Cancer & Environment Network of Southwestern Pennsylvania

Environmental Chemicals and Cancer
A Science Companion Document

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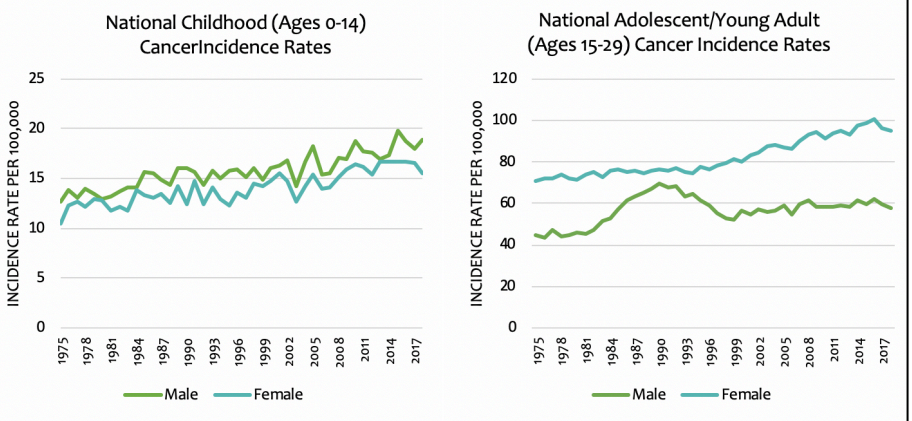
In 2010, the World Health Organization issued the Asturias Declaration – a call for the primary prevention of environmental and occupational contributors to cancers. The Declaration called for countries around the world to undertake a range of actions to prevent cancer caused by chemicals across their lifecycle–from extractive operations to manufacturing, to product use and end of life/disposal. Ten years later, a broad array of stakeholders participating in the Cancer and Environment Network of Southwestern Pennsylvania has led the development of a regional Declaration focused on preventing environmentally-mediated cancers "…to chart a course towards an equitable future where no individual in our region is diagnosed with cancer due to exposures in the environments where they live, work, play and go to school." The purpose of this document is to provide additional information about the scientific evidence which underlies the Declaration. View the Declaration at: https://censwpa.org/join-us/

I. Trends in environmentally-mediated cancers

Cancer remains a devastating health crisis nearly fifty years after President Nixon's declared a "War on Cancer". In the U.S., people with cancer are living longer, thanks to improved treatment and earlier detection. Overall, cancer rates nationally are declining (1). Particularly striking are the declines in cancer rates resulting from changes in behaviors such as smoking; for example, lung cancer incidence rates in men. Reductions in smoking rates have occurred because of an array of activities, including actions by employers, government agencies, researchers, clinicians, advocates, community organizations and individuals, among others—demonstrating that with multi-pronged strategies to reduce exposure to carcinogens, cancer can be prevented.

Figure 1. National Pediatric, Adolescent, Young Adult Cancer Trends



Source: National Cancer Institute - Surveillance Epidemiologic End Results Program, Delay-Adjusted Incidence Rates Per 100,000, 1975-2018

The rates of new cases of many types of cancer continue to increase, however. Breast cancer, multiple myeloma, non-Hodgkin lymphoma, thyroid and testicular cancer are among the cancer types that have risen dramatically since national surveillance for cancer began in 1975 (2). Common risk factors that are the primary focus of cancer prevention and control programs, such as smoking, poor diet, alcoholic beverage use and lack of exercise, cannot fully explain the rising trends in these cancer types. In addition, although most cancers occur later in life, rates of cancers among children and adolescents/young adults are also increasing (Figure 1) (2)(3).

Table 1: Are incidence rates of environmentally-sensitive cancers elevated in the counties of Southwest Pennsylvania? Comparisons of Observed versus Expected Incident Cases of Selected Cancer Types for the period 2014-2018.

	Allegheny				Beaver			
	US		PA		US		PA	
	M	F	M	F	M	F	M	F
Bladder	+18%	+35%	-5%	+7%	+41%	+39%	+14%	+10%
Breast	-	+11%	-	+5%	-	+10%	-	+4%
Kidney	+7%	+10%	-4%	0%	-5%	+9%	-15%	0%
Lung/Bronchus	+29%	+39%	+2%	+15%	+44%	25%	13%	+3%
Leukemia	+17%	+11%	+9%	+7%	+22%	-8%	+14%	-11%
Thyroid	+47%	+21%	+20%	+4%	+31%	+42%	+7%	+22%
Childhood Cancer*	-6%	-29%	-12%		+32%	-28%	+10%	

