Hidden Hazards: How the Environment Fuels Women's Cancer Risks

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Abstract

Breast cancer has become the second most common cancer worldwide. In 2022, there were over 2.2 million new cases globally (1). Breast cancer is the uncontrolled growth of abnormal cells in the breast tissue. Many elements contribute to the development of cancer, such as a combination of genetic and environmental factors. If left untreated, these cells can spread throughout the body often leading to death (2). This review examines the environmental factors contributing to breast cancer in women, focusing on demographics, diet, pollution, and cosmetics. Understanding these factors can help identify potential interventions to reduce breast cancer incidence.

Introduction

DNA is the foundation of human life and plays a major role in cellular replication development (3). It is important to understand basic concepts in biology and their association to cancer. During normal cell replication, a DNA double helix is separated to create two new identical strands (4). Sometimes during the replication process, mistakes or errors are made. These errors in DNA replication, along with hereditary mutations and environmentally induced alterations, result in cellular changes, or damage at the DNA level. Both internal (endogenous) and external (exogenous) sources can result in DNA damage (5). Certain endogenous sources of DNA damage include oxidative stress, leading to an increase of unstable molecules in the body, and a mismatch of DNA bases as a result of replication errors (6,7). Exogenous sources of DNA damage include UV radiation and chemotherapy, which can cause cross-linked DNA or modifications to individual nucleotides.

Both endogenous and exogenous sources can lead to different types of DNA damage, such as single-stranded DNA breaks, double-stranded DNA breaks or modifications made to DNA (Figure 1). These mutations may lead to what is known as cancer, or an accumulation of uncontrolled cell growth, spreading rapidly in today's world. For breast cancer, advanced screening processes make it an easily detectable cancer, but it is still the most diagnosed cancer in women (8). While it is well understood how factors like UV damage can cause mutations, it has been less studied how environmental pollutants and consumables can aid in causing mutations that lead to cancer. Understanding how these everyday use products and carbon footprint can shape cancer diagnoses will prove to be pivotal as we aim to prevent cancer in the future.

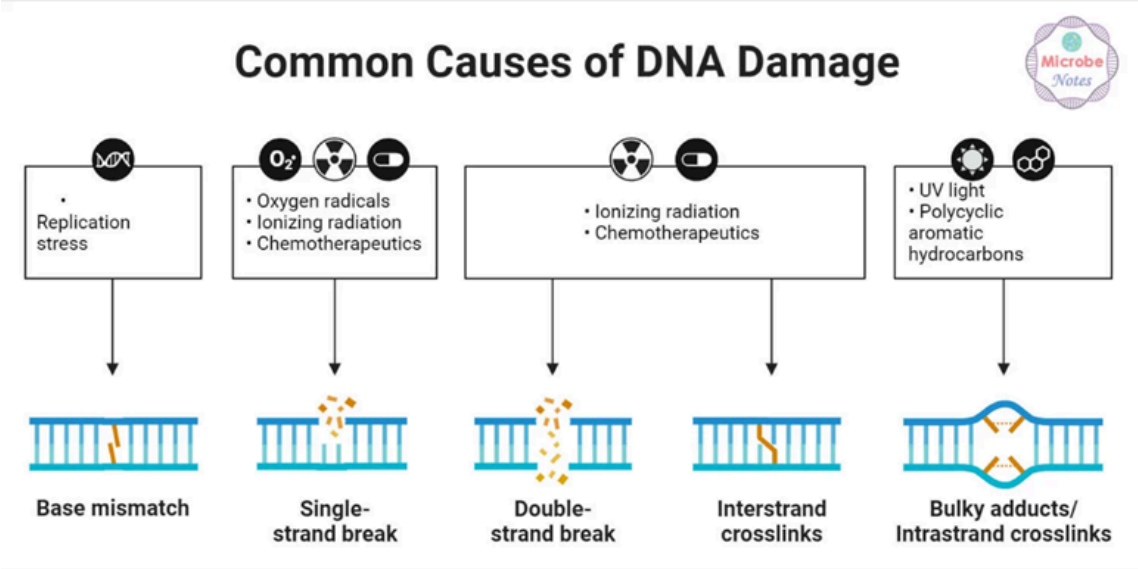

Figure 1. Endogenous (replication stress, chemotherapy, and oxygen radicals) and exogenous (UV light, polycyclic aromatic hydrocarbons, ionizing radiation) sources of DNA damage (9).

