective standards that better reflect the current science.

Robust state worker protections are imperative in the absence of strong federal policy. State agencies should share best practices, require the use of inherently safer chemicals and set exposure levels that are truly health protective.

4. Employers should provide financial compensation to workers with illnesses related to workplace chemical exposure.

OSHA acknowledges that the financial burden of workplace injuries and illness falls on workers.[6] Approximately 97 percent of workers with occupational illnesses are not compensated, and for those employees who do receive workers' compensation, only about 20 percent of work-related medical expenses are covered.[7] Clearly, these substantive gaps require more effective policies and practices.

Some workers, such as firefighters in some jurisdictions, are protected by "presumptive disability laws." These presumptive laws recognize the connection between certain occupations and exposures linked to specific medical conditions. When a worker is diagnosed with that condition, the illness is presumed to be related to work, and therefore covered by worker compensation and disability laws, unless the employer can show another cause. When sick with chronic conditions or diseases linked to workplace exposures, workers should be supported by employers using the standards of presumptive laws to allow for the immediate payment of disability benefits. Workers should never have to fight for their benefits while they fight for their lives. Requiring employers to shoulder the appropriate financial responsibility for workplace-related illness or disease will further motivate them to better protect their employees.

Few countries require employers to compensate workers for occupational exposures linked to a diagnosis of breast cancer, although some exceptions exist. For example, Denmark classifies breast cancer due to night–shift work as an occupational disease.[8] The World Trade Center cleanup included breast cancer among cancers linked to the disaster,[9] San Francisco's presumptive illness laws include breast cancer due to concerns about incidence of the disease among firefighters.[10] In addition, three Canadian provinces have also extended the compensation presumption for firefighters who are diagnosed with breast cancer.[11]

Congress should enact legislation that mandates compensation for affected workers. OSHA estimates that 50,000 workers die each year as a result of past exposure to hazardous agents.[6] The financial burden of illness (which can be chronic, enduring and debilitating) should be assessed by health care professionals and reimbursed by employers.

Federal and state laws should mandate worker compensation for chronic conditions and diseases with probable links to work and workplace exposures.

5. Federal agencies, companies and researchers should collaborate with workers to develop viable methods to monitor workplace exposures.

We must know what occupational exposures workers face. Environmental monitoring of air, dust, and water, and biomonitoring of biological fluids such as blood and urine can provide important data to help researchers and policymakers better understand which chemicals people are being exposed to in the workplace. While collecting this data, it is imperative to protect the confidentiality of workers, since participation in such research studies could have real or perceived consequences for workers' job security.

A recent review found that exposure measurement methods and cohort study analytics are available to expand biomonitoring and epidemiology related to breast cancer causes and prevention.[12] These methods could and should be applied to occupational settings.

Researchers should collect detailed occupational work and exposure histories to better understand occupational exposures that may be related to chronic conditions and diseases. Past criticisms of studies of women point to problems with analyses based solely on job title or industry.[35] In particular, gender-based differences in tasks and work assignments may not be captured by using job title alone. In some cases, men and women with the same job title do not have the same duties and exposures. Studies based on specific chemical and physical exposures and detailed job and task histories which provide greater accuracy.[13,14]

Generate more scientific data on occupational exposures. Require and fund NIOSH to undertake more exposure and monitoring studies, including tracking exposures from air, dust, and water and biomonitoring workers. Detailed occupational histories should be included in all cohort studies to accurately identify potentially hazardous exposures. All results of biomonitoring studies should be returned, in a confidential manner, to employees who request the information.

6. Health care providers need to ask about work and workplace exposures.

Health care providers should be trained to conduct occupational histories, and questions about occupation should be included in intake forms and electronic health records.

Health care providers can be natural leaders in efforts to understand and reduce occupational exposures linked to breast cancer. Providers interact with individual patients who may have unspoken concerns about occupational exposures as well as those who may have serious exposures but may not have considered the health effects of those exposures. Since most workers spend a significant proportion of their waking hours at work, exposures in the occupational setting are central and relevant for health care practice.

Providers can integrate occupational health history questions into their initial intake forms or clinical interviews.[15] These interviews can include questions about occupation, job duties, and potential exposures of concern, including chemicals, ionizing radiation, and night–shift work.

Providers can also ask about engineering and personal protective equipment use. Health care systems should integrate some occupational questions in to electronic health records.

Environmental and occupational health should be an essential part of medical and nursing school curricula. Health care providers should receive updated information on environmental and occupational health risks in general and more specifically for the populations they serve. Initial health care visits should include a detailed occupational health history. Electronic health records should consistently include occupation and exposure data.

7. We must understand and mitigate the adverse impacts of shift work.

In 2007, the International Agency for Research on Cancer (IARC) classified shift work with circadian disruption as a probably carcinogenic. As highlighted above in this report, there is a large and growing body of evidence linking night work with increased risks of breast cancer.

Evidence suggests that the specific pattern and duration of shift work undertaken by workers may be key to subsequent breast cancer risk. For instance, the IARC review cites long-term circadian disruption as a carcinogen.[16] With such a high prevalence of night work in the US and worldwide, rigorous epidemiological research is needed to understand the specific risks and to provide recommendations on optimal shift–work schedules and durations of less than 20 years to prevent breast cancer risk associated with night–shift work.[17,18,19,20,21,22]

We recognize that some sectors require work in the middle of the night. Necessity is not permission to ignore health concerns; rather, it conveys a further need to determine how to mitigate adverse health effects associated with nighttime shift work. It is imperative that we invest in understanding the health implications of night–shift work and implement policies that ameliorate the associated increased risk of breast cancer.

The federal government should provide leadership to more fully understand the impact of night–shift work on an increased risk of breast cancer. NIOSH and OSHA should work cooperatively to identify and quickly implement policies that mitigate the impact of night–shift work.

8. Workplaces must fully disclose exposures of concern, regardless of trade secrets, and must communicate with workers about their personal exposures when they are measured.

We must put an end to trade secrets and 'confidential business information' (CBI) restricting the access to important information needed for chemical safety in the workplace. Furthermore, biomonitoring studies should report results back to workers who request the information whenever possible. A recent review of biomonitoring studies[23] reported that "ethical principles and empirical observations suggest that individual report-back should become standard practice

in most studies. Studies that have implemented individual report-back provide guidance for researchers and Institutional Review Boards (IRBs) to adopt report-back practices that respond to the particular community context of research and help individuals understand the meaning of their results". The study authors drafted a handbook with guidelines on how to integrate report-back methods into research.[24] Workplace biomonitoring studies may require extra measures to protect biomonitored workers' confidentiality and job security.

Employers should be required to provide better training of workers on workplace hazards in their sectors. As one example, several studies have found that radiation exposure is decreasing in radiology technologists, radiologists and interventional cardiologists as a result of education about exposure and improved technology. However, preventive education is not common in some other specialties, such as orthopedic surgery,[25] and for those performing fluoroscopically guided interventions.[26] Similar training and education would be beneficial in a variety of job categories. Employers should provide safety data to workers that include expanded and strengthened Safety Data Sheets (SDS). SDS and other communications about the hazards of chemicals must be understandable and easily accessible (without fear of retaliation) to workers.

Chemical manufacturers should provide transparent and comprehensive information on the safety of their products to federal and state regulatory agencies and the public. States and federal agencies should share chemical data across all levels.

9. Workers should be engaged in finding solutions to reduce exposures.

As the people closest to the situation, workers often have the best handle on how a workplace can be made safer. A good example is the Putting Breast Cancer Out of Work campaign.[27] This worker-focused training program, a collaboration between unions and NGOs, includes education and practical tools to help workers and their employers identify possible breast carcinogens in the workplace and less toxic alternatives. The program utilizes an extensive database of workplace exposures with clearly presented and visually striking information on hazards and health effects.

Workers who report injuries or illness or request information about workplace hazards need better resources and protection again retaliation. Unionized workers may have additional protections

and avenues to pursue redress, yet still face many challenges and risks in stepping forward. Workers may not feel safe even asking for information about the hazards they face on the jobs, such as requesting access to Safety Data Sheets. These concerns are often greater in non-unionized workplaces.

Employers should collaborate with workers to reduce chemical hazards on the job. Federal and state agencies should provide and enforce stronger protections to prevent retaliation against workers who report illnesses or injuries, ask for safety data on chemicals or raise concerns about working conditions.

10. Broad coalitions and collaborations across movements and nations should be formed to improve workplace conditions globally.