	Butler				Fayette			
	US		PA		US		PA	
	M	F	M	F	M	F	M	F
Bladder	+11%	+30%	-10%	+3%	+14%	+6%	-6%	-16%
Breast	-	+10%	-	-1%	-	+4%	-	-1%
Kidney	+8%	+13%	-3%	+4%	+9%	+30%	-2%	+19%
Lung/Bronchus	+22%	+14%	-4%	-5%	+57%	+35%	+24%	+12%
Leukemia	+17%	+19%	+10%	+15%	+3%	+26%	-4%	+22%
Thyroid	+76%	+26%	+44%	+9%	+6%	+30%	-13%	+12%
Childhood Cancer*	-30%	-12%	-27%		-45%	-46%	-53%	

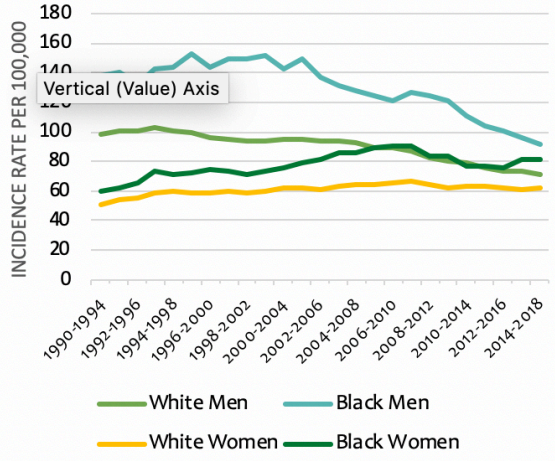
	Greene				Washington				Westmoreland			
	US		PA		US		PA		US		PA	
	M	F	M	F	M	F	M	F	M	F	M	F
Bladder	+24%	+8%	+2%	-14%	+32%	+22%	+8%	-3%	+27	+48%	+4%	+17%
Breast	-	+5%	-	0%	-	+8%	-	+3%	-	+13%	-	+7%
Kidney	+8%	+19%	-2%	+9%	+16%	+46%	+4%	+33%	+5%	+12%	-6%	+3%
Lung/Bronchus	+57%	+26%	+25%	+4%	+42%	+33%	+12%	+10%	+22%	+19%	-4%	-1%
Leukemia	+17%	+8%	+11%	+5%	+31%	+10%	+23%	+7%	+15%	0%	+8%	-3%
Thyroid	+24%	-11%	+1%	-23%	+21%	+36%	-1%	+17%	+8%	+41%	-12%	+22%
Childhood Cancer*	+83%	+83%	+94%		+8%	+35%	+28%		+6%	+44%	+32%	

Notes: *Calculated as Standardized Incidence Ratios as derived from US and PA cancer incidence rates for a given county and shown as the % above or below expected cases. Red denotes statistically significant elevations or decrements.*
*Ages 0-19.
Data sources: *(a) Surveillance Research Program, National Cancer Institute. SEER*Explorer: An interactive website for SEER cancer statistics. (b) Pennsylvania Department of Health. Enterprise Data Dissemination Exchange.*

In seven Southwestern Pennsylvania counties, incidence rates for six types of cancer that have strong links to toxic chemicals (bladder, breast, kidney, lung, leukemia and thyroid) are elevated, sometimes by more than 50% compared with national rates (Table 1). The statistically significant elevation of childhood cancer (ages 0-19) in Greene and Westmoreland counties are particularly striking, although a non-statistically significant elevation is also observed in Washington county. For lung cancer, racial disparities are also apparent. Both black men and black women in Allegheny county have higher rates of lung cancer than white men and women (Figure 2).

Although some types of cancer in Table 1—including lung, bladder as well as some types of leukemia—are strongly linked to exposure to tobacco smoke, recent analyses suggest that progress in reducing rates will require more than smoking cessation activities. These analyses conclude

Figure 2. Age Adjusted Lung Cancer Incidence Rates by Gender and Race, Allegheny County 1990-2018



Source: PA Department of Health, Enterprise Data Dissemination Informatics Exchange. 2021.

that if Allegheny County were to have succeeded in eliminating smoking twenty years ago, incidence in lung cancer would have declined by 11%, a substantial reduction but far less than the average decline of 62% in other US counties, suggesting that other important risk factors for lung cancer are prevalent in the region (4)(5).

II. The contribution of environmental chemicals to cancers

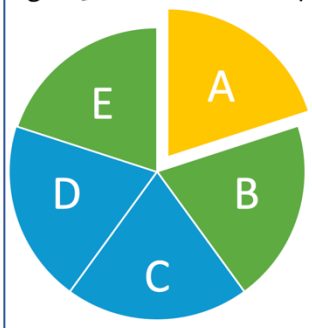
Many cancer prevention resources and public health policies focus on so-called "lifestyle" causes of cancer, notably tobacco smoke, poor diet, alcohol and excess exposure to UV radiation. In contrast, cancer prevention strategies are often silent about causes from exposures to toxic chemicals where people live, work and play. Science suggests that the contribution of environmental chemicals to cancer—and opportunities for preventing cancers by reducing exposures—should not be ignored.