Demographic Correlation to Cancer

Breast cancer incidence, or newly diagnosed cases, is influenced by a variety of demographic factors, including age, gender, ethnicity, socioeconomic status, and lifestyle. These factors contribute to differences in breast cancer rates across populations. In 2022, over 2.2 million new diagnoses were made worldwide. The highest rates of diagnosis (80 new cases per 100,000 individuals) were from Australia/New Zealand, Northern America, and Europe, whereas the lowest rates (40 new cases per 100,000 individuals) were across Asia and Africa (10) (Figure 2). In 2020, the estimated death toll from breast cancer was around 685,000. Interestingly, it was previously shown that black women have the highest mortality rate (11). This leads us to question the reasons why certain ethnicities have higher diagnosis rates of cancer than others.

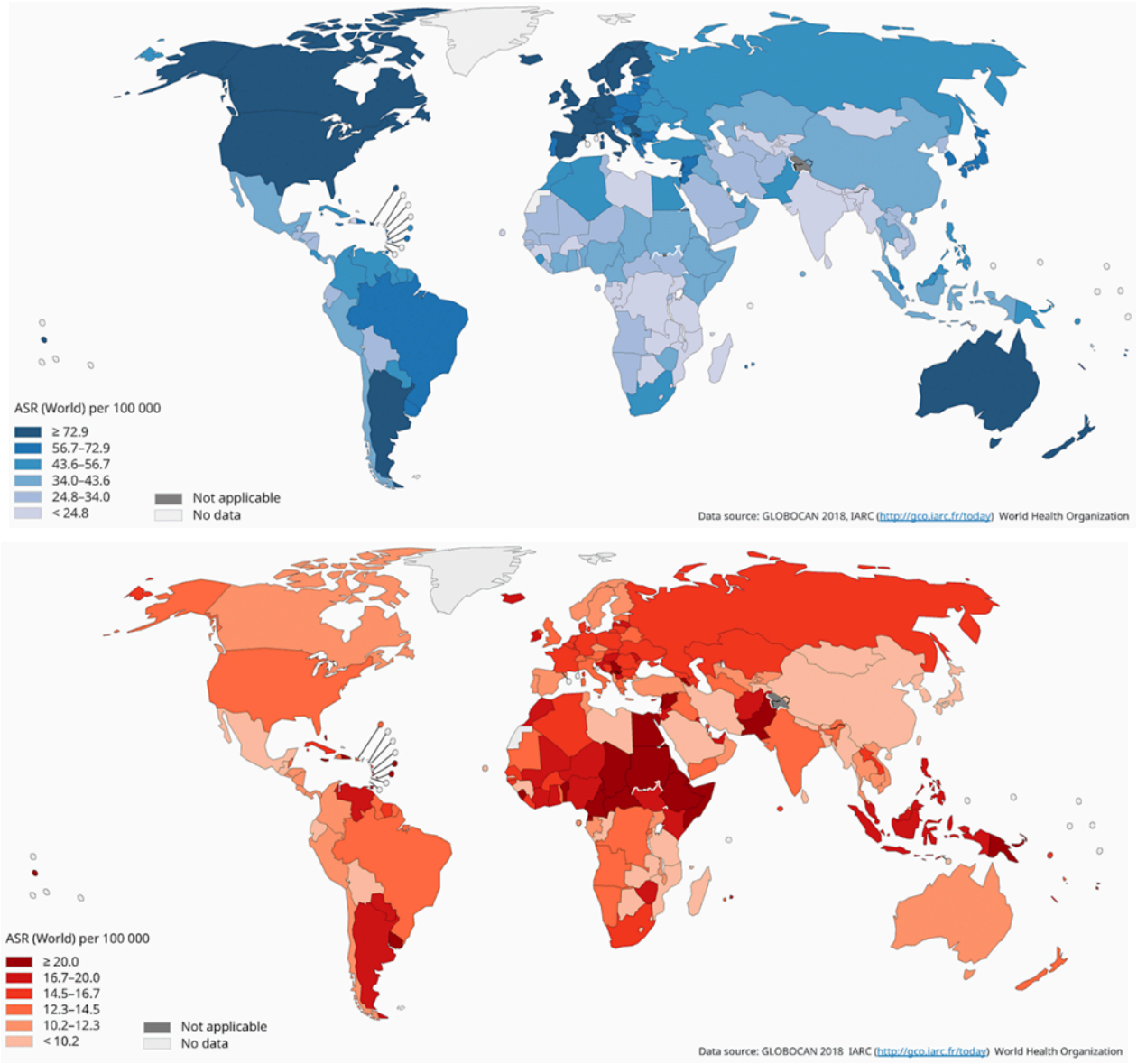

Figure 2. Discrepancy between the incidence of breast cancer (top) and mortality of breast cancer (bottom) (12).

When it comes to patient care and accessibility, there is a clear disparity between different ethnicities. A lack of care primarily amongst Black and Hispanic communities may lead to later diagnoses and therefore more later stage, aggressive cancers increasing mortality rates in these communities. In 2017, a study looking at the key factors leading to excess mortality risk found that 37% of patients with poor health insurance led to late-stage diagnoses. Meanwhile, those with hereditary tumor characteristics only displayed 23.2% late-stage diagnosis, showing the disparity among environmental versus hereditary factors (13). This late diagnosis may be a

large factor as to why the mortality rate in Black and Hispanic women is higher, aside from underlying hereditary factors.

Aside from social factors, one's ethnicity along with their habits may lead to an increase in breast cancer. Hispanic and Asian women have the lowest chance of developing breast cancer (14). One possible reason is alcohol and smoking rates between ethnic groups. It is shown that those of Hispanic heritage are less likely to smoke and drink regularly (14). Similarly, Asians have a low chance of developing breast cancer due to their low alcohol intake. Interestingly, Asian Americans are at an increased risk of developing breast cancer due to different environments and cultures (15).

Food Composition In Relation To Cancer Rates

Alongside one's ethnicity and lifestyle habits, cancer rates may also be influenced by diet. Although no particular diet can prevent the development of cancer, with the vastly growing population it has been a necessity for a faster rate of food production. Due to this need, processed food and chemical additives have become an easy solution to meet the demand but may have negative side effects.