Across movements

The NGO community needs deep collaboration between environmental, labor, women's health, environmental health, breast cancer and cancer movements.

Working together to cross-train and share information and resources among these groups is imperative to bring about safer workplaces. In addition, this can help individual workers become stronger advocates for chemicals management policies and protections in the workplace.

Internationally

In our increasingly globalized economy, we need to support workers around the world, especially in the manufacturing sector. As these jobs move off shore, workers are faced with lower wages, inconsistent regulation, higher chemical exposures and increasingly detrimental working conditions. We need to stop the "race to the bottom""approach taken by corporations and increase protections in the United States while also moving to get factories in other countries to improve conditions.

Much of our understanding about occupational cancer has been obtained from studies largely of white men in developed countries. The movement of industry from developed to developing countries underscores the need for future investigations to include more diverse populations.[28]

We need to advocate on trade policy issues, with a focus on increasing standards in countries we trade with, enforcing high levels of labor and environmental standards, and working closely with international unions and other labor groups, e.g., labor groups organizing in Asia.

We need collaborations between environmental, health, and worker advocates, as welll as researchers and community members worldwide.

Conclusions

More research on the connection between workplace exposures and the risk of breast cancer is urgently needed. Understanding risk factors through monitoring chemical exposures, obtaining detailed occupational histories and tracking and understanding the impact of shift work are critical pieces of the puzzle. Workers have a right to know what substances they are exposed to and the potential health impacts, and they should be included in efforts to improve working conditions. And when workers do get sick, employers should be required to shoulder their fair share of the financial burden.

Given what we know about breast cancer and work, OSHA needs to update its safety standards to reflect the needs of the 21st century worker.

Only by working together across movements and across borders will we create the innovation and political pressure needed to achieve these critical policy changes.

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Resources:

BlueGreen Alliance:
http://www.bluegreenalliance.org/splash

ChemHat:
http://www.chemhat.org/

Clean Production Action:
http://www.cleanproduction.org/

Lowell Center for Sustainable Production:
http://www.sustainableproduction.org/

OSHA Toolkit Transitioning to Safer Chemicals:
https://www.osha.gov/dsg/safer_chemicals/

Putting Breast Cancer Out of Work:
http://www.chemhat.org/putting-breast-cancer-out-work-training-materials

United Steelworkers, Health Safety & Environment:
http://www.usw.org/act/activism/health-safety-and-environment

Appendix A: Incidence Risk Estimates for Breast Cancer by Occupation

Citation endnotes are included for the first use of each reference.

Occupation	Study type	Study	Results
Agriculture	Case-control	2013, Oddone[1]	OR = 0.92; 90% CI, 0.75-1.11
		2012, Brophy[2]	OR = 1.36; 95% CI, 1.01-1.82
		2012, Brophy	OR = 1.71; 95% CI, 1.12-2.62 (ER-)
		2010, Ji[3]	OR = 3.20; 95% CI, 1.1-8.80 (cotton)
		2010, Ji	OR = 1.20; 95% CI, 0.94-1.60 (agricultural, animal)
		2002, Gardner[4]	OR = 2.08; 95% CI, 1.15-3.74 (farmers; >10 years of employment)
		2000, Band[5]	OR = 3.11; 90% CI, 1.24-7.81
		1993, Rubin[6]	OR = 0.84; 95% CI, 0.66-1.07 (farming, forestry and fishing; white women)
	Cohort	2010, Koutros[7]	RSIR = 1.66; 95% CI, 1.51-1.82
	Records-linkage	2009, Pukkala[8]	SIR = 0.78; 95% CI, 0.76-0.80 (farmers)
		2009, Pukkala	SIR = 0.75; 95% CI, 0.60-0.93 (forestry workers)
		2009, Pukkala	SIR = 0.76; 95% CI, 0.74-0.78 (gardeners)
		1999, Pollan[9]	RR = 0.80; 95% CI, 0.82-0.93 (agriculture, forestry and fishing)
		1998, Petralia[10]	SIR = 1.20; 95% CI, 0.50-2.50 (grain)
Artists	Case-control	2007, Peplonska[11]	OR = 1.40; 95% CI, 0.90-2.10 (writers, artists, performers and related workers)
		2002, Gardner	OR = 2.34; 95% CI, 0.80-6.79 (professional artist)
	Records-linkage	2009, Pukkala	SIR = 1.26; 95% CI, 1.18-1.33 (artistic workers)
		1999, Pollan	SIR = 1.57; 95% CI, 1.07-2.22 (performance)
		1999, Pollan	SIR = 1.22; 95% CI, 0.85-1.70 (sculptor, painter, photographer, artist)
Auto Manufacture	Case-control	2012, Brophy	OR = 2.68; 95% CI, 1.47-4.88 (auto plastics)
		2011, Villeneuve[12]	OR = 2.60; 95% CI, 1.00-6.30 (manufacture of motor vehicles, trailers, trailers and semi-trailers)
Chemical Production	Case-control	2013, Oddone	OR = 1.15; 90% CI, 0.99-1.34 (chemical industry)
		2009, Pukkala	SIR = 0.90; 95% CI, 0.84-0.97 (chemical processors)
		1999, Hansen[13]	OR = 1.84; 95% CI, 1.15-2.95
		1998, Petralia	SIR = 1.00; 95% CI, 0.60-1.50 (chemical processors)
		1991, Hall[14]	PCIR = 1.43; p<.05 (black women; no elevation reported among white women)
Clergy/Religious Workers	Records-linkage	2009, Pukkala	SIR = 1.19; 95% CI, 1.16-1.22 (religious workers, etc.)
		2009, Pollan	RR = 2.09; 95% CI, 1.16-3.78 (other religious worker)

Clerical/ Secretaries	Case-control	2012, Brophy	OR= 1.00; 95% CI, 0.62-1.61 (administration)
		2007, Peplonska	OR = 0.90; 95% CI, 0.80-1.10 (general office occupations)
		2000, Band	OR = 7.28; 90% CI, 1.22-43.4 (electronic data-processing equipment operators; premenopausal)
		2000, Band	OR = 4.65; 90% CI, 1.24-17.4 (electronic data-processing equipment operators; postmenopausal)
		1999, Coogan[15]	OR = 1.15; 95% CI, 1.06-1.24 (administrative support, clerical)
		1993, Rubin	OR = 1.35; 95% CI, 1.30-1.40 (administrative support; white women)
	Records-linkage	2009, Pukkala	SIR = 1.20; 95% CI, 1.19-1.21 (clerical)
		1999, Pollan	SIR = 1.21; 95% CI, 1.15-1.27 (secretary/typist)
		1998, Petralia	SIR = 1.60; 95% CI, 1.30-1.90 (administrative clerks)
Electronics manufacture	Case Control	2010, Villeneuve	OR = 0.90; 95% CI, 0.40-2.00 (electrical and electronics equipment workers)
	Records-linkage	2009, Pukkala	SIR = 1.24; 95% CI, 1.19-1.29 (technical)
		2007, Peplonska	OR = 1.70; 95 % CI, 1.10-2.70 (electronic components and accessories
		2007, Peplonska	OR = 1.10; 95 % CI, 0.80-1.40 (electronic and other electrical equipment (≤10 yrs.)
		2007, Peplonska	OR = 1.60; 95 % CI, 1.10-2.30 (electronic and other electrical equipment (>10 yrs.)
		1998, Petralia	SIR = 0.90; 95% CI, 0.70-1.20 (electrical and electronic equipment)
		1998, Petralia	SIR = 0.90; 95% CI, 0.80-1.10 (electrical fitters and related electrical and electronic workers)
		1991, Hall	PCIR = 1.51; p<.01 (electrical manufacture; black women; no elevation reported among white women)
Dry Cleaning/ Laundry	Case-control	2013, Oddone	OR = 2.29; 90% CI, 0.97-5.41 (20+ years)
		2012, Brophy	OR = 2.72; 95% CI, (0.56-13.2)
		2000, Band	OR = 4.85; 90% CI, 1.26-18.7 (laundering and dry cleaning; post-menopausal)
	Records-linkage	2009, Pukkala	SIR = 0.89; 95% CI, 0.85-0.94 (launderers)
Financial & Insurance	Case-control	2007, Peplonska	OR = 2.40; 95% CI, 1.20-4.60 (inspectors & compliance officers
		2003, Teitlebaum[16]	OR = 1.50; 95% CI, 0.90-2.50 (adjustors, investigators and collectors; age 20->45)
		2002, Gardner	OR = 0.95; 95% CI, 0.75-1.19 (economists and financial planners)
		2000, Band	OR = 6.64; 90% CI, 1.10-40.2 (certified accountants)
	Records-linkage	1999, Pollan	SIR = 1.17; 95% CI, 1.10-1.24 (bookkeeper, cashier)
		1999, Pollan	SIR = 1.35; 95% CI, 1.13-1.60 (insurance rater, claims adjuster)
		1999, Pollan	RR = 1.52; 95% CI, 1.04-2.24 (bank teller)
		1998, Petralia	SIR = 1.60; 95% CI, 1.40-2.00 (bookkeepers & accountants)
		1998, Petralia	SIR = 1.40; 95% CI, 1.20-1.70 (economists & financial planners)
		1998, Petralia	SIR = 2.20; 95% CI, 1.00-4.10 (bankers)