Cancers are now understood to develop through a multi-stage process in which multiple risk factors play a role. Cancers occur when damaged cells start to proliferate in an uncontrolled fashion and accumulate, over time. There are eight identified "cancer hallmarks," or specific biologic changes that need to happen for cancer to develop (6) (7). For many decades we have recognized toxic chemicals that bind to DNA and cause mutations – one of the cancer hallmarks – as carcinogens. However, we now understand that chemicals can also act to cause or contribute to cancer development in other ways. Environmental chemicals that can promote cell proliferation; change gene expression; alter signaling networks within and among cells, tissues and organ systems; or influence metabolism or immune responses are now recognized as important mechanisms of cancer causation because they can impact cancer hallmarks, directly or indirectly.

There has been debate over many years about the importance of environmental chemicals are as risk factors for cancer, and unfortunately, there is still a great deal of uncertainty about this question. In the federal government's "War on Cancer", very little research money has been spent to address this knowledge gap. The 2010 President's Cancer Panel evaluated the evidence on environmental chemicals and cancer, and concluded: "the true burden of environmentally induced cancer has been grossly underestimated"(8).

One important implication of the fact that cancers arise through a multi-stage process is that it makes little sense to try to attribute (or "blame") any case of cancer to a single cause. To see why this is important, consider the "pie" in Figure 3, which represents what epidemiologists call the Sufficient-Component Cause model for disease causation (9). Any measure which prevents the pie from being complete will prevent the disease from occurring. Thus, there will be multiple ways to prevent any cancer, including reducing exposures to one or more environmental chemicals. With current knowledge, it is impossible to know how the component causes for a specific cancer play out in a given individual and whether exposure to environmental chemicals are or are not components that complete the pie. But to be precautionary, we should do the best we can do to minimize exposure to all carcinogens wherever possible.

Figure 3: The Sufficient-Component Cause Model



- Slices A-E represent component causes of cancer.
- When slices A-E are present, there is sufficient cause for the cancer.
- If we can just prevent one component cause from occurring, slice A, we can prevent cancer.

Adapted from Rothman KJ. Epidemiology— An Introduction. Oxford: Oxford University Press; 2002.

Recent science concludes that more environmental chemicals than previously understood contribute to cancer. The Halifax Project, an exhaustive effort by multiple scientists over several years, concluded that dozens of endocrine disrupting chemicals considered non-carcinogens because they do not, in and of themselves, cause cancer, can interfere with cancer hallmarks at environmentally relevant levels of exposure

(10). Thus, although these chemicals will give negative results when tested in standard rodent cancer assays, they may nonetheless contribute to the development of cancers by influencing individual cancer hallmarks – contributing one piece to an almost complete pie.

In addition, we now know that cancer risk from environmental exposures is influenced not only by the chemical substance, but also by the timing of the exposure. Exposure to toxicants during periods of rapid growth and cell differentiation – from fetal life through puberty – increases risk of cancers later in life. For example, childhood cancers are linked with parental exposures to pesticides prior to conception, in utero exposures and direct exposures during childhood (11). A recent study demonstrates that girls exposed to elevated levels of the pesticide dichlorodiphenyltrichloroethane (DDT) before puberty—when mammary cells are more susceptible to the carcinogenic effects of hormones, chemicals and radiation—are five times more likely to develop breast cancer when they reach middle age (12).

Finally, even if exposure to any one pollutant poses a small increased risk of cancer to an individual, if exposures to that pollutant are widespread and occur in most people, even small increases in individual risk can result in substantial numbers of cases in the population. The more a population is exposed, the greater the number of cases of cancer that can be prevented by reducing those exposures.

This evidence—that environmental chemicals are among the risk factors that contribute to the cascade of events that cause a case of cancer; that many more chemicals than previously understood may contribute to cancer, even if they are not "complete carcinogens;" that timing matters and it is impossible to ensure that an individual would not be exposed during times of vulnerability—is the foundation for initiatives across multiple sectors to reduce and ultimately eliminate environmental carcinogens. Science is also informing the development of safer materials and technologies, as discussed in Section IV.

III. Priority environmental chemicals: State of the evidence and connections to Southwestern Pennsylvania

The sections below provide a brief overview of the state of the science regarding environmental chemical risk factors for cancer, including pollutants in air and water, pesticides, and contaminants in consumer products. Also reviewed are sources of exposure in Southwestern Pennsylvania that are of particular concern given wide-spread exposures and disproportionate impacts on marginalized and vulnerable communities.