Many processed foods are known to have carcinogens, which damage DNA sequences and introduce mutations, leading to the development of cancer (16,17). Foods commonly linked to increased carcinogens are bread, cereals, and pork (18). Red meat and dairy have also been linked to breast cancer risk (19). While these products offer healthy sources of protein and nutrients, they possess high levels of 2 known carcinogens: heterocyclic aromatic amines and polycyclic aromatic hydrocarbons, which can cause oxidative stress that damages DNA (19). These products are also high in saturated fatty acids, which lead to an increase in cholesterol. As a result, this increase leads to excess estrogen accumulated in the body, leading to an increased risk of breast cancer (19).

While America is known for highly processed foods, we have also made synthetically dyed food prevalent for aesthetic purposes. Commonly known dyes such as Red-40 and Red No.3, have been linked to the development of cancer. Red-40 is known to contain benzene, a naturally occurring organic substance that is odorless and often found in smoke and fuel exhaust (20,21). Also, Red No. 3 is a color additive made from petroleum. Red No. 3 is often found in candy and drinks, but as of late, it has sparked a lot of controversy leading to it being banned in California, along with many European countries (17,22). Leading us to wonder why the United States does not ban additives like European countries do.

One substance banned in various European countries but not the U.S. is Recombinant bovine growth hormone (rBGH) (23). RBGH is an artificial growth hormone (a protein important for cell replication and growth) that stimulates cow's milk production (23). This negatively affects

humans as it increases blood levels of growth hormone, aiding cancer development (23). Substances like this one along with others may be responsible for increasing cancer rates, especially in the United States.

Besides someone's diet, exercise may have a role in the development of Breast Cancer. It has been shown that an abundance of physical activity in adolescence is helpful in lowering sex hormones in the body (estrogen or progesterone) (18). A lower sex hormone is linked to a lower chance of developing Breast Cancer and as a person stays physically active throughout their life, this habit will likely cause a lower Breast Cancer risk (18). Food and daily exercise are a crucial part of one's health. Alongside, increasing pollution rates may also have a role in the current Cancer rates worldwide.