First Responders	Case-control	2012, Li[17]	OR = 1.39, 95% CI, 0.82-2.20 (female WTC rescue workers, upon 2nd follow-up)
		1993, Rubin	OR = 0.75; 95% CI, 0.40-1.38 (armed forces; white women)
	Cohort	2014, Daniels[18]	SIR = 2.66; 95% CI, 0.86 to 6.21 (firefighters; 50-55 years)
		2013, Solan[19]	SIR = 0.74; 95% CI, 0.37-1.32 (last follow-up in 2008, authors note short window for latency)
		2005, Rennix[20]	IRR = 1.48; 95% CI, 1.01–2.07 (medium to high solvent exposures within army women)
	Records-linkage	2009, Pukkala	SIR = 1.57; 95% CI, 1.03- 2.3 (military)
		1998, Petralia	SIR = 2.10; 95% CI, 1.60- 2.60 (political and security personnel)
		1999, Pollan	SIR = 0.91; 95% CI, 0.89-0.93 (services and military work)
Flight Attendants	Cohort	1998, Wartenberg[21]	SIR = 1.90; 95% CI, 1.20-2.20 (Finnish)
		1998, Wartenberg	SIR = 1.60; 95% CI, 0.9-2.70 (Danish)
		1998, Mawson[22]	SIR = 1.87; 95% CI, 1.15-2.23
		1996, Lynge[23]	SIR = 1.87; 95% CI, 0.90-2.70
	Meta-analysis	2005, Megdal[24]	SIR = 1.44; 95% CI, 1.26-16.5
Food & Beverage Production	Case-control	2013, Oddone	OR = 1.01; 90% CI, 0.91-1.13 (food industry)
		2013, Oddone	OR = 1.61; 90% CI, 0.89-2.91 (alcoholic beverage and wine production)
		2012, Brophy	OR = 2.25; 95% CI, 0.97-5.26 (food manufacturing)
		2012, Brophy	OR = 2.35; 95% CI, 1.00-5.53 (food canning)
		2012, Brophy	OR = 5.70; 95% CI, 1.03-31.5 (food canning; premenopausal, BMI = 25.0 +/-)
		2012, Brophy	OR = 1.47; 95% CI, 0.55-3.97 (food canning; postmenopausal, BMI = 25% +/-)
		2010, Ji	OR = 4.30; 95% CI, 1.30-15.2 (other food and beverage production workers)
		2010, Ji	OR = 3.50; 95% CI, 1.20-10.1 (pickling, canning and preserved food workers)
		2000, Band	OR = 3.86; 90% CI, 1.06-14.1 (food, beverage and related processing, post-menopausal)
		2000, Band	OR = 4.61; 90% CI, 1.27-16.8 (fish products, pre- and post-menopausal)
Hairdressers & Cosmetologists	Case-control	2007, Peplonska	OR = 1.00; 95% CI, 0.50-1.80 (hairdressers and cosmetologists)
		2000, Band	OR = 3.72; 90% CI, 1.23-11.3 (barber and beauty shops; pre-menopausal)
		2000, Band	OR = 6.00; 90% CI, 1.00-35.9 (Combination barber and beauty shops; pre- and post-menopausal)
	Records-linkage	2009, Pukkala	SIR = 1.06; 95% CI, 1.01-1.10 (hairdressers)
		1999, Pollan	RR = 1.27; 95% CI, 1.11-1.47 hairdresser, beautician)

Managers & Administrators	Case-control	2006, Shaham[25]	OR = 0.60; 95% CI 0.40–0.80 (administration)
	Cohort	2013, Pudrovska[26]	14.5/1000 breast cancer cases among women in professional and managerial occupations compared to 9.5/1000 cases among housewives and 5.1/1000 cases among blue collar workers
	Records-linkage	2009, Pukkala	SIR = 1.28; 95 % CI, 1.24-1.33 (administrators)
		1999, Pollan	SIR = 1.26; 95% CI, 1.14-1.39 (administrative and managerial)
		1999, Pollan	SIR = 1.42; 95% CI, 1.22-1.66 (government legislator and administrator)
		1998, Petralia	SIR = 1.30; 95% CI, 1.00-1.70 (leaders of business organizations)
		1998, Petralia	SIR = 1.70; 95% CI, 1.10-2.60 (managers of businesses & factories)
Manufacturing and Machinery	Case-control	2013, Oddone	OR = 1.06; 90% CI, 0.99-1.14 (mechanical manufacture)
		2013, Oddone	OR = 1.12; 90% CI, 1.04-1.21 (electrical manufacture)
		2007, Peplonska	OR = 1.20; 95% CI, 1.03-1.50 (machine operators, tenders (N)
		2007, Peplonska	OR = 1.30; 95% CI, 1.02-1.60 (machine operators, tenders (≤10 yrs.)
		2007, Peplonska	OR = 1.2; 95% CI, 0.95-1.50 (machine operators, tenders (>10 yrs.)
		2002, Gardner	OR = 1.49; 95% CI, 1.06-2.08 (inspectors and product analysts, pre-menopausal; >10 years of employment, dose response effect, p<.04)
		2002, Gardner	OR = 0.82; 95% CI, 0.51-1.30 (inspectors and product analysts, post-menopausal; >10 years of employment, dose response effect, p<.04)
		1993, Rubin	OR = 0.90; 95% CI, 0.88-0.97 (machine operators and assemblers)
Materials Manufacture	Case-control	2013, Oddone	OR = 0.87; 90% CI, 0.76-1.01 (wood industry)
		2011, Villeneuve	OR = 2.80; 95% CI, 1.1-7.40 (ceramics, cement & stone, employed > 5 years
		2002, Gardner	OR = 2.08; 95% CI, 1.14-3.82 (glass manufacture)
		1999, Hansen	OR = 2.40; 95% CI, 0.97-5.99 (wood & furniture)
	Records-linkage	2009, Pukkala	SIR = 0.91; 95% CI, 0.87-0.95 (glass)
		2009, Pukkala	SIR = 0.84; 95% CI, 0.73-0.97 (smelting)
		2009, Pukkala	SIR = 0.76; 95% CI, 0.7-0.81 (wood)
		1999, Pollan	SIR = 1.31, 95% CI, 0.63-2.42 (glass, ceramics painter and decorator)
		1998, Petralia	SIR = 0.70; 95% CI, 0.40-1.30 (glass workers (formers, cutters, grinders, finishers, and engravers)
		1998, Petralia	SIR = 0.80; 95% CI, 0.60-1.20 (metal refining and processing)