The evidence is clear: there are dozens of known and suspected environmental risk factors for cancer. This evidence is based on evaluations of the science from authoritative sources, including the World Health Organization's International Agency for Research on Cancer (IARC) and the U.S. National Toxicology Program (NTP). These institutions convene panels of scientific experts to evaluate the carcinogenicity of a given agent to humans based on the current state of the evidence. Meta-analyses and systematic reviews – analyses that pool data and synthesize findings across multiple studies – can also reveal important connections between environmental exposures and cancer. These analyses are useful sources of evidence, especially given that it may take decades for the science associated with a specific substance to be reviewed by IARC or NTP. Although toxicological studies and individual epidemiologic studies are never enough to definitively prove causation in humans, such studies are supportive of precautionary attention and action.

Air pollution

Decades of research has established that air pollution is a known cause of cancer. Major sources of outdoor air pollutants include industrial facilities and motor vehicles. In addition to air pollution being classified as a human carcinogen by the IARC, there are dozens of chemicals in the air pollution mixture and/or exposure circumstances that are known to cause or suspected of causing cancer (13).

The U.S. Environmental Protection Agency (EPA) has identified 71 cancer causing air pollutants which are regulated under the Clean Air Act as Hazardous Air Pollutants (HAPs). Table 2 outlines a short list of carcinogenic air pollutants as reviewed by IARC.

Table 2. Examples of known or suspected carcinogens found in air pollution (not comprehensive)

• Acetaldehyde • Arsenic compounds • Asbestos • 1,3-butadiene • Benzene • Cadmium and compounds • Carbon tetrachloride • Coke production	• Cobalt • Diesel exhaust • Dioxins • Fine particulate matter ($PM_{2.5}$) • Formaldehyde • Hexavalent chromium • Iron and steel founding	• Nickel compounds Perchloroethylene • Radon • Soot [polyaromatic hydrocarbons (PAHs)] • Styrene • Trichloroethylene

Source: IARC List Classifications. https://monographs.iarc.who.int/agents-classified-by-the-iarc/

Exposure to air pollution indoors often exceeds outdoor levels because air pollutants tend to concentrate in confined spaces where ventilation is poor, and there are indoor sources as well. Furthermore Americans spend an estimated 87% of their time inside (14) (15). Sources of exposure in indoor environments include outdoor air pollution that infiltrates indoors and contaminants in building materials, such as formaldehyde in pressed wood products or flame retardant chemicals that are used on upholstered furniture and mattresses (16). Chemicals that can volatilize from polluted soil or water from industrial or agricultural activity or from the leaching of hazardous waste sites can also be a source of indoor air pollution (16). Radon, a natural occurring substance, is a carcinogen found in indoor air that is of particular concern in many areas of the country (17). Inadequate ventilation can magnify indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the building space.

Over the last decade, several meta-analyses and systematic reviews have provided evidence that air pollution is a risk factor of concern for childhood leukemias (18) (19). Research has focused primarily on children exposed to traffic-related air pollution in which a number of carcinogens are released in the exhaust of motorized vehicles. These include 1,3-butadiene, benzene, formaldehyde and fine particulate matter ($PM_{2.5}$), among others. Children exposed during their first years of life appear to be particularly at risk (18) (19).

Air pollution: Risks in Southwest Pennsylvania

Data from the U.S, EPA's 2014 National Air Toxics Assessment (NATA) suggest that high-risk exposures to air pollution are common in Southwest Pennsylvania and could contribute substantially to cancer risks, especially in Allegheny County. Across the region, nearly all of the cancer risk from air pollution comes from a handful of pollutants: formaldehyde, coke oven emissions (which includes a mixture of toxicants), benzene, carbon tetrachloride, acetaldehyde, naphthalene, hexavalent chromium and 1,3-butadiene (20). Estimated average cancer risk from exposure to HAPs and diesel particulate in the County exceeds 100 cases per million (20). This ranks Allegheny County in the worst 4% of counties nationwide. The risk is likely to be even higher when accounting for impacts from $PM_{2.5}$, a pollutant not included in the NATA data. When considering specific sources of air pollution, Allegheny County ranks among the worst 1% of counties nationwide for cancer risks from industrial point sources, such as manufacturing facilities (20). Nearly 90% of the point source cancer risk estimated in Nearly 90% of the point source cancer risk estimated in Allegheny County is attributable to coke oven emissions, with ~90% of those emissions from the Clairton facility (20). Vehicle emissions are also problematic in Allegheny County, ranking among the worst 7% of all counties nationally (20).