Pollution Leads to Increased Risk of Cancer

It is estimated that our world population is to expand by nearly 2 billion people in the next 30 years (24). As the population continues to grow and cities become larger, pollution greatly increases. In the United States, due to the poor forms of public transportation, there is a great increase in independently owned vehicles, adding to the increase in pollution. The burning of gasoline and diesel fuel in vehicles releases harmful chemicals such as carbon monoxide, nitrogen dioxide, and benzene. These contribute to the toxic chemical, carbon dioxide, that makes up greenhouse gasses (25). This may be one cause of rising breast cancer cases.

It is commonly known that pollution and debris in the lungs may lead to lung cancer. In addition to this, there has been an increase in breast cancer cases worldwide that can be attributed to pollution (26). The small size of these environmental pollutants makes it easier to permeate cells and have access to directly damage DNA (Figure 3, 43). Pollution has been shown to cause increased ionizing radiation (27). Ionizing radiation removes electrons from the atom, causing excess energy (28,29). This energy is then capable of damaging DNA, creating mutations, which may ultimately lead to the formation of cancer cells (29). This pollution and increase in radiation is a possible cause for the appearance of not only lung cancer but breast cancer as well.

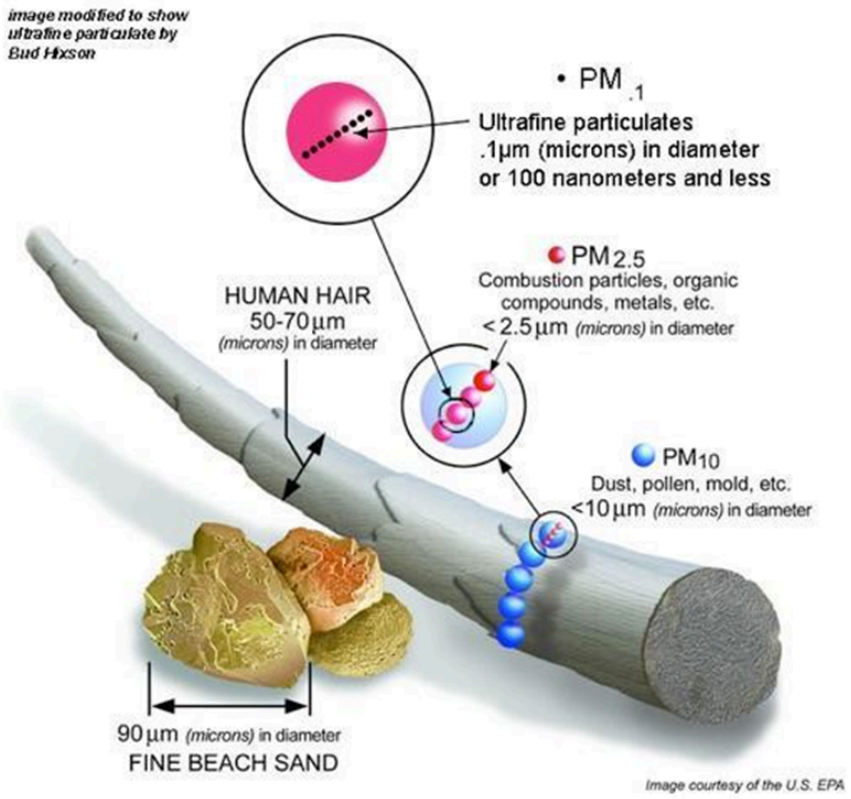

Figure 3. Common pollutant particle size compared to human hair and beach sand (30).

In addition to increased pollution affecting breast cancer rates, women in urban areas have been shown to be more prone to developing breast cancer (31). This may be due to overpopulated cities, leading to excess pollution. Specifically in California, Korean and Japanese women were found to be exposed to more mammary gland carcinogens in their neighborhoods compared to any other ethnicity (32). These mammary gland carcinogens are chemicals such as Bisphenol A and various endocrine-disrupting compounds that lead to the formation of tumors (33,34). A combination of food waste and city living may be the reason for this excess pollution affecting mainly Asian women.