Medical & Health Care	Case-control	2013, Oddone	OR = 1.08; 90% CI, 0.88-1.32 (pharmaceutical industry)
		2010, Ji	OR = 1.40; 95% CI, 1.00-1.90 (medical & health care personnel)
		2007, Peplonska	OR = 1.20; 95% CI, 0.70-2.10 (physicians)
		2007, Peplonska	OR = 2.40; 95% CI, 1.04-5.70 (health record technologists and technicians (N)
		2007, Peplonska	OR = 1.00; 95% CI, 0.80-1.20 (health services (N)
		2007, Peplonska	OR = 2.10; 95% CI, 1.30-3.40 (specialty hospitals excluding psychiatric (N)
		2000, Band	OR = 3.14; 90% CI, 1.12-8.76 (other institutional health and social services; premenopausal)
		2000, Band	OR = 3.49; 90% CI, 1.07-11.4 (nursing home care workers; premenopausal)
		2000, Band	OR = 1.38; 90% CI, 1.00-1.91 (medicine & health, post-menopausal)
	Cohort	2012, Chou[27]	SPR = 2.90; 95% CI, 1.66-4.71 (female orthopedic surgeons)
	Records-linkage	2009, Pukkala	SIR = 1.35; 95% CI, 1.25-1.45 (physicians)
		2009, Pukkala	SIR = 1.42; 95% CI, 1.31-1.55 (dentists)
		2009, Pukkala	SIR = 1.14; 95% CI, 1.11-1.17 (other health workers)
		1999, Pollan	RR = 1.55; 95% CI, 1.13-2.12 (physicians)
		1999, Pollan	SIR = 1.40; 95% CI, 1.05-1.84 (dentists)
		1999, Pollan	SIR = 1.23; 95% CI, 1.02-1.47 (medical technician)
		1999, Pollan	RR = 1.45; 95% CI, 1.09-1.93 (pharmacist)
		1998, Petralia	SIR = 7.20; 95% CI, 4.40-11.4 (Doctors of Chinese Medicine)
		1998, Petralia	SIR = 1.50; 95% CI, 5.90-30.3 (Doctors of Chinese-Western Medicine)
		1998, Petralia	SIR = 0.80; 95% CI, 0.50-1.20 (Doctors of Western Medicine)
		1998, Petralia	SIR = 1.50; 95% CI, 1.30-1.80 (medical & public health workers)
		1998, Petralia	SIR = 1.40; 95% CI, 0.50-2.90 (pharmacists and assistants)
		1991, Hall	PCIR = 1.64; p<.05 (pharmaceutical industry: black women; no elevation reported among white women)
Metal-Working & Metal Products	Case-control	2013, Oddone	OR = 1.17; 90% CI, 0.98-1.40 (iron and steel)
		2012, Brophy	OR = 1.73; 95% CI, 1.02-2.92 (metalworking)
		1999, Hansen	OR = 1.35; 95% CI, 1.01-1.83
	Records-linkage	2009, Pukkala	SIR = 0.75; 95% CI, 0.59-0.95 (welders)
		1999, Pollan	SIR = 2.04; 95% CI, 1.05-3.56
		1998, Petralia	SIR = 1.40; 95% CI, 0.80-2.10 (welders and flame cutters)
		1998, Petralia	SIR = 0.80; 95% CI, 0.60-1.20 (plumbers, welders, sheet metal and structural metal preparers and erectors)
		1998, Petralia	SIR = 0.70; 95% CI, 0.40-1.10 (sheet metal workers)
		1998, Petralia	SIR = 1.10; 95% CI, 0.90-1.40 (Metal grinders, polishers, tool sharpeners, and machine-tool operators)
		1998, Petralia	SIR = 1.10; 95% CI, 0.60-1.80 (machinery fitters and machine assemblers)

Nurses	Case-control	2011, Villeneuve	OR = 1.40; 95% CI, 0.90-2.10 (nurses employed ≥10 years)
		2007, Peplonska	OR = 0.80; 95% CI, 0.60-1.10 (registered nurses)
		2000, Band	OR = 1.54; 90% CI, 1.05-2.28 (nurses, registered, graduate and nurses in-training; post-menopausal)
	Records-linkage	2009, Pukkala	SIR = 1.18; 95% CI, 1.15-1.20 (nurses)
		2009, Pukkala	SIR = 0.95; 95% CI, 0.93-0.97 (assistant nurses)
		1999, Pollan	SIR = 1.17; 95% CI, 1.09-1.26 (nurses)
		1998, Petralia	SIR = 1.90; 95% CI, 1.40-2.50 (nurses)
Other Industry & Laborers	Case-control	2011, Villeneuve	OR = 2.00; 95% CI, 0.90-4.60 (laborers)
		2007, Peplonska	OR = 1.20; 95% CI, 1.03-1.50 (machine operators)
		2007, Peplonska	OR = 1.20; 95% CI, 0.99-1.60 (fabricators and hand-working occupations)
		2006, Shaham	OR = 4.10; 95% CI, 2.00-8.40
		1993, Rubin	OR = 1.72; 95% CI, 1.24-2.40 (mechanics and repairers)
		1993, Rubin	OR = 0.99; 95% CI, 0.64-1.56 (construction trades)
		1993, Rubin	OR = 0.82; 95% CI, 0.75-0.90 (equipment cleaners, laborers and helpers)
		1993, Rubin	OR = 1.06; 95% CI, 0.97-1.16 (technicians and related support occupations)
	Records-linkage	1998, Petralia	SIR = 1.00; 95% CI, 0.70-1.30 (industrial technician)
		1998, Petralia	SIR = 1.00; 95% CI, 0.50-1.90 (electricians (electrical wiremen), other electric linemen and cable jointers)
Paper & Printing	Case-control	1999, Hansen	OR = 1.50; 95%9CI, 1.1-2.04 (paper & printing)
		2013, Oddone	OR = 1.25; 90% CI, 1.06-1.46 (paper industry)
		2012, Brophy	OR = 0.74; 95% CI, 0.23-2.40 (printing)
		2007, Peplonska	OR = 3.10; 95% CI, 1.40-7.00 (printing operators.)
	Records-linkage	2009, Pukkala	SIR = 1.15; 95% CI, 1.15-1.22 (printing)
		1999, Pollan	SIR = 1.16, 95% CI, 0.76-1.70 (other printing worker)
		1998, Petralia	SIR = 0.90; 95% CI, 0.60-1.40 (printers and related
		1998, Petralia	SIR = 0.90; 95% CI, 0.70-1.30 (paper product makers)
		1998, Petralia	SIR = 1.00; 95% CI, 0.40-1.90 (printing pressmen)
		1991, Hall	PCIR = 1.76, p,<05 (printing; black women; no elevation
Postal and Communication	Case-control	2002, Gardner	OR = 2.98; 95% CI, 1.50-5.92 (postal & communication)
	Records-linkage	2009, Pukkala	SIR = 1.40; 95% CI, 0.80-2.40 (postal and communication workers)
		1999, Pollan	RR = 1.41; 95% CI, 1.17-1.70 (telephone operator)
		1999, Pollan	RR = 1.87; 95% CI, 1.26-2.79 (telegraphy/radio)
		1998, Petralia	SIR = 1.08; 95% CI, 1.05-1.11 (postal workers)
		1998, Petralia	SIR = 1.30; 95% CI, 0.60-4.30 (telephone and telegraph operators)

Precision Production, Craft & Repair	Case-control	2007, Peplonska	OR = 2.20; 95% CI, 1.20-4.30 (specialty trade contractors)
		1998a, Petralia	OR = 4.29; 95% CI, 0.9-20.35 (precision product, craft, repair, premenopausal)
		1996, Coogan	OR = 1.26; 95% CI, 0.98-1.62 (precision production)
		1993, Rubin	OR = 1.12; 95% CI, 1.01-1.23 (precision production)
	Records-linkage	1998, Petralia	SIR = 0.60; 95% CI, 0.60-1.90 (home appliance repair)
		1998, Petralia	SIR = 1.06; 95% CI, 0.80-1.10 (machinery fitters, assemblers, precision instruments except electrical)
		1998 Petralia	SIR = 1.40; 95% CI, 0.80-1.20 (machinery, motor vehicle and aircraft engine mechanics)
Professionals in Legal and Social Services	Case-control	2007, Peplonska	OR = 2.10; 95% CI, 1.10-3.80 (economists (N)
		2007, Peplonska	OR = 2.70; 95% CI, 1.30-5.70 (public administration, general government not elsewhere classified
		2007, Peplonska	OR = 1.30; 95% CI, 0.90-2.10 (librarians, archivists, and curators)
		2007, Peplonska	OR = 4.50; 95% CI, 1.90-10.3 (managers; marketing, advertising and public relations
		2007, Peplonska	OR = 1.70; 95% CI, 1.01-2.90 (social scientists and urban planners (N)
		2003, Teitlebaum	OR = 1.40; 95% CI, 1.00-1.90 (Social Scientists, social workers, religious workers and lawyers (ever); ages 20-44)
		2002, Gardner	OR = 0.10; 95% CI, 0.01-0.87 (lawyers; all women)
		1993, Rubin	OR = 1.55; 95% CI, 1.48-1.61 (professional)
	Records-linkage	2009, Pukkala	SIR = 1.36; 95% CI, 1.25-1.48 (journalists)
		1999, Pollan	SIR = 1.12; 95% CI, 1.09-1.15 (professional & technical)
		1999, Pollan	RR = 1.31; 95% CI, 1.06-1.63 (social worker)
		1999, Pollan	SIR = 1.22; 95% CI, 1.03-1.44 (librarian)
		1999, Pollan	SIR = 1.79; 95% CI, 1.15-1.67 (systems analyst)
		1998, Petralia	SIR = 2.30; 95% CI, 1.20-4.00 (librarians)
		1998, Petralia	SIR = 1.60; 95% CI, 1.00-2.50 (cultural workers)
		2006, Doody[28]	RR = 2.10; 95% CI, 1.10-3.40 (started work before 1940)
		2006, Doody	RR = 2.90; 95% CI, 1.30-6.20 (started work before 1935)