NATA data also reveal disparities in cancer risk experienced by environmental justice communities (defined as those census tracts in which 20% or more of individuals live at or below the federal poverty line and/or 30% or more of the population identifying as a non-white minority in a given census tract (20)). Estimated cancer risks from HAPs and diesel particulate matter were 26% greater among those living in environmental justice

communities versus non-environmental justice communities (20). A principal driver of the cancer risk in environmental justice communities is coke oven emissions as well as HAPs from mobile sources including benzene, 1,3-butadiene and naphthalene (20).

There are numerous facilities in Allegheny County that release carcinogenic air pollutants. Recently, Penn Environment updated its "Toxic Ten" report. Data available through EPA's Toxic Release Inventory were analyzed and facilities were ranked based on the overall toxicity of their emissions using EPA's Risk-Screening Environmental Indicators (RSEI) Hazard model. The ten most toxic facilities in the County all release carcinogens. Table 3 lists these facilities and their respective carcinogenic emissions.

Table 3: Carcinogenic Emissions from Penn Environment's 2019 "Toxic 10"

Facility by TOXICITY rank	Carcinogenic Air Releases (TRI, 2010)
1. ATI Flat Rolled Products Holdings LLC	Chromium Compounds, Cobalt Compounds, Lead Compounds, Nickel Compounds
2. Harsco Metals	Chromium Compounds, Lead Compounds, Nickel Compounds
3. U.S. Steel Clairton Coke Works	Benzene, Ethylbenzene, Lead Compounds, Naphthalene, Polycyclic Aromatic Compounds, Pyridine, Styrene
4. Universal Stainless and Alloy Products	Chromium, Lead, Nickel
5. Thermal Transfer Corp.	Chromium, nickel
6. Holtec Manufacturing	Chromium, Lead, Nickel
7. Cheswick Power Plant	Dioxin and Dioxin-Like Compounds, Lead Compounds
8. USS Mon Valley Works - Edgar Thomson Plant	Benzene, Beryllium Compounds, Chromium Compounds, Lead Compounds, Nickel Compounds
9. Carpenter Powder Products, Inc.	Chromium, Cobalt, Nickel
10. PPG Industries Inc. – Springdale Complex	Chromium Compounds, Cobalt Compounds, Cumene, Ethylbenzene, Methyl Isobutyl Ketone, Naphthalene, Nickel Compounds, Styrene
Note – only hexavalent chromium is a carcinogen, however it is unclear what type of chromium is being released by these facilities as only "chromium" or "chromium compounds" was reported.	
Source: Penn Environment. 2019. Toxic Ten. Available at: https://toxicten.org/	

Over the last two decades, the emergence of Unconventional Natural Gas Development (UNGD) in the Southwest Pennsylvania region has created additional sources of concern for carcinogenic air pollution. UNDG includes the processes of extracting, processing and transporting of natural gas, using well pads, compressor stations, condensate tanks, process plants and many other pieces of infrastructure. Air pollution associated with fracking, flaring and vehicle emissions is significant. Among the 200+ air pollutants that have been measured in association with UNGD activities, nearly two dozen are considered known or suspected carcinogens as listed in Table 4 (21) (22). Although the UNGD industry in Pennsylvania is required to report yearly emissions of just 13 compounds, carcinogens are among the compounds reported, including emissions of benzene, $PM_{2.5}$, formaldehyde and ethylbenzene (23). A recent pilot-level study found carcinogenic chemicals known to be associated with UNGD activities in the air (as measured through the use of personal air monitors) and in the urine of families residing near UNGD operations in Southwest Pennsylvania counties (24). Given that cancer is a disease of long latency, cancer effects associated with exposure to carcinogens from UNGD activities still unknown. However, studies outside of Pennsylvania are beginning to show associations between UNGD

Table 4. Known or suspected carcinogens found as air pollutants in association with UNGD activities

• Acetaldehyde • Acrylonitrile • 1,3-butadiene • Benzene • Carbon tetrachloride • Chrysene • Cumene • Dibenz(a,h)anthracene • Diesel exhaust • Ethylbenzene	• Fine particulate matter ($PM_{2.5}$) • Formaldehyde • Indeno(1,2,3-cd)pyrene • Isoprene • Lead • Napthalene • Radon • Styrene • Tetrachloroethylene
Source: Elliott EG, et al. Sci Total Environ. 2017;576:138-147	

activities and childhood leukemias (25). Exposures of concern include not just air pollutants, but also drinking water contamination associated with UNGD activities.