Besides clean air, another human necessity is clean water. The need for fast, plentiful clean water has led to increased water contamination. Excessive pollutants reach water easily, building up over long periods of time (35). These are difficult to detect and may not be seen until their negative side effects are revealed (35). Specifically, water pollution has increased bladder cancer and skin cancer rates in recent years. For instance, water from private wells has been linked to high levels of arsenic (36). Arsenic is a small molecule that can cause cell harm and death, making the body more susceptible to various cancers (37). This leads us to discuss the cosmetics industry, which is largely formulated with water, in the next section.

Toxic Chemicals Have Been Lowering The Beauty Industry Standards

The cosmetics and beauty industry has taken the world by storm in recent years with raging popularity. It is believed that 85% of women between ages 18-34 and 77% of women between ages 55+ routinely wear makeup (38). The common use of various skincare items and the growing use of ultraviolet light may be responsible for recent breast cancer rates.

To combat factors such as dry skin, aging, and changing physical appearance, the rampant use of skincare and lotion has increased. Interestingly, with the increased use of cosmetic products among white women, breast cancer rates have also increased (39). This may be due to the chemicals in these products, specifically phthalates (39). Phthalates are a group of chemicals commonly known to disrupt the hormonal system, which is a critical system for growth, fertilization, and reproduction (40,41). They are known for increasing the production of some hormones while decreasing the production of others, ultimately leading to various health concerns (42). When looking at different cosmetics in the beauty industry, it is important to analyze what makes them harmful to the body.

Often when reading ingredient lists or labels, the abundant use of different chemicals can be overwhelming. In recent years, problematic chemicals have been shown to increase the risk of cancer. One common chemical used in anti-aging creams in popular brands like Garnier and Olay is called perfluorooctanoic acids (PFOA). This contains a toxin found in products used for a smooth finish on cookware (43). Although helpful for cleaning, this is an extremely toxic chemical when used in cosmetics due to its role in decreasing antibodies and an increase in enzymes (43). Along with PFOA, formaldehyde is a commonly used carcinogen (44). It is estimated that around 20% of all cosmetics in the U.S. contain formaldehyde which is concerning since it is a highly toxic systemic poison (45,46). Besides chemicals found in cosmetics, ultraviolet light use has increased in recent years.

With the popularity of gel manicures and the use of tanning beds, the risk factors of ultraviolet light have been shed on. It is estimated that in the United States, around 30 million people use indoor tanning beds annually (47). This excessive use of UV light has been shown to increase the likelihood of developing skin cancer. Commonly, radiation is released, and two forms of UV (48). UVA has long wavelengths and contributes to aging while UVB has shorter wavelengths and burns the skin (48). Long exposure to these UV rays has many detrimental side effects such as genetic defects, mutations, and the development of skin cancer (48).

Figure 4. Banned cosmetic ingredients in Europe (49).

Although chemicals like Phthalates and PFOA are still used in the United States, they are banned in many European countries (Figure 4, 49). It is estimated that within the EU, around 1,300 chemicals have been banned while in the United States, there are only 11 chemicals banned (50). Interestingly, the US has no legal requirement to test products for harmful

chemicals as it is up to the manufacturer to test their safety (50). This lack of regulation may be one cause for the rampant cancer rates within the US.

Discussion

With breast cancer being one of the top diagnosed cancers among women, it is important to look beyond the genetic factors that can cause cancer, and instead dive deeper into the environmental factors. It is interesting to see that certain countries with the cleanest diets that are low in saturated fats are among the least diagnosed. Interestingly, Asian countries have high pollution rates but are diagnosed 50 percent less than other countries, leading us to look at other factors apart of daily life, such as cosmetics. Since many countries have banned various ingredients in cosmetic products, this may be one factor responsible for increased cancer rates within the United States. In this review, we have studied various environmental factors that may lead to the development of cancer, showing that genetics is not the sole contributor. While continued research to fully understand the complex interplay between environmental and genetic factors is warranted, addressing environmental factors through lifestyle changes, stricter FDA regulations, and improved access to care can significantly reduce breast cancer incidence worldwide.

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