Retail/Sales	Case-control	2011, Villeneuve	OR = 2.20; 95% CI, 1.00–4.80 (managers wholesale and retail trade; all women)
		2007, Peplonska	OR = 1.20; 95% CI, 1.04-1.50 (retail (N)
		2007, Peplonska	OR = 1.30; 95% CI, 1.04-1.60 (retail trade; food stores
		2007, Peplonska	OR = 1.70; 95% CI, 1.20-2.30 (retail trade; grocery stores
		2007, Peplonska	OR = 2.00; 95% CI, 1.20-3.40 (miscellaneous shopping good stores (N)
		2000, Band	OR = 2.21; 90% CI, 1.24-3.96 (sales; premenopausal)
		2000, Band	OR = 4.32; 90% CI, 1.06-17.6 (sales, services; premenopausal)
	Records-linkage	2009, Pukkala	SIR = 1.10; 95% CI, 1.06-1.13 (sales agents)
		2009, Pukkala	SIR = 1.00; 95% CI, 0.99-1.02 (shop workers)
		1998, Petralia	SIR = 1.10; 95% CI, 0.90-1.30 (salesman, shop assistants and related workers)
		1998, Petralia	SIR = 1.20; 95% CI, 0.60-2.20 (sales personnel and suppliers)
Rubber & Plastic Products	Case-control	2013, Oddone	OR = 1.25; 90% CI, 1.03-1.54 (rubber industry)
		2013, Oddone	OR = 0.94; 90% CI, 0.84-1.05 (plastic industry)
		2011, Villeneuve	OR = 1.80; 95% CI, 0.90–3.50 (rubber and plastic product makers)
		2010, Ji	OR = 2.00; 95% CI, 0.90-4.30
		2002, Gardner	OR = 1.39; 95% CI, 0.80-2.40 (rubber and plastic products)
	Records-linkage	1999, Pollan	SIR = 1.13; 95% CI, 0.82-1.52 (rubber products worker)
		1998, Petralia	SIR = 1.80; 95% CI, 1.40-2.30 (rubber and plastic products makers)
		1998, Petralia	SIR = 1.80; 95% CI, 1.10-2.80 (rubber manufacturing and product makers)
		1998, Petralia	SIR = 1.30; 95% CI, 0.90-1.80 (plastic manufacturing and product makers)
Scientists	Case-control	2007, Peplonska	OR = 2.00; 95% CI, 1.05-3.80 (engineers; agricultural, electrical, electronic, industrial, computer and others
		2002, Gardner	OR = 9.94; 95% CI, 1.20-82.37 (laboratory technicians)
	Records-linkage	2009, Pukkala	SIR = 1.21; 95% CI, 1.14-1.28 (laboratory assistants)
		1998, Petralia	SIR = 1.80; 95% CI, 1.10-2.80 (electrical and electronic engineers)
		1998, Petralia	SIR = 2.00; 95% CI, 1.00-3.60 (lab technicians)
		1998, Petralia	SIR = 3.30; 95% CI, 1.40-6.50 (scientific research workers)

Service Workers	Case-control	2012, Brophy	OR = 2.28; 95% CI, 0.94-5.53 (casino/restaurant workers)
		2010, Ji	OR = 1.50; 95% CI, 1.00-2.20 (service workers)
		2010, Ji	OR = 1.50; 95% CI, 1.00-2.10 (odd-job workers)
		2000, Band	OR = 6.78; 90% CI, 1.70-27.1 (food; premenopausal)
		1993, Rubin	OR = 0.81; 95% CI, 0.77=0.84 (service)
	Records-linkage	2009, Pukkala	SIR = 1.02; 95% CI, 0.88-1.17 (beverage workers)
		2009, Pukkala	SIR = 0.99; 95% CI, 0.96-1.03 (waiters)
		2009, Pukkala	SIR = 1.02; 95% CI, 0.88-1.17 (beverage workers)
		2009, Pukkala	SIR = 0.86; 95% CI, 0.83-0.94 (food workers)
		2009, Pukkala	SIR = 0.86; 95% CI, 0.84-0.87 (building caretakers)
		2009, Pukkala	SIR = 0.93; 95% CI, 0.91-0.94 (domestic assistants)
		1998, Petralia	SIR = 0.60; 95% CI, 0.40-1.80 (waiters)
		1998, Petralia	SIR = 1.00; 95% CI, 0.81.10 (public service workers)
		1998, Petralia	SIR = 1.40; 95% CI, 0.70-2.50 (hotel and restaurant personnel)
		1998, Petralia	SIR = 1.00; 95% CI, 0.70-1.30 (babysitters and childcare workers; age-adjusted)
		1998, Petralia	SIR = 0.60; 95% CI, 0.30-1.10 (housekeepers; age adjusted)
		1998, Petralia	SIR = 0.70-1.30; 95% CI, 0.30-1.30 (sanitation personnel, street cleaners and garbage men; age-adjusted)
		1998, Petralia	SIR = 1.10; 95% CI, 0.60-1.90 (other public service workers; age-adjusted)
		1998, Petralia	SIR = 0.70; 95% CI, 0.50-0.90 (warehouse workers; age-adjusted)
		1998, Petralia	SIR = 1.10; 95% CI, 0.70-0.90 (miscellaneous workers (doormen, messengers, janitors; age-adjusted)

Teachers	Case-control	2011, Villeneuve	OR = 1.80; 95% CI, 0.90–3.90 (head teachers)
		2010, Ji	OR = 1.30; 95% CI, 1.00-1.70 (teaching personnel)
		2010, Ji	OR = 2.00; 95% CI, 1.20-3.40 (university teachers)
		2003, Teitlebaum	OR = 1.30; 95% CI, 1.00-1.70 (teachers, librarians and counselors; parous only; ages 20-44)
		2003, Teitlebaum	OR = 1.00; 95% CI, 0.60- 1.50 (teachers, librarians and counselors; nulliparous only; ages 20-44)
		2002, Gardner	OR = 1.06; 95% CI, 0.79-1.42
		1998a, Petralia[29]	OR = 1.36; 95% CI, 0.78-2.35 (post-menopausal)
	Cohort	1999, Reynolds[30]	SIR = 1.21; 95% CI, 1.15-1.28
	Records-linkage	2009, Pukkala	SIR = 1.22; 95% CI, 1.20-1.24 (teachers)
		2007, Peplonska	OR = 2.10; 95% CI, 1.10-3.90 (day care)
		2007, Peplonska	OR = 0.90; 95% CI, 0.70-1.10 (teachers, except post-secondary)
		2000, Band	OR = 1.57; 90% CI, 1.01-2.45 (elementary and secondary school teaching; post-menopausal)
		2000, Band	OR = 1.80; 90% CI, 1.28-2.53 (educational services; post-menopausal)
		1999, Pollan	RR = 1.22; 95% CI, 1.03-1.44 (teacher, theoretical subjects)
		1999, Pollan	RR = 1.26; 95% CI, 1.15-1.37 (schoolmaster)
		1998, Petralia	SIR = 2.00; 95% CI, 1.80-2.20 (teachers)