Radon is a naturally occurring radioactive gas that can enter buildings from the surrounding soil or from underground water wells. As with other indoor air pollutants, radon levels can concentrate when ventilation systems are insufficient. Despite availability of effective mitigation systems for radon, the PA Department of Environmental Protection estimates that 40% of homes in the state have elevated radon levels (17). Radon levels in Southwest Pennsylvania schools are also of concern, but testing has been limited (26).

Water pollution

Many water pollutants can increase cancer risk (Table 5). Exposure to these pollutants can occur by drinking contaminated water, bathing, showering and/or swimming.

One major water pollutant that increases cancer risk comes from disinfection processes in place to prevent other diseases. Disinfecting public water supplies with chlorine reduces illness and death associated with waterborne microbes. However, when chlorine interacts with organic compounds often found in surface water, hundreds of different chemical mixtures—called disinfection byproducts—can form. In experimental animal studies, several disinfection byproducts were found to cause cancer, including chloroform, other trihalomethanes, and some haloacetic acids (27). Evidence suggests that long-term exposure to disinfection byproducts in drinking water increases the risk of bladder cancer and possibly colon, rectal and esophageal cancers (27). Given the large number of people who receive their water from public drinking water systems, even a modest elevation in cancer risk from disinfection byproducts can have a significant impact on public health.

Table 5. Known or suspected carcinogens found as drinking water contaminants

- Arsenic
- Benzene
- Chlorinated solvents (e.g., trichloroethylene, perchloroethyene)
- Disinfection by-products
- Perfluorooctanoic acid (PFOA)
- Perfluorooctanesulfonic acid (PFOS)
- Radioactive nuclides, e.g., radium and radon

Sources: (a) Cantor KP, et al. Water contaminants. In Cancer Epidemiology and Prevention. 4th Ed. 2017; (b) Hu XC, Andrews DQ, Lindstrom AB, et al. Environ Sci Technol Lett. 2016 Oct 11;3(10):344–50.

Additional carcinogens of concern in drinking water include inorganic arsenic, radionuclides and a variety of contaminants from hazardous waste sites as well as industrial, agricultural, commercial uses. Exposure to arsenic in drinking water is an established cause of cancer (27). Some areas of the U.S. have high levels of arsenic in private well water because the inorganic chemical occurs naturally in ground water sources (27). Other sources include past use of arsenical pesticides, as well as mining/ore processing and various industrial activities. Cancer risks associated with water contamination from UNDG activities have been reported. For example, studies have revealed that exposing human cells to waste water from Marcellus shale fracking operations can induce malignant transformations (28).

Radium, which can be found in drinking water from both natural sources and contamination from industrial activities, behaves chemically like calcium and, therefore, deposits in significant quantities in bone mineral, where it is retained. IARC classifies radium-224, -226, and -228 as known carcinogens of the bone (29). Public and private water supplies can be also contaminated by a range of pollutants that come from industrial, commercial and domestic sources. Studies of water contamination by solvents (e.g., benzene, trichloroethylene, perchloroethylene), heavy metals (e.g., hexavalent chromium), chlorophenols, and agricultural chemicals (e.g., pesticides and nitrates) have observed elevated risks of several types of cancer (27).

Over the last 15 years, evidence has emerged linking the ubiquitous compounds, per- and poly-fluoroalkyl substances (PFAS) with cancer. These chemicals are used in an extensive array of applications and products as they are highly effective at providing water, stain and oil resistance. Epidemiologic studies link specific PFAS

– perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) – with kidney and testicular cancers (30). Even though these particular PFAS are no longer produced in the U.S., they are extremely persistent in the environment and thus continued exposure is of concern. Based on monitoring data, harmful levels of PFAS have been detected in the public drinking water supplies of over 16 million people across 33 states (31). More recent analyses suggest more widespread contamination (32).

Water pollution: Risks in Southwest Pennsylvania

In the Southwest Pennsylvania region, public drinking water systems are routinely contaminated by disinfection by-products, which are suspected carcinogens. As part of a national study of public drinking water systems (2012-2017) the Pittsburgh Water and Sewer Authority reported 16.8 parts per million of bromodichloromethane, a disinfection by-product (33) (34). This concentration of a suspected carcinogen was nearly three times higher than the national average of 5.7 parts per billion (ppb) and double the state average of 8.34 ppb (31). Additional disinfection by-products with suspected carcinogenic properties, such as chloroform, were also detected, as was hexavalent chromium. Water contaminants from power plants as well as UNDG operations contribute to the formation of these disinfection by-products (35) (36) (37). Despite these cancer risks, there are no federal (or state) legal limits for an array of disinfection by-products in drinking water.

Populations served by private wells, especially those living near UNDG operations, have experienced drinking water contamination. According to the Pennsylvania Department of Environmental Protection, there have been over 300 confirmed reports of private drinking water wells impacted by UNDG operations in the state, including numerous reports in Southwest Pennsylvania counties (38).