Textiles & Clothing	Case-control	2013, Oddone	OR = 1.03; 90% CI, 0.92-1.15 (leather & shoes)
		2013, Oddone	OR = 1.07; 90% CI 1.01-1.14 (garment industry)
		2012, Brophy	OR = 1.73; 95% CI, 1.73 (0.37-8.04)
		2011, Villeneuve	OR = 2.40; 95% CI, 0.90-6.00 (textile workers)
		2011, Villeneuve	OR = 1.50; 95% CI, 0.90-2.60 (tailors, dressmakers, employed >10 years)
		2007, Peplonska	OR = 1.30, 95% CI, 1.03-1.50 (textiles)
		2007, Peplonska	OR = 2.00; 95% CI, 1.20-3.40 (hand-sewing)
		2006, Shaham	OR = 2.10; 95%CI, 1.30-3.30 (textile & clothing)
		2002, Gardner	OR = 3.25; 95% CI, 1.11-9.53 (leather & fur)
		1999, Hansen	OR = 1.40; 95% CI, 1.12-1.76 (textile & weaving; 15 years lag)
	Records-linkage	1998, Petralia	SIR = 1.10; 95% CI, 1.00-1.20 (textile workers; spinners, weavers, knitters, dyers and related workers)
		1998, Petralia	SIR = 1.30; 95% CI, 0.80-2.00 (bleachers, dyers and textile product finishers)
		1998, Petralia	SIR = 1.30; 95% CI, 1.00-1.60 (knitters)
		1998, Petralia	SIR = 1.00; 95% CI, 0.70-1.20 (tailors and sewers)
		1998, Petralia	SIR = 0.90; 95% CI, 0.40-1.80 (textile machinery mechanics)
		1998, Petralia	SIR = 0.10; 95% CI, 0.60-1.50 (leather and fur processors)
		1998, Petralia	SIR = 0.40; 95% CI, 0.10-0.70 (other textile workers)
		2009, Pukkala	SIR = 1.01; 95% CI, 0.94-1.08 (shoe and leather workers)
		2009, Pukkala	SIR = 0.99; 95% CI, 0.97-1.01 (textile workers)
Transportation	Case-Control	2000, Band	OR = 5.13; 90% CI, 1.31-20.1 (transport; pre-menopausal)
		1993, Rubin	OR = 0.80; 95% CI, 0.70-1.07 (transportation; white women; data not reported for black women)
	Records-linkage	2009, Pukkala	SIR = 1.15; 95% CI, 1.04-1.27 (transport workers)
		2009, Pukkala	SIR = 0.81; 95% CI, 0.75-0.88 (drivers)
		1998, Petralia	SIR = 0.60; 95% CI, 0.30-0.90 (dockers and freight handlers)
		1998, Petralia	SIR = 0.30; 95% CI, 0.20-0.60 (transportation and equipment operators)

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Appendix B: Mortality Risk Estimates for Breast Cancer by Occupation

Citation endnotes are included for the first use of each reference.

Occupation	Study	Results
Artists	2007, MacArthur[1]	MOR = 1.69; 95% CI, 1.03-2.75 (musicians)
Clergy/Religious Workers	2007, MacArthur	MOR = 1.79; 95% CI, 1.16-2.75 (religious)
	1993, Rubin[2]	PMR = 1.65; 95% CI, 1.39-1.96 (clergy, religious; white women)
	1993, Rubin	PMR = 1.52; 95% CI, 0.87-2.47 (clergy, religious; black women)
Clerical/Secretaries	1998, Calle[3]	RR = 1.14; 95% CI, 1.01-1.31 (administrative support, mortality)
	1993, Rubin	PMR = 1.33; p<.01 (administrative support; black women)
	1993, Rubin	PMR = 1.21; 95% CI, 1.18-1.24 (clerks; white women)
	1993, Rubin	PMR = 1.47; 95% CI, 1.29-1.66 (clerks; black women)
	1993, Rubin	PMR = 1.32; 95% CI, 1.29-1.36 (secretaries; white women)
	1993, Rubin	PMR = 1.68; 95% CI, 1.40-2.00 (secretaries; black women)
	1993, Rubin	PMR = 1.47; 95% CI, 1.29-1.66 (clerks; black women)
	1993, Rubin	PMR = 1.32; 95% CI, 1.29-1.36 (secretaries; white women)
	1993, Rubin	PMR = 1.68; 95% CI, 1.40-2.00 (secretaries; black women)
Electronics Manufacture	2006, Clapp[4]	PCMR = 1.15; 95% CI, 1.06-1.25 (computer microelectronics)
Financial & Insurance	2007, MacArthur	MOR = 1.41; 95% CI, 1.2-1.65 (bookkeepers)
	2007, MacArthur	MOR = 1.68; 95% CI, 1.28-2.19 (accountants)
	2007, MacArthur	MOR = 3.69; 95% CI, 2.11-6.47 (brokers/financial salesmen)
	1993, Rubin	PMR = 1.32; 95% CI, 1.20-1.45 (finance officers; white women)
	1993, Rubin	PMR = 1.89; 95% CI, 1.17-2.89 (finance officers; black women)
	1993, Rubin	PMR = 1.25; 95% CI, 1.06-1.45 (bank tellers; white women)
	1993, Rubin	PMR = 1.86; 95% CI, 0.86-4.05 (bank tellers; black women)
First Responders	2007, MacArthur	MOR = 4.57; 95% CI, 1.39-15.0 (police)
	2005, Ma[5]	SMR = 7.41; 95% CI, 1.99-18.96 (male breast cancer)
Hairdressers/Cosmetologists	2001, Lamba[6]	MOR = 1.10; 95% CI, 1.03-1.17 (white women)
	2001, Lamba	MOR = 1.15; 95% CI, 0.98-1.36 (black women)

Occupation	Study	Results
Managers & Administrators	2007, MacArthur	MOR = 1.19; 95%CI, 1.03-1.38 (owners, managers, government)
	1998, Calle[7]	RR = 1.93; 95% CI, 1.03-3.62 (executives, mortality)
	1998a, Petralia[8]	MOR = 1.22; 95% CI, 0.67-2.22 (post-menopausal)
	1993, Rubin	PMR = 1.17; 95% CI, 1.13-1.22 (managers, administrators; white women)
	1993, Rubin	PMR = 15.3; 95% CI, 1.25-1.86 (managers, administrators; black women)
	1993, Rubin	PMR = 1.26; 95% CI, 1.09-1.45 (supervisors; white women)
	1993, Rubin	PMR = 1.44; 95% CI, 0.77-2.47 (supervisors; black women)
	1993, Rubin	PMR = 1.27; 95% CI, 1.20-1.35 (executive, administrative, managerial; white women)
Manufacturing	2008, Shannon[9]	SMR = 2.04; 95% CI, 0.88-4.02; SMR = 3.23; 95% CI, 1.05-7.53, among longer latency cases (lamp manufacturing)
	1998, Calle	RR = 1.54; 95% CI, 0.99-2.39 (technicians, mortality)
Medical and Health Care	2007, MacArthur	MOR = 2.38; 95% CI, 1.08-5.25 (physicians)
	2007, MacArthur	MOR = 2.09, 95% CI, 1.28-3.40 (medical/dental technicians)
	1999, Petralia[10]	MOR = 1.40; 95% CI, 1.00-1.80 (physicians, white women)
	1999, Petralia	MOR = 1.50; 95% CI, 0.50-4.40 (physicians, black women)
	1999, Petralia	MOR = 1.50; 95% CI, 1.1-2.00 (pharmacists, white women)
	1999, Petralia	MOR = 1.60; 95% CI, 1.10-2.40 (other practitioners, white women)
	1999, Petralia	MOR = 1.40; 95% CI, 1.10-1.70 (dental hygienists & assistants, white)
	1999, Petralia	MOR = 2.60; 95% CI, 1.40-5.00 (dental hygienists & assistants, black)
	1993, Rubin	PMR = 1.27; 95% CI, 0.78-1.97 (pharmacists; white women)
	1993, Rubin	PMR = 3.66; 95% CI, 0.75-10.68 (pharmacists; black women)
	1993, Rubin	PMR = 0.97; 95% CI, 0.64-1.42 (physicians; white women)
	1993, Rubin	PMR = 5.90; 95% CI, 2.37-12.15 (physicians; black women)
	1993, Rubin	PMR = 1.05; 95% CI, 0.86-1.26 (dieticians; white women)
	1993, Rubin	PMR = 1.94; 95% CI, 0.68-1.51 (dieticians; black women)
Motor Vehicle Manufacture	1994, Delzell[11]	SMR = 0.68; 95% CI, 0.48-0.92 (motor vehicles; white women)
	1994, Delzell	SMR = 0.97; 95% CI, 0.52-1.66 (motor vehicles; black women)
Nurses	2007, MacArthur	MOR = 1.39; 95% CI, 1.24-1.57 (nurses)
	2007, Dimich-Ward[12]	SMR = 0.87; 95% CI, 0.77-0.98
	1999, Petralia	MOR = 1.10; 95% CI, 1.00-1.10 (RN, white, all)
	1999, Petralia	MOR = 1.20; 95% CI, 1.10-1.40 (RN, black, all)
	1999, Petralia	MOR = 0.80; 95% CI, 0.70-0.90 (LPN; white women)
	1999, Petralia	MOR = 1.20; 95% CI, 1.00-1.40 (LPN; black women)
	1993, Rubin	PMR = 1.09; 95% CI, 1.04-1.14 (nurses; white women)
	1993, Rubin	PMR = 1.25; 95% CI, 1.07-1.44 (nurses; black women)
Postal & Communication	2007, MacArthur	MOR = 6.50; 95% CI, 1.55-27.2 (communication inspectors)
	2007, MacArthur	MOR = 3.15; 95% CI, 1.06-9.39 (postal workers)
	2007, MacArthur	MOR = 1.36; 95% CI, 1.00-1.84 (telephone operators)