Dozens of pollutants—including carcinogens—associated with UNDG activities have been identified in surface and groundwater serving private and public water systems in Western Pennsylvania (22) (39). There have been few attempts to study links between these exposures and cancers, in part because of long latency periods between exposure and the development of cancer. The apparent clustering of osteosarcoma and leukemia among children in the Southwestern Pennsylvania counties of Washington and Westmoreland – currently the focus of a study by the University of Pittsburgh researchers – is of significant concern, especially given known associations between these types of cancers and substances associated with UNDG activities such as radium (bone) and benzene (leukemia) (29).

PFAS contaminated drinking water is still another issue in Pennsylvania. The Pennsylvania Department of Environmental Protection recently released a report documenting PFAS contamination across hundreds of sites (40). PFOS and PFOA, the two PFAS linked with cancer, were detected at over 20% of sites (40). Although minimal testing has been conducted in Southwest Pennsylvania counties, completed tests suggest less significant impacts than in other parts of the state (41). Counties most heavily impacted by PFAS contamination include those with former military bases and airports that used a PFAS-containing product called aqueous film forming foam (AFFF) to fight fuel fires (or for fire-fighting training exercises).

Pesticides

Pesticides are routinely used by migrant farm workers, landscapers, maintenance workers as well as individuals for use in homes and gardens. Not all pesticides can cause the same types of cancer. For example, studies support links between non-Hodgkin lymphoma and glyphosate (a.k.a. Roundup), prostate cancer and non-Hodgkin lymphoma with malathion, and non-Hodgkin lymphoma and lung cancer with diazinon (42). As shown in Table 6, numerous pesticides that are still registered for use in the U.S. are considered known or suspected

Table 6. Examples of known or suspected carcinogens currently registered for use as pesticides in the US by EPA

• 2,4-D	• Glyphosate
• Diazinon	• Lindane*
• Dichlorvos	• Malathion
• Heptachlor*	• Parathion
• Ethylene dibromide	• Pentachlorophenol*
• Formaldehyde	• Toxaphene

*restricted uses. *Source: IARC List Classifications. https://monographs.iarc.who.int/agents-classified-by-the-iarc/*

carcinogens. Others, such as DDT, dieldrin and similar chlorinated pesticides are banned in the U.S., but may still be present in the environment because of their persistent properties.

Results from the U.S. Agricultural Health Study (AHS) provide compelling insights regarding cancer risks from pesticide exposures. This ongoing prospective study of nearly 90,000 individuals, which includes licensed private pesticide applicators (mostly farmers), their spouses, and commercial pesticide applicators,(43) has revealed higher incidence of several types of cancer associated with higher exposure to pesticides, though overall cancer incidence is lower than in the general population. Compared to the general public, increased cancer risks were seen for lip and prostate cancer, leukemias, non-Hodgkin lymphoma, thyroid cancer, and testicular cancer (44). These results are consistent with historical reviews of the evidence, which in addition showed observed associations between pesticide exposure and multiple myeloma, brain and stomach cancers (45).

Children are highly vulnerable to pesticide exposure and subsequent cancer risk. A robust evidence-base now links early life exposures to pesticides used at home to increased risk of leukemia and brain tumors (46)(47)(48). Studies have also examined parental occupational exposure to pesticides and risk of childhood cancer. Associations are particularly strong for mothers' exposure during pregnancy and subsequent risk of childhood leukemia (49). Both maternal and paternal exposures from working in the agricultural sector are associated with elevated rates of childhood brain tumors (50). The childhood vulnerability to pesticides is compounded by the fact that those exposed to high levels of agricultural pesticides are often low-income and immigrant children.

Indirect exposure to pesticides is another significant problem for people living in agricultural areas. Studies confirm that pesticides used in agricultural areas can be found miles from where they are applied and "take-home" occupational exposures can be significant (51). These pesticides are often found in dust in people's homes, at concentrations that may be 10- to 200-fold higher than indoor air levels (52). Pesticide-laden dust can also resist degradation in indoor areas where sunlight is limited (51). Indoor pesticide exposure can be especially problematic for children, since they spend time on the floor and experience the world by putting objects in their mouths (53).

Similar to many areas of the country, Southwest Pennsylvania is highly reliant on migrant farmworkers in agricultural production. Because of their working and housing conditions, farmworkers are often disproportionately exposed to pesticides (54). Cancer among farm workers is an under-researched area given the difficulty of conducting long-term studies of a highly mobile population. However, studies of migrant farmworkers have observed elevated cancer risk (55).