Occupation	Study	Results
Professionals in Legal and Social Services	2007, MacAuthur	MOR = 1.96; 95% CI, 1.20-3.21 (journalists)
	2007, MacArthur	MOR = 2.22; 95% CI, 1.42-3.48 (librarians)
	1993, Rubin	PMR = 1.29; p<.01 (professionals; white women)
	1993, Rubin	PMR = 1.50; p<.01 (professionals; black women)
	1993, Rubin	PMR = 1.43; 95% CI, 1.03-1.94 (counselors; white women)
	1993, Rubin	PMR = 2.60; 95% CI, 1.39-4.45 (counselors; black women)
	1993, Rubin	PMR = 1.63; 95% CI, 1.42-1.86 (librarians; white women)
	1993, Rubin	PMR = 1.58; 95% CI, 0.64-3.25 (librarians; black women)
	1993, Rubin	PMR = 1.21; 95% CI, 0.80-1,76 (lawyers and judges; white women)
	1993, Rubin	PMR = 3.95; 95% CI, 0.82-11.56 (lawyers and judges; black women)
Radiological Technologists	2014, Liu[13]	HR = 2.51; 95% CI, 1.24-5.05 (mortality among women who started work before 1940)
	2009, Zielinski[14]	SMR = 0.99; 95% CI, 0.90-1.10
	2002, Mohan[15]	RR = 1.76, p=.07, mortality among those working with fluoroscopy prior to 1950 compared with after 1960 and RR = 2.1, p=.01 among those working with multi-film procedures before 1950, compared to after 1960
	1999, Petralia	MOR = 1.40; 95% CI, 1.10-1.40 (white women)
	1999, Petralia	MOR = 2.30; 95% CI, 1.00-5.40 (black women)
	1998, Doody	SMR = 0.70; 95% CI, = 0.50-0.90 (fewer than 10 years certification)
	1998, Doody	SMR = 1.40, 95% CI, = 1.20-1.70 (more than 30 years certification)
Retail/Sales	2007, MacArthur	MOR = 1.36; 95% CI, 1.20-1.54 (retail sales clerks)
	1993, Rubin	PMR = 1.35; p<.01 (sales; black women)
Scientists	2007, MacArthur	MOR = 1.91; 95% CI, 1.37-2.67 (scientists)
	1999, Petralia	MOR = 1.40; 95% CI, 1.20-1.60 (clinical laboratory technicians, white)
	1999, Petralia	MOR = 1.10; 95% CI, 0.70-1.60 (clinical laboratory technicians, black)
	1999, Burnett[16]	PCMR = 1.14; 95% CI, 1.00-1.30 (clinical laboratory technologists)
	1993, Rubin	PMR = 1.39; 95% CI, 1.04-1.81 (mathematicians or computer scientists; white women)
	1993, Rubin	PMR = 2.83; 95% CI, 0.77-5.55 (mathematicians or computer scientists; black women)
Service Workers	2007, MacArthur	MOR = 0.76; 95% CI, 0.64-0.89 (domestics)
	2007, MacArthur	MOR = 0.51; 95% CI, 0.39-0.67 (bartenders and waitresses)
Teachers	2007, MacArthur	MOR = 1.77; 95% CI, 1.57-1.99 (schoolteachers)
	1993, Rubin	PMR = 1.62; 95% CI, 1.58-1.67 (teachers; white women)
	1993, Rubin	PMR = 2.14; 95% CI, 1.91-2.39 (teachers; black women)

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Appendix C: Chemical Classes and Health Effects:

A Listing of Individually Listed Compounds

Chemical Class	International Agency for Research on Cancer	Nat'l Toxicology Program Report on Carcinogens	Prop 65
Aromatic Amines	**Known:** • 4-Aminobiphenyl (4-Abp) • Benzidine • 4,4'-Methylenebis(2-Chloroaniline) (Mboca) **Possible:** • 4,4-Diaminodiphenylether (4,4-DPE) • 2, 4-Diaminoanisole • 2,6-Dimethylaniline • 3,3'-Dimethylbenzidinee (3,3'-DMB) • 4,4'-Methylenedianiline • O-Toluidine (O-T) • P-Phenylenediamine (P-PDA)	**Known:** • 4-Aminobiphenyl (4-Abp) • Benzidine **Reasonably Anticipated:** • 3,3'-Dimethylbenzidinee (3,3'-DMB) • 4,4'-Methylenedianiline, O-Anisidine	• 4-Aminobiphenyl (4-Abp) 92-67-1 • O-Anisidine • Aniline • Benzidine • 4,4'-Diaminodiphenylether (4,4'-DPE) • 3,3'-Dimethylbenzidinee (3,3'-DMB) • 4,4'-Methylenebis(2-Chloroaniline) (MBOCA) • 4,4'-Methylenedianiline • 2,4,5-Trimethylaniline
Chemotherapy agents/ Antineoplastic drugs/ Cytotoxic and cytoplastic drugs	**Known:** • Cyclophosphamide • Etoposide In Combination With Cisplatin And Bleomycin • Tamoxifen • Thiotepa **Probable:** • Adriamycin • Bischloroethyl Nitrosourea • Chlorambucil • Cisplatin • Procarbazine Hydrochloride **Possible:** • Bleomycins • Dacarbazine • Mitomycin C • Mitoxantrone	**Known:** • Chlorambucil • Cyclophosphamide • Thiotepa • **Reasonably Anticipated:** Adriamycin • Chlorozotocine • Cisplatin • Dacarbazine • Procarbazine Hydrochloride • Streptozotocin	• Adriamycin • Azacitidine • Chlorambucil • Cisplatin • Certain Combined Chemotherapy For Lymphomas • Etoposide • Etoposide In Combination With Cisplatin And Bleomycin • Mitomycin C • Tamoxifen
Dyes/ Pigments	**Known:** • Dyes That Metabolize To Benzidene **Possible:** • Benzyl Violet 4B • CI Acid Red 114 • CI Basic Red 9 • Ci Direct Blue 15 • Citrus Red No. 2 • Disperse Blue 1 • HC Blue No. 1 • Magenta • Trypan Blue	**Known:** • Dyes That Metabolize To Benzidine **Reasonably Anticipated:** • Basic Red 9 Monohydrochloride • Dyes Metabolized To 3,3'-Dimethoxybenzidine • Dyes Metabolized To 3,3'-Dimethylbenzidine • Disperse Blue 1	• Benzidine-Based Dyes • C. I. Acid Red 114 • C.I. Basic Red 9 • C.I. Direct Blue 15 • C.I. Direct Blue 218 • C.I. Disperse Yellow 3 • C.I. Solvent Yellow 14 • Citrus Red, No. 2 • D&C Orange No. 17 • D&C Red No. 8 • D&C Red No. 9 • D&C Red No. 19 • HC Blue 1,
Flame retardants	**Possible:** • Chlorendic Acid • Chlorinated Paraffins	**Reasonably Anticipated:** • 2,2-Bis(Bromomethyl)-1,3-Propanediol • Tris(2,3-Dibromopropyl) Phosphate	• 2,2-Bis(Bromomethyl)-1,3-Propanediol • Tris (2-Chloroethyl) Phosphate • Tris (1,3-Dichloro-2-Propyl) Phosphate (TDCPP)