Consumer products

Over 3,000 chemical are used in consumer products (56). Known or suspected chemical carcinogens can be found in personal care products, cleaning products, building products and furniture, among others (Table 7).

Some studies have documented links between consumer products and cancers. For example, an extensive literature examines associations between chemicals in hair dyes and cancer risk, mostly among hairdressers using the products in a professional setting (57). However, recent studies have also revealed increased risk of breast cancer from consumer or personal hair dye use, especially among black women (58). Use of hair straighteners also increases risk of breast cancer among both black and white women and increased risk of premenopausal breast cancer in young women exposed to these products during adolescence (58).

Research on the risk of cancer from consumer products would also benefit from new investment. What we know about cancer risks from chemicals in consumer products is primarily from evidence related to other parts of the product life cycle, in particular exposures during product manufacturing or exposures via contamination (air or water pollution) at the end of the product lifecycle.

Table 7: Examples of known and suspected carcinogens found in consumer products (not comprehensive)	
Known or suspected carcinogen	**Consumer product types**
1,4 dioxane	Personal care products (shampoos, soaps), cleaning products (soaps)
Aromatic amines	Hair dyes
Flame retardants	Electronics; mattresses, upholstered furniture; carpets; children's sleepwear
Formaldehyde	Personal care products (hair straighteners/keratin treatments); textiles/apparel; building materials (pressed wood products; gypsum board)
PFAS	Personal care products (make-up, e.g., mascara, foundation); textiles (water resistant and stain resistant fabric); carpets/rugs; upholstered furniture; non-stick cookware; food packaging
Parabens	Personal care products
Phthalates	Personal care products; fragrances; shower curtains; food and beverage containers
Sources: (a) Singla V. Trends Cancer. 2020 Aug;6(8):619–22. (b) Clapp RW, Jacobs MM, Loechler EL. Rev Environ Health. 2008 Mar;23(1):1–37. (c) Takkouche B, Regueira-Méndez C, Montes-Martínez A. Int J Epidemiol. 2009 Dec;38(6):1512–31. (d) Eberle CE, Sandler DP, Taylor KW, White AJ. Int J Cancer. 2020 Jul 15;147(2):383–9. (e) Gray JM, Rasanayagam S, Engel C, Rizzo J. Environ Health. 2017 Sep 2;16(1):94. (f) Ward MH, Colt JS, Deziel NC, et al. Environ Health Perspect. 2014 Oct;122(10):1110-6. (g) Agency for Toxic Substances and Disease Registry. Toxicological Profile for Perfluoroalkyls. May 2021.	

IV. Prevention is Possible

An essential and powerful step towards change is understanding that prevention is possible. Primary prevention efforts that control common sources of exposure to carcinogens are likely to be more effective than trying to persuade thousands (sometimes millions) of people to each change their individual behaviors (59). Thus, policies and practices that promote healthy working and living environments are clear pathways for cancer prevention.

There are several historical examples in which a reduction in exposure to a carcinogen resulted in dramatic reductions in cancer risk. These include for example reductions of bladder cancers among dye workers after eliminating exposure to aromatic amine dyes, reductions in nasal cancers among furniture workers exposed to wood dust, and declines in non-Hodgkin lymphoma after Sweden banned the pesticide 2,4-Dichlorophenoxyacetic Acid (2,4-D) in the 1970s (60)(61). Additionally, a wide range of interventions—from institutional purchasing to environmental policies to ingredient and product substitutions—are known to reduce exposures to toxic chemicals that can cause cancer. For example, leading wood product manufacturers have substituted the use of the carcinogen formaldehyde in pressed wood products (such as particle board and plywood) with safer soy-based adhesives (62). Use of ultrasonic aqueous processes for metal degreasing are available rather than using the carcinogenic solvent, trichloroethylene (63). Professional wet-cleaning can be used rather than dry cleaning clothes with perchloroethylene, a suspected carcinogen (64). Transitioning fleets to electric vehicles and incentivizing clean public transportation can dramatically reduce levels of carcinogens in air pollution (65). Organic agriculture or use of integrated pest management practices reduce exposures to carcinogenic pesticides (66)(67).

The availability of safer alternatives makes clear that prevention doesn't mean "doing without". It is technologically possible to substitute carcinogens with safer alternatives and still satisfy the products and societal functions needed. Research and development investments are important—from both the public and private sectors—to bring these alternatives to scale. Yet the most significant obstacle in the prevention pathway is the lack of conviction and commitment on the part of the many stakeholders that have a role to play in ensuring healthy environments. Endorsing "Reducing Pollution: Critical Pathway for Cancer Prevention"—an evidence-based statement of concern, solutions and aspiration—is one step we can all take towards realizing a cancer-free future.

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