	Mammary gland tumors	Endocrine Disrupting Compounds	Developmental Toxicant
	• 2,4-Diaminoanisole Sulfate • Benzidine • Ortho-Toluidine Hydrochloride		
	• Acronycine • Adriamycin • Amsacrine • 5-Azacytidine • Chloroambucil • Cyclophosphamide • Dacarbazine • N,N'-Dimethylnitrosourea • Merphalan • Mitomycin-C • Phenesterin • Procarbazine Hydrochloride • Thiotepa • Uracil Mustard		• Adriamycin • Carboplatin • Daunorubicin Hydrochloride • Etoposide • Fluorouracil • Idarubicin Hydrochloride Leuprolide Acetate • Megestrol Acetate • Mitoxantrone Hydrochlorid, Paclitaxel • Tamoxifen • Vinblastine Sulfate • Vincristine Sulfate
	• C.I. Basic Red 9 Monohydrochloride • C.I. Direct Black 38 • Guinea Green B • C.I. Acid Red 114 • FD&C Violet No. 1 • Malachite Green • Pre-Cursors to dyes, auch as 2,4-Diaminotoluene and Benzidine		
	• 2,2-Bis(Bromomethyl)-1,3-Propanediol • 2,3-Dibromo-1-Propanol (A Metabolite of Tris(2,3-Dibromopropyl) Phosphate (Tris))	• 2,2',4,4'-Tetrabrominated Diphenyl Ether (2,2',4,4'-TetraBDE) • Decabrominated Diphenyl Ether (DecaBDE) • Octabrominated Diphenyl Ether (OctaBDE) • Pentabrominated Diphenyl Ether (PentaBDE)	• DecaBDE (ECHA Candidate List Substances of High Concern)

Chemical Class	International Agency for Research on Cancer	Nat'l Toxicology Program Report on Carcinogens	Prop 65
Other solvents	**Probable:** • 1,2,3-Trichloropropane • Urethane (listed as Ethyl Carbamate) **Possible:** • Chloroform, 1,2-Dichloropropane • Nitrobenzene • Nitromethane	**Reasonably Anticipated:** • Chloroform • 1,2-Dichloroethane • 1,3-Dichloropropene • Nitrobenzene • Nitromethane • 1,2,3-Trichloropropane • Urethane	• Chloroform • 1,1-Dichloroethane • 1-2-Dichloropropane • Nitrobenzene • Nitromethane • 1,2,3-Trichloropropane • Urethane
Pesticides	**Known:** • Formaldehyde **Probable:** • Creosotes • Dichloromethane **Possible:** • Acetaldehyde • Chlordane, Chloroform • Dichlorvos • Heptachlor • Polychlorophenols • Propylene Oxide • Sulfallate • 1,1,2,2,-Tetrachloroethane	**Reasonably Anticipated:** • Acetaldehyde • Amitrole • Chloroform, • Lindane • Sulfallate	• Acetaldehyde • Alachlor • Aldrin • Amitrole • Cacodylic Acid • Captan • Carbaryl • Chlordimeform • Chloroform • Daminozide (Alar) • DDT/DDE • Dichloromethane • Dieldrin • Diclofop-Methyl • Fenoxycarb • Folpet • Heptachlor • Imizalil • Iprodione • Lactofen • Maneb • Metham Sodium • Metiram • Oryzalin • Oxydiazon • Pentachlorophenol • Procymidone • Pronamide, Propylene Oxide • Sulfallate • 1,1,2,2,-Tetrachloroethane • Thiodicarb

	Mammary gland tumors	Endocrine Disrupting Compounds	Developmental Toxicant
	• 1,1-Dichloroethane • 1,2-Dichloroethane • 1,2-Dichloropropane • Nitrobenzene • Nitromethan • 1,2,3-Trichloropropane • Urethane	**TEDX listed:** • Ethylene Glycol Monomethyl Ether (EGME) • Nitrobenzene	• Chloroform • Ethylene Glycol Monoethyl Ether (EGME) • Ethylene Glycol Monoethyl Ether Acetate • Ethylene Glycol Monomethyl Ether • Ethylene Glycol Monomethyl Ether Acetate • Nitrobenzene • Urethane
	• Atrazine • Captafol • Chlordane • Clonitralid • Dichlorvos • Fenvalerate • Simazine • Sulfallate	**EU Tier 1:** • Acetochlor • Alachlor • Amitrol • Atrazine • Chlordane • Chlordane (Cis- And Trans-) • Kepone (Chlordecone) • Mirex, Toxaphene (Camphechlor) • DDT • P,P'-DDT (Clofenotane), Tetrachloro DDT = 1,1,1,2-Tetrachloro-2,2-Bis(4-Chlorophenyl)Ethane • Lindane • Linuron • Maneb • Metam • Natrium • Nitrofen • Thiram • Vinclozolin • Zineb **EU Tier 2:** • Aldrin • Dichlorophenoxy Acetic Acid (2,4-D) Dieldrin • Dicofol = Kelthane • Diuron, Diazinon • Dimethoate • Endosulfan • Endosulfan (Alpha) • Endosulfan (Beta) • Endrin Oxychlordane • Heptachlor • Iprodione • Malathion • Methylbromide • Methylparathion • Parathion • Photomirex, 2,4- • Propanil • Prochloraz • Simazine • Ziram	• Amitraz • Benomyl • Carbaryl • Chloroform • Cyanazine • Diclofop-Methyl • Heptachlor • Linuron • Metham Sodium • Metiram • Oxydiazon • Triadimefon

Chemical Class	International Agency for Research on Cancer	Nat'l Toxicology Program Report on Carcinogens	Prop 65
Phthalates		**Reasonably Anticipated:** • Di(2-Ethylhexyl)Phthalate (DEHP)	• Di(2-Ethylhexyl)Phthalate (DEHP) • Diisononyl Phthalate (DINP)
Polycyclic Aromatic Hydrocarbons	**Known:** • Benzo[a]pyrene **Probable:** • Dibenz[a,h]anthracene • Dibenzo[a,l]pyrene **Possible:** • Benzo[b]fluoranthene • Benzo[j]fluoranthene • Benzo[k]fluoranthene • Dibenz[c,h]acridine • Dibenzo[a,h]pyrene • Dibenzo[a,i]pyrene • Indeno[1,2,3-cd]pyrene	PAHs are listed as a class	• Benz[a]anthracene • Benzo[a]pyrene • Benzo[j]fluoranthene • Benzo[k]fluoranthene • Dibenz[a,h]acridine • Dibenz[a,j]acridine • Dibenz[a,h]anthracine • Dibenzo[a,e]pyrine • Dibenzo[a,h]Pyrene • Dibenzo[a,l]Pyrene, • 7,12-Dimethylbenz(a)anthracene • Indeno[1,2,3-cd]pyrene • 3-Methylcholanthrene • 5-Methylchrysene • 1-Nitropyrene
Volatile organic compounds	• **Possible:** Bromodichloromethane • Chloroform • 1, 2-Dichloroethane • 1,4-Dioxane • Ethyl Acrylate • Ethylbenzene • Naphthalene • 1,1,2,2-Tetrachloroethane • Vinyl Acetate • VOC solvents listed elsewhere in Table 2.	**Reasonably Anticipated:** • Naphthalene • VOC solvents listed elsewhere in Table 2.	• Benzyl Chloride • Bromodichloromethane • Chloroform • 1,2-Dichloroethane • 1,3-Dichloropropene • 1,4-Dioxane • Ethyl Acrylate • Ethylbenzene • Naphthalene • 1,1,2,2-Tetrachloroethane • VOC solvents listed elsewhere in Table 2.

	Mammary gland tumors	Endocrine Disrupting Compounds	Developmental Toxicant
		EU Tier 1: • Butylbenzylphthalate (BBP) • Di-(2-Ethylhexyl)Phthalate (DEHP) • Di-N-Butylphthalate (DBP) **EU Tier 2:** • Diisodecyl Phthalate • Diisononyl Phthalate (DINP)	• Butyl Benzyl Phthalate (BBP) • Di(2-Ethylhexyl)Phthalate (DEHP) • Di-Isodecyl Phthalate (DIDP) • Di-N-Butyl Phthalate (DBP) • Di-N-Hexyl Phthalate (Dnhp)
	• 1-Nitropyrene • 1,3-Dinitropyrene, • 1,8-Dinitropyrene • 2-Nitrofluorene • 7,12-Dimethylbenz[a]anthracene • benzo[a]pyrene • dibenz[a,h]anthracene	**TEDX listed:** • Anthracene • Benzo(a)anthracene • Benzo[b]fluoranthene • Benzo[j]fluoranthene • Benzo[k]fluoranthene • Benzo(a)pyrene • Chrysene • Dibenzo[a,e]fluoranthene • Dibenzo(a,h)anthracene • 7,12-Dimethylbenz[a]anthracene • Dibenzo(a,e)pyrene • Dibenzo(a,h)pyrene • Dibenzo(a,l)pyrene • Fluoranthene • 5-Methylchrysene • Phenanthrene • Pyrene,	
	• 1,2-Dichloroethane • 1,1-Dichloroethane • 1,2-Dibromoethane • VOC solvents listed elsewhere in Table 2.		• Chloroform